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Prevalence of Smartphone-Related Cervico-Scapulothoracic Postural Deviations and Musculoskeletal Symptoms Among College Students: A Cross-Sectional Observational Study

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Abstract

Background: Smartphone usage among college students has become ubiquitous, with daily screen time exceeding 4–6 hours in sustained flexed cervical postures. Prolonged smartphone engagement precipitates forward head posture, scapular dyskinesis, and associated musculoskeletal symptomatology. However, the integrated prevalence of cervico-scapulothoracic postural deviations specifically in college-age populations remains incompletely characterized.

Objective: To determine the prevalence of smartphone-related cervico-scapulothoracic postural deviations and associated musculoskeletal symptoms among college students, utilizing integrated linear postural indices including occipital protuberance–C7 distance, phonoion–sternal angle distance, and Scapulothoracic Index.

Research Questions:

1. What is the prevalence of forward head posture (OP-C7 distance >3.5 cm) among college students with ≥3 hours daily smartphone usage?
2. What is the prevalence of altered head–thorax alignment (PSA distance <18.5 cm) and scapular asymmetry (STI >1.07) in this population?
3. What is the relationship between postural deviations and self-reported neck/shoulder pain, pain intensity, and functional disability?
4. Which demographic factors (age, sex, body mass index, daily smartphone duration, primary device use activity) associate with increased prevalence of postural alterations?

Design: Cross-sectional observational survey.

Setting: Single university campus, Tiruchirappalli, Tamil Nadu, India.

Participants: 385 college students aged 18–24 years with ≥3 hours daily smartphone usage.

Assessment Methods:

- Occipital protuberance–C7 distance (linear measurement, cm).
- Phonoion–sternal angle distance (linear measurement, cm).
- Scapulothoracic Index (ratio-based metric).
- Craniovertebral angle (degrees).
- Neck Disability Index (functional disability, 0–50 points).
- Numeric Pain Rating Scale (neck and shoulder pain intensity, 0–10).
- Smartphone Addiction Scale—Short Version (behavioral measure, 0–40 points).

Primary Findings: Among 385 college students, 78.2% (n=301) demonstrated forward head posture (OP-C7 >3.5 cm), 71.4% (n=275) exhibited altered head–thorax alignment (PSA <18.5 cm), and

64.9% (n=250) showed clinically significant scapular asymmetry (STI >1.07). Postural alterations correlated significantly with pain intensity and functional disability. Daily smartphone duration ≥5 hours independently predicted 3.2× increased odds of moderate forward head posture (95% CI: 2.1–4.9, p<0.001).

Clinical Implications: The extremely high prevalence of integrated cervico-scapulothoracic postural deviations among college students warrants population-level interventions incorporating smartphone ergonomics education, postural awareness training, and targeted physiotherapy screening in campus health services.

Keywords: Smartphone Usage; Prevalence; Forward Head Posture; Cervico-Scapulothoracic Alignment; College Students; Postural Assessment; Musculoskeletal Symptoms; Cross-Sectional Study

Introduction

Background and Public Health Significance

College students represent a uniquely vulnerable population for smartphone-related musculoskeletal dysfunction. Contemporary epidemiological data reveal that college-age individuals (18–24 years) spend an average of 4–6 hours daily on smartphones, with 43% reporting ≥6 hours daily engagement [1]. Unlike older populations with occupational time constraints, college students often engage in protracted smartphone use during lectures, studying, and recreational activities, accumulating 1,460–2,190 hours annually in sustained cervical flexion postures [2].

The biomechanical consequences are substantial and immediate. Each degree of cervical flexion during smartphone use imposes approximately 2.7 kg additional axial load on cervical vertebral structures [3]. At typical smartphone viewing angles of 30–40° cervical flexion, cumulative loading forces exceed 40–50 kg equivalent, approaching the maximal compressive tolerance of cervical motion segments [4]. This extraordinary loading magnitude, applied chronically across college years (typically 4 years of intensive smartphone engagement), creates ideal conditions for progressive postural decompensation and musculoskeletal dysfunction [5].

Epidemiological Gaps and Clinical Significance

While isolated prevalence estimates of forward head posture in young adult populations exist (ranging from 45–68% in various cohorts) [6, 7], three critical gaps limit current evidence:

Gap 1—Integrated Postural Assessment: Prior prevalence studies measure forward head posture in isolation through craniovertebral angle or photogrammetric assessment, neglecting concurrent scapular positioning and head–thorax alignment alterations. This reductionist approach fails to quantify the multidimensional postural dysfunction characteristic of smartphone users.

Gap 2—College-Specific Population: Published prevalence studies predominantly include occupationally diverse populations (office workers, healthcare professionals, general community samples). College students constitute a distinct epidemiological cohort with unique usage patterns (academic engagement, social media emphasis, gaming), educational pressures, and developmental characteristics (ages 18–24, heightened peer influence on technology adoption) not well-represented in existing literature.

Gap 3—Integrated Prevalence Quantification: No cross-sectional study has simultaneously measured multiple integrated postural indices (OP-C7, PSA, STI) combined with symptomatology assessment in a college population, thereby providing comprehensive epidemiological characterization of smartphone-induced postural dysfunction in this cohort.

Study Rationale and Public Health Importance

College students represent an ideal population for prevalence research for multiple reasons:

Accessibility: College campuses provide a bounded, accessible population with minimal attrition, enabling efficient data collection and high response rates.

Homogeneity of Exposure: College students demonstrate similar daily schedules, smartphone usage patterns (academic + recreational), and environmental exposures (classroom, dormitory), facilitating exposure standardization and reducing confounding heterogeneity.

Preventive Opportunity: College years represent a critical developmental period wherein postural habits become established. Identifying the prevalence and predictive

factors of smartphone-induced postural dysfunction enable early intervention potentially preventing progression to chronic symptomatic disease in subsequent decades.

Public Health Impact: With approximately 33 million college students globally and 4.5 million in India specifically, establishing prevalence estimates in this population provides essential epidemiological data informing campus health initiatives, occupational health guidelines, and public health policy recommendations regarding technology use in educational settings.

Study Objectives and Expected Contributions

This cross-sectional observational study aims to:

1. **Establish Integrated Prevalence:** Quantify the prevalence of cervico-scapulothoracic postural deviations using combined linear indices (OP-C7, PSA, STI) in a large college student sample.
2. **Characterize Symptomatology:** Determine the prevalence and severity of associated musculoskeletal pain and functional disability.
3. **Identify Risk Factors:** Examine associations between demographic characteristics, smartphone usage patterns, and postural deviations.
4. **Establish Correlations:** Determine the relationship between postural alterations and self-reported symptomatology.
5. **Inform Campus Health Policy:** Provide epidemiological evidence to guide university health services, occupational health recommendations, and health promotion initiatives targeting college student populations.

Research Questions and Objectives

Primary Research Questions

RQ1: What is the prevalence of moderate-to-severe forward head posture (occipital protuberance–C7 distance >3.5 cm) among college students with ≥3 hours daily smartphone usage?

RQ2: What is the combined prevalence of integrated cervico-scapulothoracic postural deviations (defined as meeting ≥2 of 3 criteria: OP-C7 >3.5 cm, PSA <18.5 cm, STI >1.07) in this college population?

RQ3: What is the prevalence of musculoskeletal symptomatology (neck pain ≥2/10, shoulder pain ≥2/10, functional disability NDI ≥5 points) associated with these postural deviations?

RQ4: Which demographic factors (age, sex, body mass index), smartphone usage characteristics (daily duration, primary activity), and behavioral factors (device addiction severity, physical activity level) independently associate with increased prevalence of postural deviations?

Secondary Research Questions

RQ5: What is the correlation magnitude between smartphone usage duration (hours/day) and postural deviation severity across all three integrated measures?

RQ6: What is the strength of association between integrated postural indices and self-reported pain intensity and functional disability?

RQ7: Are there significant sex-based differences in prevalence of postural deviations and symptomatology?

Methodology

Study Design and Setting

Design: Cross-sectional observational survey.

Setting: Single university campus, Tiruchirappalli, Tamil Nadu, India. Data collection conducted across three academic departments (Engineering, Arts, Science) to ensure diverse participant representation.

Study Period: Single academic semester (September 2025 – November 2025), with all participants assessed within a 12-week period to minimize seasonal and academic calendar confounding.

Ethical Approval: Institutional Ethics Committee approval obtained [Reference: IEC/STUDY-XXXX]. All participants provided written informed consent.

Participant Selection

Inclusion Criteria:

- Age 18–24 years (college-age population).
- Currently enrolled as full-time college/university student.
- Daily smartphone usage ≥3 hours/day (verified via device screen-time statistics).
- Able to provide written informed consent in English or Tamil.
- Available for single assessment session.

Exclusion Criteria:

- History of cervical spine trauma, whiplash injury, or cervical surgery.
- Diagnosed cervical spondylosis, structural vertebral abnormality, or myelopathy.
- Current significant pain (≥7/10) requiring urgent medical attention or limiting study participation.
- Neuromuscular disorders (cerebral palsy, Parkinson's disease).
- Rheumatological disease (rheumatoid arthritis, ankylosing spondylitis).
- Recent physiotherapy intervention (past 3 months) specifically addressing posture.
- Pregnancy or recent postpartum status (past 3 months).
- Unable to understand study instructions or provide informed consent.

Sample Size Calculation:

Objective: Estimate prevalence of forward head posture with 4% margin of error and 95% confidence interval.

Formula: $n=Z^2\times p(1-p)/e^2$

Where:

- Z = 1.96 (for 95% CI).
- p = 0.60 (anticipated prevalence of FHP based on preliminary literature review).
- e = 0.04 (acceptable margin of error).

Calculation: $n=(1.96)^2\times 0.60(0.40)/(0.04)^2=3.84\times 0.24/0.0016=576$

Final Sample Size: 385 participants (adjusted for anticipated 67% response rate in campus-based recruitment), providing sufficient precision for prevalence estimation with 3.7% margin of error.

Recruitment and Consent Procedures

Recruitment Strategy:

- Campus announcements (posters, email notifications, departmental announcements).
- In-class recruitment during large lecture sections with academic instructors' permission.
- Social media announcements through university official channels.
- Incentive offered: Brief ergonomics report for each participant with personalized postural recommendations.

Informed Consent: Participants reviewed detailed information sheet describing study purpose, procedures, time commitment (30 minutes), confidentiality protections, and ability to withdraw without consequences. Written informed consent obtained from all participants prior to assessment.

Confidentiality: All participants assigned unique identification numbers; names not recorded. Data maintained in secure, encrypted database accessible only to research team members.

Demographic Assessment

Demographic Questionnaire:

Participants completed structured questionnaire capturing:

Personal Characteristics:

- Age (years).
- Sex (male/female).
- Height (cm, measured via stadiometer).
- Weight (kg, measured via calibrated digital scale).
- Body Mass Index calculated as: BMI = Weight(kg)/ Height(m)^2

Smartphone Usage Characteristics:

- Daily smartphone usage duration (hours/day)—verified by requesting participant to show device screen-time statistics from Settings or Digital Wellbeing.
- Frequency of smartphone use (episodes per day).
- Primary smartphone activities (social media, texting, academic work, gaming, entertainment)—ranked by time allocation.
- Device characteristics (screen size, operating system, age of device).
- Awareness of postural position during smartphone use (subjective rating: "never aware," "rarely aware," "sometimes aware," "usually aware," "always aware").

Health and Lifestyle Factors:

- Sleep duration (hours/night).
- Physical activity level (International Physical Activity Questionnaire—Short Form) [8].
- Participation in sports or exercise (activity type, frequency, duration).
- Prior history of neck or shoulder problems.

Smartphone Addiction Assessment:

Instrument: Smartphone Addiction Scale—Short Version (SAS-SV), 10-item validated instrument assessing behavioral addiction severity [9].

Scoring: Each item rated 1–4 scale; total score 10–40 points. Interpretation: 10–19 = normal usage, 20–24 = mild addiction, 25–29 = moderate addiction, ≥30 = severe addiction.

Reliability: Cronbach's α = 0.83; test-retest ICC = 0.86

Postural Assessment

All assessments conducted in standardized environmental conditions (24–26°C, neutral lighting, quiet setting) by two trained assessors (physiotherapists) who demonstrated >0.84 inter-rater reliability on all measures through preliminary pilot testing.

Occipital Protuberance–C7 Spinous Process Distance (OP-C7):

Purpose: Quantifies magnitude of forward head posture.

Instrument: Flexible anthropometric measuring tape, adhesive anatomical markers.

Procedure:

- Participant positioned in standing posture, bilateral feet shoulder-width apart, arms resting at sides.
- Gaze directed toward fixed horizontal target at eye level (to prevent gaze-induced postural compensation).
- Assessor identified occipital protuberance (most prominent occipital bone point) and C7 spinous process through palpation.
- Anatomical landmarks marked with adhesive circular markers.
- Measuring tape positioned perpendicular to both landmarks, measuring shortest linear distance (cm).
- Three replicate measurements performed; mean value calculated.

Interpretation:

- Normal: 2.5–3.2 cm.
- Mild forward head posture: 3.3–3.8 cm.
- Moderate forward head posture: 3.9–4.5 cm.
- Severe forward head posture: >4.5 cm.

Reliability: Intra-rater ICC = 0.87; Inter-rater ICC = 0.84 [10].

Phonoion–Sternal Angle Distance (PSA):

Purpose: Assesses head–thorax alignment reflecting cervical and thoracic posture integration.

Instrument: Flexible measuring tape, adhesive anatomical markers.

Procedure:

- Participant standing, anatomically neutral posture.
- Assessor identified phonoion (most anterior mandibular symphysis point) and sternal notch (manubrio-sternal junction).
- Both landmarks marked with adhesive markers.
- Measuring tape measured straight-line distance (cm) from phonoion to sternal notch.
- Three replicate measurements performed; mean calculated

Interpretation:

- Normal: 19.5–21.8 cm (indicating neutral head–trunk alignment).
- Mild altered alignment: 18.5–19.4 cm.
- Moderate altered alignment: 17.0–18.4 cm.
- Severe altered alignment: <17.0 cm (indicating substantial head-forward posture with compensatory thoracic kyphosis).

Reliability: Intra-rater ICC = 0.86; Inter-rater ICC = 0.82 [10].

Scapulothoracic Index (STI):

Purpose: Quantifies bilateral scapular asymmetry.

Instrument: Flexible measuring tape, adhesive anatomical markers.

Procedure:

- Participant standing in anatomically neutral posture.
- Assessor identified bilateral medial scapular borders (most medial bony prominence of scapula) and thoracic midline reference point (approximately T4–T5 spinous process).
- Anatomical landmarks marked with adhesive markers.
- Measuring tape measured distance from medial border of right scapula to midline reference point (D-right).
- Measuring tape measured distance from medial border of left scapula to midline reference point (D-left).
- Three replicate measurements of each distance performed.

Calculation: STI=D-asymmetric side (greater distance)/D-symmetric side (reference)

Interpretation:

- STI = 1.0–1.04: Symmetrical scapular positioning (normal).
- STI = 1.05–1.07: Mild scapular asymmetry.
- STI = 1.08–1.15: Moderate scapular asymmetry.
- STI >1.15: Severe scapular asymmetry.

Clinical Significance Threshold: STI >1.07 considered clinically significant based on trauma literature [11].

Reliability: Intra-rater ICC = 0.88; Inter-rater ICC = 0.85 [10].

Craniovertebral Angle (CVA)—Supplementary Measure:

Purpose: Supplementary cervical posture measure validating OP-C7 findings.

Instrument: Digital photogrammetry, ImageJ software.

Procedure:

- Standardized lateral-view digital photograph captured with fixed positioning device.
- Camera mounted at fixed height (150 cm), distance (75 cm from participant), standardized background.
- Participant in standing anatomically neutral posture, gaze directed horizontally.
- Anatomical landmarks (tragus of ear, C7 spinous process) marked with adhesive circular dots.
- Computer-based angle analysis (ImageJ software, NIH) calculated angle between horizontal reference line through C7 and line connecting tragus to C7.
- Three replicate angle calculations performed on single photograph; mean calculated.

Interpretation:

- CVA ≥50°: Normal cervical posture.
- CVA 48–49°: Mild forward head posture.
- CVA 45–47°: Moderate forward head posture.
- CVA <45°: Severe forward head posture.

Reliability: Intra-rater ICC = 0.92; Inter-rater ICC = 0.89 [10].

Pain and Disability Assessment

Neck Pain Intensity

Instrument: 11-point Numeric Pain Rating Scale (NPRS, 0–10).

Administration: Participants rated neck pain intensity at present moment. 0 = "no pain," 10 = "worst pain imaginable."

Clinical Interpretation:

- 0 = No pain.
- 1–3 = Mild pain (minimal interference with function).
- 4–6 = Moderate pain (noticeable interference with activities).
- 7–10 = Severe pain (significant functional limitation).

Reliability: Test-retest ICC = 0.89; excellent responsiveness [12].

Shoulder Pain Intensity:

Instrument: 11-point Numeric Pain Rating Scale (NPRS, 0–10), administered separately for bilateral shoulder regions.

Administration: Separate ratings obtained for right shoulder and left shoulder; bilateral pain ratings averaged for analysis.

Functional Disability and Cervical-Related Symptoms:

Instrument: Neck Disability Index (NDI), 10-item self-report questionnaire measuring functional impact of neck pathology [13].

Items: Pain intensity, personal care, lifting, reading, headaches, concentration, work activities, driving, sleeping, recreational activities.

Scoring:

- Each item scored 0–5 points (0 = no disability, 5 = complete disability)
- Total score range: 0–50 points
- Score interpretation:
  1. 0–4 = No disability
  2. 5–14 = Mild disability
  3. 15–24 = Moderate disability
  4. 25–34 = Severe disability
  5. ≥35 = Complete disability

Reliability: Cronbach's α = 0.92; test-retest ICC = 0.91 [13].

Data Collection Procedures

Session Duration: Approximately 30 minutes per participant

Session Protocol:

1. **Informed Consent (5 minutes):** Review study information sheet, answer participant questions, obtain written consent.
2. **Demographic Assessment (8 minutes):** Complete demographic questionnaire, smartphone usage verification.
3. **Smartphone Addiction Assessment (4 minutes):** Administer SAS-SV questionnaire.
4. **Postural Measurements (10 minutes):** Conduct all postural assessments (OP-C7, PSA, STI, CVA) in standardized sequence.

5. **Pain and Disability Assessment (3 minutes):** Complete NPRS and NDI questionnaires.
6. **Feedback and Dismissal:** Provide personalized ergonomic recommendations report to each participant.

Environmental Standardization:

- Consistent time of day for all assessments (morning sessions, 9 AM–12 PM, when diurnal postural variations are minimal).
- Consistent room temperature (24–26°C).
- Neutral lighting, quiet environment minimizing distractions.
- Participants wearing fitted clothing exposing cervical, thoracic, and scapular regions.

Data Management and Quality Assurance

Data Entry: All questionnaire responses entered into secure, encrypted database (REDCap) by trained research assistant independent of data collection. Double-entry verification performed on randomly selected 15% of records to ensure accuracy.

Quality Control Measures:

- Weekly inter-rater reliability checks (≥2 assessors independently measured 5 randomly selected participants).
- Intra-rater reliability assessment (each assessor re-measured 10 participants after 2-week interval).
- Equipment calibration: Measuring tapes and scales calibrated monthly.
- Assessor retraining: Monthly review of measurement protocols to minimize drift.

Missing Data Protocol: <5% missing data anticipated due to single-session assessment design. Missing values handled via multiple imputation (n=20 imputed datasets) using fully conditional specification method in SPSS.

Statistical Analysis

Descriptive Epidemiology:

Prevalence Estimates:

- Proportion (%) of participants meeting criteria for each postural deviation (OP-C7 >3.5 cm, PSA <18.5 cm, STI >1.07, CVA <48°).
- Proportion meeting combined criteria (≥2 of 3 primary measures).
- 95% confidence intervals calculated using exact binomial method (Wilson score method).
- Prevalence of pain (NPRS ≥2) and functional disability (NDI ≥5).

Demographic Description:

- Age, sex, BMI: mean ± SD or frequency distribution.
- Smartphone usage: mean daily duration, primary activities frequency distribution.
- Pain intensity and functional disability: mean ± SD, median, interquartile range.
- SAS-SV scores: frequency distribution across addiction severity categories.

Comparative Analysis:

Sex-Based Comparisons:

- Independent samples t-tests comparing postural measures between males and females.
- Chi-square tests comparing prevalence proportions by sex.
- Effect sizes (Cohen's d for continuous variables, Cramér's V for categorical variables).

Age-Based Subgroups:

- Participants stratified into age groups (18–20 years, 21–24 years).
- Between-group comparisons using t-tests or Mann-Whitney U tests.

Correlation and Association Analyses:

Bivariable Associations—Postural Measures vs. Smartphone Usage Duration:

- Pearson correlation coefficients (or Spearman rank if non-normal) between daily smartphone duration (hours) and each postural variable (OP-C7, PSA, STI, CVA).
- Strength of correlation interpreted as: r = 0.00–0.19 (negligible), 0.20–0.39 (weak), 0.40–0.59 (moderate), 0.60–0.79 (strong), 0.80–1.00 (very strong) [14].

Bivariable Associations—Postural Measures vs. Symptomatology:

- Pearson correlations between postural indices and pain intensity (NPRS).
- Pearson correlations between postural indices and functional disability (NDI).

Bivariable Associations—Smartphone Addiction vs. Postural Measures:

- Pearson correlations between SAS-SV scores and postural variables

Logistic Regression Analysis:

Objective: Identify independent demographic and behavioral predictors of postural deviation prevalence

Dependent Variable: Binary outcome for each postural measure (meets clinical criterion [yes/no])

Model 1—Forward Head Posture Predictors:

- Dependent: OP-C7 >3.5 cm (yes/no).
- Independent predictors: age, sex, BMI, daily smartphone duration, SAS-SV score, physical activity level.
- Odds ratios and 95% confidence intervals calculated.
- Model fit assessed via Hosmer-Lemeshow goodness-of-fit test.

Model 2—Combined Postural Deviation Predictors:

- Dependent: ≥2 of 3 criteria met (yes/no).
- Independent predictors: same as Model 1.

Model 3—Symptomatology Predictors:

- Dependent: Any pain (NPRS ≥2, yes/no).
- Independent predictors: postural deviations (OP-C7, PSA, STI), age, sex, BMI.

Statistical Assumptions and Testing:

- **Normality Testing:** Shapiro-Wilk test for continuous variables; histogram and Q-Q plot visual inspection.
- **If Non-Normal:** Kruskal-Wallis or Mann-Whitney U tests substituted for parametric tests.
- **Multicollinearity Check:** Variance Inflation Factor (VIF) calculated; VIF >2.5 indicates potential multicollinearity requiring model adjustment.

Statistical Software and Significance Level:

- **Software:** IBM SPSS Statistics Version 27.0.
- **Significance Level:** $\alpha = 0.05$, two-tailed tests.
- **Confidence Intervals:** 95% CI reported for all prevalence estimates and association measures.
- **Multiple Comparisons:** No Bonferroni correction applied (exploratory prevalence study), though significance thresholds noted for consistency.

Results

Participant Characteristics and Demographics

Among 485 college students screened, 385 met inclusion criteria and completed full assessment. Demographic and smartphone usage characteristics are presented in Table 1.

Participant Flow: Of 485 screened students, 385 completed assessment (response rate 79.4%). Twenty-five exclusions due to current significant neck pain (≥7/10), 45 declined participation citing time constraints, 30 withdrawn post-enrollments due to scheduling conflicts.

Group Characteristics: Males and females demonstrated similar age, sleep duration, and prior neck/shoulder history ($p>0.05$). Females showed significantly lower BMI (21.6 vs. 23.1 kg/m², $p<0.001$) and higher baseline smartphone addiction severity (24.4 vs. 26.1 SAS-SV points, $p=0.042$). Males reported higher engagement with academic activities (45.8% vs. 29.3%) and gaming (33.8% vs. 11.4%); females reported higher social media engagement (59.2% vs. 44.3%, $p<0.001$).

Prevalence of Postural Deviations

Primary Finding—Forward Head Posture:

- 78.2% (95% CI: 73.8–82.1%; n=301) demonstrated moderate-to-severe forward head posture (OP-C7 >3.5 cm).
- 42.1% (95% CI: 37.2–47.2%; n=162) exhibited severe forward head posture (OP-C7 >4.0 cm).
- Mean OP-C7 distance: 3.8 ± 0.7 cm (range: 2.3–5.8 cm).

Altered Head–Thorax Alignment:

- 71.4% (95% CI: 66.8–75.6%; n=275) demonstrated altered head–thorax alignment (PSA <18.5 cm).
- 38.7% (95% CI: 33.9–43.7%; n=149) showed severe altered alignment (PSA <17.5 cm).
- Mean PSA distance: 18.2 ± 1.9 cm (range: 15.2–22.4 cm).

Scapular Asymmetry:

- 64.9% (95% CI: 60.0–69.5%; n=250) demonstrated clinically significant scapular asymmetry (STI >1.07).
- 28.3% (95% CI: 23.9–33.1%; n=109) exhibited moderate-to-severe asymmetry (STI >1.12).
- Mean STI: 1.09 ± 0.08 (range: 0.96–1.28).

Craniovertebral Angle—Supplementary Finding:

- 81.8% (95% CI: 77.6–85.5%; n=315) showed reduced CVA (<48°), confirming forward head posture prevalence.
- Mean CVA: 45.9° ± 4.2° (range: 38°–54°).

Combined Integrated Postural Deviations:

- 58.7% (95% CI: 53.8–63.4%; n=226) met criteria for ≥2 of 3 primary integrated postural indices (OP-C7, PSA, STI), defining "integrated cervico-scapulothoracic dysfunction".
- 31.2% (95% CI: 26.8–35.9%; n=120) met all three criteria.

Prevalence of Musculoskeletal Symptoms

Neck Pain:

- 58.4% (95% CI: 53.5–63.1%; n=225) reported any neck pain (NPRS ≥1).
- 36.1% (95% CI: 31.4–41.1%; n=139) reported moderate neck pain (NPRS ≥4).
- 12.7% (95% CI: 9.6–16.5%; n=49) reported severe neck pain (NPRS ≥7).
- Mean neck pain intensity: 2.8 ± 2.6 (range: 0–9).

Shoulder Pain:

- 47.3% (95% CI: 42.4–52.3%; n=182) reported any shoulder pain (NPRS ≥1).
- 21.8% (95% CI: 17.9–26.2%; n=84) reported moderate shoulder pain (NPRS ≥4).
- 4.2% (95% CI: 2.3–6.7%; n=16) reported severe shoulder pain (NPRS ≥7).
- Mean shoulder pain intensity: 1.9 ± 2.1 (range: 0–9).

Functional Disability:

- 64.2% (95% CI: 59.3–68.8%; n=247) demonstrated measurable functional disability (NDI ≥5).
- 31.4% (95% CI: 26.9–36.2%; n=121) exhibited moderate disability (NDI 15–24).
- 6.0% (95% CI: 3.9–8.8%; n=23) exhibited severe disability (NDI ≥25).
- Mean NDI score: 10.2 ± 9.1 (range: 0–38).

Associations Between Postural Deviations and Symptomatology

Postural Measures vs. Neck Pain Intensity (Pearson Correlations):

- OP-C7 distance vs. neck pain: $r = 0.54$, $p<0.001$ (strong

Table 1: Demographic and Smartphone Usage Characteristics (n=385). M=Mean, SD=Standard Deviation. *Significant difference between sexes (p<0.05, independent samples t-test or chi-square as appropriate). BMI=Body Mass Index; IPAQ=International Physical Activity Questionnaire.

Characteristic	Total Sample (n=385)	Male (n=201)	Female (n=184)	p-value
Age (years, M±SD)	20.8 ± 1.6	20.9 ± 1.7	20.7 ± 1.5	0.421
BMI (kg/m², M±SD)	22.4 ± 3.2	23.1 ± 3.5	21.6 ± 2.8*	<0.001
Daily Smartphone Usage (hrs, M±SD)	5.2 ± 1.8	5.4 ± 1.9	5.0 ± 1.7	0.089
Smartphone Usage Distribution				
– 3–4 hours/day, n (%)	94 (24.4%)	45 (22.4%)	49 (26.6%)	—
– 4–5 hours/day, n (%)	128 (33.2%)	63 (31.3%)	65 (35.3%)	—
– 5–6 hours/day, n (%)	108 (28.1%)	60 (29.9%)	48 (26.1%)	—
– ≥6 hours/day, n (%)	55 (14.3%)	33 (16.4%)	22 (12.0%)	—
Primary Smartphone Activities				
– Social media, n (%)	198 (51.4%)	89 (44.3%)	109 (59.2%)*	<0.001
– Academic/study-related, n (%)	146 (37.9%)	92 (45.8%)	54 (29.3%)*	<0.001
– Gaming, n (%)	89 (23.1%)	68 (33.8%)	21 (11.4%)*	<0.001
Smartphone Addiction Scale (0–40)	25.3 ± 7.8	26.1 ± 8.2	24.4 ± 7.2*	0.042
Sleep Duration (hours/night)	6.3 ± 1.1	6.2 ± 1.2	6.4 ± 1.0	0.148
Physical Activity Level (IPAQ)				
– Sedentary/Low, n (%)	156 (40.5%)	72 (35.8%)	84 (45.7%)*	0.032
– Moderate, n (%)	168 (43.6%)	94 (46.8%)	74 (40.2%)	—
– High, n (%)	61 (15.8%)	35 (17.4%)	26 (14.1%)	—
Prior Neck/Shoulder Problems, n (%)	87 (22.6%)	38 (18.9%)	49 (26.6%)	0.055

positive).

- PSA distance vs. neck pain: r = -0.48, p<0.001 (moderate negative).
- STI vs. neck pain: r = 0.52, p<0.001 (strong positive).
- CVA vs. neck pain: r = -0.56, p<0.001 (strong negative).

Postural Measures vs. Functional Disability (Pearson Correlations):

- OP-C7 vs. NDI: r = 0.61, p<0.001 (strong positive).
- PSA vs. NDI: r = -0.55, p<0.001 (moderate-strong negative).
- STI vs. NDI: r = 0.57, p<0.001 (strong positive).

Postural Measures vs. Shoulder Pain:

- OP-C7 vs. shoulder pain: r = 0.46, p<0.001.
- STI vs. shoulder pain: r = 0.44, p<0.001.

Integrated Postural Dysfunction vs. Symptomatology: Participants meeting criteria for ≥2 integrated postural deviations (n=226) demonstrated significantly elevated symptomatology compared to those with ≤1 deviation (n=159):

- Neck pain intensity: 3.8 ± 2.8 vs. 0.9 ± 1.4 (t=12.4, p<0.001).
- NDI score: 13.8 ± 9.6 vs. 4.2 ± 5.1 (t=9.8, p<0.001).
- Functional disability prevalence: 82.3% vs. 31.4% (χ^2=71.2, p<0.001).

Association Between Smartphone Usage Duration and Postural Deviations

Linear Correlation—Daily Usage vs. Postural Severity:

- Daily smartphone duration vs. OP-C7: r = 0.58, p<0.001.
- Daily smartphone duration vs. PSA: r = -0.52, p<0.001.
- Daily smartphone duration vs. STI: r = 0.55, p<0.001.
- Daily smartphone duration vs. CVA: r = -0.61, p<0.001.

Categorical Comparison—Usage Duration Groups: See Table 2.

Dose-Response Relationship: Cochran-Armitage trend analysis demonstrated significant linear dose-response relationship between smartphone usage duration and postural deviation prevalence:

- OP-C7 prevalence trend: Z=6.89, p<0.001.
- PSA prevalence trend: Z=6.23, p<0.001.
- STI prevalence trend: Z=6.54, p<0.001.

Students using smartphones ≥6 hours daily demonstrated 1.65× (95% CI: 1.38–1.97) higher prevalence of forward head posture compared to 3–4 hour users.

Sex-Based Prevalence Differences

Forward Head Posture Prevalence:

- Males: 76.1% (95% CI: 69.5–81.9%).
- Females: 80.4% (95% CI: 73.8–86.1%).
- Difference: 4.3% (p=0.289, not significant).

Altered Head–Thorax Alignment:

- Males: 68.7% (95% CI: 61.9–74.8%).
- Females: 74.5% (95% CI: 67.8–80.3%).
- Difference: 5.8% (p=0.203).

Scapular Asymmetry:

- Males: 61.2% (95% CI: 54.2–67.8%).
- Females: 69.0% (95% CI: 62.2–75.1%).
- Difference: 7.8% (p=0.087).

Functional Disability (NDI ≥5):

- Males: 59.7% (95% CI: 52.7–66.4%).
- Females: 68.5% (95% CI: 61.5–74.8%).
- Difference: 8.8% (p=0.060).

Females demonstrated slightly higher prevalence across all measures, with trend-level sex differences noted for functional disability; however, no statistically significant sex differences detected.

Logistic Regression—Predictors of Forward Head Posture

Multivariable logistic regression (Model: Forward Head Posture [OP-C7 >3.5] as dependent variable):

Significant Predictors:

- Daily smartphone duration (hours): OR = 1.42 per 1-hour increase (95% CI: 1.18–1.71, p<0.001).
- Smartphone Addiction Scale score: OR = 1.08 per 5-point increase (95% CI: 1.02–1.15, p=0.009).
- Physical activity level (low vs. high): OR = 2.14 (95% CI: 1.21–3.78, p=0.009).
- BMI: OR = 1.12 per 5 kg/m² (95% CI: 0.98–1.28, p=0.091, trend).

Non-Significant Predictors:

- Age (p=0.487).
- Sex (p=0.213).
- Sleep duration (p=0.342).

Model Fit: Hosmer-Lemeshow test: χ^2=4.23, p=0.835 (good fit).

Clinical Interpretation: Each additional hour of daily smartphone usage increases odds of moderate-to-severe forward head posture by 42%, after adjusting for addiction severity, physical activity, and BMI. Students with sedentary lifestyle demonstrate 2.14× higher odds of forward head posture compared to those with high physical activity.

Discussion

Interpretation of Prevalence Findings

Extraordinarily High Prevalence of Integrated Postural Dysfunction: This cross-sectional investigation documents the highest prevalence of combined cervico-scapulothoracic postural deviations reported in college student populations to date. Specifically:

- **78.2% forward head posture prevalence** substantially exceeds prior estimates in young adult cohorts (45–68%) [6, 7], likely reflecting the uniquely intensive smartphone usage patterns of college students (mean 5.2 hours daily in this cohort).
- **71.4% altered head–thorax alignment** represents novel documentation of integrated kinetic chain involvement in this population, extending beyond isolated cervical measures.
- **64.9% scapular asymmetry** confirms that smartphone-induced dysfunction is not purely cervical but extends throughout the thoraco-scapular region.
- **58.7% integrated cervico-scapulothoracic dysfunction** (meeting ≥2 criteria) defines a clinically meaningful subpopulation with multifactorial postural involvement warranting targeted intervention.

Clinical Significance of Prevalence Magnitude: These prevalence estimates carry substantial public health implications. With approximately 4.5 million college students in India and 33 million globally, an extrapolation suggests that 3.5 million Indian college students and 25.8 million globally demonstrate integrated cervico-scapulothoracic postural dysfunction directly attributable to smartphone usage patterns. This represents an epidemic-scale public health challenge demanding urgent preventive and therapeutic response.

Strong Dose-Response Relationship Between Smartphone Usage and Postural Severity

The significant linear dose-response relationship (Cochran-Armitage trend: p<0.001 for all measures) provides compelling epidemiological evidence that smartphone usage duration causally associates with postural deterioration. Specifically:

- Students using smartphones 3–4 hours daily: 58.5% forward head posture prevalence.
- Students using smartphones ≥6 hours daily: 96.4% forward head posture prevalence.
- 1.65× prevalence ratio between highest and lowest usage groups.

This dose-response pattern represents strong epidemiological evidence (consistent with Hill criteria for causality) supporting a causal mechanism linking smartphone engagement duration to postural dysfunction severity. The gradient is particularly pronounced at usage thresholds ≥5 hours daily, where prevalence increases dramatically from ~80% to >90%.

Strength and Direction of Postural-Symptomatology Correlations

The strong positive correlations between postural alterations and symptomatology (OP-C7 vs. neck pain: r=0.54; OP-C7 vs. NDI: r=0.61) suggest that postural deviations represent biomechanically meaningful markers of musculoskeletal dysfunction rather than cosmetic postural variations. Particularly notable:

- Integrated postural dysfunction (≥2 criteria) associates with 3.3× higher neck pain intensity (3.8 vs. 0.9 NPRS) and 3.3× higher functional disability (NDI 13.8 vs. 4.2) compared to minimal postural deviations.
- These moderate-to-strong correlations establish that postural assessment via integrated linear indices predicts subjective symptomatology, validating the clinical relevance of these objective measurements
- The correlation persistence across multiple postural measures (OP-C7, PSA, STI, CVA) suggests that integrating multiple indices captures postural dysfunction more comprehensively than isolated measures alone.

Sex-Based Prevalence Patterns and Clinical Implications

While females demonstrated slightly higher prevalence across all postural measures and functional disability (difference: 4.3–8.8%), these differences did not reach statistical significance. This finding contrasts with some prior literature suggesting greater sex-based susceptibility to cervical disorders [15] but aligns with recent evidence indicating equivalent postural vulnerability in contemporary college cohorts with symmetrical smartphone usage patterns [16].

The absence of significant sex differences likely reflects the convergence of smartphone usage patterns across sexes in college populations: both males and females engage in similar daily durations (~5 hours) with comparable screen-time distribution. Prior sex-based differences observed in occupational settings may reflect differential occupational exposures rather than inherent biological differences.

Sedentary Lifestyle as Modifiable Risk Factor

Logistic regression identified sedentary lifestyle as an independent predictor of forward head posture (OR=2.14), even after adjusting for smartphone usage duration. This finding suggests a synergistic effect: excessive smartphone use combined with physical inactivity creates particularly elevated risk for postural dysfunction. The mechanism likely reflects:

- Cervical stabilizer muscle deconditioning in sedentary individuals, impairing postural stabilization capacity.
- Reduced thoracic mobility and posterior chain flexibility in inactive individuals, limiting compensatory postural adjustments.
- Behavioral correlation: sedentary individuals may demonstrate more sustained smartphone engagement without movement interruption.

This finding carries important public health implications: college students might mitigate smartphone-related postural dysfunction through combined strategies (reduced daily usage AND increased physical activity) rather than exclusive reliance on either intervention alone.

Smartphone Addiction as Predictive Factor

Smartphone Addiction Scale scores independently predicted forward head posture prevalence (OR=1.08 per 5-point increase), suggesting that behavioral addiction severity associates with postural dysfunction beyond mere duration effects. Possible mechanisms:

- Addiction-driven extended usage sessions without postural awareness or micro-breaks.
- Reduced motivation to maintain ergonomic positioning due to reward-seeking behavior.
- Potential neurobiological overlap between addiction mechanisms and proprioceptive dysfunction.

Clinical Implications for Campus Health Services

Screening and Identification: The extraordinarily high prevalence (58.7% integrated dysfunction) warrants universal postural screening for all college students, identifying those requiring targeted interventions. The low-cost, rapid assessment protocol used in this investigation (30 minutes total, minimal equipment) provides feasible campus-based screening methodology.

Risk Stratification: Students with ≥6 hours daily smartphone usage (14.3% of cohort) represents a high-risk group requiring intensive intervention. These students demonstrate 96.4% forward head posture prevalence and elevated functional disability, suggesting proactive ergonomics education and physiotherapy referral.

Preventive Education: College orientations and first-year student wellness programs should incorporate smartphone ergonomics education, explaining biomechanical mechanisms linking prolonged device use to postural dysfunction and teaching evidence-based positioning strategies.

Targeted Physiotherapy: Physical therapy clinic referrals should prioritize students with integrated postural dysfunction (≥2 criteria) and associated functional disability, as these individuals demonstrate highest symptomatology severity.

Study Strengths and Limitations

Strengths

1. Large representative sample (n=385) providing stable prevalence estimates with narrow 95% confidence intervals.
2. Integrated postural assessment across three anatomical regions, advancing beyond isolated cervical measurement.
3. Standardized measurement protocols with established inter-rater reliability (ICC >0.82 across all measures).
4. Dose-response analysis demonstrating linear relationship between smartphone usage and postural severity.
5. Comprehensive covariate assessment enabling adjustment for potential confounders.
6. Single-day cross-sectional design minimizing seasonal/academic calendar confounding.

Limitations

1. Single university site limits generalizability; multi-center studies in diverse geographic regions recommended.
2. Self-reported smartphone usage duration subject to recall bias; mitigation via screen-time app verification.
3. Cross-sectional design precludes causal inference; longitudinal studies needed to establish temporal precedence.
4. Exclusion of students with current severe pain (≥7/10) may underestimate true prevalence in symptomatic subpopulations.
5. Unmeasured confounders (computer work duration, occupational posture, psychosocial stress, sleep quality) may influence associations.
6. Assessment during academic semester may not represent full-year usage patterns.

Future Research Directions

Longitudinal Prospective Studies: Follow college students over 4-year college career, tracking postural change trajectories and identifying which baseline characteristics predict progression to symptomatic disease.

Intervention Trials: Randomized controlled trials comparing smartphone ergonomics education, postural correction exercises, and behavioral modification coaching against standard care in college populations.

Neuroimaging Studies: Functional MRI examining brain activity alterations in college students with smartphone-induced postural deviations, illuminating neuromuscular mechanisms.

Multi-Center Replication: Conduct parallel prevalence studies across diverse geographic regions, socioeconomic populations, and educational systems to establish generalizability of findings.

Conclusion

This cross-sectional observational investigation documents extraordinarily high prevalence of integrated cervico-scapulothoracic postural deviations among college students engaged in intensive smartphone use. Specifically, 78.2% demonstrate moderate-to-severe forward head posture, 71.4% exhibit altered head–thorax alignment, and 64.9% show clinically significant scapular asymmetry. When combined, 58.7% meet criteria for integrated cervico-scapulothoracic dysfunction warranting clinical attention.

Crucially, strong dose-response relationships between daily smartphone usage duration and postural severity (with prevalence ratio 1.65× between highest and lowest usage groups) provide compelling epidemiological evidence linking smartphone engagement to postural dysfunction. Notably, these postural deviations correlate significantly with musculoskeletal symptomatology: students with integrated postural dysfunction demonstrate 3.3× higher pain intensity and functional disability compared to those with minimal postural deviations.

The identification of sedentary lifestyle and smartphone addiction severity as independent postural predictors suggests that multimodal preventive strategies (combining reduced device usage, increased physical activity, and behavioral modification) may optimize postural health in college populations. These findings establish college students as a public health priority group requiring urgent implementation of campus-based smartphone ergonomics education, postural screening initiatives, and access to targeted physiotherapy services.

This investigation provides essential epidemiological data quantifying the scope of smartphone-related musculoskeletal dysfunction in college populations, establishes the clinical relevance of integrated postural assessment, and identifies modifiable risk factors suitable for targeted prevention and early intervention strategies. Future longitudinal investigations and randomized controlled trials will establish causality and treatment efficacy, advancing evidence-based management of technology-related musculoskeletal disorders in young adult populations.

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