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Measuring Craniovertebral Angle Reference Values in Adults Using Kinovea Software

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Abstract: The clinical examination of patients with cervical spine pathology includes measures of posture, mobility, strength, and stability. The forward head position as measured by craniovertebral angle (CVA) has been suggested as a risk factor for cervical spine pathology. The purpose of this study was to describe CVA reference values in healthy adults and assess the relationship with age and sex. This prospective cross-sectional observational study measured the CVA in 122 healthy adults using digital analysis of a lateral view photograph. To facilitate this analysis, a marker was placed at the level of the C7 vertebra, with the tragus of the ear visible in the photograph. The CVA was measured using Kinovea 0.8.15 software, where the CVA was calculated using the intersection of a horizontal line with a line joining the spinous process of C7 and the tragus of the ear. Mean CVA values were 48.76° (6.77) across all participants, 50.07° (6.63) for females, and 47.46° (6.71) for males. Linear regression analysis indicated significant relationships with age and with sex. The study established CVA reference values in healthy adults and identified a significant difference in head position between males and females and a 1.6° decrease in CVA per decade of increased age.

Keywords: craniovertebral angle; head; neck; posture; cervical vertebrae; reference values; photogrammetry

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1. Introduction

The clinical examination of patients with cervical spine pathology often includes measures of posture, mobility, strength, and stability [1–3]. With regard to posture, the forward head position has been suggested as a risk factor for the development of cervical spine pathology [4–7]. Several articles and meta-analyses in recent years have studied the relationship between forward head posture (FHP) and various head and neck conditions. These include a variety of cervical spine pathologies, headaches, temporal mandibular disfunction, visual disturbances, tinnitus, and changes in the activity of facial and cranial muscles leading to altered sleep quality [4–16]. Recently, forward head posture has been proposed as accompanying not only cervicogenic headaches but also tension-type headaches in patients with neck pain and cervical range of motion loss [12].

Forward head posture is characterized by the extension of the upper cervical spine (C0 to C3 cervical segments) and flexion of the lower cervical and upper thoracic segments. This position implies an anterior displacement of the center of gravity of the head in relation to the typical axis of motion for the flexion and extension of the vertebral column [17].

It has been suggested that increased thoracic kyphosis could facilitate a forward head posture [18,19].

Forward head posture can affect the muscular balance of the neck, head, shoulder girdle, and upper thoracic muscles due to a combination of shortened and overactivated muscles, and weak and lengthened muscles. The muscles prone to be shortened and overactivated are the suboccipitals, sternocleidomastoid, levator scapula, upper trapezius, scalenes, and pectoralis major and minor bilaterally [20]. In addition, muscles that tend to be weak and lengthened are the deep neck flexors, lower trapezius, and rhomboids bilaterally [20]. Finally, an increase in masticatory muscle electromyographic activity on the same side of the upper trapezius muscle myofascial trigger points has been identified [11].

The combination of forward head posture with thoracic kyphosis and the protraction of the shoulder girdles has been termed "upper crossed syndrome" by Janda [21]. This syndrome not only impacts neck and shoulder function but also may decrease the forced vital capacity and one-second expiratory volume due to spinal and rib cage motion restriction and posture alterations [22,23]. Other functions like proprioception could be altered by changes in the head position leading to fatigue in other muscles, coordination deficits, and dizziness [24].

The method most frequently used to measure head posture is the craniovertebral angle (CVA), defined as the angle of the line passing through the tragus of the ear and the spinous process of the seventh cervical vertebra with respect to the horizontal. This angle represents the position of the head in relation to the position of C7 vertebra, with a smaller angle representing a greater forward head position, and a higher craniovertebral angle representing a more erected position with the head closer to the plumb line as the craniovertebral angle is increased. Traditionally, the forward head posture has been measured using a plumb line and a tape measure or with a goniometer. With the emergence of commercially available high-speed motion capture cameras, powerful computer systems, and image processing software, more precise measurements of forward head postures are now possible. For example, Kinovea, a free-to-use and open-source software, has been shown to provide good reliability compared with three-dimensional optical motion capture systems [25,26].

Kinovea is a two-dimension motion analysis software widely used to analyze movement and measure angles in digital images like photographs and videos [25]. This software does not need the use of markers to make measurements, however, its reliability does improve when markers are used [26]. Examples of Kinovea's use in assessing motion include estimating body segment movements during falls [27], the height and velocity of vertical jumps [28], neck movement in the sagittal plane [29], knee angles during a variety of movements [30], and hip and knee kinematics in patients with low back pain [31].

Mahmoud et al. (2019) conducted a review and meta-analysis to investigate the relationship between neck pain and forward head posture [4]. When all age groups were analyzed together, there were no statistically significant differences in forward head posture between symptomatic and asymptomatic groups across the seven studies. However, when studies including adolescent or elderly participants were removed, a statistically significant mean difference of 4.84° (95% CI 0.14, 9.54) was identified between groups, suggesting that age may be a confounding factor in the relationship between forward head posture and neck pain. The same review reported a statistically significant correlation between forward head posture and neck pain intensity, and between forward head posture and disability as measured by the Neck Disability Index (NDI) [4]. A meta-analysis by Andias and Silva (2019) reported no difference in posture between adolescents with neck pain and asymptomatic adolescents [15]. However, their analysis included three low-quality studies with high heterogeneity of study data, which limits the reliability of their results [15].

Literature studying the relationship between head position and headaches is highly variable. A low level of evidence exists suggesting that individuals with tension headaches have a more forward head posture than those without tension headaches [6]. In the case of migraine headaches, moderate evidence suggests there is no difference in head position compared with asymptomatic subjects [6,16]. With regard to primary headaches, the forward head position was greater in individuals with chronic headaches than in those with episodic headaches [7]. In the case of head position and cervicogenic headaches, authors of one previous review were unable to perform a meta-analysis due to the low methodological quality of the available studies [16].

Meta-analyses show great heterogeneity in the results of studies investigating relationships between craniovertebral angle and neck pain or headaches. Despite this, relationships of varying strength have been reported between increased forward head posture (decreased craniovertebral angle) and neck pain, tension headaches, and primary chronic headaches. The lack of relationship reported between forward head posture and neck pain in the adolescent population suggests that age may be a confounding variable with respect to the craniovertebral angle. One existing meta-analysis presents valuable accumulated samples of craniovertebral angle values; however, the report does not include accumulated averages from all studies in the analysis [4]. Furthermore, no studies investigating the effect of age and sex on craniovertebral angle were identified. Therefore, it would benefit clinicians and researchers to establish the craniovertebral angle reference values in a healthy population and to investigate the effect of age and sex on head position in individuals without cervical pathology.

The purpose of the present study is to identify craniovertebral angle reference values in healthy adults and describe the effect of age and sex on head position in the same population as measured by the craniovertebral angle. The authors hypothesize that there is a relationship between age, sex, and head position measured by craniovertebral angle in healthy adults.

2. Materials and Methods

2.1. Design and Sample Selection

This cross-sectional observational study was approved by the Universitat Internacional de Catalunya Ethics Committee (FIS-2020-03 2 November 2020). Volunteers were recruited through an email disseminated to faculty members and students of the Universitat Internacional de Catalunya and paper advertisements posted around campus. The primary investigator screened the eligibility of each individual interested in participating via a phone interview. The sample consisted of men and women between the ages of 18 and 75. Those who met one or more of the following criteria according to self-report were excluded: neck pain requiring treatment by a health care provider in the last year, history of surgery in the cervical region, history of headaches more often than once per month, known congenital differences in the cervical spine, head trauma or whiplash within the last year, presence of chronic systemic conditions or acute infections at the time of data collection, pregnancy (confirmed or suspected), and language limitations that would not allow for informed consent in Spanish. Participants were also excluded if they were unable to perform any of the evaluation techniques during the study and/or had a positive result on any of the cervical spine stability tests during data collection.

2.2. Sample Size Calculation

Sample size was calculated using the Select Statistical Services online calculator to obtain a population mean [14,32]. A margin of error of five degrees with a 95% confidence level was used. The population considered was 46 million, with a population variance of 63.52 obtained from the review and meta-analysis of Mahmoud et al. (2019), taking into account the worst situation (SD 7.97°) from Mani et al. (2017) [4,33]. The result of the sample size calculation was 10 participants; therefore, authors recruited 10 volunteers of each sex for each age group, resulting in a total of 120 participants sought.

2.3. Data Collection

Each eligible participant attended one data collection session at the Universistat Internacional de Catalunya physiotherapy functional assessment room. Following completion of informed consent, the following data were obtained from each participant during an interview: age (years), sex, medication use, presence of neck pain in the last year, presence of neck pain at the time of the interview, hours per day of computer or mobile device screen use, hours per day spent sitting, hours per week of physical activity, presence of impaired vision, and use of dental hardware to manage the presence of bruxism. Participants then completed one digital questionnaire to assess depression and anxiety levels, the Hospital Anxiety and Depression Scale (HADS), and a second digital questionnaire to assess the degree of disability related to neck pain, the Neck Disability Index (NDI) [34,35].

The HADS is a scale used to evaluate depression and anxiety. It evaluates a total of 14 items: seven items about anxiety and seven about depression. The scale asks the participant to consider the last week when completing the questionnaire. Each item has four Likert-type options that score from 0 to 3 points, with a higher score representing a greater level of depression and/or anxiety and a maximum score of 42 points. The validated Spanish version has shown a very good reliability with intraclass correlation coefficients (ICC) from 0.85 to 0.91 [36,37].

The NDI is a questionnaire with 10 items that score from 0 to 5 based on six response options, with a total possible score of 50 points. This questionnaire evaluates disability based on the impact of neck pain in daily activities and social relationships. The degree of disability is given in accordance with the score. A higher score indicates greater disability. The test demonstrates a high test–retest reliability with ICC 0.88 [35].

Measurement of the craniovertebral angle was performed using digital image analysis of a lateral view photograph of each participant seated in the same standard chair. The participant was asked to position him/herself in a relaxed posture with the thoracic and lumbar regions contacting the backrest, eye gaze to the horizon, and both feet resting on the floor with their knees flexed 90°. A Sony DSC-W830 camera (Sony Corporation, Tokyo, Japan) was placed one meter from the participant on a level tripod at the participant's shoulder height. To facilitate measurement using the software, a marker was placed with adhesive tape at the level of the C7 vertebra and it was ensured that the tragus of the participant's ear was visible in the photo frame. Identification of the C7 vertebrae was performed using active cervical rotation as described elsewhere [10,38]. The image was analyzed using Kinovea 0.8.15 software, considering the craniovertebral angle as the angle measured between a horizontal line and the line that joins the spinous process of C7 and the tragus of the ear (Figures 1 and 2) [39,40].

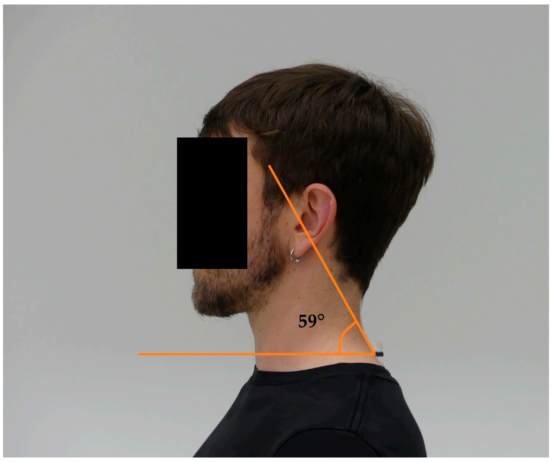

Figure 1. Cranial vertebral angle (CVA) measurement using photograph and digital measurement software.

Figure 2. Detail of equipment setup to measure CVA.

2.4. Data Analysis

Statistical analysis was performed using SPSS 20.0 statistical software. Descriptive analysis including frequency, percentage, mean, and standard deviation was performed for the independent and dependent variables.

Linear regression models (LRM) were developed to understand the relationship of age and sex with the craniovertebral angle. Once the models for age and sex were developed, adjusted models were developed taking into account all the other independent variables studied. Adjusted models were developed by first performing a linear regression model for each independent variable, then the independent variables that returned a $p < 0.05$ were introduced into the new model while maintaining the main predictor variable (age or sex). The linear regression coefficient represents the difference between groups in the same unit and the variable considered in the model. Additionally, 95% confidence intervals were obtained. The normality assumption of the regression residuals was assessed visually by means of the graphs of predicted values on the x-axis and residual values on the y-axis. For the assumption to be met, the points had to conform to the normal line. The homoscedasticity assumption was assessed visually by scatter plots of the standardized predicted values on the x-axis and the standardized residual values on the y-axis. The assumption was considered fulfilled when the scatter of the points was random without a cone appearance. The absence of collinearity of the predictor variables was confirmed by the variance inflation value (VIF) statistic. The assumption was fulfilled when the VIF value was less than 5, with the ideal value being close to 1. Linear regression coefficients with 95% confidence intervals and their significance values are presented in the Results Section.

Mean comparisons between men and women by age strata were made through the Student t test or Mann–Whitney U test considering normality and homoscedasticity.

3. Results

A total of 128 volunteers were recruited for the study, 122 of which met the inclusion criteria and gave consent to participate. The CONSORT flowchart (Figure 3) illustrates this process and reasons for participant exclusion. The reasons for exclusion were headaches more than once per month (three participants), a history of cervical spine surgery (one participant), and having received medical care for a cervical complaint in the last year (two participants). Participant characteristics are summarized in Tables 1 and 2. The sample consisted of 50% men and 50% women with a mean age of 45.16 (16.76) years. Each of the six age groups was composed of 10–11 participants. Forty-eight participants (39.3%) reported having neck pain in the last year, 12 (9.8%) reported neck pain on the date of evaluation, and the mean NDI score was 1.80 (2.65) indicating no associated disability.

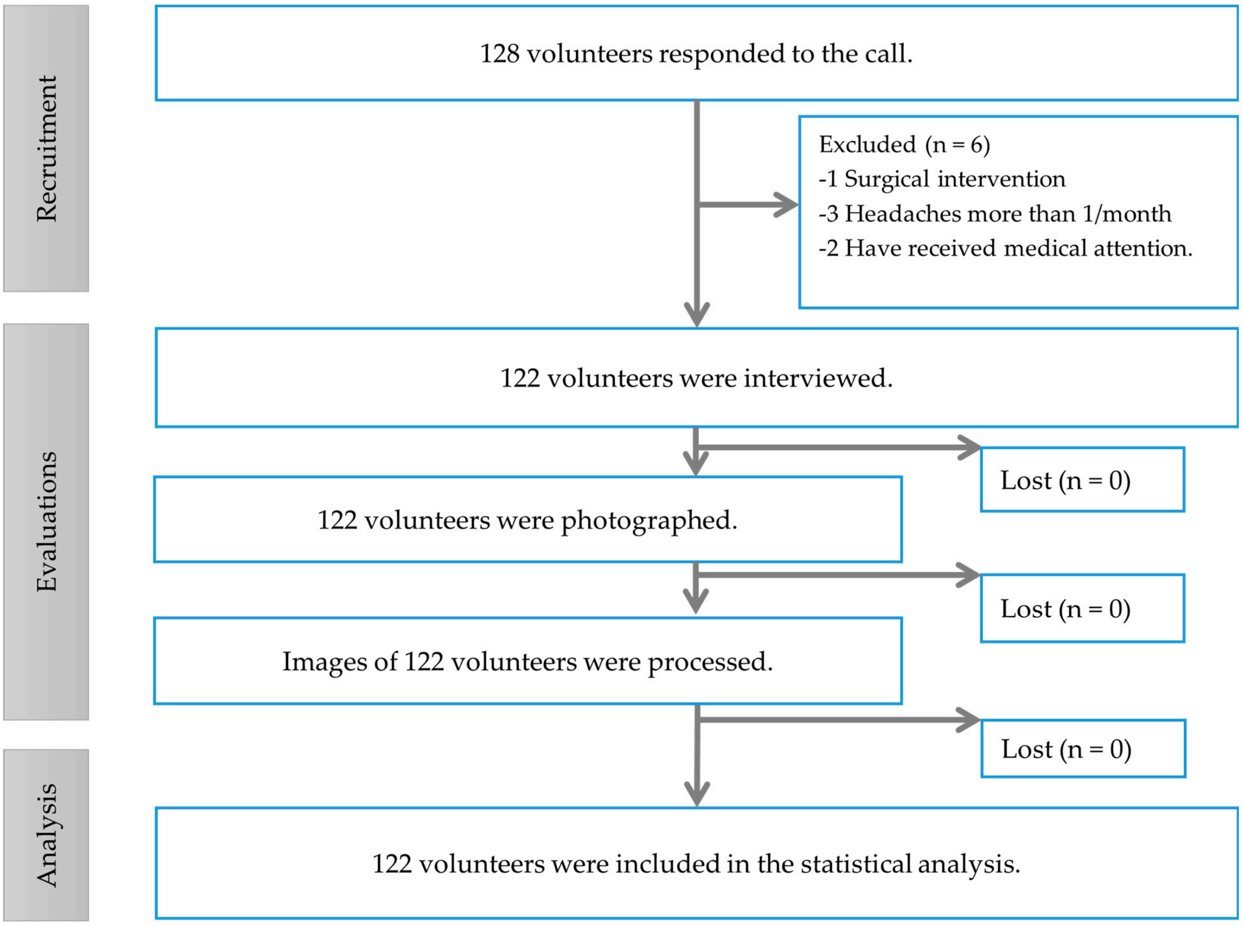

Figure 3. CONSORT flow chart.

Table 1. Descriptive data for quantitative independent variables, n = 122.

	Minimum	Maximum	Mean	Standard Deviation
Age (years)	18	75	45.16	16.76
Hours of use of screens/day	0.5	14	6.61	3.53
Sitting hours/day	1	15	7.49	3.31
Hours of physical activity/week	0	40	7.26	6.84
Days of physical activity/week	0	7	4.17	2.27
HADS tot (max. 42)	0	25	6.99	4.68
NDI tot (max. 50)	0	13	1.80	2.65

HADS: Hospital Anxiety and Depression Scale, NDI: Neck Disability Index.

Table 2. Descriptive data for categoric independent variables, n = 122.

	Frequency	Percentage
Male	61	50
Female	61	50
Visual impairment	83	68
Dental splint	29	23.8
Medication use	34	27.9
Neck pain during last year	48	39.3
Current neck pain	12	9.8

The mean craniovertebral angle was 48.76° (6.77) for all participants, 47.46° (6.71) for males, and 50.07° (6.63) for females (Table 3). Unadjusted LRM by sex demonstrated a significant linear regression coefficient of −2.61° (95% CI −5, −0.22), indicating a more forward head in males (Table 4). When adjusted for the other independent variables that showed significance in the modeling process (age, medication intake) the linear regression coefficient between groups was −2.46° (95% CI −4.52, −0.4) (Table 4). The results of the analysis performed between men and women by age group show significant differences just for 36–45 and 46–55 age groups (Table 5 and Figure 4). Table 6 displays the mean craniovertebral angle by age group and Figure 5 the distribution of craniovertebral angle by age group. Unadjusted LRM by age demonstrated a significant mean decrease of 1.92° (95% CI 2.53, 1.29) per decade, and when adjusted for sex and medication intake demonstrated a significant mean decrease of 1.6° (95% CI 2.27, 0.93) per decade (Table 7).

Table 3. CVA values in degrees.

	N	Mean (SD)	Min	Max
Whole sample	122	48.76° (6.77)	32.00	64.00
Men	61	47.46° (6.71)	35.00	64.00
Women	61	50.07° (6.63)	32.00	63.00

CVA: craniovertebral angle, SD: standard deviation, N: number.

Table 4. Linear regression of CVA by sex.

	Value (95% CI)	*p*-Value
Unadjusted difference	−2.61° (−5, −0.22)	0.033
Adjusted difference *	−2.46° (−4.52, −0.4)	0.020

CVA: craniovertebral angle, * adjusted by age group and medication intake.

Table 5. Mean CVA values by age group and sex.

	18–25		26–35		36–45		46–55		56–65		66–75	
	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women	Men
CVA mean (SD) (degrees)	54.5 (5.32)	50.6 (7.76)	50.64 (5.7)	54.3 (3.89)	52.3 (3.06)	46.6 (5.99)	50.9 (7.75)	46.64 (3.75)	48.5 (6.84)	44.6 (6.1)	43.5 (5.74)	42.1 (5.55)
Mean difference CI 95%	−8.17, 0.84		−2.35, 10.15		0, 11 [b]		2, 9 [b]		−2.18, 9.98		−3.9, 6.7	
p value	0.105 [a]		0.206 [a]		0.037 *		0.016 *		0.195 [a]		0.586 [a]	

CVA: craniovertebral angle, SD: standard deviation, [a] Student *t* test, [b] Hodges–Lehman median difference, * Mann–Whitney U test.

Table 6. Mean CVA values by age group.

	18–25	26–35	36–45	46–55	56–65	66–75
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
CVA (degrees)	52.55 (6.78)	52.38 (5.15)	49.45 (5.47)	48.67 (6.23)	46.55 (6.61)	42.80 (5.54)

CVA: craniovertebral angle, SD: standard deviation.

Table 7. Linear regression of CVA by age.

	Value (95% CI)	*p*-Value
Unadjusted difference	−1.92° (−2.54, −1.29)	0.000
Adjusted difference *	−1.6° (−2.27, −0.93)	0.000

CVA: craniovertebral angle, * adjusted by sex and medication intake.

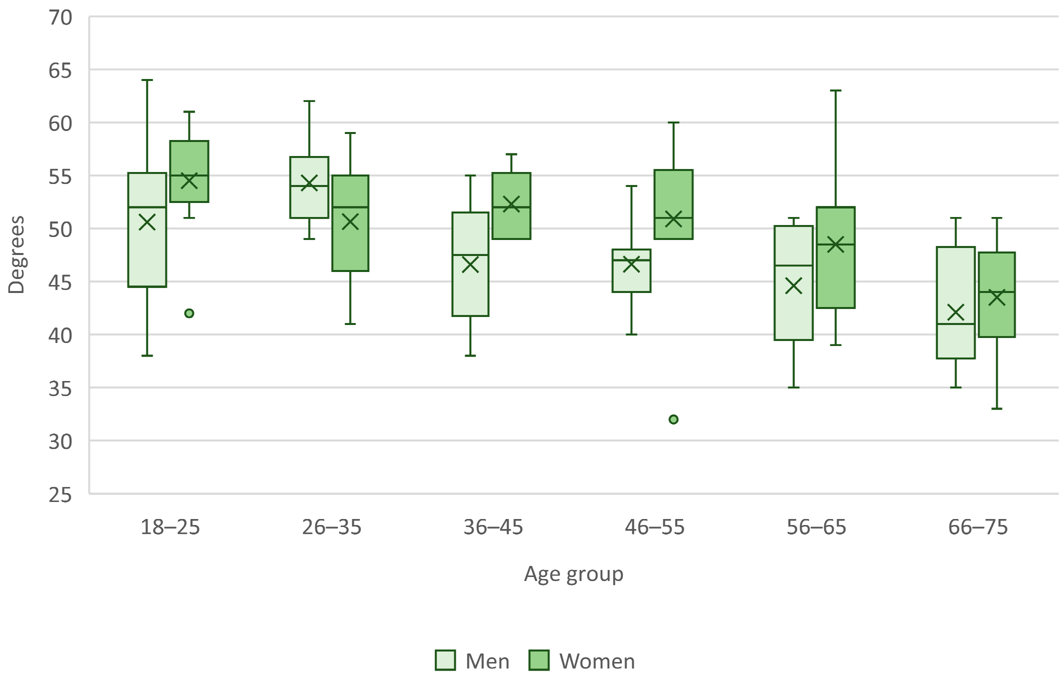

Figure 4. Distribution of CVA by age and sex.

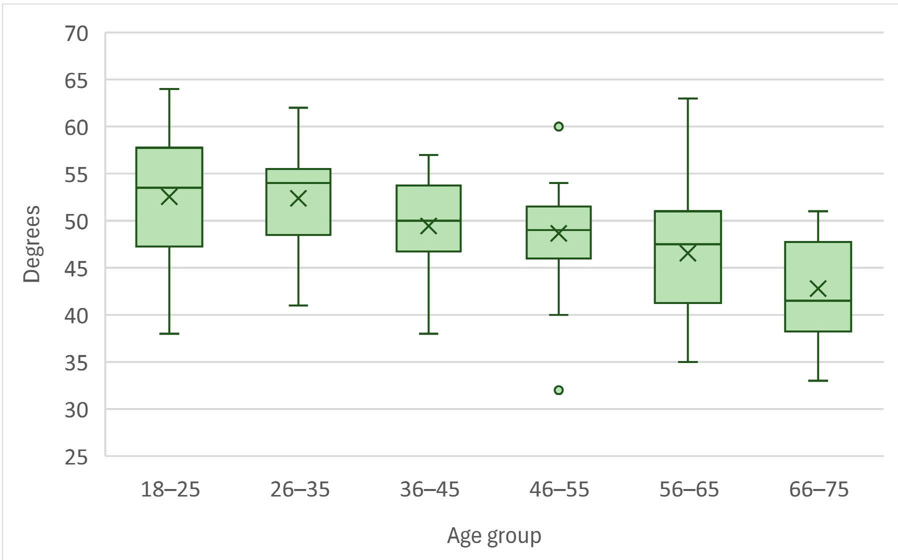

Figure 5. Distribution of CVA stratified by age.

4. Discussion

The purposes of this study were to identify craniovertebral angle reference values in healthy adults and describe the effect of age and sex on head position measured by craniovertebral angle in the same population. The study sample of 122 healthy adults demonstrated a mean craniovertebral angle of 48.76° (6.77), which is similar to values reported in previous meta-analyses [4,6].

Linear regression analysis in the present study indicated a lower craniovertebral angle in men compared to women with a difference of 2.46° (95% CI −4.52, −0.4 $p < 0.05$). In contrast, no significant differences were found when the comparison was made between sex by each age strata, except for the 36–45 and 46–55 age groups. This is likely due to the small size of each subgroup when considering both age and sex. Differences between groups and linear regression coefficients, although significant, were small in size. Also, a significant reduction in the craniovertebral angle of 1.6° per decade of age was shown (95% CI 2.27, 0.93 $p < 0.001$). Despite its small size, it has an important effect across all age groups, reducing the craniovertebral angle by about 10 degrees. No prior studies directly exploring the relationship between craniovertebral angle and age or sex were identified for comparison. However, our findings align with the meta-analysis by Mahmoud et al. (2019), which differentiated between adolescent and adult participants and raised the possibility of age-related differences in the craniovertebral angle as a confounding factor in the study of the relationship between forward head posture and neck pain [4].

A 2023 study by Zarate et al. investigating the relationship between age, sex, and sagittal plane cervical range of motion identified a significant decrease in active range of motion with increasing age, and significantly less upper cervical and global cervical spine extension in males compared with females [41]. When considered in combination with the present study, these results suggest that a relationship may also exist between the craniovertebral angle and one or more sagittal plane cervical active range of motion values.

The results of the present study may serve as reference values for future research investigating sagittal plane head position in the presence of cervical spine pathology and associated functional limitations and disability. Furthermore, the reference values may aid researchers aiming to investigate whether physiotherapy interventions to address non-structural causes of forward head posture are effective for changing head position and/or reducing neck pain, headaches, or associated disabilities.

Limitations

Since cross-sectional studies identify relationships between the variables studied, this study cannot establish a cause–effect relationship. Extrapolation of the results is limited to populations meeting the inclusion criteria due to the use of convenience sampling in a university community with specific socioeconomic and employment characteristics that could have introduced a selection bias. External validity of the results could be limited because a single examiner performed all the procedures and measurements and was aware of the age and sex of each participant. It would be beneficial for future studies to include multiple evaluators blinded to the measurements using digital tools to avoid this potential bias.

5. Conclusions

Reference values for sagittal plane head posture in healthy adults have been determined using photograph digital processing measurement of the craniovertebral angle. The mean value has been established for all participants, for both females and males. The values represent a significant difference in head position between males and females. Additionally, age is associated with a 1.6° reduction in the craniovertebral angle per decade of increased age.

Author Contributions: Conceptualization, C.A.Z.-T. and C.H.-G.; Data curation, C.A.Z.-T. and O.L.-L.; Formal analysis, C.A.Z.-T., O.L.-L. and P.R.R.-R.; Investigation, C.A.Z.-T.; Methodology, C.A.Z.-T., O.L.-L. and C.H.-G.; Project administration, C.A.Z.-T. and P.R.R.-R.; Resources, C.A.Z.-T. and P.R.R.-R.; Software, L.B. and J.K.; Supervision, C.A.Z.-T., O.L.-L. and C.H.-G.; Validation, C.A.Z.-T., L.B., J.K. and C.H.-G.; Visualization, C.A.Z.-T. and M.H.-S.; Writing—original draft preparation, C.A.Z.-T., O.L.-L., L.B., J.K., M.H.-S. and C.H.-G.; Writing—review and editing, C.A.Z.-T., O.L.-L., L.B., J.K., M.H.-S. and C.H.-G. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Universitat Internacional de Catalunya (FIS-2020-03 2 November 2020).

Informed Consent Statement: Informed consent was obtained from all participants involved in the study.

Data Availability Statement: Anonymized sociodemographic data and dependent variable values are available upon reasonable request to the first author (czarate@uic.es) for the validation of the study results and/or additional analysis of the research.

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