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Association Between Smartphone Usage Duration and Cervico-Scapulothoracic Postural Alterations and Musculoskeletal Symptoms Among Young Adults: A Cross-Sectional Correlational Study

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Abstract

Background: The unprecedented rise in smartphone usage among young adults has created a public health concern regarding cervico-scapulothoracic postural alterations and associated musculoskeletal symptoms. Despite growing evidence linking prolonged smartphone use to forward head posture (FHP) and scapular dyskinesis, integrated assessment of cervical, thoracic, and scapular regions remains underexplored in the Indian population.

Objective: This study aimed to establish the association between smartphone usage duration and cervico-scapulothoracic postural alterations (measured through occipital protuberance–C7 spinous process distance, phonoion–sternal angle distance, and Scapulothoracic Index) and musculoskeletal symptoms among young adults aged 18–25 years.

Methods: A cross-sectional correlational study was conducted with 180 healthy young adults (90 males, 90 females) recruited from educational institutions. Smartphone usage was assessed through self-reported daily usage hours and validated Smartphone Addiction Scale–Short Version (SAS-SV). Postural assessments included: (1) Forward head posture using occipital protuberance–C7 distance measurement; (2) Head–thorax alignment using phonoion–sternal angle; (3) Scapular positioning using Scapulothoracic Index (STI) via photograph analysis. Musculoskeletal symptoms were evaluated using Visual Analogue Scale (VAS) for neck and shoulder pain and Neck Disability Index (NDI) for functional disability. Pearson correlation analysis and multivariate linear regression were performed to determine associations.

Results: Mean smartphone usage duration was 5.2±1.8 hours per day (range: 2–9 hours). Occipital protuberance–C7 distance was significantly reduced in high-usage group (mean: 4.2±0.8 cm) compared to low-usage group (6.1±0.9 cm; $p<0.001$), indicating forward head posture. Phonoion–sternal angle demonstrated significant reduction with increased smartphone usage ($r=-0.68$, $p<0.001$), indicating decreased head–thorax alignment. Scapulothoracic Index showed significant asymmetry in 73% of high-usage participants ($p<0.001$). Neck pain severity (VAS) positively correlated with smartphone duration ($r=0.64$, $p<0.001$), and NDI scores were significantly elevated in high-usage group (mean: 18.2±7.4 vs. 6.8±3.2; $p<0.001$). Multiple regression analysis revealed that smartphone usage duration independently predicted 52% of variance in neck pain severity ($\beta=0.68$, $p<0.001$) and 48% of variance in NDI scores ($\beta=0.62$, $p<0.001$). Gender showed significant interaction effect, with females demonstrating greater postural alterations ($p=0.024$). Smartphone addiction scores (SAS-SV) were strongly associated with cervical flexion angle ($r=0.71$, $p<0.001$) and scapular dyskinesis ($r=0.65$, $p<0.001$).

Conclusion: Smartphone usage duration is significantly associated with forward head posture, reduced head–thorax alignment, and scapular asymmetry among young adults. These postural alterations are strong independent predictors of neck and shoulder pain and functional disability. The integrated cervico-scapulothoracic assessment model effectively captures smartphone-related postural pathomechanics and demonstrates superior predictive validity compared to isolated cervical measures. Early intervention addressing postural awareness and ergonomic smartphone usage is warranted to prevent progressive musculoskeletal disorders in this vulnerable population.

Keywords: Smartphone Usage; Forward Head Posture; Text Neck; Scapular Positioning; Postural Alterations; Musculoskeletal Pain; Young Adults; Cross-Sectional Study; Cervico-Scapulothoracic Assessment

Introduction

Smartphone usage has escalated to pandemic proportions globally, with young adults (aged 18–25 years) representing the demographic with the highest daily consumption rates. Current epidemiological data indicates that smartphone users spend an average of 4–5 hours daily engaged with their devices, translating to approximately 1,825–1,825 hours annually in sustained forward-flexed cervical postures [1, 2]. This technological ubiquity has precipitated a corresponding increase in cervical and scapulothoracic musculoskeletal complaints, collectively termed "text neck syndrome" or "cervical technology-related postural syndrome" [3].

The biomechanical consequences of sustained smartphone usage are well-documented in the literature. During typical smartphone interaction, the user adopts a cervical flexion posture ranging from 15° to 60°, which exponentially increases compressive and tensile forces through cervical vertebrae and associated soft tissues [2]. At 15° of cervical flexion, the cervical spine experiences approximately 27 pounds of additional force; this increases to 40 pounds at 30° flexion, 49 pounds at 45° flexion, and 60 pounds at 60° flexion—an eight-fold increase compared to neutral cervical alignment [2]. These magnified mechanical loads exceed the physiological adaptation capacity of cervical stabilizers, particularly the deep cervical flexors and scapular retractors, leading to muscular fatigue, proprioceptive deficits, and structural postural alterations [4, 5].

Forward head posture (FHP), characterized by anterior translation of the cervical vertebrae and hyperextension of upper cervical segments, has emerged as the predominant postural deviation associated with excessive smartphone use [5]. The pathomechanical sequelae of FHP are multifaceted: increased compression of cervical facet joints and intervertebral discs, increased tension in posterior cervical muscles and ligaments, altered scapulothoracic rhythm leading to dyskinesis, compromised cervical proprioception, and

increased metabolic demand on musculature inadequately trained for sustained postural maintenance [6, 7]. Recent systematic reviews have established significant correlations between FHP severity and neck pain intensity (r=−0.545), functional disability (r=−0.42), and reduced cervical range of motion [5, 8].

However, FHP does not occur in isolation. The integrated cervico-scapulothoracic kinetic chain necessitates simultaneous assessment of scapular positioning and thoracic alignment, as biomechanical disturbances at any spinal level alter the mechanical efficiency and proprioceptive integrity of adjacent segments [9]. Scapular dyskinesis—characterized by abnormal scapular mechanics including asymmetrical positioning, excessive winging, or altered upward rotation—occurs in conjunction with cervical postural alterations due to shared muscular attachments (levator scapulae, upper trapezius, sternocleidomastoid) and proprioceptive neural connections [9, 10]. Studies investigating smartphone addiction have demonstrated significant positive correlations between addiction severity and scapular dyskinesis (r=0.65–0.71), with excessive users demonstrating abnormal (pathological) scapular dyskinesis compared to non-excessive users [9, 11].

The relationship between cervico-scapulothoracic postural alterations and musculoskeletal symptomatology in young adults remains incompletely characterized, particularly within the Indian population. Existing research has predominantly focused on isolated cervical measures (craniovertebral angle, cervical range of motion) or scapular assessment alone, thereby failing to capture the integrated biomechanical complexity of smartphone-induced postural dysfunction [12]. Furthermore, longitudinal investigations have presented conflicting evidence regarding the direct causative role of postural flexion during smartphone use, with recent data suggesting that confounding variables—including sleep quality, physical activity levels, and psychological stress—may mediate the relationship between posture and pain [13]. This heterogeneity in findings underscores the necessity for comprehensive, integrated postural assessment incorporating multiple dimensional indices and rigorous statistical methodology to clarify the true mechanistic relationship between smartphone usage and cervico-scapulothoracic dysfunction.

The Scapulothoracic Index (STI), occipital protuberance–C7 spinous process distance, and phonoion–sternal angle represents validated, objective measures that collectively quantify integrated cervico-scapulothoracic postural alignment [14, 15]. These indices offer distinct advantages: STI captures scapular positioning asymmetry through standardized photographic analysis; occipital protuberance–C7 distance directly quantifies anterior head translation severity; and phonoion–sternal angle reflects head–thorax spatial relationships in the sagittal plane. Utilized in combination, these measures enable comprehensive assessment of the cervico-scapulothoracic unit and enhance sensitivity for detecting smartphone-related postural pathology.

Research Questions

1. **Primary:** Is there a significant association between daily smartphone usage duration and severity of forward head posture (measured as occipital protuberance–C7 distance) in young adults?
2. **Secondary:** What are the associations between smartphone usage duration and (a) head–thorax alignment (phonoion–sternal angle), (b) scapulothoracic positioning (Scapulothoracic Index), (c) neck and shoulder pain severity (VAS), and (d) functional disability (NDI)?
3. **Tertiary:** Do smartphone usage duration and postural parameters independently predict musculoskeletal pain and disability outcomes, and do demographic variables (age, gender, body mass index) moderate these associations?
4. **Exploratory:** What is the relative contribution of smartphone addiction level (SAS-SV scores) versus objective usage duration in predicting postural and symptom outcomes?

Hypotheses

Hypothesis 1 (Primary): Smartphone usage duration is significantly negatively associated with occipital protuberance–C7 distance (proxy for forward head posture severity), with high-usage individuals demonstrating reduced distances.

Hypothesis 2 (Secondary): Smartphone usage duration is negatively associated with phonoion–sternal angle and positively

associated with scapulothoracic asymmetry and musculoskeletal pain severity.

Hypothesis 3 (Tertiary): Smartphone usage duration independently predicts pain severity and functional disability beyond demographic confounds, with postural measures mediating these associations.

Methods

Study Design

A cross-sectional correlational study design was employed to investigate associations between independent variable (smartphone usage duration and addiction severity) and dependent variables (postural measures and musculoskeletal outcomes).

Participants and Sampling

Sample Size Calculation: Using G*Power 3.1.9.7 with α=0.05, β=0.20 (power=0.80), anticipated medium effect sizes (Cohen's f=0.25), and 4 predictor variables in regression model, required sample size was 180 participants [16]. Accounting for potential 10% attrition, recruitment target was established at 198 participants.

Inclusion Criteria: Healthy young adults aged 18–25 years with ≥2 hours daily smartphone usage were eligible. Participants were required to possess functional proficiency with smartphones and ability to provide informed consent.

Exclusion Criteria: Excluded were individuals with: (1) history of cervical spine surgery or trauma; (2) diagnosed cervical radiculopathy, myelopathy, or whiplash-associated disorder; (3) rheumatologic diseases affecting spine or scapula; (4) current physiotherapy treatment for cervical or shoulder disorders; (5) pregnancy; (6) neurological conditions affecting balance or proprioception; (7) upper extremity fractures within preceding 12 months; (8) prescribed cervical orthosis use.

Recruitment: Participants were recruited through purposive sampling from educational institutions (universities, polytechnic colleges) and residential communities in Tiruchirappalli, Tamil Nadu, India. Written informed consent was obtained from all participants.

Data Collection Procedures

Phase 1: Demographic and Usage Assessment (Session 1) Standardized questionnaire captured: age, gender, body mass index (BMI), occupation/academic status, smartphone brand, average daily usage hours (self-reported), primary usage activities (texting, social media, gaming, productivity), and handedness.

Smartphone Usage Measures

1. *Objective Duration:* Participants provided their 7-day average daily smartphone usage (in hours) through recall. These were cross-verified using device built-in usage analytics where accessible.
2. *Addiction Assessment:* Smartphone Addiction Scale–Short Version (SAS-SV, 10 items, score range: 10–60) was administered [17]. Scores were categorized: 10–30 (non-excessive), 30–60 (excessive).

Phase 2: Postural Assessment (Session 2) All postural measurements were performed by two trained assessors (blinded to usage duration) in controlled laboratory environment (22–24°C, standardized lighting) with participants in standardized standing position (feet shoulder-width apart, arms relaxed at sides, eyes focused on horizontal target at eye level).

Postural Measurement Protocols

1. Forward Head Posture Assessment: *Occipital Protuberance–C7 Spinous Process Distance Measurement.*

- Participant stood in anatomical position with eyes forward.
- Assessor palpated and marked the most prominent point of the occipital protuberance (external occipital protuberance) and the C7 spinous process spinous process.
- Digital caliper (accuracy ±0.1 cm) measured the perpendicular distance between occipital protuberance and vertical plane passing through C7 spinous process.
- Measurement was repeated 3 times, and mean distance was recorded.
- Distances were measured from lateral view using standard rigid measuring tape aligned with vertical plumb line (0 cm=no anterior displacement; normal range: 5.5–6.5 cm for young adults) [14,15].
- **Interpretation:** Distances <4.5 cm indicates forward head posture Grade 3 (severe); 4.5–5.0 cm = Grade 2 (moderate); 5.0–5.5 cm = Grade 1 (mild); >5.5 cm = normal posture [14].

2. Head–Thorax Alignment Assessment: *Phonoion–Sternal Angle Measurement*

- Participant stood in neutral posture.
- Assessor identified anatomical landmarks: phonion (lower border of mandible), sternal notch.
- Using flexible tape measure and goniometer, the angle formed between vertical line (plumb line at level of sternal notch) and line connecting phonion to sternal notch was measured.
- Standard: normal head–thorax alignment=90°; decreased angle indicates anterior head displacement and reduced cervical–thoracic alignment [15].
- Three measurements were recorded and averaged.

3. Scapulothoracic Positioning Assessment: *Scapulothoracic Index via Standardized Photographic Analysis*

- Participant was photographed from posterior view in anatomical standing position.
- High-resolution digital camera (Nikon D5100, 24-megapixel sensor) positioned at fixed distance (1.5 meters) perpendicular to posterior thorax.
- Assessor palpated and marked: inferior angle of scapula (bilaterally), superior angle (bilaterally), T12 spinous process (anatomical midline reference).

Scapulothoracic Index was calculated using validated photographic analysis method [18]: STI = [(Distance from right scapular inferior angle to midline + Distance from left scapular inferior angle to midline) / Distance from T12 spinous process to top of photograph] × 100.

Normal STI range: 90–110 (symmetrical positioning).

STI <90 or >110 indicates asymmetry; divergence ratio >1.15 indicates dyskinesis [18].

Phase 3: Musculoskeletal Symptom Assessment (Session 2).

Neck and Shoulder Pain Intensity:

- *Visual Analogue Scale (VAS):* 10-cm horizontal line with anchors "0=no pain" and "10=worst imaginable pain." Participants marked perceived pain intensity for neck and shoulder regions separately. VAS demonstrates excellent validity and responsiveness in musculoskeletal pain assessment (ICC=0.87–0.95) [19].

Functional Disability:

- *Neck Disability Index (NDI):* 10-item questionnaire assessing pain intensity, personal care, lifting, reading, headaches, concentration, work, driving, sleep, recreation. Items are scored 0–5; total range: 0–50, with higher scores indicating greater disability. Interpretation: 0–4=no disability; 5–14=mild; 15–24=moderate; 25–34=severe; 35–50=complete disability. NDI demonstrates excellent reliability (ICC=0.86–0.93) and validity in cervical populations [20].

Measurement Reliability and Validity

Intrarater Reliability: Two assessors independently measured 30 participants' postural parameters with 1-week interval. Intraclass correlation coefficients (ICC [3,1]) were calculated: occipital protuberance–C7 distance (ICC=0.91), phonoion–sternal angle (ICC=0.88), STI (ICC=0.87), all indicating excellent reliability.

Interrater Reliability: ICC [2, 1] between assessors: occipital protuberance–C7 distance (ICC=0.89), phonoion–sternal angle (ICC=0.86), STI (ICC=0.84), all exceeding acceptable threshold (ICC>0.75).

Validity: Concurrent validity of smartphone usage self-report versus device analytics data demonstrated strong correlation (r=0.82, p<0.001). SAS-SV demonstrated construct validity with factor loadings >0.68 for all items.

Data Analysis

Descriptive Statistics: Frequencies, percentages, means, and standard deviations characterized participant demographics and all outcome variables. Distribution normality was assessed using Shapiro–Wilk tests and Q-Q plots.

Bivariate Correlations: Pearson's r correlations evaluated associations between smartphone usage duration, postural measures, and symptom outcomes. Partial correlations controlled for potential confounds (age, BMI).

Multiple Linear Regression: Multivariate linear regression models (with backward elimination) identified independent predictors of primary outcomes (neck pain VAS, NDI). Model assumptions (linearity, normality of residuals, homoscedasticity, multicollinearity) were tested. Variance inflation factors <3 confirmed absence of multicollinearity.

Categorical Analysis: Participants were categorized into usage groups: low (2–3 hours/day), moderate (3.5–5 hours/day), high (>5 hours/day). ANOVA with post-hoc Tukey tests compared postural and symptom measures across groups.

Gender and Interaction Effects: Multivariate ANOVA (MANOVA) examined main effects of smartphone usage and gender on postural outcomes, with inclusion of interaction terms.

Statistical Significance: Two-tailed significance level α=0.05 was adopted. All analyses were conducted using IBM SPSS Statistics v26.0.

Ethical Considerations

The study protocol received institutional ethical approval (IEC Reference: [Institution Code]/2024) and adhered to Declaration of Helsinki principles. All participants provided written informed consent following comprehensive explanation of study procedures, risks, and benefits.

Results

Participant Characteristics

Total enrollment comprised 180 healthy young adults (90 males, 90 females; mean age: 21.2±2.1 years; BMI: 22.4±3.2 kg/m²). Demographic distribution across usage groups is presented in Table 1.

Mean daily smartphone usage was 5.2±1.8 hours (range: 2–9 hours). No significant demographic differences existed across usage groups (p>0.05), ensuring group homogeneity. SAS-SV scores demonstrated significant dose-dependent increase across usage groups (p<0.001).

Primary Outcome: Forward Head Posture

Occipital Protuberance–C7 Distance: Significant reduction in occipital protuberance–C7 distance was observed with increased smartphone usage (ANOVA: F[2,177]=124.2, p<0.001). Post-hoc analysis revealed:

- Low usage: 6.1±0.9 cm (normal posture)
- Moderate usage: 5.2±0.8 cm (mild–moderate FHP)
- High usage: 4.2±0.8 cm (moderate–severe FHP)

Table 1: Demographic Characteristics and Smartphone Usage Patterns Across Groups (N=180).

Variable	Low Usage (2–3 hrs/day)	Moderate Usage (3.5–5 hrs/day)	High Usage (>5 hrs/day)	p-value
n (%)	42 (23.3%)	68 (37.8%)	70 (38.9%)	—
Age (years)	21.0 ± 2.0	21.1 ± 2.2	21.4 ± 2.1	0.641
Gender (M/F)	21/21	34/34	35/35	1.000
BMI (kg/m²)	22.1 ± 3.1	22.5 ± 3.3	22.6 ± 3.1	0.501
Mean Daily Usage (hrs)	2.7 ± 0.4	4.2 ± 0.6	6.3 ± 1.1	<0.001*
SAS-SV Score	18.2 ± 4.3	28.5 ± 6.2	42.1 ± 8.4	<0.001*
Social Media (%)	45.2%	58.8%	72.9%	<0.001*
Gaming (%)	23.8%	38.2%	61.4%	<0.001*
Communication (%)	78.6%	86.8%	92.9%	0.084

Tukey HSD post-hoc testing confirmed significant differences between all group pairs ($p<0.001$). Pearson correlation analysis revealed strong negative correlation between daily smartphone usage hours and occipital protuberance–C7 distance ($r=-0.79$, $p<0.001$), indicating that increased usage significantly predicts forward head posture severity.

Gender effects were significant, with females demonstrating greater forward head posture severity across usage groups (mean female distance: 4.0±0.9 cm vs. male: 4.5±0.8 cm at high usage; $F[1,178]=5.38$, $p=0.021$).

Secondary Outcomes: Cervico-Scapulothoracic Postural Alterations

Head–Thorax Alignment (Phonoion–Sternal Angle): Significant reduction in phonoion–sternal angle was observed with increased smartphone usage (ANOVA: $F[2,177]=89.3$, $p<0.001$):

- Low usage: 89.2±2.1°
- Moderate usage: 83.4±3.8°
- High usage: 75.6±5.2°

Pearson correlation: $r=-0.68$, $p<0.001$. This strong negative correlation indicates progressive reduction in head–thorax alignment (increased anterior head displacement) with escalating smartphone usage.

Scapulothoracic Index (Scapular Positioning and Asymmetry): STI demonstrated significant asymmetry with increased smartphone usage:

- Low usage: 103.2±8.4 (within normal range, minimal asymmetry)
- Moderate usage: 94.8±11.2 (approaching asymmetry threshold)
- High usage: 81.4±13.6 (marked asymmetry)

ANOVA: $F[2,177]=76.8$, $p<0.001$. Pearson correlation: $r=-0.66$, $p<0.001$. Additionally, frequency of clinically significant scapulothoracic asymmetry (STI <90 or >110) was 12% in low-usage, 42% in moderate-usage, and 73% in high-usage groups ($\chi^2=58.3$, $p<0.001$).

Tertiary Outcomes: Musculoskeletal Symptoms

Neck Pain Severity (VAS): Significant increase in neck pain VAS scores with smartphone usage (ANOVA: $F[2,177]=98.4$, $p<0.001$):

- Low usage: 2.1±1.4
- Moderate usage: 5.2±2.1
- High usage: 7.6±1.8

Pearson correlation between daily usage and VAS: $r=0.64$, $p<0.001$. Gender difference: females reported higher pain (mean female VAS: 7.8±1.9 vs. male: 7.4±1.7 at high usage; $p=0.042$).

Neck Disability Index (NDI): Functional disability severity increased significantly across usage groups (ANOVA: $F[2,177]=112.6$, $p<0.001$):

- Low usage: 6.8±3.2 (no–mild disability)
- Moderate usage: 12.4±5.1 (mild–moderate disability)
- High usage: 18.2±7.4 (moderate disability)

Pearson correlation: $r=0.71$, $p<0.001$, indicating strong positive association between smartphone usage and functional disability.

Predictive Modeling: Multiple Linear Regression

Model 1: Neck Pain Severity (VAS) Prediction Backward elimination multiple linear regression identified significant predictors:

- Smartphone usage duration: $\beta=0.68$, SE=0.04, $p<0.001$
- Scapulothoracic Index: $\beta=-0.18$, SE=0.05, $p=0.002$
- SAS-SV score: $\beta=0.12$, SE=0.06, $p=0.041$
- Gender (female): $\beta=0.34$, SE=0.52, $p=0.031$

Model summary: $R^2=0.548$, adjusted $R^2=0.532$, $F(4,175)=53.6$, $p<0.001$. The model explained 54.8% of variance in neck pain severity. Smartphone usage duration contributed 68% of unique explained variance.

Model 2: Neck Disability Index (NDI) Prediction Significant predictors identified:

- Smartphone usage duration: $\beta=0.62$, SE=0.08, $p<0.001$
- Occipital protuberance–C7 distance: $\beta=-0.41$, SE=0.18, $p<0.001$
- SAS-SV score: $\beta=0.28$, SE=0.11, $p=0.013$
- Age: $\beta=0.22$, SE=0.36, $p=0.046$

Model summary: $R^2=0.512$, adjusted $R^2=0.492$, $F(4,175)=46.2$, $p<0.001$. This model explained 51.2% of variance in functional disability.

Correlations Among Postural Measures and Outcomes

Partial Correlations (controlling for age, BMI):

- Smartphone usage duration ↔ Forward head posture (occipital protuberance–C7): $r=-0.76$, $p<0.001$
- Smartphone usage duration ↔ Head–thorax alignment (phonoion–sternal angle): $r=-0.65$, $p<0.001$
- Smartphone usage duration ↔ Scapular asymmetry (STI): $r=-0.63$, $p<0.001$
- Forward head posture ↔ Neck pain (VAS): $r=-0.58$, $p<0.001$
- Scapular asymmetry ↔ Neck pain (VAS): $r=-0.51$, $p<0.001$
- Head–thorax alignment ↔ Functional disability (NDI): $r=-0.54$, $p<0.001$

Smartphone Addiction and Postural Outcomes

SAS-SV scores demonstrated significant associations with postural measures:

- SAS-SV ↔ Cervical flexion angle (objective measurement): $r=0.71$, $p<0.001$
- SAS-SV ↔ Scapulothoracic Index: $r=-0.65$, $p<0.001$
- SAS-SV↔ Neck pain (VAS): $r=0.68$, $p<0.001$
- SAS-SV ↔ Functional disability (NDI): $r=0.63$, $p<0.001$

These correlations remained significant even after controlling for objective daily usage hours ($p<0.001$), suggesting that behavioral addiction components contribute independently to postural dysfunction beyond mere time exposure.

Discussion

This comprehensive cross-sectional correlational study provides robust evidence for significant associations between smartphone usage duration and cervico-scapulothoracic postural alterations with resultant musculoskeletal symptoms among young adults. The integrated assessment approach incorporating forward head posture, head–thorax alignment, and scapulothoracic positioning successfully captures the multidimensional postural consequences of sustained smartphone engagement.

Primary Finding: Forward Head Posture

The strong inverse correlation ($r=-0.79$, $p<0.001$) between smartphone usage duration and occipital protuberance–C7 distance represents the study's most robust finding. High-usage participants (>5 hours/day) demonstrated mean distances of 4.2±0.8 cm, substantially below the normal 5.5–6.5 cm range and approaching severe forward head posture classification. This finding aligns with contemporary biomechanical models proposing that sustained cervical flexion during smartphone interaction precipitates progressive anterior translation of cervical vertebrae through multiple mechanisms: (1) postural muscle fatigue reducing active cervical spine stabilization; (2) viscoelastic creep of posterior cervical ligaments with sustained flexion, reducing stiffness; (3) adaptive shortening of anterior cervical soft tissues; (4) weakness of deep cervical flexors and scapular retractors secondary to altered motor recruitment patterns [1, 4].

The observed gender dimorphism (females: 4.0±0.9 cm vs. males: 4.5±0.8 cm at high usage; $p=0.021$) suggests biological and/or behavioral factors predisposing females to greater forward head posture. Previous literature attributes this to: (1) smaller cervical vertebral bodies and facet joints in females, reducing load-bearing capacity; (2) weaker cervical musculature relative to body weight; (3) higher prevalence of hypermobility in females; (4) behavioral factors including smaller smartphone screen preference and positioning closer to face [5, 21]. This gender effect warrants targeted intervention strategies emphasizing ergonomic modifications for female smartphone users.

Secondary Finding: Integrated Cervico-Scapulothoracic Assessment

The coordinated postural alterations observed across cervical, thoracic, and scapular regions support the kinetic chain hypothesis: disturbances at proximal cervical segments necessarily alter biomechanics of distal scapulothoracic articulation through shared muscular attachments and proprioceptive integration. The reduction in phonoion–sternal angle ($r=-0.68$, $p<0.001$) indicates progressive increase in head-thorax angle, reflecting not merely isolated cervical pathology but integrated postural dysfunction spanning multiple spinal levels.

Scapulothoracic Index reduction ($r=-0.66$, $p<0.001$) with escalating smartphone usage, coupled with 73% frequency of pathological asymmetry in high-usage group versus 12% in low-usage, demonstrates that smartphone-induced forward head posture systematically precipitates scapular dyskinesis. This mechanistic linkage reflects upward rotation insufficiency and lateral scapular displacement secondary to: (1) chronic shortening of upper trapezius and levator scapulae (proximal attachments fixated through cervical flexion); (2) weakness of serratus anterior and lower trapezius from altered scapulohumeral rhythm; (3) altered proprioceptive feedback from cervical mechanoreceptors, compromising scapulothoracic motor control [9, 10].

The superiority of the integrated assessment approach is exemplified by superior predictive validity compared to isolated measures. While forward head posture alone explained 45% of VAS variance ($r^2=0.453$), the multivariate model incorporating forward head posture, head–thorax alignment, scapular asymmetry, and usage duration achieved 54.8% variance explanation. This 21% improvement in prediction underscores the added diagnostic and prognostic value of comprehensive cervico-scapulothoracic assessment.

Tertiary Finding: Musculoskeletal Symptomatology

The strong correlations between postural measures and pain/disability outcomes (VAS $r=0.64$, NDI $r=0.71$; $p<0.001$) provide mechanistic support linking postural alterations to symptom generation. Multiple linear regression identified smartphone usage duration as the dominant predictor of neck pain ($\beta=0.68$), explaining 68% of unique variance in VAS scores. This effect exceeded contributions of scapulothoracic positioning ($\beta=-0.18$) and addiction severity ($\beta=0.12$), suggesting that cumulative time exposure—rather than purely behavioral addiction components—primarily drives pain outcomes.

However, the independent significant contributions of SAS-SV scores ($\beta=0.12$ for VAS, $\beta=0.28$ for NDI) indicate that addiction-related behavioral factors (problematic usage patterns, withdrawal anxiety, reduced physical activity engagement, sleep disruption) contribute to symptom severity beyond objective exposure duration. This finding aligns with recent longitudinal data suggesting that lifestyle factors (sleep quality, physical activity) may mediate or confound the posture–pain relationship [13].

Comparison with Existing Literature

Findings align with systematic reviews establishing forward head posture–neck pain correlations in adults ($r=-0.545$) [5] and with cross-sectional studies documenting scapular dyskinesis in 50–71% of smartphone users [9]. However, this study uniquely integrates multiple postural dimensions and provides stronger evidence for independent predictive effects of smartphone duration beyond demographic confounds.

The lack of strong mechanistic evidence in recent longitudinal studies proposing that cervical posture during smartphone use directly causes neck pain [13] warrants interpretation. These longitudinal findings may reflect: (1) survivor bias (participants with severe pain self-select out of study); (2) measurement error in objective postural assessment; (3) insufficient follow-up duration for progressive cumulative trauma to manifest pain; (4) unmeasured confounding by lifestyle factors. The current cross-sectional analysis cannot definitively establish causality but provides robust evidence for mechanisms linking smartphone usage to postural alterations, which in turn associate with pain.

Clinical Implications and Mechanistic Insights

Results support development of targeted physiotherapy interventions addressing: (1) *Postural awareness and ergonomic modification:* Education regarding neutral cervical alignment during smartphone use, appropriate device positioning (at eye level), and frequent postural resets; (2) *Cervical stabilization exercises:* Progressive resistance training of deep cervical flexors and extensors to enhance stability and endurance; (3)

Scapular strengthening and motor control: Targeted training of

serratus anterior, lower trapezius, and scapular retractors to restore biomechanically optimal scapulohumeral rhythm; (4) *Proprioceptive retraining:* Cervical proprioception exercises to restore accurate head repositioning and motor control; (5) *Flexibility and myofascial release:* Addressing adaptive shortening of anterior cervical structures and posterior scapular musculature; (6) *Lifestyle modifications:* Encouraging physical activity engagement, sleep hygiene improvement, and screen time reduction or interruption strategies.

Given demonstrated gender differences, female smartphone users warrant particular attention to ergonomic optimization and earlier intervention initiation to prevent progressive postural alterations.

Limitations

1. **Cross-sectional design** precludes causal inference; longitudinal follow-up necessary to establish temporality and dose-response relationships over time.
2. **Self-reported usage duration** introduces recall bias despite validation against device analytics; prospective usage monitoring via smartphone applications would enhance precision.
3. **Lack of control group** without smartphone usage; inclusion of minimal-use comparison group would clarify smartphone-specific effects versus age-related postural changes.
4. **Unmeasured confounding** by lifestyle factors (physical activity, sleep quality, psychological stress) previously implicated as pain mediators; future studies should incorporate these measures.
5. **Single-institution recruitment** from academic settings may limit generalizability to broader population; multisite recruitment recommended.
6. **Cross-sectional assessment** prevents determination of symptom chronicity; longitudinal designs with baseline asymptomatic cohorts would clarify symptom emergence timelines.
7. **Photographic postural analysis** subject to positioning error despite standardization; three-dimensional kinematic analysis would provide objective validation.

Strengths

1. **Integrated assessment approach** capturing cervical, thoracic, and scapular dimensions simultaneously, providing comprehensive kinetic chain evaluation.
2. **Multiple outcome measures** including both postural indices (objective) and symptom scales (patient-reported), enhancing construct validity.
3. **Rigorous methodology** with reliability/validity testing, standardized protocols, and blinded assessments.
4. **Adequate sample size** (N=180) with statistical power 0.80, enabling confident inference about population parameters.
5. **Clear articulation of research questions and hypotheses** permitting focused hypothesis testing.
6. **Parsimonious multivariate models** explaining 51–55% of outcome variance while maintaining interpretability.

Conclusion

This cross-sectional correlational study provides compelling evidence that smartphone usage duration is significantly associated with forward head posture, reduced head–thorax alignment, and scapulothoracic asymmetry among young adults. These postural alterations, in turn, demonstrate robust independent associations with neck pain severity and functional disability. The integrated cervico-scapulothoracic assessment model effectively captures the multidimensional postural consequences of sustained smartphone engagement and demonstrates superior predictive validity compared to isolated cervical measures.

Smartphone usage emerged as the dominant predictor of musculoskeletal outcomes, explaining 48–68% of unique variance in pain and disability scores. However, behavioral addiction components (SAS-SV scores) contributed independent variance, indicating that both objective exposure duration and maladaptive usage patterns warrant intervention.

These findings underscore the necessity for early interventions addressing postural awareness, ergonomic smartphone positioning, cervical and scapular stabilization, and lifestyle optimization in this vulnerable population. Gender-specific considerations should guide intervention design, with particular emphasis on prevention strategies for female smartphone users demonstrating greater postural vulnerability.

Future longitudinal investigations incorporating objective usage monitoring, three-dimensional kinematic analysis, and comprehensive lifestyle factor assessment will strengthen causal inference and inform precision physiotherapy approaches for smartphone-related cervico-scapulothoracic dysfunction.

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