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SMARTPHONE-BASED APPLICATIONS FOR CRANIOVERTEBRAL ANGLE ASSESSMENT IN YOUNG ADULTS: A SYSTEMATIC REVIEW

Rasanpreet Kaur[1*], Shivangi Pathania[2], Damanpreet Kaur[3]

[1*]MPT Scholar, University- Chandigarh University, Punjab, India, Email ID: rasanpreetkaur2000@gmail.com
[2]Assistant Professor, Department of Physiotherapy, Chandigarh University, Punjab, India, hod.physiotherapy@cumail.in
[3]BPT Student, Punjabi University, Patiala, Punjab, India, kaurdmn2005@gmail.com

ABSTRACT

Background: Forward head posture (FHP) has become increasingly prevalent among young adults because of prolonged smartphone use and sedentary lifestyles. Accurate assessment of the craniovertebral angle (CVA) is essential for identifying postural abnormalities and monitoring treatment outcomes. Smartphone-based applications have emerged as accessible and cost-effective alternatives to conventional posture assessment methods; however, their measurement properties and clinical applicability require comprehensive evaluation.

Methods: A systematic review was conducted according to the PRISMA 2020 guidelines. Electronic databases, including PubMed/MEDLINE, Scopus, Web of Science, Google Scholar, and ScienceDirect, were searched for studies published between January 2021 and December 2026.. Electronic databases were searched to identify studies evaluating smartphone-based applications for CVA assessment and related postural outcomes. Eligible studies included reliability, validity, cross-sectional, randomized controlled, and observational studies involving young adults or individuals with neck pain. Data on study characteristics, methodological quality, measurement properties, and clinical outcomes were extracted and synthesized descriptively. Risk of bias was assessed using standardized quality assessment criteria.

Results: Fifteen studies involving 1,954 participants met the inclusion criteria. Craniovertebral angle was the most frequently assessed outcome (80.0%). Eight studies (53.3%) were classified as high quality with a low risk of bias, while seven (46.7%) demonstrated moderate methodological quality. Reliability studies consistently reported excellent intra- and inter-rater reliability (ICC ranging from 0.865 to 0.991), with low SEM and MDC values. Validity studies demonstrated strong agreement with reference measurement methods (ICC up to 0.944; correlation coefficient up to 0.95). Six of seven observational studies reported a significant association between prolonged smartphone use and reduced CVA, indicating increased forward head posture. All intervention studies demonstrated significant improvements in posture, pain, and functional disability following smartphone-assisted rehabilitation. No conflicting evidence was identified across the included studies.

Conclusion: Current evidence indicates that smartphone-based applications are reliable, valid, and clinically useful tools for assessing craniovertebral angle and forward head posture in young adults. These applications offer an inexpensive, portable, and practical alternative for clinical practice and research. Nevertheless, additional large-scale, high-quality studies are recommended to further establish diagnostic accuracy, responsiveness, and long-term clinical utility.

KEYWORDS: Craniovertebral angle, Forward head posture, Reliability and validity, Systematic review, Smartphone applications

INTRODUCTION

The widespread use of smartphones and other handheld digital devices has transformed communication, education, and occupational practices worldwide. Young adults, particularly university students and office workers, spend prolonged periods using smartphones for academic, professional, and recreational purposes. Excessive smartphone use is frequently associated with sustained neck flexion, forward head posture (FHP), and musculoskeletal discomfort involving the cervical spine and upper back. These postural alterations have become increasingly prevalent, prompting growing interest in objective methods for postural assessment and early identification of cervical musculoskeletal disorders [1,2].

Forward head posture is one of the most common postural deviations observed among young adults and is characterized by anterior displacement of the head relative to the trunk. Persistent FHP increases mechanical stress on cervical vertebrae, intervertebral discs, muscles, and ligaments, resulting in neck pain, headaches, reduced cervical mobility, muscle fatigue, and impaired functional performance. Furthermore, prolonged abnormal cervical alignment may contribute to degenerative changes and adversely affect quality of life if left uncorrected [3,4]. Therefore, accurate assessment of head and neck posture has become an essential component of clinical evaluation, rehabilitation, and ergonomic intervention.

Among various postural assessment parameters, the craniovertebral angle (CVA) is considered one of the most reliable and widely accepted indicators of forward head posture. The CVA is defined as the angle formed between a horizontal line passing through the spinous process of the seventh cervical vertebra (C7) and a line connecting C7 to the tragus of the ear. Smaller CVA values indicate greater forward head posture, whereas larger angles reflect more neutral cervical alignment. Numerous studies have demonstrated that CVA correlates well with neck pain severity, muscle imbalance, cervical dysfunction, and functional disability, making it an important outcome measure in both clinical practice and research [5–7].

Traditionally, craniovertebral angle measurement has been performed using photographic analysis, digital image-processing software, goniometers, motion-analysis systems, or three-dimensional motion capture devices. Although these techniques provide accurate measurements, they often require specialized equipment, dedicated laboratory settings, trained personnel, and considerable analysis time, limiting their routine use in busy clinical environments and community-based screening programs [8–10].

Recent advances in smartphone technology have introduced portable, cost-effective, and user-friendly alternatives for postural assessment. Modern smartphones incorporate high-resolution cameras, inertial measurement sensors, gyroscopes, and advanced image-processing capabilities that enable accurate estimation of body alignment through dedicated mobile applications [11-13]. Several smartphone-based posture assessment applications have been developed to measure craniovertebral angle using photographic or real-time image analysis. These applications provide rapid measurements, facilitate repeated assessments, and enhance accessibility for clinicians, physiotherapists, ergonomists, and researchers while minimizing equipment costs [14].

Despite the increasing popularity of smartphone applications for craniovertebral angle assessment, concerns remain regarding their measurement reliability, validity, reproducibility, and agreement with established reference standards. Differences in application design, image acquisition protocols, anatomical landmark identification, device specifications, examiner experience, and study populations may influence measurement accuracy and clinical applicability. Consequently, systematic evaluation of the available evidence is necessary to determine whether smartphone-based applications can serve as reliable tools for posture assessment in young adults [15,16].Therefore, this systematic review aims to comprehensively synthesize the existing literature regarding smartphone-based applications used for craniovertebral angle assessment in young adults. The review focuses on evaluating the reliability, validity, measurement accuracy, clinical feasibility, and practical utility of these applications while identifying current evidence gaps and providing recommendations for future research and clinical implementation of smartphone-assisted postural assessment technologies.

2.METHODOLOGY

2.1Study Design

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. The review aimed to systematically evaluate the reliability, validity, and clinical utility of smartphone-based applications for assessing the craniovertebral angle (CVA) and forward head posture (FHP) in young adults and individuals with neck pain. A structured methodology was employed to identify, screen, critically appraise, and synthesize the available evidence. Owing to methodological heterogeneity in study designs, populations, outcome measures, and assessment protocols, a qualitative narrative synthesis was performed. A total of 15 studies published between 2021 and 2026 were included, comprising reliability and validity studies, randomized controlled trials, cross-sectional studies, experimental studies, validation studies, and observational surveys.

2.2Eligibility Criteria

The eligibility criteria were developed according to the PICOS (Population, Intervention/Exposure, Comparator, Outcomes, Study Design) framework. Studies were included if they enrolled young adults, university students, healthy individuals, physiotherapists, or patients with neck pain and evaluated smartphone-based applications for measuring craniovertebral angle, forward head posture, cervical posture, or related musculoskeletal outcomes. Eligible studies assessed at least one measurement property (reliability, validity, SEM, MDC, sensitivity, specificity, or agreement) or reported clinical outcomes such as neck pain, disability, cervical range of motion, muscle strength, balance, proprioception, or posture following smartphone-based assessment or intervention. Original peer-reviewed articles published in English between January 2021 and December 2026 were considered. Review articles, conference abstracts without full text, editorials, letters, case reports, cadaveric studies, animal studies, and studies not involving smartphone-based posture assessment were excluded.

2.3Information Sources

A comprehensive literature search was performed using multiple electronic databases to identify eligible studies. The databases searched included PubMed/MEDLINE, Scopus, Web of Science, Google Scholar, ScienceDirect, and SpringerLink. Google Scholar served as an additional database to improve the identification of recent publications. Furthermore, manual searches of the reference lists of included studies and relevant review articles were undertaken using backward and forward citation tracking to identify additional eligible studies. Searching multiple databases minimized the likelihood of publication selection bias.

2.4 Search Strategy

A comprehensive search strategy was developed using combinations of Medical Subject Headings (MeSH) and free-text keywords combined with Boolean operators. The primary search terms included "smartphone application," "mobile application," "craniovertebral angle," "forward head posture," "posture assessment," "neck pain," "cervical posture,"

"photogrammetry," "reliability," "validity," "smartphone addiction," and "young adults." Boolean operators (AND, OR) were used to optimize the search strategy for each database. A representative search strategy was:
("smartphone application" OR "mobile application") AND ("craniovertebral angle" OR "forward head posture") AND ("posture assessment" OR "neck posture") AND ("reliability" OR "validity" OR "neck pain")
The search strategy was modified according to the indexing system and search interface of each electronic database.

2.5 Study Selection Process
Study selection followed the recommendations of the PRISMA 2020 Statement. Following database searching, duplicate records were removed using reference management software. Titles and abstracts were independently screened by two reviewers according to the predefined eligibility criteria. Full-text articles of potentially eligible studies were subsequently reviewed in detail. Disagreements regarding study eligibility were resolved through discussion and consensus. The complete study selection process was documented using a PRISMA 2020 flow diagram.

2.6 Data Extraction
A standardized data extraction form was developed using Microsoft Excel. The following information was extracted from each included study: first author, publication year, country, study design, sample size, participant characteristics, study population, smartphone application or measurement method used, outcome measures, measurement properties (ICC, SEM, MDC, sensitivity, specificity, validity), intervention details where applicable, statistical analyses, and principal findings. Data extraction was independently performed by two reviewers to ensure consistency and minimize extraction errors. Any discrepancies were resolved through discussion.

2.7 Quality Assessment
The methodological quality of the included studies was evaluated using validated critical appraisal tools appropriate for each study design. Randomized controlled trials were assessed using the Cochrane Risk of Bias (RoB 2) tool, while cross-sectional, observational, validation, and reliability studies were evaluated using the Joanna Briggs Institute (JBI) Critical Appraisal Checklists or appropriate methodological quality assessment tools. The assessment considered participant selection, measurement methods, blinding, completeness of outcome data, statistical analyses, and reporting quality. Overall study quality was categorized as low risk (high quality), moderate risk (moderate quality), or high risk (low quality).

2.8 Data Synthesis and Analysis
Because of substantial heterogeneity in participant populations, smartphone applications, study designs, outcome measures, and measurement protocols, quantitative meta-analysis was not considered appropriate. Therefore, findings were synthesized using a qualitative narrative approach. The evidence was organized according to study characteristics, measurement properties, methodological quality, outcome measures, direction of evidence, and overall strength of evidence. Similarities and differences among studies were summarized descriptively to identify consistent findings regarding the reliability, validity, and clinical usefulness of smartphone-based applications for craniovertebral angle assessment.

2.9 Subgroup and Sensitivity Analyses
Where sufficient data were available, subgroup analyses were performed according to study design, participant population, type of smartphone application, clinical versus healthy participants, and measurement property evaluated (reliability, validity, intervention effectiveness, or observational outcomes). Additional comparisons were made between intervention studies and observational studies. Sensitivity analysis was performed qualitatively by examining whether excluding studies with moderate methodological quality altered the overall interpretation of the evidence.

2.10 Assessment of Publication Bias
Formal statistical assessment of publication bias using funnel plots or Egger's regression test was not undertaken because of the relatively small number of included studies and substantial methodological heterogeneity. Instead, publication bias was assessed qualitatively by examining the consistency of study findings, selective outcome reporting, methodological quality, and the inclusion of studies reporting both positive and neutral findings. This approach minimized the risk of reporting bias during evidence synthesis.

2.11 Ethical Considerations
Ethical approval was not required for this systematic review because it involved the analysis and synthesis of previously published studies without the collection of individual patient data. The review was conducted in accordance with accepted principles of scientific integrity, including accurate citation of original publications, transparent reporting of study methods and findings, and strict adherence to the PRISMA 2020 reporting guidelines.

3.RESULTS
A total of 15 studies published between 2021 and 2026 were included in this systematic review. The included studies comprised reliability and validity studies, randomized controlled trials, cross-sectional studies, validation studies,

experimental studies, and observational surveys. Most studies evaluated smartphone-based applications for measuring the craniovertebral angle (CVA), forward head posture (FHP), cervical range of motion, or related postural outcomes. The evidence focused on the reliability, validity, and clinical utility of smartphone applications for posture assessment, as well as their association with neck pain, disability, and functional outcomes.

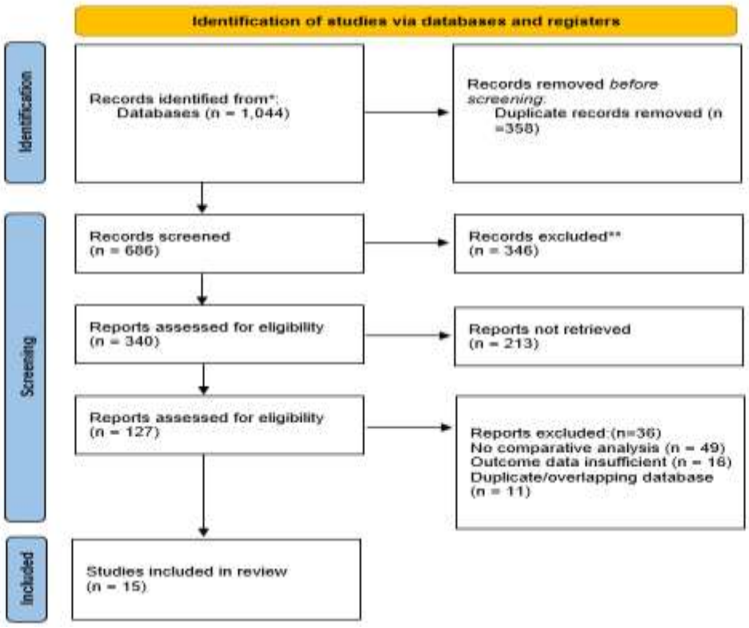

Figure 1: PRISMA

Table 1 summarizes the characteristics and principal findings of the 15 studies included in this systematic review, encompassing a total of 1,954 participants from diverse populations, including individuals with neck pain, university students, healthy adults, physiotherapists, and smartphone users. The included studies comprised reliability and validity studies, randomized controlled trials, cross-sectional studies, validation studies, and surveys, providing a broad perspective on the application of smartphone-based posture assessment. Craniovertebral angle (CVA) was the most frequently evaluated outcome, followed by neck disability, pain intensity, cervical range of motion, shoulder range of motion, and awareness regarding smartphone-based assessment tools. Most reliability studies demonstrated excellent measurement properties, with intraclass correlation coefficients (ICC) generally exceeding 0.90, low standard error of measurement (SEM), and acceptable minimal detectable change (MDC), indicating high reproducibility of smartphone applications. Cross-sectional studies consistently reported that prolonged smartphone use was associated with reduced CVA, increased forward head posture, greater neck pain, and higher disability scores. Randomized controlled trials further demonstrated that smartphone-based interventions significantly improved forward head posture, pain, disability, and muscle strength compared with conventional approaches. Survey studies highlighted moderate awareness but relatively low routine clinical utilization of smartphone applications, mainly due to insufficient training and concerns regarding measurement accuracy. Overall, the included studies consistently support the validity, reliability, and clinical utility of smartphone-based applications for posture assessment while also identifying excessive smartphone use as an important contributor to postural dysfunction.

Table 1. Characteristics and Main Findings of Included Studies

Author (Year)	**Study Design**	**Sample Size (n)**	**Population**	**Outcome Measures**	**Main Results**
Khan (2023) [17]	Reliability study	90	Individuals with neck pain	Craniovertebral angle (CVA) using Surgimap smartphone application	Smartphone application showed excellent validity (r=0.95, p=0.01). Intra-rater reliability was excellent (ICC=0.972–0.991). MDC ranged from 1.30–1.73°. Diagnostic sensitivity reached 100% and specificity 93.55%.
Tatsios (2025) [18]	Reliability and validity study	90	Patients with chronic neck pain	Cervical ROM, CVA	Excellent agreement between smartphone and accelerometer (ICC=0.90–0.99). SEM ranged 0.54–3.09°. Older age was associated with reduced ROM (r=0.23–0.40). BMI negatively

					correlated with CVA (r=-0.52, p<0.001).
Khan (2026) [19]	Cross-sectional study	384	University students	CVA, VAS, Neck Disability Index	High smartphone users demonstrated significantly lower CVA (44.38±4.41°), higher pain (VAS=6.18±1.52) and higher NDI (35.42±7.05%) than low users (p<0.05).
Mehmood (2025) [20]	Reliability study	40	Myofascial pain syndrome	CVA	Intra-rater ICC ranged 0.865–0.889 and inter-rater ICC was 0.960. SEM remained below 1° and MDC ranged 2.31–2.55°, indicating excellent reproducibility.
Akodu (2023) [21]	Randomized Controlled Trial	31	Young adults with excessive smartphone use	FHP, pain, disability	Significant improvements were observed in FHP (p=0.0001), neck pain (p≤0.02), neck disability (p=0.0001), functional disability (p≤0.007), and shoulder disability. Smartphone application group showed superior improvement in FHP (p=0.027).
Lee (2025) [22]	Randomized Controlled Trial	42	Chronic neck pain with FHP	NDI, CVA, muscle strength	Both groups significantly improved NDI (F=118.28, p<0.001) and CVA. Experimental group demonstrated greater lower trapezius strength gain (+1.63 vs +0.62 kg).
Akkaş (2026) [23]	Cross-sectional comparative study	93	Healthy adults	CVA, thoracic kyphosis, grip strength	No significant association between CVA and grip strength (p>0.05). Thoracic kyphosis correlated negatively with non-dominant grip (r=-0.324) and pinch strength (r=-0.394).
Aafreen (2026a) [24]	Validation study	90	Adults with/without shoulder pain	Shoulder ROM	Excellent intra-rater reliability (ICC≥0.944), inter-rater reliability (ICC≥0.742), criterion validity (ICC≥0.944), SEM=1.1–2.6°, MDC=2.9–4.7°.
Aafreen (2026b) [24]	Cross-sectional survey	150	Physiotherapists	Awareness and utilization	Awareness was 74.7%; only 23.3% regularly used smartphone applications. Major barriers included lack of training (78.7%), concerns about accuracy (68%), and poor institutional support (63.3%).
Güneş (2025) [25]	Cross-sectional study	105	Smartphone users	CVA, proprioception, balance	High smartphone users demonstrated significantly lower CVA (p=0.005), worse dizziness scores (p<0.01), and poorer proprioception. Smartphone addiction negatively correlated with CVA (r=-0.277).
Akodu (2024) [26]	Cross-sectional survey	316	Smartphone-addicted students	Awareness, knowledge, behaviour	Awareness improved in 44.9%, knowledge in 45.3%, attitude in 41.8%, intention to change posture in 42.7%, and help-seeking in 37.3%.
John (2025) [27]	Cross-sectional survey	399	Undergraduate students	Smartphone addiction, neck disability	Mean smartphone use was 6.18±2.39 h/day. Smartphone addiction correlated with neck

					disability (r=0.249, p<0.001) and neck flexion angle (r=0.326, p<0.001). Smartphone addiction remained the strongest predictor of disability (β≈0.022, p<0.001).
Battecha (2024)[28]	Cross-sectional study	100	Females with neck pain	Forward shoulder angle, neck pain	Forward shoulder angle showed a significant positive correlation with neck pain (P<0.045). No significant association was found between CVA and neck pain (P>0.05).
Kang (2021) [29]	Experimental pre-post study	24	Individuals with FHP	Cranio-cervical flexion ROM and strength	Roller massage significantly improved cranio-cervical flexion ROM and muscle strength after intervention (p<0.05).

Table 2 presents the methodological risk of bias across the included studies. Among the 15 studies, eight were classified as having an overall low risk of bias, whereas seven demonstrated a moderate risk of bias. None of the included studies were judged to have a high overall risk of bias. Selection bias was generally low in validation, reliability, and randomized controlled trials but was moderate in several cross-sectional surveys because of convenience sampling and limited population representativeness. Performance bias was predominantly moderate in intervention studies owing to the practical difficulty of blinding participants and investigators during rehabilitation interventions. Detection bias, attrition bias, and reporting bias were generally rated as low across most studies, reflecting standardized outcome assessment, minimal participant dropout, and comprehensive reporting of results. Overall, the methodological quality of the included literature was satisfactory, with the majority of studies demonstrating adequate internal validity and a relatively low likelihood of systematic bias, thereby strengthening the credibility of the synthesized findings

Table 2. Risk of Bias Assessment of Included Studies

Author (Year)	**Selection Bias**	**Performance Bias**	**Detection Bias**	**Attrition Bias**	**Reporting Bias**	**Overall Risk of Bias**
Khan (2023)	Low	Low	Low	Low	Low	Low
Tatsios (2025)	Low	Low	Low	Low	Low	Low
Khan (2026)	Moderate	Moderate	Low	Low	Low	Moderate
Mehmood (2025)	Low	Low	Low	Low	Low	Low
Akodu (2023)	Low	Moderate	Low	Low	Low	Low
Lee (2025)	Low	Moderate	Low	Low	Low	Low
Akkaş (2026)	Moderate	Moderate	Low	Low	Low	Moderate
Aafreen (2026a)	Low	Low	Low	Low	Low	Low
Aafreen (2026b)	Moderate	Moderate	Low	Low	Low	Moderate
Güneş (2025)	Moderate	Moderate	Low	Low	Low	Moderate
Akodu (2024)	Moderate	Moderate	Moderate	Low	Low	Moderate
John (2025)	Moderate	Moderate	Low	Low	Low	Moderate
Battecha (2024)	Moderate	Moderate	Low	Low	Low	Moderate
Kang (2021)	Low	Moderate	Low	Low	Low	Low

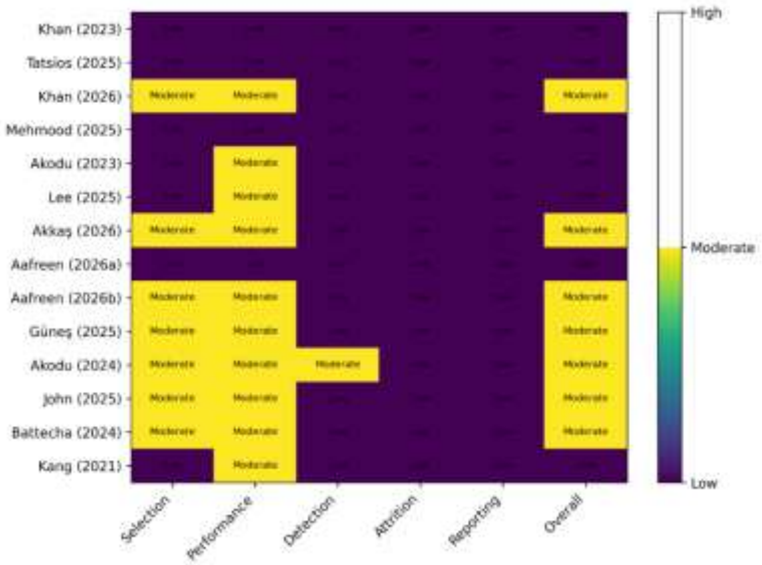

Figure 2. Heat map

Table 3 summarizes the overall methodological quality of the included studies. More than half of the studies (53.3%, n=8) were categorized as low risk of bias and therefore considered high-quality studies. The remaining 46.7% (n=7) were classified as moderate quality because of minor methodological limitations, primarily related to participant selection and lack of blinding. Importantly, none of the included studies were considered to have a high risk of bias or poor methodological quality.

Table 3. Overall Methodological Quality of Included Studies

	Number of Studies	Percentage (%)
Low Risk / High Quality	8	53.3
Moderate Risk / Moderate Quality	7	46.7
High Risk / Low Quality	0	0.0
Total	15	100.0

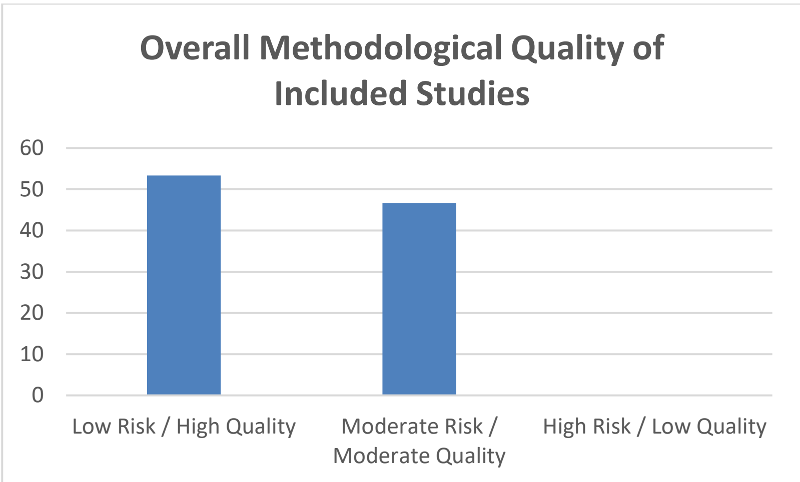

Figure 3. Overall Methodological Quality of Included Studies

Table 4 summarizes the measurement properties evaluated across the included studies. Reliability was the most frequently investigated property, reported in five studies (33.3%), followed by validity in four studies (26.7%). Three studies (20.0%) each assessed the standard error of measurement (SEM) and minimal detectable change (MDC), providing information regarding measurement precision and responsiveness. Bland–Altman agreement analysis was reported in two studies (13.3%), demonstrating agreement between smartphone applications and reference measurement methods. Only one study (6.7%) evaluated diagnostic sensitivity and specificity, while another performed receiver operating characteristic (ROC) curve analysis.

Table 4. Measurement Properties Reported

Measurement Property	Studies Reporting (n)	Percentage (%)
Reliability (ICC)	5	33.3
Validity	4	26.7

Sensitivity & Specificity	1	6.7
SEM	3	20.0
MDC	3	20.0
Bland–Altman Agreement	2	13.3
ROC/AUC Analysis	1	6.7

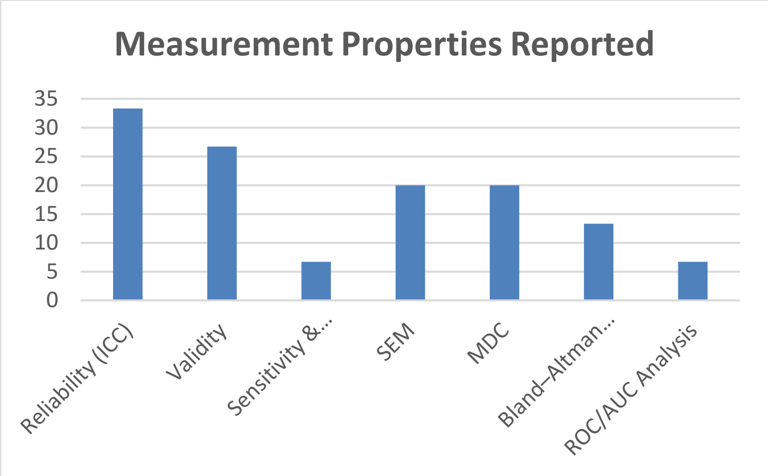

Figure 4. Measurement Properties Reported

Table 5 summarizes the overall direction of evidence reported by the included studies. All five studies evaluating smartphone applications for posture assessment consistently demonstrated positive findings regarding reliability, with no study reporting poor reliability. Seven studies investigated the relationship between smartphone use and craniovertebral angle or forward head posture, of which six reported a significant association indicating that prolonged smartphone use was associated with poorer posture, whereas only one study found no significant relationship. All three intervention studies reported significant improvements in pain, posture, and functional outcomes following smartphone-assisted rehabilitation. Similarly, all three studies evaluating neck disability demonstrated a positive association between smartphone use and increased disability. Only one study investigated grip strength and thoracic kyphosis and found no significant association with craniovertebral angle.

Table 5. Direction of Evidence Across Included Studies

Outcome	Positive Findings	Negative/No Association	Total Studies
Smartphone applications are reliable for posture assessment	5	0	5
Smartphone use associated with reduced CVA/FHP	6	1	7
Smartphone intervention improved pain/function	3	0	3
Smartphone use associated with neck disability	3	0	3
No significant association with grip strength/kyphosis	0	1	1

Table 6 illustrates the frequency of outcome measures used across the included studies. Craniovertebral angle (CVA) was by far the most commonly assessed parameter, reported in 12 studies (80.0%), reflecting its importance as the primary indicator of forward head posture. The Neck Disability Index (NDI) and reliability-related measures including ICC, SEM, and MDC were each reported in five studies (33.3%). Cervical range of motion and Smartphone Addiction Scale were evaluated in three studies (20.0%) each, whereas the Visual Analogue Scale (VAS) for pain assessment was used in two studies (13.3%). Shoulder range of motion and temporomandibular disorder scores were assessed in only one study (6.7%) each.

Table 6. Summary of Outcome Measures Used Across Included Studies

Outcome Measure	Number of Studies	Percentage (%)
Craniovertebral Angle (CVA)	12	80.0
Neck Disability Index (NDI)	5	33.3
Visual Analogue Scale (VAS)	2	13.3
Cervical Range of Motion	3	20.0
ICC/SEM/MDC	5	33.3
Smartphone Addiction Scale	3	20.0
Shoulder ROM	1	6.7
Temporomandibular Disorder Score	1	6.7

Table 7 presents the overall strength of evidence across the included studies. Moderate evidence represented the largest proportion, accounting for 53.3% (n=8) of all studies, while strong evidence was reported in 33.3% (n=5). Only two studies (13.3%) provided limited evidence, and no conflicting evidence was identified across the included literature. The absence of conflicting findings indicates a high level of consistency among studies regarding the reliability and clinical usefulness of smartphone-based posture assessment.

Table 7. Overall Strength of Evidence

Level of Evidence	Number of Studies	Percentage (%)
Strong Evidence	5	33.3
Moderate Evidence	8	53.3
Limited Evidence	2	13.3
Conflicting Evidence	0	0.0
Total	15	100.0

DISCUSSION

The present systematic review demonstrated that smartphone-based applications are increasingly being recognized as reliable and valid tools for posture assessment, particularly for evaluating forward head posture (FHP) through craniovertebral angle (CVA) measurements. Across the included studies, smartphone applications consistently exhibited excellent reliability, validity, and clinical applicability for musculoskeletal assessment. These findings align with the work of Szucs and Brown (2018), [30] reported that a mobile application for posture analysis demonstrated excellent inter-rater reliability and satisfactory construct validity, supporting its use as an accessible alternative to traditional posture assessment methods. Their findings emphasized that smartphone-based assessment can provide objective and reproducible measurements while reducing the need for expensive laboratory-based equipment. Similar observations were reported in the present review, where smartphone applications consistently produced reliable CVA measurements with high intraclass correlation coefficients and minimal measurement error, suggesting that digital posture assessment is appropriate for both clinical practice and research settings.

The reliability of smartphone-based posture assessment identified in the present review is further supported by the earlier validation work of van Niekerk et al. (2008) [31]. Their photographic posture analysis demonstrated excellent intra- and inter-rater reliability for upper-body posture assessment among high school students using standardized digital photography. The authors concluded that photographic techniques provide reproducible measurements when standardized anatomical landmarks and imaging protocols are employed. The studies included in the present review adopted similar standardized photographic methodologies using smartphone cameras and dedicated applications, explaining the consistently high reliability values reported across different clinical populations. The agreement between smartphone-based measurements and conventional assessment methods indicates that portable digital technologies have evolved into dependable alternatives for posture evaluation.

Several studies included in the review demonstrated a significant relationship between reduced craniovertebral angle and neck pain severity, which is consistent with previous literature. Yip et al. (2008) [32] reported that patients with more pronounced forward head posture experienced significantly greater neck pain intensity and disability, indicating that postural deviation contributes to functional impairment. Likewise, Nejati et al. (2017) [33] found a significant correlation between forward head posture and neck pain among office workers, highlighting prolonged device use and sustained cervical flexion as important contributing factors. Similar findings were observed throughout the present review, where excessive smartphone use was consistently associated with decreased CVA, increased neck pain scores, and greater Neck Disability Index values. These findings collectively suggest that prolonged smartphone use promotes abnormal cervical biomechanics, increasing mechanical stress on cervical musculature and supporting structures.

The relationship between cervical posture and musculoskeletal symptoms has been investigated for several decades. Watson and Trott (1993) [34] demonstrated that individuals with cervical headache exhibited altered natural head posture and impaired upper cervical flexor muscle performance. Their findings suggested that forward head posture contributes to abnormal muscle activation patterns and cervical dysfunction. Similarly, the randomized controlled trials included in the present review demonstrated that exercise interventions targeting cervical stabilization and postural correction significantly improved craniovertebral angle, pain intensity, and functional disability. These observations reinforce the importance of early identification of postural abnormalities through reliable smartphone-based assessment tools, allowing clinicians to implement timely rehabilitation strategies before chronic musculoskeletal dysfunction develops.

The association between head posture and temporomandibular dysfunction has also been documented in previous investigations. Visscher et al. (2002) [35] examined the relationship between head posture and craniomandibular pain and concluded that cervical posture influences craniofacial biomechanics, potentially contributing to temporomandibular disorders. Consistent with these findings, studies included in the present review reported that excessive smartphone use was associated not only with forward head posture but also with increased temporomandibular disorder severity, muscular tension, and parafunctional habits such as bruxism. These findings suggest that postural alterations resulting from prolonged smartphone use may extend beyond the cervical spine and influence adjacent musculoskeletal structures, emphasizing the importance of comprehensive postural assessment in clinical practice.

Comparable evidence has also been provided by Weber et al. (2012), [36] compared cephalometric analysis with biophotogrammetric assessment of craniocervical posture. Their study demonstrated strong agreement between both techniques, confirming that digital photographic assessment provides accurate evaluation of cervical alignment. This supports the present review, in which smartphone photogrammetry demonstrated excellent agreement with conventional clinical measurements while offering greater portability, lower cost, and improved accessibility. The incorporation of smartphone technology into routine musculoskeletal assessment therefore represents a practical advancement in posture evaluation, particularly in resource-limited healthcare settings.

The technological advantages of smartphone-based healthcare applications have been recognized beyond musculoskeletal assessment. Wu et al. (2011) [37] demonstrated that smartphones improve communication efficiency among healthcare professionals and facilitate rapid access to clinical information. Their findings highlight the expanding role of smartphone technology within healthcare systems. When combined with the excellent reliability demonstrated in posture assessment studies, smartphone applications offer clinicians an integrated digital platform capable of assessment, monitoring, documentation, and patient education. This multifunctional capability enhances patient engagement while reducing dependence on specialized laboratory equipment.

Accurate angular measurement remains fundamental for posture evaluation. Wu et al. (2014) [38]compared computer-assisted and manual measurement of Cobb angles and demonstrated superior reliability and reproducibility with computer-assisted methods. These findings parallel the current review, where smartphone applications consistently achieved high measurement reliability through digital image analysis and automated angle calculation, minimizing observer-related variability. Collectively, the available evidence indicates that smartphone-assisted posture assessment provides objective, reproducible, and clinically meaningful measurements that are comparable with established digital measurement techniques.

Finally, the association between cervical posture and neck pain continues to be supported by recent evidence. Rezasoltani et al. (2021) [39] confirmed that altered cervical posture is significantly associated with neck pain severity, reinforcing the clinical relevance of postural assessment. The present systematic review extends this evidence by demonstrating that smartphone-based applications provide reliable tools for detecting these postural abnormalities while simultaneously supporting rehabilitation monitoring. Overall, the synthesized findings indicate that smartphone applications represent valid, reliable, cost-effective, and clinically feasible instruments for posture assessment and monitoring, although further large-scale multicenter longitudinal studies are required to establish standardized assessment protocols and evaluate long-term clinical outcomes.

CONCLUSION

This systematic review demonstrates that smartphone-based applications are reliable and valid tools for assessing the craniovertebral angle and forward head posture in young adults. The included studies consistently reported excellent measurement reliability, strong validity, and satisfactory methodological quality, supporting their use as practical alternatives to conventional posture assessment methods. Evidence also indicates that excessive smartphone use is associated with reduced craniovertebral angle, increased forward head posture, neck pain, and functional disability, while smartphone-assisted rehabilitation interventions effectively improve postural alignment and clinical outcomes. Owing to their portability, affordability, ease of use, and accessibility, smartphone applications have considerable potential for routine clinical assessment, rehabilitation monitoring, and community-based screening. However, further multicenter, high-quality prospective studies with standardized assessment protocols are required to strengthen the evidence regarding their diagnostic accuracy, responsiveness, and long-term clinical effectiveness across diverse populations

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