



Research Article

CT Morphometry of the Thoracic Spine in Congolese Melanoderm Subjects: Reference Norms for Spinal Surgery

Leon Boukassa^{1, 2, *} , Regis Moyikoua^{1, 3}, Paule Sandrine Moussounda Afejee¹,
Rel Boukaka Kala⁴, Sinclair Brice Kinata Bambino²,
Olivier Brice Ngackosso¹, Hugues Brioux Ekouele Mbaki^{1, 2}

¹Faculty of Health Sciences, Marien Ngouabi University, Brazzaville, Congo

²Neurosurgery Department, Brazzaville University Hospital, Brazzaville, Congo

³Medical Imaging Department, Brazzaville University Hospital, Brazzaville, Congo

⁴Neurosurgery Department, Hopital Meres et Enfants Blanche Gomes, Brazzaville, Congo

Abstract

Spinal morphometry exhibits significant interpopulation variability, which is well documented for the cervical and lumbar segments but remains poorly understood for the thoracic spine. This lack of specific data limits the clinical relevance of foreign reference standards in sub-Saharan populations. The objective of this study was to show normal computed tomography (CT) parameters for the thoracic vertebrae in healthy Congolese subjects and to analyze their variations according to sex and body mass index (BMI). A prospective cross-sectional study conducted at the Brazzaville University Hospital (April–September 2024) involving 81 dark-skinned volunteers (43 men, 38 women), aged 18 to 30 years, free of any spinal pathology. The sagittal (SD) and transverse (TD) diameters, vertebral body height (VH), right and left pedicular diameters (PD), and disc heights (DH) were measured on computed tomography (CT) slices with multiplanar reconstructions. The SD increased from T1 (1.63 cm) to T9 (2.54 cm) and then decreased through T12; the TD decreased from T1 to T4 and then increased through T12 (3.45 cm); and vertebral height increased steadily from T1 (1.57 cm) to T12 (2.27cm). The volume of the vertebral bodies, estimated using the elliptical cylinder model, increased from 5.35 cm³ (T1) to 15.23 cm³ (T12), representing a ratio of 2.85. The PDs were minimal at T4–T6 (0.51 cm) and maximal at T12 (0.78 cm), with no significant right-left asymmetry. Sexual dimorphism was observed from T3 to T8 ($p < 0.02$) on the HV and on the right DP at T1 ($p = 0.03$). DH values were higher in men at T2–T3, T3–T4, T6–T7, T7–T8 and T11–T12 ($p < 0.05$). BMI did not influence bone dimensions, except for an isolated difference at T5–T6 ($p = 0.019$). This study provides the first thoracic morphometric norms for Congolese individuals with dark skin. The cranio-caudal growth of vertebral volumes reflects biomechanical adaptation to an upright posture. Sexual dimorphism, limited to vertebral height in the mid-thoracic region, and the absence of pedicle dimorphism provide a precise framework for surgical planning. These data improve surgical safety in settings where neuronavigation is unavailable and support the development of local population-based standards.

Keywords

Thoracic Spine, Morphometry, Computed Tomography, Pedicle Screw, Melanoderma, Congo

*Correspondence: Leon Boukassa (lboukassalouf@gmail.com)

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1. Introduction

The thoracic spine constitutes the middle segment of the vertebral column, extending from T1 to T12. Deeply situated within the thoracic cage, it is in close proximity to vital mediastinal structures: the descending thoracic aorta, the esophagus, the azygos vein, and the hilar vascular pedicles. Its mobility is considerably reduced by the costovertebral joints and by its physiological kyphosis of 20° to 45°, which confers predominant axial stability at the expense of flexibility. This unique architecture directly influences the disc-vertebral morphology and the distribution of biomechanical stresses, making the thoracic segment a functional entity distinct from the cervical and lumbar segments [1, 2].

Like the other spinal segments, the thoracic spine is affected by a variety of pathologies: deformities (scoliosis, pathological kyphosis), degenerative conditions, primary or secondary tumors, spondylodiscitis, and traumatic injuries. Surgical management of these conditions has seen major advances over the past two decades, with the development of pedicle screw osteosynthesis, intersomatic cage arthrodesis, total disc replacement, and percutaneous or minimally invasive surgical techniques [3, 4]. The safety and efficacy of these procedures rely on a precise understanding of the normal dimensions of the vertebral bodies, pedicles, and discs, whether or not this is supplemented by intraoperative planning tools such as neuronavigation.

While morphometric studies abound for the cervical and lumbar segments, they remain relatively rare for the thoracic spine [5, 6]. Furthermore, the available data have been primarily collected from Caucasian or Asian populations and report significant ethnic variations, which limit the direct application of these foreign reference standards to other population groups [7-9]. In resource-limited countries such as the Republic of the Congo, where the unavailability of neuronavigation makes preoperative planning entirely dependent on local morphometric data, this gap poses a major challenge to surgical safety.

In this context, our overall objective was to determine the computed tomography (CT) morphometric parameters of the thoracic spine in healthy Congolese individuals of African descent. Secondly, we analyzed variations in these measurements according to sex and body mass index (BMI).

2. Materials and Methods

2.1. Study Type, Period, and Setting

This was a prospective, descriptive, cross-sectional study conducted over a six-month period (April–September 2024) in the medical imaging department of the Brazzaville University Hospital (B-UH). The facility is equipped with an 80-slice multibar scanner (Siemens SOMATOM Definition AS, Siemens Healthineers, Erlangen, Germany) with multiplanar reconstruction stations, enabling high-resolution imaging.

2.2. Study Population and Sampling

The target population consisted of Congolese subjects of both sexes with dark skin tones residing in Brazzaville.

Inclusion criteria:

Included were subjects of any gender, aged 18 to 30 years, who had signed an informed consent form, had no history of or progressive spinal pathology (traumatic, infectious, inflammatory, neoplastic, or congenital), and, for women, were not pregnant or suspected of being pregnant. The absence of any contraindications to computed tomography (CT) scanning was also required.

Exclusion criteria (radiological):

Based on the CT scan, we excluded subjects with transitional anomalies at the cervicothoracic or thoracolumbar junctions, those with vertebral malformations (vertebral block, hemivertebra, spina bifida), and those with significant signs of osteoarthritis or osteophytosis.

Of the 100 volunteers initially included, 19 cases (11 men, 8 women) were excluded, bringing the final sample to 81 subjects.

2.3. Image Acquisition Protocol

Acquisitions were performed according to the department's standard protocols (1-mm slice thickness, reconstruction of bone and soft tissue levels, 120 kV, 150–200 mAs with automatic current modulation). The raw DICOM images were transferred to dedicated visualization software (Tridicom, version 5.2, or equivalent) for multiplanar reconstructions (sagittal and coronal) and measurements.

2.4. Morphometric Parameters Studied

All measurements were performed using a double-reader approach: first by a specialist radiologist (5 years of experience) and then by a medical student nearing graduation, following training on 15 pilot subjects. For each thoracic vertebra (T1 to T12), uniaxial sections and sagittal reconstructions, the following were measured:

On the vertebral bodies:

Sagittal diameter (SD): the distance between the midpoints of the ventral and dorsal edges of the vertebral body, measured on an axial section passing through the midpoint of the vertebral body. Transverse diameter (TD): the greatest distance between the two lateral edges of the vertebral body, measured on the same axial section. Vertebral height (VH): the average of the ventral, median, and dorsal distances separating the upper and lower endplates, measured on the sagittal reconstructions.

On the pedicles:

Pedicle transverse diameter (PD): the smallest pedicle diameter, measured perpendicular to the axis of the pedicle, from the medial edge to the lateral edge, individually on the

right and left, on axial sections passing through the base of the pedicle.

On the intervertebral discs:

Disc height (DH): the average of the distances between the endplates of the superior and inferior vertebrae, measured in the ventral, central, and dorsal regions on sagittal reconstructions.

Epidemiological variables (age, sex, occupation) and anthropometric variables (height, weight, BMI) were also collected.

2.5. Statistical Analysis

Data entry was performed using Microsoft Excel 2016, and statistical analysis was conducted using SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Quantitative variables were expressed as means $\pm$ standard deviations.

Comparisons of means between two groups (sex, BMI) used Student's t-test for independent samples, after verifying the normality of the distributions using the Shapiro-Wilk test. The significance level was set at $p \leq 0.05$.

2.6. Ethical Considerations

This research received research certification from the Faculty of Health Sciences, approval from the Health Sciences Research Ethics Committee, and authorization from the general administration of B-UH. Anonymity and confidentiality were strictly maintained, with each participant identified by a code number. Informed consent was obtained after an information sheet was provided. Risks associated with radiation exposure were minimized through the use of low-dose protocols (ALARA principle).

3. Results

3.1. Characteristics of the Study Population

Of the 81 subjects included, there were 43 men and 38 women (male-to-female ratio = 1.13). The mean age was 25.06 ± 3.6 years (range: 18–30). The 25–30 age group accounted for 59.3% ($n = 48$). The anthropometric characteristics are summarized in Table 1.

Table 1. Anthropometric characteristics of the study population ($n = 81$).

Parameter	Mean $\pm$ SE	Minimum	Maximum
Height(cm)	171.00 $\pm$ 8.73	140	195
Weight(kg)	74.63 $\pm$ 10.41	52.0	95.0
BMI(kg/m ²)	25.12 $\pm$ 2.66	17.00	33.87

Forty-eight subjects (59.3%) had a BMI < 25 kg/m² (normal weight), and 33 (40.7%) had a BMI ≥ 25 kg/m² (overweight or obese according to WHO criteria, with a maximum BMI of 33.87 kg/m², excluding severe obesity).

3.2. Vertebral Body Morphometry and Estimated Volumes

The dimensions of the vertebral bodies are presented in Table 2. The DS increased gradually from T1 (1.63 cm) to T9 (2.54 cm), then decreased slightly to T12 (2.48 cm). The DT

showed a biphasic trend: a decrease from T1 (2.66 cm) to T4 (2.48 cm), followed by a continuous increase up to T12 (3.45 cm). The VH increased steadily from T1 (1.57 cm) to T12 (2.27 cm).

By modeling the vertebral body as an elliptical cylinder, whose volume is given by the formula $V = \pi \times (SD/2) \times (TD/2) \times HV$, we calculated the estimated vertebral volumes. The results, presented in Table 3, show a considerable and progressive increase in volume in the cranio-caudal direction, with the volume increasing nearly threefold between T1 (5.35 cm³) and T12 (15.23 cm³).

Table 2. Dimensions of the thoracic vertebral bodies (cm, $n = 81$).

Vertebra	DS (cm)	DT (cm)	VH (cm)
T1	1.63 $\pm$ 0.26	2.66 $\pm$ 0.26	1.57 $\pm$ 0.30
T2	1.86 $\pm$ 0.26	2.62 $\pm$ 0.46	1.86 $\pm$ 0.32
T3	1.99 $\pm$ 0.28	2.57 $\pm$ 0.32	1.81 $\pm$ 0.20

Vertebra	DS (cm)	DT (cm)	VH (cm)
T4	2.07 ±0.25	2.48 ±0.27	1.82 ±0.15
T5	2.15 ±0.22	2.51 ±0.28	1.82 ±0.13
T6	2.26 ±0.25	2.54 ±0.32	1.78 ±0.16
T7	2.37 ±0.28	2.64 ±0.31	1.88 ±0.22
T10	2.53 ±0.25	3.05 ±0.44	2.07 ±0.18
T11	2.49 ±0.36	3.25 ±0.48	2.13 ±0.23
T12	2.48 ±0.38	3.45 ±0.48	2.27 ±0.37

DS: sagittal diameter; DT: transverse diameter

Table 3. Estimated Volumes of Thoracic Vertebral Bodies (cm³).

Vertebra	Volume (cm ³)
T1	5.34
T2	7.12
T3	7.27
T4	7.34
T5	7.71
T6	8.04
T7	9.24
T8	10.05
T9	10.81
T10	12.54
T11	13.53
T12	15.23

3.3. Morphometry of the Pedicles

The transverse diameters of the pedicles (Table 4) decreased from T1 to T4–T6 (minimum: 0.51 ±0.14 cm on the left, 0.53 ±0.12 cm on the right), then gradually increased up to T10–T12 (0.78 ±0.18 cm on the left, 0.74 ±0.18 cm on the right). No significant right-left asymmetry was observed ($p > 0.05$ for all levels).

Table 4. Transverse diameters of the thoracic pedicles (cm, $n = 81$).

Vertebra	Left pedicle	Right pedicle
T1	0.71 ±0.18	0.67 ±0.16
T2	0.58 ±0.17	0.64 ±0.13
T3	0.56 ±0.15	0.57 ±0.12
T4	0.53 ±0.11	0.57 ±0.13
T5	0.51 ±0.14	0.54 ±0.12

Vertebra	Left pedicle	Right pedicle
T6	0.51 ± 0.12	0.53 ± 0.12
T7	0.57 ± 0.14	0.57 ± 0.13
T8	0.56 ± 0.14	0.61 ± 0.14
T9	0.65 ± 0.16	0.66 ± 0.21
T10	0.78 ± 0.18	0.74 ± 0.18
T11	0.72 ± 0.26	0.72 ± 0.22
T12	0.78 ± 0.21	0.74 ± 0.19

3.4. Disc Heights

Disc heights (Table 5) showed a cranio-caudal increase, with higher values ranging from T8–T9 (0.31 cm) to T11–T12 (0.40 cm).

Table 5. Heights of thoracic intervertebral discs (cm, n = 81).

Disc	Height(cm)
T1–T2	0.25 ± 0.10
T2–T3	0.26 ± 0.07
T3–T4	0.26 ± 0.08
T4–T5	0.24 ± 0.06
T5–T6	0.27 ± 0.11
T6–T7	0.26 ± 0.11

Disc	Height(cm)
T7–T8	0.27 ± 0.12
T8–T9	0.31 ± 0.12
T9–T10	0.37 ± 0.11
T10–T11	0.37 ± 0.11
T11–T12	0.40 ± 0.14

3.5. Variations by BMI

No significant differences in vertebral body dimensions or pedicle diameters were observed between subjects with a BMI ≥ 25 and those with a BMI < 25 ($p > 0.05$ for all levels). Regarding disc heights (Table 6), a significant difference was noted only for T5–T6 ($p = 0.019$), with a greater height in the BMI < 25 group (0.30 ± 0.11 cm vs. 0.24 ± 0.11 cm). No significant differences were found for the other disc levels.

Table 6. Comparison of disc heights by BMI (cm).

Disc	BMI ≥ 25	BMI < 25	p
T1–T2	0.24 ± 0.10	0.25 ± 0.11	0.77
T2–T3	0.25 ± 0.06	0.26 ± 0.08	0.52
T3–T4	0.26 ± 0.07	0.27 ± 0.09	0.82
T4–T5	0.23 ± 0.06	0.25 ± 0.06	0.23
T5–T6	0.24 ± 0.11	0.30 ± 0.11	0.019
T6–T7	0.25 ± 0.10	0.27 ± 0.11	0.52
T7–T8	0.25 ± 0.10	0.29 ± 0.13	0.27
T8–T9	0.30 ± 0.10	0.32 ± 0.14	0.98
T9–T10	0.36 ± 0.10	0.39 ± 0.12	0.11
T10–T11	0.36 ± 0.10	0.39 ± 0.13	0.32
T11–T12	0.39 ± 0.13	0.40 ± 0.15	0.95

3.6. Variations by Sex

3.6.1. Vertebral Body Measurements (Table 7)

Sexual dimorphism in vertebral body measurements was observed primarily in vertebral height, with significantly

higher values in men from T3 to T8 ($p < 0.02$) and at T10 ($p = 0.043$). Sagittal diameter showed no significant differences between sexes at any level ($p > 0.05$). The transverse diameter showed a significant difference only at T1 ($p = 0.049$) and T9 ($p = 0.038$), in favor of men.

Table 7. Comparison of vertebral body measurements by sex.

Vertebra	Parameter	Male (cm)	Women(cm)	p
T1	SD	1.67 ± 0.27	1.60 ± 0.25	0.51
	TD	2.71 ± 0.26	2.61 ± 0.26	0.049
	VH	1.59 ± 0.31	1.54 ± 0.28	0.49
T2	SD	1.87 ± 0.29	1.84 ± 0.23	0.66
	TD	2.67 ± 0.45	2.57 ± 0.47	0.31
	VH	1.89 ± 0.29	1.83 ± 0.35	0.11
T3	SD	2.00 ± 0.26	1.98 ± 0.29	0.62
	TD	2.62 ± 0.35	2.51 ± 0.28	0.23
	VH	1.87 ± 0.14	1.75 ± 0.23	0.015
T4	SD	2.12 ± 0.25	2.02 ± 0.24	0.07
	TD	2.52 ± 0.31	2.44 ± 0.22	0.30
	VH	1.87 ± 0.14	1.77 ± 0.14	0.003
T5	SD	2.20 ± 0.24	2.09 ± 0.18	0.53
	TD	2.55 ± 0.31	2.47 ± 0.24	0.54
	VH	1.86 ± 0.14	1.78 ± 0.09	0.007
T6	SD	2.30 ± 0.26	2.20 ± 0.22	0.21
	TD	2.60 ± 0.33	2.47 ± 0.30	0.08
	VH	1.83 ± 0.17	1.73 ± 0.13	0.017
T7	SD	2.42 ± 0.29	2.32 ± 0.28	0.13
	TD	2.69 ± 0.33	2.58 ± 0.29	0.17
	VH	1.90 ± 0.23	1.84 ± 0.21	0.018
T8	SD	2.54 ± 0.31	2.41 ± 0.22	0.05
	TD	2.72 ± 0.38	2.62 ± 0.31	0.12
	VH	1.98 ± 0.23	1.88 ± 0.22	0.007
T9	SD	2.61 ± 0.32	2.47 ± 0.26	0.10
	TD	2.81 ± 0.43	2.61 ± 0.38	0.038
	VH	2.02 ± 0.24	1.97 ± 0.15	0.22
T10	SD	2.58 ± 0.24	2.48 ± 0.25	0.09
	TD	3.10 ± 0.46	3.00 ± 0.43	0.17
	VH	2.10 ± 0.19	2.03 ± 0.18	0.043
T11	SD	2.51 ± 0.39	2.47 ± 0.32	0.37

Vertebra	Parameter	Male (cm)	Women(cm)	p
T12	TD	3.31 ±0.55	3.18 ±0.37	0.33
	VH	2.15 ±0.26	2.11 ±0.18	0.17
	SD	2.53 ±0.42	2.43 ±0.32	0.43
	TD	3.52 ±0.55	3.36 ±0.37	0.15
	VH	2.31 ±0.38	2.22 ±0.36	0.15

3.6.2. Pedicle Measurements(Table 8)

There were no significant differences between the sexes in the left pedicles at any level ($p > 0.12$ for all levels). On the right side, only the T1 pedicle was significantly larger in men ($p = 0.036$). No other significant differences were observed, including at the critical T4–T6 levels.

Table 8. Comparison of Pedicle Measurements by Sex.

Vertebra	Parameter	Male (cm)	Female(cm)	p
T1	LP	0.73 ±0.19	0.68 ±0.16	0.20
	RP	0.69 ±0.16	0.64 ±0.15	0.036
T2	LP	0.60 ±0.17	0.55 ±0.16	0.20
	RP	0.64 ±0.16	0.64 ±0.09	0.51
T3	LP	0.58 ±0.16	0.53 ±0.12	0.36
	RP	0.58 ±0.13	0.57 ±0.10	0.72
T4	LP	0.53 ±0.12	0.53 ±0.10	0.53
	RP	0.57 ±0.13	0.56 ±0.14	0.72
T5	LP	0.53 ±0.15	0.48 ±0.14	0.12
	RP	0.55 ±0.13	0.53 ±0.11	0.77
T6	LP	0.53 ±0.13	0.49 ±0.10	0.35
	RP	0.54 ±0.10	0.52 ±0.13	0.26
T7	LP	0.57 ±0.13	0.57 ±0.15	0.90
	RP	0.57 ±0.14	0.57 ±0.12	0.75
T8	LP	0.57 ±0.13	0.55 ±0.15	0.17
	RP	0.61 ±0.14	0.61 ±0.15	0.82
T9	LP	0.64 ±0.16	0.65 ±0.15	0.61
	RP	0.67 ±0.21	0.65 ±0.21	0.50
T10	LP	0.76 ±0.19	0.79 ±0.17	0.35
	RP	0.74 ±0.18	0.74 ±0.18	0.88
T11	LP	0.73 ±0.26	0.71 ±0.26	0.58
	RP	0.71 ±0.21	0.73 ±0.23	0.49
T12	LP	0.76 ±0.22	0.80 ±0.20	0.53
	RP	0.74 ±0.18	0.74 ±0.21	0.97

LP: left pedicle; RP: right pedicle

3.6.3. Disc Heights (Table 9)

Men had significantly greater disc heights at the T2-T3 ($p = 0.027$), T3-T4 ($p = 0.005$), T6-T7 ($p = 0.007$), T7-T8 ($p = 0.031$), and T11-T12 ($p = 0.048$).

Table 9. Comparison of disc heights (cm) by sex.

Disc	Men(cm)	Women(cm)	p
T1-T2	0.26 $\pm$ 0.10	0.23 $\pm$ 0.09	0.13
T2-T3	0.27 $\pm$ 0.08	0.23 $\pm$ 0.06	0.027
T3-T4	0.29 $\pm$ 0.09	0.23 $\pm$ 0.06	0.005
T4-T5	0.25 $\pm$ 0.06	0.23 $\pm$ 0.06	0.67
T5-T6	0.28 $\pm$ 0.12	0.25 $\pm$ 0.10	0.69
T6-T7	0.29 $\pm$ 0.11	0.23 $\pm$ 0.10	0.007
T7-T8	0.28 $\pm$ 0.11	0.24 $\pm$ 0.12	0.031
T8-T9	0.33 $\pm$ 0.13	0.28 $\pm$ 0.09	0.09
T9-T10	0.39 $\pm$ 0.13	0.35 $\pm$ 0.08	0.31
T10-T11	0.40 $\pm$ 0.13	0.35 $\pm$ 0.09	0.10
T11-T12	0.42 $\pm$ 0.14	0.36 $\pm$ 0.12	0.048

4. Discussion

4.1. Morphometry of the Vertebral Bodies: A Cranio-Caudal Biomechanical Adaptation

Our results reveal an irregular pattern of change, which is consistent with the literature [1, 9, 10]. The sagittal diameter peaks at T9 (2.54 cm) and then decreases through T12. The transverse diameter is characterized by a decrease from T1 to T4 (2.48 cm), followed by a gradual increase through T12 (3.45 cm). Vertebral height increases steadily from T1 (1.57 cm) to T2 (), stabilizes between T3 and T6, and then increases between T7 and T12 (2.27 cm).

A distinctive feature of this study is the inclusion of these three parameters in the volumetric estimation using the elliptical cylinder model. The vertebral body volume thus obtained at all levels reveals significant cranio-caudal growth, increasing from 5.34 cm³ at T1 to 15.23 cm³ at T12, representing a ratio of 2.85. This increase, consistent with the biomechanical model proposed by Liebsch et al. [11], reflects structural adaptation to increasing axial stresses. These data may be useful in disc- bodyreconstructive surgery, such as the placement of intervertebral cages.

In comparison with data from the literature, Kaur et al. [9], in a CT study of an Indian population, report vertebral body

dimensions that are generally larger than ours: the anterior height of the vertebral body ranges from 18.91 mm (T1) to 28.91 mm (T12), and the average width from 33.06 mm (T1) to 44.21 mm (T12). Our values, which are lower across the board, confirm the existence of significant interethnic variations, as reported by Tan et al. [7] and Acharya et al. [12]. These differences underscore the crucial importance of having local population-based reference data for surgical planning.

4.2. Sexual Dimorphism of Vertebral Bodies: The Mid-Thoracic Region as an Area of Divergence

Analysis of the data by sex reveals a heterogeneous pattern of dimorphism depending on the parameters and vertebral levels.

The sagittal diameter is similar between the sexes at all levels ($p > 0.05$). The transverse diameter shows significant differences at T1 ($p = 0.049$) and T9 ($p = 0.038$), with men having larger values. This observation suggests that sagittal and transverse growth of the thoracic vertebrae is only slightly influenced by sex. This finding was also reported by Zindrick et al. [2], but contrasts with what is observed in the lumbar region [13].

Vertebral height, on the other hand, appears to be the most discriminating parameter. Dimorphism is greatest in the mid-thoracic region (T3–T8), with particularly low p-values (T4: $p = 0.003$; T5: $p = 0.007$; T8: $p = 0.007$). This topographic

gradient is unique: it suggests that the male pubertal growth spurt—which occurs later and is more intense—primarily affects the mid-thoracic segment, which is the last to complete its growth in height. This phenomenon may be related to the later closure of the growth plates in the mid-thoracic vertebrae compared to the upper or lower vertebrae [14]. This characteristic must be taken into account in vertebral reconstructions for this specific vertebral segment.

4.3. Pedicular Morphometry: A Critical Segment in the Mid- Thoracic Region and an Absence of Sexual Dimorphism

Our pedicle diameters (0.51–0.78 cm) are comparable to the Kenyan data (0.45–0.84 cm) reported by Mwangi et al. [15] and to European values [16], but greater than Asian data (0.40–0.65 cm) [17]. The critical narrowing observed in the mid-thoracic region (T4–T6, minimum 0.51 cm), somewhat similar to that observed in the transverse diameter of the vertebral bodies, constitutes a major risk factor for transpedicular screw placement. If the 0.3-mm safety margin on each side proposed by Cinotti et al. [4] is observed, the ideal screw diameter for use between T4 and T6 (0.51 cm in diameter, or 5.1 mm for a theoretically circular pedicle) should be between 3.5 and 4.0 mm. These recommendations will apply regardless of sex, due to the near absence of sexual dimorphism in the thoracic region. Furthermore, the absence of right-left asymmetry simplifies bilateral screw placement planning, allowing for a symmetrical approach.

The absence of sexual dimorphism in pedicle diameters contrasts with European data [2] and those of Bunmaprasert et al. [18] in a Thai population, who reported marked sexual dimorphism at nearly all thoracic levels. Kretzer et al. [19], in an American population, found significant differences by sex (on average 1.4 mm wider in men), along with substantial interindividual variations. Our values, which are more homogeneous between the sexes, may reflect genetic or environmental factors specific to the Congolese population, as has been suggested for other vertebral parameters [13].

4.4. Disc heights: Sexual Dimorphism and Limited Influence of BMI

The craniocaudal increase in disc heights confirms the findings of Fletcher et al. [20]. Our values (0.24–0.40 cm) are slightly lower than those reported in some Western series, likely due to ethnic differences, as suggested by Debois et al. [21]. al disc sexual dimorphism (greater heights in men at T2–T3, T3–T4, T6–T7, T7–T8, and T11–T12) is consistent with Wang et al. [22] and may influence segmental spinal kinematics, with potentially greater mobility in men at these levels.

No effect of BMI: The absence of an effect of BMI on bone dimensions, with the exception of a chance difference at T5–T6 ($p = 0.019$), is consistent with Demiroz et al. [23] and sug-

gests that variations in body weight within a non-obese population (maximum BMI of 33.87 kg/m²) do not significantly alter vertebral bone morphology. Disc heights, on the other hand, may be more sensitive to load variations, as suggested by the isolated difference observed at T5–T6; however, the clinical significance of this single observation is debatable in the absence of confirmation at other levels. These results are also consistent with the work of Ritzel et al. [24] on sex-related variations in vertebral geometry, which highlight the predominance of hormonal and genetic factors over weight-related factors in determining bone morphology.

4.5. Cross-Population Comparisons: Validation of the Hypothesis of Ethnic Variations

Our data confirm the hypothesis of significant ethnic variations in vertebral morphology. Compared to the data from Panjabi et al. [1] on a Caucasian population, our pedicular diameters are slightly smaller in the mid-thoracic region (0.51 cm vs. 0.55–0.60 cm) but comparable in the thoracolumbar region. Compared to Asian data from Liao et al. [25] and Tan et al. [7], our values are generally higher (0.51–0.78 cm vs. 0.40–0.65 cm), placing the Congolese population in an intermediate position between Asian and Caucasian populations for this parameter.

These variations underscore the importance of having local data to guide surgical decisions. Using Asian reference values for a Congolese population could lead to the use of oversized screws, with an increased risk of pedicle fracture or neurological injury. Conversely, the use of Caucasian reference values could lead to under-sizing, with a ly increased risk of loosening or pseudarthrosis. This observation is particularly relevant in the absence of neuronavigation, which remains the norm in most neurosurgical and orthopedic surgery centers in sub-Saharan Africa.

4.6. Strengths and Limitations of the Study

Strengths: This study is the first to provide normative morphometric data for the thoracic spine in a dark-skinned population from Central Africa. The inclusion of subjects aged 18 to 30 in the study limits the risk of analyzing vertebrae deformed by degenerative lesions. The rigorous methodology—including double-blind readings, preliminary training on pilot subjects, and the use of multiplanar reconstructions for optimal accuracy—strengthens the validity of the results. The detailed analysis of sexual dimorphism, highlighting a unique topographic gradient, constitutes a significant scientific contribution.

Limitations: Our sample ($n = 81$), although comparable to the seminal studies in this field [1, 5, 6], is modest and limited to a single geographic area (Brazzaville). The lack of measurements of the pedicle angle in the transverse plane and of pedicle length is a shortcoming for surgical navigation planning. Finally, the lack of correlation between the subjects' body size and vertebral

measurements limits the ability to objectively assess inter individual differences beyond sex and BMI.

Multicenter studies including subjects of various body types and from different geographic regions of the Republic of the Congo, as well as cadaveric correlation studies are needed to validate and expand these local reference standards.

5. Conclusion

This study establishes the first thoracic computed tomography (CT) standards for healthy Congolese subjects of dark skin tone. It confirms the cranio-caudal growth of the vertebral body volume, consistent with biomechanical adaptation to an upright posture. The pedicle diameter, which is comparable between the two sexes, remains critical in the mid-thoracic region ($T4-T6 \leq 5.1$ mm), requiring careful selection of screws (3.5–4.0 mm) and a meticulous screw placement technique in this high-risk segment.

The sex-related morphometric divergence observed in the mid-thoracic region for vertebral height, combined with the absence of pedicle dimorphism, provides a precise framework for preoperative planning:

- 1) Standardization of pedicle screws regardless of sex, with a selection grid based on vertebral level;
- 2) Mandatory adaptation of the shape of disc-vertebral reconstruction hardware according to sex for the T3–T8 levels, to optimize stability and fusion rates.

These findings improve surgical safety in resource-limited countries where neuronavigation is often unavailable. They support the development of local population-based morphometric reference standards—the only way to ensure optimal and personalized surgical practice—and underscore the need for continued anthropometric research in sub-Saharan Africa.

Abbreviations

CT	Computed Tomography
BMI	Body Mass Index
SD	Sagittal Diameter
TD	Transverse Diameter
VH	Vertebral Body Height
PD	Pedicular Diameter
DH	Disc Height
B-UH	Brazzaville University Hospital
WHO	World Health Organization
T	Thoracic Vertebra

Author Contributions

Leon Boukassa: Conceptualization, Writing – original draft

Regis Moyikoua: Funding acquisition, Methodology

Paule Sandrine Moussounda Afejee: Data curation, Investigation

Rel Boukaka Kala: Formal Analysis

Sinclair Brice Kinata Bambino: Data curation, Resources

Olivier Brice Ngackosso: Ressource

Hugues Brioux Ekouele Mbaki: Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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