RESEARCH ARTICLE

Reliability of Image J. Software to Evaluate the Craniovertebral Angle in Participants with and without Neck Pain

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Abstract

Objectives: Forward head posture (FHP) is one of the most common postural disorders affecting the head and neck region, typically assessed by measuring the craniovertebral angle (CVA). Selecting an appropriate tool for quantifying this angle is crucial. The primary aim of the present study was to evaluate the reliability of ImageJ software in assessing the CVA in participants with and without neck pain.

Methods: The study included twenty participants with neck pain and twenty without. Reflective markers were placed on the tragus of the ear and the spinous process of C7. Three lateral images were captured from the dominant side while the participants were seated, with measurements taken at two-hour and one-week intervals. The craniovertebral angle (CVA) was then analyzed using ImageJ software.

Results: The Intraclass Correlation Coefficient (ICC) values for both within-day and between-day reliability in both groups ranged from 0.89 to 0.94. The Standard Error of Measurement (SEM) ranged from 0.92° to 1.02°, while the Minimal Detectable Change (MDC) values ranged from 2.56° to 2.84°. Furthermore, the absolute Technical Error of Measurement (TEM) ranged from 0.91° to 1.06°, and the relative TEM (rTEM) ranged from 2.13% to 2.42%.

Conclusion: ImageJ software appears to be a suitable tool for assessing the craniovertebral angle (CVA) in individuals with or without neck pain, demonstrating good to excellent reliability.

Level of evidence: III

Keywords: Cranial, Neck pain, Reliability, Software, Vertebrae

Introduction

Posture is defined as the alignment of body segments maintained over a specific period. When appropriate muscular and skeletal balance is achieved, stress and strain on the spinal column are minimized, resulting in optimal postural alignment. With the increasing use of computers, laptops, and smartphones, individuals tend to spend prolonged periods in a seated position.[1] Repetitive behaviors and sustained poor postures have been associated with the development of neck pain, with its prevalence in the general population reported to range from 14% to 70%.[2,3,4] Forward head posture (FHP) is one of the most common postural abnormalities affecting the head and neck region. It is characterized by anterior positioning of the head relative to the body's vertical center of gravity—where the upper cervical spine is extended and the lower cervical spine is flexed.[5] The prevalence of FHP has been reported to be high across various populations, including students,[6] mobile gamers,[7] and car drivers,[8] with rates ranging from approximately 60% to 70% Postural assessment is a critical

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component of clinical evaluation and plays a significant role in designing effective treatment programs. Forward head posture (FHP) is commonly assessed using the craniovertebral angle (CVA), which is defined in the lateral view as the angle formed between a line connecting the tragus of the ear to the spinous process of C7 and a horizontal line passing through the C7 spinous process.[9] The craniovertebral angle (CVA), commonly used as a criterion for classifying head posture, demonstrates variability across different studies.[6,9-11] Reports indicate that the angle for normal head posture is greater than 53 or 55 degrees, while for FHP, it is less than 44 or 54 degrees.[6,11] Evidence suggests that a CVA greater than 53° or 55° is indicative of normal head posture, whereas values below 44° or 54° are associated with forward head posture (FHP).[12] Collectively, these factors may contribute to the development of neck pain. Several studies have demonstrated a relationship between the craniovertebral angle (CVA) and neck pain, indicating that individuals experiencing neck pain or discomfort tend to exhibit a smaller CVA.[13,14]

Therapists continually seek simpler, safer, more objective, and more reliable tools for evaluating head posture.[15] Given the importance of craniovertebral angle (CVA) assessment in diagnosing forward head posture (FHP), several measurement methods have been identified, including photographic and radiographic techniques,[16] the Electronic Head Posture Instrument,[15] the Modified Head Posture Spinal Curvature Instrument,[17] and various software applications such as AutoCAD,[18] Surgimap,[19] and Image J.[20]

Image J is an image processing and analysis software developed by the National Institutes of Health (NIH) in the United States.[21] While a limited number of studies have investigated the reliability of this software for measuring various parameters, such as joint angles, distances, and lower limb alignment.[22,23]—No study to date has evaluated its reliability in assessing head and neck angles, particularly the craniovertebral angle (CVA). Therefore, the present study aimed to investigate the reliability of ImageJ software in measuring the CVA in individuals with and without neck pain.

Materials and Methods

A total of forty participants (20 with neck pain and 20 without) were included in the present study.[15,22] Informed consent was obtained from all participants after they were informed of their right to withdraw from the study at any time. Ethical approval was granted by the Ethics Committee of the University of Social Welfare and Rehabilitation Sciences, Tehran, Iran (Approval Code: IR.USWR.REC.1402.058).

The inclusion criteria for the asymptomatic group required participants to have no history of neck pain within the past year. For the symptomatic group, participants were required to report neck pain with a minimum intensity of 3 cm on the Visual Analog Scale (VAS) at the time of study enrollment. Exclusion criteria for both groups included a history of cervical fractures or surgeries, structural abnormalities such as scoliosis, and any auditory, visual, or respiratory disorders.[24,25]

Procedure

In the present study, within-day and between-day reliability were assessed. For within-day reliability, two measurements were taken from participants at a two-hour interval on the same day. For between-day reliability, a third measurement was recorded one week later.

Measurement

ImageJ software includes tools for calculating angles between two reference points and features a digitizing function that allows for the determination of two-dimensional coordinates (X, Y) with an accuracy of 0.01 degrees.[21] To measure the craniovertebral angle (CVA), participants were seated on a standard chair with their feet flat on the floor and thighs parallel to the ground. A digital camera (Canon IXUS, Canon, Tokyo, Japan) was positioned 1.5 meters from the dominant side of each participant at shoulder height.[18] To ensure consistent head positioning during measurements, participants were instructed to gaze at a monitor placed directly in front of them. The monitor was positioned 60 cm away from the participant, with its center aligned 20 degrees below the participant's natural line of sight. Before imaging, each participant performed three repetitions of neck flexion and extension to reach a relaxed, natural head position. During these movements, the examiner palpated the most prominent spinous process at the base of the neck—typically corresponding to the seventh cervical vertebra (C7)—using the index finger or thumb.[26] The tragus of the ear on the dominant side and the spinous process of C7 were marked using adhesive markers and double-sided tape. Following marker placement, lateral images were captured and subsequently transferred to a laptop equipped with ImageJ software (version 1.54g). To measure the craniovertebral angle (CVA), the angle measurement tool within the software was selected. From the file menu, the desired image was opened. Using the mouse pointer, the examiner first clicked on the tragus marker and then drew a line to the C7 marker by clicking again at that point. This line, connecting the tragus and the C7 spinous process, was then fixed. Subsequently, a horizontal line was drawn from the C7 spinous process marker, and the software calculated the angle between the two lines, which was recorded as the craniovertebral angle (CVA). Figure 1 illustrates the placement of the markers, with an asterisk (*) indicating the CVA [Figure 1]. Figures 2, 3, and 4 demonstrate the measurement procedure and the CVA values obtained using ImageJ software at three different time points for a single participant [Figures 2, 3, and 4].

Statistical analysis

Data were analyzed using SPSS software (version 26), with a p-value of less than 0.05 considered statistically significant. An independent t-test was conducted to compare baseline characteristics between the two groups. To assess reliability, within-day (comparison between the first and second assessments) and between-day (comparison between the first and third assessments) analyses were performed using Intraclass Correlation Coefficients (ICC), Standard Error of Measurement (SEM), and Minimal Detectable Change (MDC). Additionally, absolute and relative Technical Error of Measurement (TEM and rTEM) were calculated to quantify observer error in recording measurements.[27]

According to Koo et al. (2016), Intraclass Correlation coefficient (ICC) values can be interpreted as follows: values below 0.50 indicate poor reliability; values between 0.50 and 0.75 indicate moderate reliability; values from 0.75 to 0.90 indicate good reliability; and values greater than 0.90 indicate excellent reliability.[27] The Standard Error of Measurement (SEM), Minimal Detectable Change (MDC), and both absolute and relative Technical Error of Measurement (TEM and rTEM) were calculated using the following equations: $SEM = SD\sqrt{(1-ICC)}$

$MDC = SEM \times 1.96 \times \sqrt{2}$

$\text{Absolute } TEM = \sqrt{(\Sigma D^2)/2N}$

$rTEM = TEM/\text{Mean} \times 100$

SD: Standard Deviation (the SD of the First measurement).

D^2: The squared difference between the first and second (or third) measurements.

N: The measured sample size.

Mean: The measurement's average.

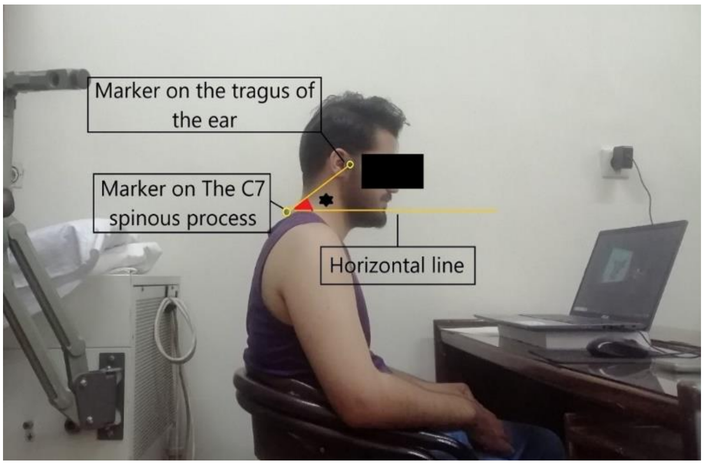

Figure 1. The placement of markers and The Craniovertebral Angle (the asterisk (*))

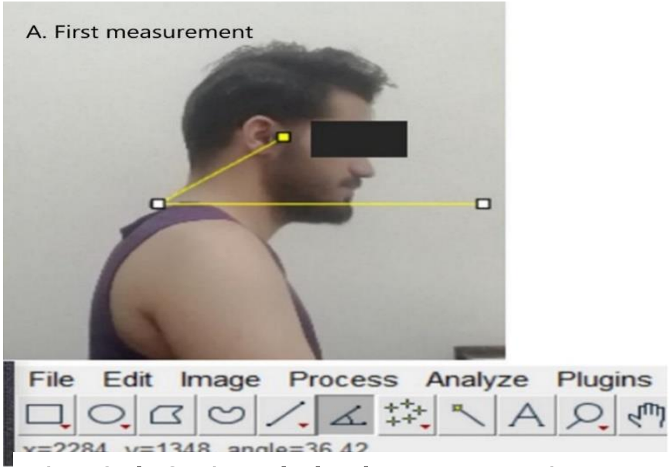

Figure 2. The Craniovertebral Angle measurement using Image J software at the first time point

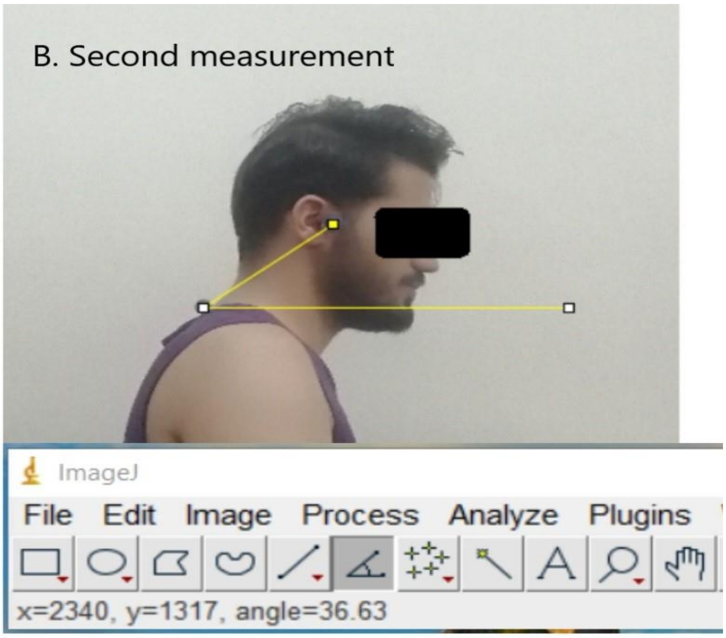

Figure 3. The Craniovertebral Angle measurement using Image J software at the second time point

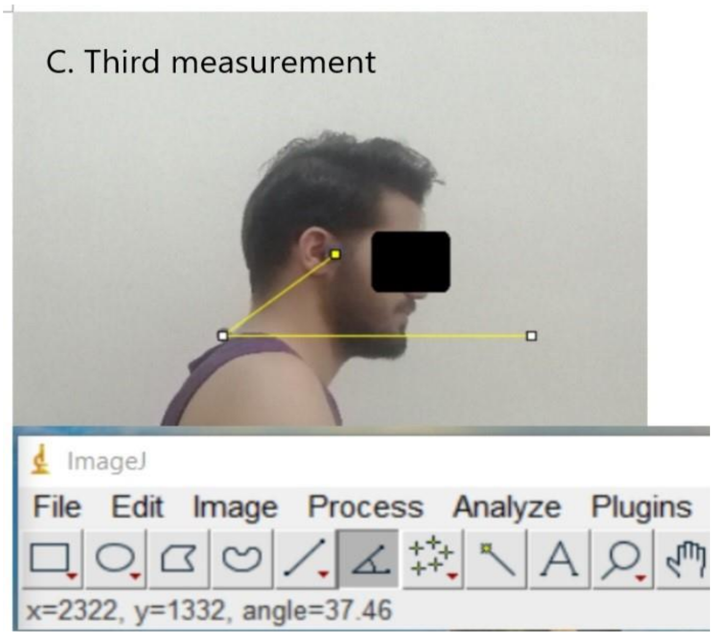

Figure 4. The Craniovertebral Angle measurement using Image J software at the third time point

Results

A total of 40 participants were included in the study, comprising 20 individuals with neck pain (14 women and six men) and 20 without neck pain (12 women and eight men). Demographic characteristics of the participants (mean ± standard deviation), categorized by group (with and without neck pain), along with the results of the independent t-test used to examine differences in age, height, weight, and body mass index (BMI), are presented in [Table 1].

Table 1. Demographic characteristics of both groups

Variables	Group with neck pain Mean±SD	Group without neck pain Mean±SD	P-value*
Age (year)	26.35±2.81	25.55±2.74	0.96
Height (cm)	164.80±9.11	168.40±11.97	0.29
Weight (kg)	66.85±13.60	71.00±11.49	0.53
BMI (kg/m^2)	24.52±4.03	25.24±4.58	0.38

cm: centimeter, kg: kilogram, m: meter, BMI: body mass index, SD: Standard Deviation/ * Independent t-test

As shown in Table 1, there were no statistically significant differences between the two groups in terms of age (p = 0.96), height (p = 0.29), weight (p = 0.53), and body mass index (BMI) (p = 0.38).

The results of within-day and between-day reliability for craniovertebral angle (CVA) measurements are presented in Tables 2 and 3 for participants with and without neck pain, respectively [Tables 2 and 3].

The Intraclass Correlation Coefficient (ICC) value for within-day reliability was 0.94 for the neck pain group and 0.89 for the group without neck pain, with 95% confidence intervals (CI) ranging from 0.86 to 0.97 and 0.76 to 0.95, respectively. For between-day reliability, the ICC was 0.94 for the neck pain group and 0.91 for the group without neck pain, with 95% CI ranges of 0.85 to 0.97 and 0.80 to 0.96, respectively. The Minimal Detectable Change (MDC) at the 95% confidence level ranged from 2.56° to 2.84° across measurements, indicating the threshold beyond which changes can be considered greater than the measurement error. In the neck pain group, the absolute Technical Error of Measurement (TEM) and relative TEM (rTEM) for within-day measurements (first vs. second) were 1.01° and 2.42%, respectively. For between-day measurements (first vs. third), the values were 0.91° and 2.17%, respectively. In the group without neck pain, within-day TEM and rTEM were 1.06° and 2.33%, respectively, while between-day values were 0.97° and 2.13%, respectively.

Table 2. Within and between-day reliability (ICC, SEM, MDC) of CVA in the group with neck pain

Variables		Mean±SD	Within-day(a)					Between-day(b)				
			ICC (%95 CI)	SEM	MDC	TEM	rTEM %	ICC (%95 CI)	SEM	MDC	TEM	rTEM %
CVA (degree)	First measurement	41.97±3.78	0.94 (0.86-0.97)	0.92	2.56	1.01	2.42	0.94 (0.85-0.97)	0.92	2.56	0.91	2.17
	Second measurement	41.40±4.13										
	Third measurement	41.67±3.73										

CVA: Craniovertebral Angle, ICC: Intraclass Correlation Coefficients, SEM: Standard Error of the Mean, MDC: Minimal Detectable Changes, SD: Standard Deviation, CI: Confidence Interval, (a): ICC for the first and second measurement, (b): ICC for the first and third measurement, TEM: Technical Errors of Measurement, rTEM: relative Technical Errors of Measurement

Table 3. Within and between-day reliability (ICC, SEM, MDC) of CVA in the group without neck pain

Variables		Mean±SD	Within-day(a)					Between-day(b)				
			ICC (%95 CI)	SEM	MDC	TEM	rTEM %	ICC (%95 CI)	SEM	MDC	TEM	rTEM %
	First measurement	45.61±3.09										

CVA (degree)	Second measurement	45.17±3.40	0.89 (0.76-0.95)	1.02	2.84	1.06	2.33	0.91 (0.80-0.96)	0.92	2.57	0.97	2.13
	Third measurement	45.77±3.85										

CVA: Craniovertebral Angle, ICC: Intraclass Correlation Coefficients, SEM: Standard Error of the Mean, MDC: Minimal Detectable Changes, SD: Standard Deviation, CI: Confidence Interval, (a): ICC for the first and second measurement, (b): ICC for the first and third measurement, TEM: Technical Errors of Measurement, rTEM: relative Technical Errors of Measurement

Discussion

The present study aimed to assess the reliability of craniovertebral angle (CVA) measurements using ImageJ software in individuals with and without neck pain. To the best of our knowledge, few studies have employed ImageJ for CVA assessment.[20,29] and this appears to be the first study to evaluate its reliability for this specific purpose. The findings demonstrated good to excellent reliability across both within-day and between-day measurements.

Previous studies have examined the reliability of ImageJ software for measuring movement angles, reach distances in two-dimensional motion, and lower limb alignment. The results of the present study regarding CVA measurement are consistent with those reported in earlier research.[22,23,30] For example, Suzuki et al. (2021) assessed the reliability of ImageJ for evaluating reach distance and joint angles during the Functional Reach Test (FRT). The ICC values for three angles—measured between the acromion and malleolus lateralis, acromion and greater trochanter, and greater trochanter and malleolus lateralis—relative to a vertical reference line ranged from 0.86 to 0.95. Additionally, ICC values for distance measurements based on the third metacarpal head, anterior superior iliac spine (ASIS), and greater trochanter ranged from 0.84 to 0.95.[22] Similarly, Ashnagar et al. (2016) investigated the reliability of ImageJ in assessing lower extremity alignment in individuals with and without flatfeet. The ICC values in both groups ranged from 0.82 to 0.92, indicating good to excellent reliability.[23]

Several studies have examined both intra-rater and inter-rater reliability of ImageJ software. Relph et al. (2015) assessed knee joint position sense in 10 asymptomatic participants using ImageJ and reported intra- and inter-rater reliability coefficients of 0.96 and 0.98, respectively.[31] Maeoka et al. (2008) evaluated the reliability of ImageJ for measuring trunk flexion angles during the transition from sitting to standing, and reported ICC values exceeding 0.97 for both intra- and inter-rater reliability.[30] These high ICC values reflect excellent rater consistency and support the reliability of ImageJ in kinematic assessments. The findings of the present study are consistent with those results, demonstrating excellent intra-rater reliability of ImageJ for craniovertebral angle (CVA) measurement.

In the present study, the Standard Error of Measurement (SEM) ranged from 0.92° to 1.02°, while the Minimal Detectable Change (MDC) ranged from 2.56° to 2.84°. These findings suggest that any change in CVA exceeding 2.84°, as measured using ImageJ software, can be considered a true change rather than a result of measurement error. Previous studies assessing the reliability of ImageJ have primarily focused on trunk and lower limb angles,[22,23,30,31] The SEM and MDC values reported in those studies vary widely due to differences in anatomical regions and measurement protocols, and therefore are not directly comparable to the current research. However, other studies have evaluated the reliability of various tools for measuring the craniovertebral angle (CVA). Subbarayalu (2016) assessed the modified Head Posture Spinal Curvature Instrument and reported intra-rater SEM and MDC values of 0.98° and 2.73°, respectively.[17] Gallego et al. (2020) examined a mobile application for CVA assessment, reporting SEM values ranging from 1.79° to 2.13° and MDC values from 4.96° to 5.90°.[32] In another study, Aafreen et al. (2023) evaluated the reliability of the Surgimap software and application for measuring CVA in both sitting and standing positions. Their findings revealed SEM values between 0.2° and 0.3°, and MDC values ranging from 1.3° to 1.7°.[18] Compared to these studies, the SEM and MDC values obtained in the present study for ImageJ software fall within the mid-range of previously reported values, suggesting that ImageJ provides a reasonably reliable alternative for CVA measurement.

The Technical Error of Measurement (TEM) is an index of accuracy used to quantify intra- or inter-evaluator variability.[33] One of the advantages of TEM is that it is expressed in the same units as the measurement itself, facilitating straightforward interpretation. In contrast, the relative TEM (rTEM) represents a unitless measure of precision that is independent of the measurement scale or sample size, allowing for direct comparisons across studies and variables.[27,34] Previous studies evaluating the reliability of ImageJ software did not report absolute or relative TEM values. (Refs) However, according to the criteria proposed by Perini et al. (2005), rTEM values below 7% are considered acceptable for intra-rater assessments.[33] Therefore, based on the findings of the present study, the accuracy of CVA measurements using ImageJ software can be considered acceptable. In other words, the repeated measurements conducted by the same evaluator at different time points demonstrated a high degree of consistency.

Another notable finding of the present study was that the ICC values for both within-day and between-day measurements were higher in the group with neck pain compared to the group without neck pain. A similar pattern was reported by Cheung Lau et al. (2009), who assessed the reliability of an electronic head posture instrument for measuring CVA in two separate groups—with and without neck pain.[15] Their findings showed higher intra- and inter-rater ICC values in the neck pain group. To our knowledge, this is the only study to date that has independently reported reliability values for both groups using a specific CVA measurement tool. In contrast, Subbarayalu (2016) included participants with and without neck pain in the same sample but reported reliability values in aggregate, without stratifying by group. [17] Given the limited number of studies comparing these groups separately, it is difficult to draw definitive conclusions regarding the observed differences in ICC values. One possible explanation could be related to biomechanical or neuromuscular characteristics common among individuals with neck pain, such as altered muscle strength, endurance, or compensatory stabilization strategies. Further research is needed to explore these potential mechanisms.

Limitations and Suggestions

Although the present study offers a novel contribution to the field, several limitations should be acknowledged. First, the relatively low average age of participants limits the generalizability of the findings to older populations. Second, inter-rater reliability was not assessed, which restricts conclusions regarding measurement consistency across different evaluators. Third, CVA was measured only in the seated position. Previous research has shown that the mean CVA in the standing posture is, on average, more than 4 degrees greater than in the seated posture.[13] This difference is likely due to the relationship between CVA and spinal alignment, which may vary depending on body posture. Future studies are recommended to include older adults, assess CVA in multiple positions (including standing), and explore additional anatomical angles—particularly in the upper limb region—to provide a more comprehensive understanding of postural assessment.

Conclusion

This study highlights the reliability and precision of ImageJ software in measuring the craniovertebral angle (CVA) in individuals with and without neck pain. The findings demonstrate a high level of measurement consistency, supporting the use of ImageJ as a valid tool for postural assessment in the head and neck region. These results may aid clinicians in accurately identifying postural disorders and in monitoring the effectiveness of therapeutic interventions over time.

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Declaration of Informed Consent: Informed consent was obtained from all subjects. Health, dignity, integrity of the participants was ensured and objectives, procedures, and potential risks and benefits of the study were clearly communicated to them. Participation in this study was completely voluntary, and participants could withdraw from the research at any stage. The names of participants were not published, even in abbreviated form, and all collected data were kept strictly confidential.

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