



Sexual Dimorphism in the Atlas Vertebra of Normal and Overweight Patients with its Possible Surgical Implications

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■ **BACKGROUND:** We aimed to detect the sexual dimorphism in the width and external anteroposterior length (EAPL) values of the atlas vertebra, and to detect significant correlations between the width and EAPL with height, weight, and body mass index (BMI) in normal weight and in overweighted patients.

■ **METHODS:** The width and EAPL were measured in 63 (32 female, 31 male) normal weight individuals and in 61 (30 female, 31 male) overweighted individuals who underwent a cervical spine computed tomography scan. Data was first compared between all female patients and male patients, and secondly was compared between normal and overweight individuals. Spearman's correlation analysis was used to evaluate correlations between width and EAPL with height, weight, and BMI.

■ **RESULTS:** Atlas width and EAPL were significantly higher in normal and overweight males ($P < 0.001$). No correlations were found between height, weight, and BMI and the width and EAPL in normal and overweight individuals. The only significant correlation found was between width and EAPL in both normal and overweight individuals ($P < 0.001$).

■ **CONCLUSIONS:** There is sexual dimorphism in atlas width and EAPL, with male patients presenting

significantly higher values, but there are no correlations between height, weight, and BMI and the width and EAPL in both normal and overweight individuals. In addition, being overweight does not affect the correlation between width and EAPL.

INTRODUCTION

The craniovertebral junction is the first junction that connects the skull to the spine via the atlanto-axial joint, which is the joint between the first 2 cervical vertebrae, the atlas and axis, and the atlanto-occipital joint, which is the joint between the occiput and atlas.^{1,2}

Anatomically, the atlas vertebra or C1 is shaped like a ring consisting of an anterior and a posterior arch, 2 lateral masses, and the neural canal.^{3,4,5} Currently there is no much information about sexual dimorphism in the atlas vertebra morphometric values,^{6,7} although knowledge of anatomic data of C1 is important in, for example, pedicle screw placement.⁸

On the other hand, the World Health Organization defines individuals with a body mass index (BMI) from 18.5 to less than 25 kg/m² as normal/healthy weight patients, while those with BMI from 25 to 29.9 kg/m² as overweight patients.⁹ It is reported in the literature that BMI may be associated with different diseases of the spine, such as degenerative spondylolisthesis and lumbar

Key words

- Anthropometric data
- Atlas
- Body mass index
- Computed tomography
- Sexual dimorphism

Abbreviations and Acronyms

- BMI:** Body mass index
CT: Computed tomography
EAPL: External anteroposterior length

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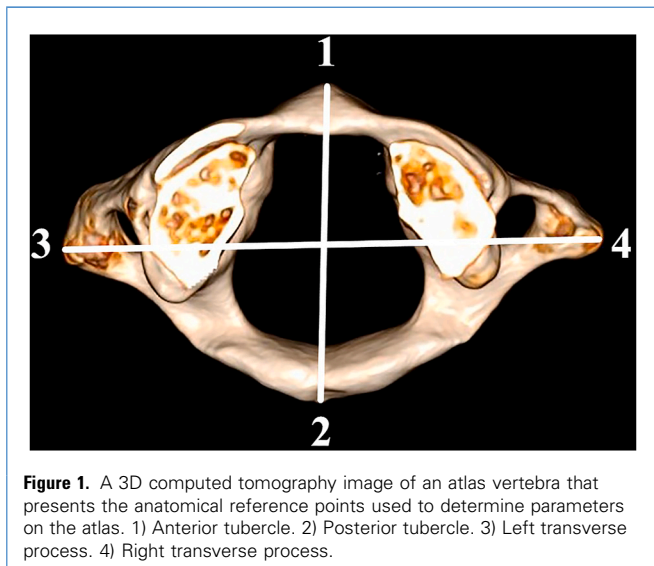


Figure 1. A 3D computed tomography image of an atlas vertebra that presents the anatomical reference points used to determine parameters on the atlas. 1) Anterior tubercle. 2) Posterior tubercle. 3) Left transverse process. 4) Right transverse process.

spinal canal stenosis,^{10,11} but there is not enough information about the possible correlations between anthropometric data (including height, weight, and BMI) on the atlas morphometric values as the distance between the right and left external transverse processes of the atlas vertebra (width), and the distance between the outermost points of the anterior and posterior tubercles (the external anteroposterior length [EAPL]) in both normal and overweight individuals.

Highlighting the above, we aimed: 1) to reveal if there is sexual dimorphism in the atlas vertebra width and EAPL of both normal and overweight patients; 2) to analyze whether there are differences in width and EAPL values between normal and overweighted patients; 3) to detect if there is a relationship between the width and EAPL values and the height, weight, and BMI in both normal and overweight patients; and 4) to discuss the possible clinical implications of the above results.

METHODS

We reviewed computed tomography (CT) cervical scans performed at the ASCIRES CT Unit of Valencia, Spain. The study was carried out following the tenets of the Declaration of Helsinki and was approved by the ethics committee of the University of Valencia (ref. H1414410627187). Written consent from each participant was obtained after a verbal explanation of the protocol and the nature and possible consequences of the study.

All patients underwent a CT scan study based on suspected neoplasm metastasis. To be included in the study, all patients needed to be free of metastasis, have no cervical spine pathologies, and be aged between 30 and 45 years. The patients were measured and weighed before their CT scan and their BMI was calculated. Those with BMI ranging from 18.5–24.9 kg/m² were assigned to the normal weight group (n = 63) and those with BMI ranging from 25–29.9 kg/m² were assigned to the overweight group (n = 61).

Images of the atlas vertebra were analyzed on a GE LightSpeed VCT 64 Slice CT system (General Electric, Milwaukee, WI), which

Table 1. Demographic Characteristics of Normal-Weight Patients

	Male (n = 31)		Female (n = 32)		P Value
	Mean ± SD	Min-Max	Mean ± SD	Min-Max	
Age (years)	39.2 ± 2.1	37–45	38.8 ± 2.7	32–45	0.567
Height (cm)	176.6 ± 4.2	170–184	166.3 ± 5.6	158–177	<0.001*
Weight (kg)	73.9 ± 4.3	75–82	61.7 ± 5.2	55–72	<0.001*
BMI (kg/m ²)	23.7 ± 0.9	20.3–24.5	22.3 ± 1.3	19.7–24.9	<0.001*

BMI, body mass index; SD, standard deviation; Min, minimum; Max, maximum.
*Statistically significant.

provides an axial-field of view of 350–400 mm and a transaxial slice thickness of 0.5 mm. We measured the width and EAPL (Figure 1). The width and EAPL measurements were performed on reconstructed 3-dimensional models using AUTOBONE and VESSELLQ XPRESS software (General Electric).

Statistical Package for Social Sciences (SPSS) 25.0 (IBM, Armonk, NY) was used to statistically analyze the measured parameters. Shapiro-Wilk analysis was used to determine whether the variables were normally distributed. When comparing variables according to sex, the Student's t test was used for those with normal distribution and the Mann Whitney-U test was used for non-parametric variables. Spearman's correlation analysis was used to evaluate possible correlations between variables according to sex. A P-value of ≤0.05 was considered significant.

RESULTS

Tables 1 and 2 present the demographic characteristics of the normal and overweight patients analyzed in this study. Table 3 and Table 4 revealed sexual dimorphism in the values of the width and EAPL in both male and female individuals who were normal in weight and who were overweight. The intraclass correlation coefficient used to assess measurement accuracy for width and EAPL were 0.985 (95% CI, 0.978–0.989) and 0.979 (95% CI, 0.969–0.986) which reflects excellent reliability.¹²

There were no significant differences between the atlas width of normal and overweight male individuals (P = 0.278) and

Table 2. Demographic Characteristics of the Overweight Patients

	Male (n = 31)		Female (n = 30)		P Value
	Mean ± SD	Min-Max	Mean ± SD	Min-Max	
Age (years)	38.8 ± 2.5	31–45	38.2 ± 3.6	30–44	0.448
Height (cm)	176.9 ± 4.6	170–186	164.3 ± 4.0	159–170	<0.001*
Weight (kg)	82.8 ± 4.0	75–92	70.2 ± 3.4	65–76	<0.001*
BMI (kg/m ²)	26.6 ± 0.4	26.7–27.1	26.2 ± 0.6	25.5–28.9	0.008*

BMI, body mass index; SD, standard deviation; Min, minimum; Max, maximum.
*Statistically significant.

Table 3. Descriptive Statistics of the Atlas Parameters in Normal Weight Patients (cm)

	Male		Female		P Value
	Mean ± SD	Min-Max	Mean ± SD	Min-Max	
Width	7.2 ± 0.5	5.7–8.1	6.7 ± 0.4	6.0–7.6	<0.001*
EAPL	4.4 ± 0.4	3.2–5.2	3.9 ± 0.3	3.1–4.5	<0.001*

EAPL, external anteroposterior length; SD, Standard Deviation; Min, Minimum; Max, maximum.
*Statistically significant.

between the width of normal and overweight female individuals ($P = 0.350$). We also found no significant differences between the EAPL of normal and overweight male individuals ($P = 0.165$), and between the EAPL of normal and overweight female individuals ($P = 0.502$).

No significant correlations were found between the height, weight, and BMI and the width and EAPL in both normal and overweight male and female patients. Nevertheless, we found significant correlations between the width and EAPL in normal weight male patients ($r_s = 0.761$, $P < 0.001$), normal weight female patients ($r_s = 0.642$, $P < 0.001$), overweight male patients ($r_s = 0.591$, $P < 0.001$) and overweight female patients ($r_s = 0.454$, $P = 0.012$).

DISCUSSION

The study aimed to examine the effects of height, weight, BMI, and sex on atlas morphometry and showed that there is sex-related dimorphism in atlas width and EAPL in both normal and overweight subjects.

In this context, it has been said that the morphometric parameters of the atlas vertebra are important for preoperative assessment.⁶ On the other hand, obesity is considered a risk factor due to the technical difficulties and postoperative complications that may arise in spine surgery.¹³ In particular, anterior cervical discectomy and fusion¹⁴ and cervical disc arthroplasty are frequently used procedures,¹⁵ and the literature states that obesity should be taken into consideration in patient and also in surgical method selection.¹³ Therefore, understanding how the anatomical structures in the region are affected by the increase in weight and BMI may help

Table 4. Descriptive Statistics of the Atlas Parameters in Overweight Patients (cm)

	Male		Female		P Value
	Mean ± SD	Min-Max	Mean ± SD	Min-Max	
Width	7.4 ± 0.3	6.8–8.0	6.6 ± 0.3	6.0–7.2	<0.001*
EAPL	4.5 ± 0.3	3.7–5.2	3.8 ± 0.3	3.2–4.6	<0.001*

EAPL, external anteroposterior length; SD, Standard Deviation; Min, Minimum; Max, Maximum.
*Statistically significant.

reduce complications.¹⁵ Nevertheless, we found no significant differences in width and EAPL between normal and overweight patients, thus it seems that overweight does not affect the atlas morphometry in adults of similar age.

On the other hand, we see that the correlation between the atlas width and EAPL is presented in both normal and overweight individuals. Thus, being overweight seems not to affect the correlation between the atlas width and EAPL.

Luo and Lee¹⁶ reported that, in addition to BMI, visceral adipose tissue mass is a more dangerous factor for vertebral fractures. In our study, we observed that BMI was higher in male individuals, regardless of whether they had normal weight or were overweight, and although our patients did not have any vertebral pathology, we observed differences in atlas morphometry. Nevertheless, we did not analyze the visceral adipose tissue mass. In addition, weight may affect BMI values in different manners: For example, the same high BMI value may be due to the accumulation of adipose tissue in sedentary patients, and in patients who increase their weight due to physical activity of their muscle while training bodybuilding. Regarding this issue about musculature, the muscles that provide head extension are the suboccipital muscles, which include the rectus capitis posterior major, rectus capitis posterior minor, obliquus capitis inferior, and obliquus capitis superior muscles. Except for the obliquus capitis inferior muscle, the others are extensors, and their origin or insertion points are the transverse process.¹⁷ Thus, we believe that neck muscle changes may be one of the possible factors affecting the transverse process and, subsequently, the atlas morphology. Nevertheless, specific research analyzing these items is needed.

There is literature suggesting that the fatty tissue around the vertebrae may provide physical support for the neck. However, this has also been reported to have negative effects on bone metabolism and bone structure.¹⁸ The different fat metabolism in male and female individuals likely causes the bones to exhibit different morphologic appearances.

The values we obtained were similar to those presented by other authors^{6,7,19–21} in research carried out in samples of known and unknown sex and age, and as we have observed it seems that male patients had higher average width and EAPL values than female patients.^{6,7}

There is agreement, however, among researchers about the importance of a precise preoperative CT imaging knowing of atlas morphometry in order to reduce surgical risks^{22,23} during C1 lamina screw procedures, because incorrect screwing may cause damage to the vertebral artery, C1–C2 nerve roots, and dural sac.⁸ Thus, we believe our research adds to the body of the knowledge of atlas anatomy and morphometry needed to prevent and avoid cervical spine surgical complications.

Limitations

One of this study's limitations is its small sample size. Another important limitation for the generalizability of this study is that all CT scans were obtained in cancer patients suspected to have metastasis. In addition, we only examined adult patients with a similar age range. Another limitation is that the sample group did not include low-weight or obese individuals and that we do not know the changes in weight during the years before the CT scans were carried out. Studies with larger sample sizes and

analyzing the weight and BMI changes during the life span are needed to understand the real impact of weight changes on the atlas morphometry.

CONCLUSIONS

We have demonstrated that there is sexual dimorphism in atlas morphometry in normal-weight and overweight individuals, and that there is a correlation between width and EAPL in both normal and overweight individuals. We observed that being overweight does not affect the correlation between atlas width and EAPL. We also found that there are no correlations between height, weight, and BMI and width and EAPL in normal and overweight individuals.

CRedit AUTHORSHIP CONTRIBUTION STATEMENT

Nilgün Tuncel Çini: Validation, Project administration, Formal analysis, Conceptualization. **Mathias Orellana-Donoso:** Writing – review & editing, Visualization, Software, Funding acquisition,

Conceptualization. **Guinevere Granite:** Supervision, Methodology, Funding acquisition, Data curation. **Pablo Nova-Baeza:** Writing – original draft, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis. **Federico Mata-Escolano:** Validation, Software, Project administration, Formal analysis. **Esther Blanco-Perez:** Validation, Supervision, Software, Investigation, Data curation. **Juan José Valenzuela-Fuenzalida:** Writing – original draft, Visualization, Validation, Supervision, Funding acquisition, Formal analysis, Conceptualization. **Maria Piagkou:** Visualization, Supervision, Methodology, Formal analysis, Data curation. **George Triantafyllou:** Writing – review & editing, Writing – original draft, Validation, Software, Resources, Data curation. **Marko Konschake:** Writing – review & editing, Writing – original draft, Visualization, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Juan A. Sanchez-Gimeno:** Writing – original draft, Validation, Supervision, Software, Resources, Project administration, Formal analysis, Data curation, Conceptualization.

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Data Availability Statement: The datasets generated and/or analyzed during this study are not publicly available, as CT data and DICOM headers contain patient information that could compromise the privacy of research participants. Data can be obtained on reasonable requests from the corresponding author.

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