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# Craniovertebral Angle Measurement with MicroDicom and Digital Photography Method, A Reliability Testing

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## ABSTRACT
***Background:*** *The craniovertebral angle (CVA) is a practical photogrammetric metric for quantifying forward head posture (FHP) in clinical populations, yet reliability data for measurements analyzed with MicroDicom in symptomatic cohorts are limited.* ***Objective:*** *To determine the intra- and inter-rater reliability of CVA measured from standardized digital photographs analyzed with MicroDicom in patients with myofascial pain syndrome (MPS).* ***Methods:*** *In a GRRAS-informed reliability study, 40 adults with MPS were photographed in a standardized seated posture across three consecutive days. Three raters (A–C) independently acquired images (three per day) and measured CVA in MicroDicom 2023.3. For intra-rater reliability, each rater's three day means per participant were analyzed using ICC(3,1) and ICC(3,3). For inter-rater reliability, each rater's grand mean across days was used to estimate ICC(2,1) and ICC(2,3). Absolute error indices (SEM,* MDC95$_{95}$ *CV) and Bland–Altman agreement (bias, 95% limits of agreement [LoA]) were reported. Day effects (within rater) and mean differences between raters were tested with Friedman's test (k=3, df=2).* ***Results:*** *Mean CVA values were similar across raters (A 42.83°, B 42.49°, C 42.68°). Intra-rater reliability was good to excellent (ICC(3,1)=0.865–0.889; ICC(3,3)=0.952–0.960). Inter-rater reliability was excellent (ICC(2,1)=0.960, 95% CI 0.930–0.978; ICC(2,3)=0.986). Absolute error was small (SEM 0.833–0.919°) with* MDC95$_{95}$ *2.31–2.55° (intra-rater) and 2.40° (inter-rater); CV ≈5%. Bland–Altman analyses showed minimal bias (A vs B +0.34°, B vs C −0.19°, A vs C +0.15°) with 95% LoA within ±2.4° and no proportional bias (slopes <0.1). No significant day effects were observed for raters B and C; rater A showed a small, non-significant trend (p=.060). A small between-rater mean difference was statistically detectable ($\chi^2(2)=6.752$, p=.034) but clinically trivial given the high ICCs and narrow LoA.* ***Conclusion:*** *Standardized smartphone photogrammetry analyzed with MicroDicom yields highly reproducible CVA measurements in MPS, with SEM <1° and* MDC95$_{95}$ *≈2.3–2.6°. The protocol is suitable for routine assessment and longitudinal monitoring of FHP in clinical settings, particularly where low-cost, radiation-free methods are preferred. Future work should isolate pure rating agreement using shared images and validate against radiographic or 3D motion-capture references.*

***Keywords***
*Craniovertebral angle; Forward head posture; Reliability; Intraclass correlation; Photogrammetry; Myofascial pain syndrome;*

## INTRODUCTION
Myofascial pain syndrome (MPS) is a chronic musculoskeletal condition characterized by localized muscle pain, myofascial trigger points, and fascial restrictions, often accompanied by referred pain and functional or emotional impairment [23,13]. Postural abnormalities frequently coexist with painful cervical conditions, and forward head posture (FHP)—an anterior translation of the head relative to the shoulders—has been repeatedly associated with neck pain, altered muscle behavior, and limited cervical range of motion [14,20,21]. The craniovertebral angle (CVA) is a widely used photogrammetric metric for quantifying FHP; it is defined as the angle formed by a horizontal line through the spinous process of C7 and a line from C7 to the tragus of the ear, with smaller angles indicating greater forward head translation [22,26]. Although study-specific thresholds vary, cut-offs around 48°–50° are commonly used to classify FHP in clinical and research settings [22].

Multiple methods exist to assess sagittal head–neck alignment, including cephalometric radiography, three-dimensional motion analysis, and two-dimensional photogrammetry. While radiography can serve as a reference standard, its cost, access constraints, and ionizing radiation limit routine clinical use [18]. Photogrammetry using standardized digital photographs is a practical alternative that has demonstrated acceptable validity and reliability when anatomical landmarks are identified consistently and appropriate software is used [5,16,18]. Recent work has extended posture assessment to consumer and computer-vision tools, including smartphone-based applications and tele-rehabilitation workflows, further supporting

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the feasibility of image-based CVA measurement in diverse settings [1–3,9,12]. Nevertheless, evidence on the reliability of CVA measurements derived specifically from MicroDicom—a freely available imaging viewer with angle-measurement functionality—remains limited, particularly in symptomatic populations such as patients with MPS.

Establishing measurement reliability is essential to distinguish true postural change from measurement error. Intra-rater reliability evaluates the consistency of repeated measurements by the same examiner, whereas inter-rater reliability evaluates agreement across different examiners. Best practice recommends transparent planning and reporting of reliability studies (e.g., GRRAS) and the use of appropriate intraclass correlation coefficient (ICC) models tailored to the design and generalizability targets [10,24]. Against this background, the present study aimed to determine the intra- and inter-rater reliability of CVA measured from standardized digital photographs analyzed with MicroDicom software in patients with MPS, following GRRAS recommendations for design, analysis, and reporting [10].

## MATERIALS AND METHODS

This was a reliability study conducted in the Department of Physiotherapy, National Hospital, Bahawalpur, Pakistan. The objective was to determine intra- and inter-rater reliability of the craniovertebral angle (CVA) measured from standardized digital photographs analyzed with MicroDicom (version 2023.3). The study followed the Guidelines for Reporting Reliability and Agreement Studies (GRRAS) in design, analysis, and reporting. All procedures adhered to the Declaration of Helsinki, and ethical approval was obtained from the Institutional Review Board (Ref. No. NOGH/ERC/0125/006). Written informed consent was obtained from all participants.

Inclusion criteria. Adults clinically diagnosed with myofascial pain syndrome (MPS), with mild–to–moderate severity, who provided informed consent. **Exclusion criteria**. History of spinal or cervical surgery; relevant neurological or additional musculoskeletal comorbidities; or any contraindication to digital photography. **Sample size**. A priori calculations for intraclass correlation coefficient (ICC) reliability were based on Walter et al. (1998), assuming 3 repeated measurements/raters ($k = 3$), null ICC ($\rho_0$) = 0.70 versus expected ICC ($\rho_1$) = 0.85, $\alpha = 0.05$ (two-sided) and power = 0.80, yielding $n \approx 22$. We recruited 40 participants to improve precision (narrower 95% CIs). All measurements were obtained in a dedicated room with uniform lighting and a non-reflective white background. Participants sat on a backless stool in a neutral seated posture (knees ~90°, feet flat, arms relaxed) and fixated an eye-level target ~3 m ahead to standardize head position. Two trained physiotherapists palpated and marked the tragus and C7 spinous process with 1 cm circular reflective markers.

A tripod-mounted Samsung Galaxy A35 smartphone (50 MP primary sensor; ~26 mm 35-mm-equivalent focal length; fixed aperture f/1.8) was placed 2.90 m from the participant at shoulder height, with the lens perpendicular to the sagittal plane and centered near the C7 marker to minimize parallax. The device's gyroscope was used to level the camera. No digital zoom was used. The tripod position and participant footprint were taped on the floor to ensure reproducibility across sessions. Each of three raters (A, B, C) independently captured three images per participant on each of three consecutive days. Participants were repositioned between images and between days. De-identified image filenames masked participant identity and session order. Raters were blinded to their own previous values and to the other raters' measurements throughout data collection and analysis.

Images were analyzed with MicroDicom 2023.3. The CVA was defined as the acute angle between (1) a horizontal reference line through the C7 marker and (2) a line joining C7 to the tragus. MicroDicom's angle tool was used for all measurements. For each rater and day, the mean of the three images constituted that rater's day value. Figure 1 illustrates the construction of CVA. (If figures are not included at submission, remove this sentence.) Primary outcomes were intra-rater reliability and inter-rater reliability of CVA. Secondary agreement outcomes included standard error of measurement (SEM), minimum detectable change at 95% confidence ($MDC_{95}$), and coefficients of variation (CV), as well as Bland–Altman mean bias and 95% limits of agreement (LoA).

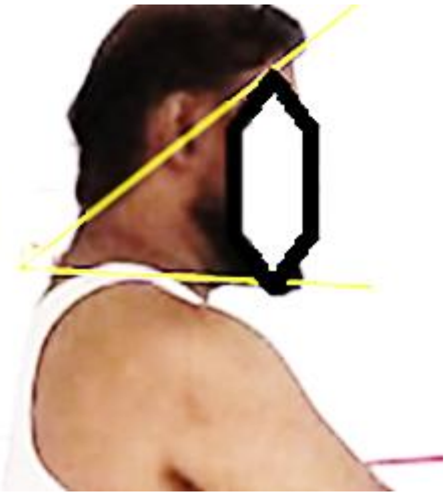

*Figure 1 Measurement of CVA in MicroDicom Software | 41.08°/318.92°*

Statistical analyses were performed in SPSS v26 (IBM) and R v4.3.1 (packages irr and blandr). For reliability, intra-rater analyses used, for each rater, three day values per participant (each day value was the mean of that day's three images) to estimate ICCs across days: ICC(3,1) (two-way mixed-effects, absolute agreement, single-measure) and ICC(3,3) (average of three day values). For inter-rater reliability, each participant's grand mean per rater across the three days was computed, and ICC(2,1) (two-way random-effects, absolute agreement, single-measure) and ICC(2,3) (average of three raters) were estimated. Because each rater captured their own images, inter-rater reliability reflects combined acquisition and rating variability, not pure rating on a shared image set. Normality of participant-level means and model residuals was assessed using Shapiro–Wilk and Kolmogorov–Smirnov tests and by inspecting Q–Q plots/histograms to support parametric ICC modeling. Potential day effects within raters and mean differences between raters were tested using Friedman's test ($k = 3$, $df = 2$); repeated-measures ANOVA would be used where assumptions were fully met, but Friedman's test was applied for consistency and to accommodate mild deviations from normality. Error and agreement indices included SEM = SDpooled * sqrt(1 − ICC), MDC95 = 1.96 * SEM * sqrt(2), and CV = (SDpooled / mean) * 100. Bland–Altman analyses (pairwise between raters) reported mean bias and 95% limits of agreement, with proportional bias examined by regressing differences on means. Two-sided alpha = 0.05 was used. ICCs are reported with 95% confidence intervals, and all angles are in degrees (°).

## RESULTS

Forty patients with myofascial pain syndrome (MPS) were enrolled (mean age 29.03 ± 5.44 years; mean body weight 76.75 ± 17.33 kg; mean BMI 29.32 ± 5.98 kg/m²). Age was approximately normally distributed with most participants between 24–36 years. BMI showed mild positive skew with most values 25–35 kg/m². These characteristics are shown in Figure 2a–c and are relevant because age and adiposity can influence cervical alignment and postural control. As a representative example, the distribution of Rater A's participant-level mean CVA met normality assumptions (Table 1). Similar patterns were observed for the other raters and for model residuals, supporting the use of parametric ICC models.

*Table 1. Descriptive statistics and normality for mean CVA (Rater A)*

| Statistical parameter | Value |
|---|---|
| **Mean CVA (°)** | 42.83 |
| **Standard Deviation (°)** | 2.21 |
| **Standard Error of Mean (°)** | 0.35 |
| **95% CI (°)** | 42.12–43.53 |
| **Skewness** | 0.40 |
| **Kurtosis** | −0.51 |
| **Shapiro–Wilk p-value** | 0.252 |
| **Kolmogorov–Smirnov p-value** | 0.200 |

Note: p > .05 indicates no departure from normality.

Mean CVA values were similar across raters (A: 42.83°; B: 42.49°; C: 42.68°). Single-measure intra-rater reliability was good to excellent for all raters (ICC(3,1) = 0.865–0.889), and averaging three repetitions per rater further improved reliability (ICC(3,3) = 0.952–0.960). Absolute error was small (SEM 0.83–0.92°), with corresponding $MDC95_{95}$ 2.31–2.55° and CV ≈ 5% (Table 2).

*Table 2. Intra-rater (inter-session) reliability metrics*

| Rater | Mean CVA (°) | ICC(3,1) (95% CI) | ICC(3,3) | SEM (°) | $MDC95_{95}$ (°) | CV (%) | p-value |
|---|---|---|---|---|---|---|---|
| **A** | 42.83 | 0.865 (0.778–0.922) | 0.952 | 0.919 | 2.55 | 5.1 | < .001 |
| **B** | 42.49 | 0.885 (0.816–0.933) | 0.958 | 0.878 | 2.43 | 5.0 | < .001 |
| **C** | 42.68 | 0.889 (0.822–0.936) | 0.960 | 0.833 | 2.31 | 4.9 | < .001 |

Notes: ICC (3,1) = two-way mixed, absolute agreement, single measurement; ICC(3,3) = average of 3 repetitions. SEM = SDpooled_\text{pooled}pooled·√(1–ICC). $MDC95_{95}$ 1.96·SEM·√2. Angles in degrees. To probe potential systematic differences across days (three repeated sessions per rater), we used Friedman's test (k = 3 days, df = 2). Results indicated no statistically significant day effect for B or C; A showed a small, non-significant trend (Table 3).

*Table 3. Tests for systematic differences across days (Friedman's test; k = 3, df = 2)*

| Rater | $\chi^2$ | p-value |
|---|---|---|
| **A** | 5.623 | .060 |
| **B** | 1.841 | .398 |
| **C** | 2.661 | .264 |

Inter-rater reliability was computed from day-averaged CVA values per rater and therefore reflects combined acquisition (photography) and rating variability. Agreement was excellent (ICC(2,1) = 0.960, 95% CI 0.930–0.978, p < .001), with improved precision when averaging across raters (ICC (2,3) = 0.986). Absolute error was small (SEM 0.867°), with $MDC95_{95}$ 2.40° and CV 5.0% (Table 4).

*Table 4. Inter-rater reliability metrics (day-averaged values per rater)*

| Metric | Value |
|---|---|
| **Mean CVA across raters (°)** | 42.66 |
| **ICC(2,1) (95% CI)** | 0.960 (0.930–0.978) |
| **ICC(2,3)** | 0.986 |
| **SEM (°)** | 0.867 |
| **$MDC95_{95}$ (°)** | 2.40 |
| **CV (%)** | 5.0 |
| **p-value** | < .001 |

We also tested for mean differences between raters using Friedman's test across the raters' averaged scores (df = 2). A small but statistically significant difference was detected ($\chi^2(2)$=6.752, p=.034). Given the very high ICCs, low SEM/MDC, and tight limits of agreement (below), this difference is not clinically meaningful. Pairwise Bland–Altman analyses showed minimal bias and narrow limits of agreement: A vs B mean bias +0.34°, B vs C −0.19°, and A vs C +0.15°, with 95% LoA within ±2.4° and <5% of points outside the LoA for all pairs; no proportional bias was detected (slopes < 0.1). Intra-rater reliability was good to excellent with ICC(3,1) = 0.865–0.889 and ICC(3,3) = 0.952–0.960, SEM < 1°, and $MDC95_{95}$ ≈ 2.3–2.6°; there were no significant day effects for raters B and C, and rater A showed a small, non-significant trend (p = .060). Inter-rater reliability was excellent with ICC(2,1) = 0.960 (95% CI 0.930–0.978) and ICC(2,3) = 0.986, SEM = 0.867°, MDC95_{95}95 = 2.40°, and CV = 5%; a small between-rater mean difference was statistically detectable but clinically trivial. Overall, CVA measured from standardized digital photographs analyzed in MicroDicom is highly reproducible in patients with MPS, with measurement error sufficiently small to detect clinically meaningful longitudinal changes that exceed $MDC95_{95}$.

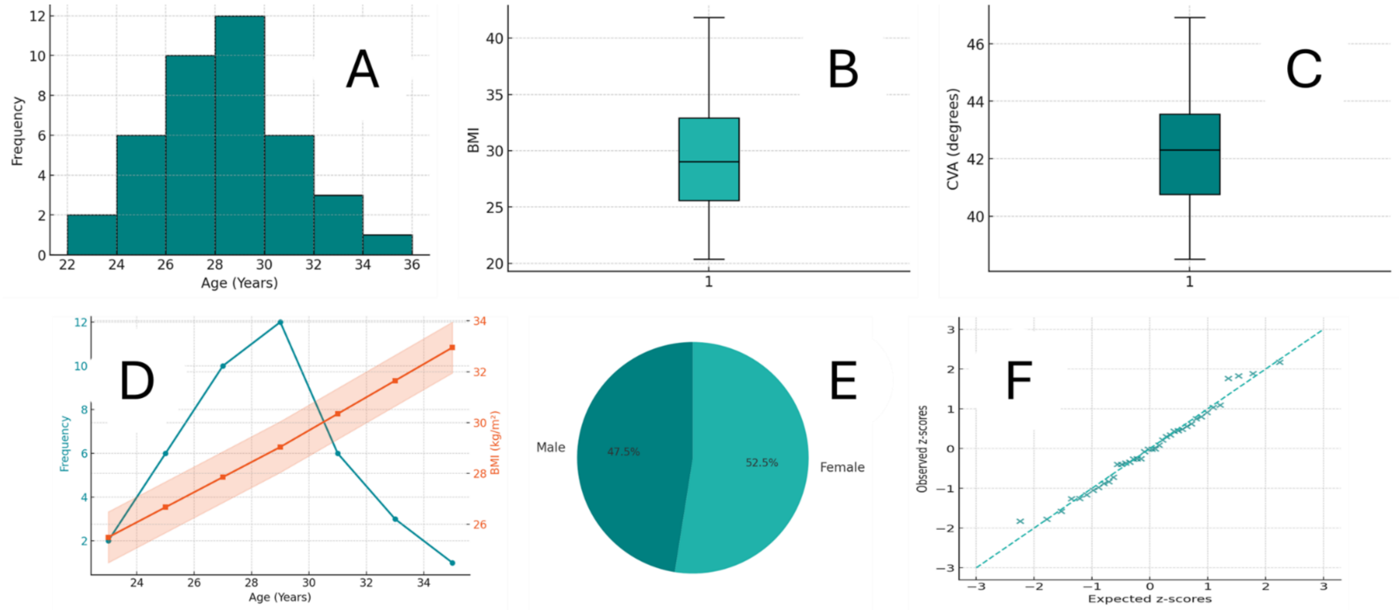


***Figure 2 Figure 2. Participant characteristics and distributional diagnostics. (A) Histogram of age (years). (B) Box plot of BMI (kg/m²). (C) Box plot of mean craniovertebral angle (CVA, degrees). (D) Age-bin frequency (left axis, teal) with overlaid mean BMI by age bin and 95% CI band (right axis, orange). (E) Sex distribution (female 52.5%, male 47.5%). (F) Normal Q–Q plot of participant-level mean CVA z-scores with reference line.***

Across the 40 participants, age was approximately normal with most individuals clustered between 24 and 36 years (A). BMI showed a mild right-skew, with the majority between 25 and 35 kg/m² and a few higher values (B); the age–BMI panel suggests a gradual rise in mean BMI across age bins (D). Mean CVA values were tightly distributed around ~42–43° with a relatively narrow interquartile range and no extreme outliers (C). The sex split was balanced (female 52.5%, male 47.5%; E). The Q–Q plot for participant-level mean CVA showed points closely tracking the 45° line, indicating no material departures from normality and supporting the use of parametric reliability models (F).

# DISCUSSION

This study evaluated the reliability of craniovertebral angle (CVA) measurement from standardized digital photographs analyzed in MicroDicom among patients with myofascial pain syndrome (MPS). The findings demonstrate good-to-excellent intra-rater reliability (ICC(3,1) = 0.865–0.889; ICC(3,3) = 0.952–0.960) and excellent inter-rater reliability (ICC(2,1) = 0.960; ICC(2,3) = 0.986), with low absolute error (SEM < 1°) and clinically small detection thresholds ($MDC95_{95} \approx$ 2.3–2.6° intra-rater; 2.40° inter-rater). Bland–Altman analyses showed minimal biases (≤ 0.34°) and tight 95% limits of agreement (± 2.4°), with no proportional bias. Collectively, these results indicate that standardized smartphone photogrammetry with MicroDicom yields highly reproducible CVA estimates in symptomatic cervical populations.

Our results align with and extend prior work supporting the reliability of non-radiographic CVA methods. Photogrammetric and software-assisted posture assessments have reported comparable or slightly lower ICCs across healthy and mixed samples [5,9,16–18,22]. For example, reliability reported for dedicated posture software and smartphone/computer-vision-based tools generally falls in the good-to-excellent range [1–3,5,9,12,16–18,22]. The present study's inter-rater ICC(2,1) of 0.960—despite incorporating both acquisition and rating variability because each rater captured their own images—compares favorably with software-based reports using shared images (e.g., PAS/SAPO, Surgimap, and recent computer-vision pipelines) [5,9,2]. This suggests that protocol standardization (marker placement, camera distance/height, leveling, and participant setup) can mitigate additional variance from image acquisition in real-world workflows.

The absolute measurement error observed here (SEM 0.83–0.92°; $MDC95_{95}$ 2.31–2.55° intra-rater; 2.40° inter-rater) is small in relation to CVA values (~43°) and consistent with clinical expectations for angular postural metrics [5,16–18]. From a practical perspective, longitudinal CVA changes exceeding $MDC95_{95}$ can be interpreted as true rather than artifactual. Many posture-focused interventions report CVA improvements on the order of 3–5°, which would exceed our MDC thresholds and thus be detectable with confidence using this protocol [8,14,25]. Accordingly, the present approach is suitable for monitoring treatment response in MPS and related cervical conditions.

Two ancillary findings inform implementation. First, day-to-day (inter-session) effects were not significant for two raters (B, C) and showed only a small, non-significant trend for rater A, indicating the protocol's stability across repeated sessions when participants are repositioned. Second, although a small between-rater mean difference was statistically detected (Friedman $\chi^2(2)$=6.752, p=.034), the magnitude was clinically trivial given the very high inter-rater ICC, low SEM, and tight limits of agreement. In practice, brief calibration/training in landmarking and adherence to the acquisition checklist (distance, height, leveling, no zoom) should minimize such differences.

Strengths include (i) a symptomatic clinical sample (MPS) where reliability is most relevant, (ii) rigorous standardization of image acquisition, (iii) blinded and independent multi-rater measurements over three days, (iv) reporting of both relative (ICC) and absolute (SEM, $MDC95_{95}$ indices, and (v) agreement analysis (Bland–Altman) to complement ICCs. The design adheres to GRRAS recommendations and employs appropriate ICC models matched to the study aims and generalizability targets [10,24].

Limitations should guide interpretation and future work. First, because each rater acquired their own images, inter-rater reliability reflects combined acquisition + rating variability and does not isolate pure rating agreement on shared images. A follow-up study should include a shared-image condition to quantify rater agreement independent of acquisition. Second, this was a single-center study in a seated posture with a specific smartphone model and software; generalizability to other settings (standing, dynamic tasks), devices, and populations (e.g., older adults, asymptomatic cohorts, radiculopathy) warrants evaluation [18,20,25]. Third, while reflective markers and training were used, landmark placement remains a potential source of error [6]. Finally, although thresholds around 48–50° are often used to classify FHP, cut-offs vary across studies; thus, CVA should be interpreted contextually rather than as an absolute diagnostic boundary [22].

Implications for practice and research. For clinics seeking a low-cost, radiation-free method to quantify FHP, standardized smartphone photogrammetry analyzed with MicroDicom provides reliable CVA estimates suitable for screening and longitudinal monitoring in MPS. We recommend (i) using reflective markers on the tragus and C7, (ii) maintaining fixed distance/height with camera leveling and no digital zoom, (iii) averaging ≥3 images per session to improve precision (ICC(3,3)), and (iv) interpreting change against $MDC95_{95}$. Future studies should (a) validate MicroDicom measurements against radiographic or 3D motion capture references [18], (b) isolate pure rater agreement with shared-image designs, and (c) explore integration with tele-rehabilitation and computer-vision pipelines to enhance scalability [1–3,12,16].

## CONCLUSION

Standardized smartphone photogrammetry analyzed with MicroDicom provides reliable and precise craniovertebral angle (CVA) measurements in patients with myofascial pain syndrome. Intra-rater reliability was good to excellent (ICC(3,1) = 0.865–0.889; ICC(3,3) = 0.952–0.960) and inter-rater reliability was excellent (ICC(2,1) = 0.960; ICC(2,3) = 0.986). Absolute error was small (SEM < 1°), yielding clinically useful detection thresholds ($MDC95_{95}$ ≈ 2.3–2.6° intra-rater; 2.40° inter-rater). Bland–Altman analyses showed minimal bias and narrow limits of agreement (±2.4°), corroborating the ICC results.

These properties support this protocol for routine assessment and longitudinal monitoring of forward head posture in clinical settings, especially where low-cost, radiation-free methods are preferred. Adhering to the acquisition checklist (accurate landmarking, fixed distance/height, camera leveling, no digital zoom) and averaging ≥3 images further enhances precision. Because the inter-rater design included acquisition plus rating variability, future studies should isolate pure rating agreement using shared images and validate against radiographic or 3D motion-capture references across broader populations and postures.

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