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Effectiveness of a Targeted Cervico-Scapular Physiotherapy Intervention on Smartphone Induced Postural Deviations and Musculoskeletal Symptoms: A Randomized Controlled Trial

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Abstract

Background: Smartphone-induced forward head posture, scapular dyskinesis, and associated musculoskeletal symptoms represent a growing public health concern among young adults. While postural dysfunction is well-documented, evidence-based intervention protocols integrating cervical stabilization, scapular motor control, and thoracic mobility remain limited. This randomized controlled trial evaluates the effectiveness of a targeted cervico-scapular physiotherapy intervention on postural alterations and functional outcomes in smartphone users.

Objective: To investigate the effectiveness of a structured 8-week cervico-scapular physiotherapy intervention (integrating cervical stabilization exercises, scapular stabilization and motor control training, thoracic mobility work, and smartphone ergonomics education) compared to standard care on smartphone-induced postural deviations and musculoskeletal symptoms.

Research Questions:

1. Does a targeted cervico-scapular physiotherapy intervention produce significantly greater improvements in forward head posture (measured via occipital protuberance–C7 distance and craniovertebral angle) compared to standard care?
2. Does the intervention significantly improve head–thorax alignment (phonoion–sternal angle distance) and reduce scapular asymmetry (Scapulothoracic Index) compared to control?
3. What is the magnitude of intervention effect on neck and shoulder functional disability (Neck Disability Index, Shoulder Pain and Disability Index) and pain intensity?
4. What is the intervention adherence rate, and which participant characteristics predict treatment response?

Design: Parallel-group, single-blinded randomized controlled trial (assessor-blinded), adhering to CONSORT 2010 guidelines.

Participants: 160 smartphone-dependent young adults (18–35 years) with smartphone usage ≥3 hours/day and forward head posture (craniovertebral angle <48°), randomly allocated to intervention (n=80) or standard care control group (n=80).

Intervention: Eight-week structured program delivered bi-weekly (16 sessions, 45 minutes each), comprising: (1) cervical deep flexor stabilization exercises, (2) cervico-cervical proprioceptive training, (3) scapular stabilization and motor control exercises, (4) thoracic extension and mobility training, and (5) individualized smartphone ergonomics education with behavioral modification coaching.

Control Condition: Standard care consisting of a single ergonomics educational pamphlet and advice to maintain physical activity.

Primary Outcome Measures:

- Occipital protuberance–C7 spinous process distance (cm)
- Craniovertebral angle (degrees)
- Phonoion–sternal angle distance (cm)
- Scapulothoracic Index (ratio)

Secondary Outcome Measures:

- Neck Disability Index (0–50 points)
- Shoulder Pain and Disability Index (0–100%)
- Neck pain intensity (Numeric Pain Rating Scale, 0–10)
- Shoulder pain intensity (Numeric Pain Rating Scale, 0–10)
- Adherence to exercise program (session attendance, home exercise frequency)
- Patient satisfaction and perceived benefit

Hypotheses:

- H1: The intervention group will demonstrate significantly greater reductions in occipital protuberance–C7 distance (increased craniovertebral angle ≥8°, $p<0.05$) compared to control at 8-week post-intervention.
- H2: Intervention participants will show significantly greater improvements in head–thorax alignment and scapular positioning ($p<0.05$) compared to control.
- H3: The intervention will produce clinically meaningful reductions in neck (≥2 points on NPRS) and shoulder disability (≥13.2 points on SPADI) compared to control ($p<0.05$).
- H4: Intervention adherence will be ≥75%, with baseline postural severity and pain intensity predicting treatment response.

Expected Outcomes: This RCT will provide Level 1 evidence establishing the efficacy of an integrated cervico-scapular intervention for smartphone-induced postural dysfunction. Findings will inform clinical practice guidelines and enable physiotherapists to deliver evidence-based, cost-effective interventions addressing the multidimensional nature of technology-related musculoskeletal disorders in young adults.

Keywords: Randomized Controlled Trial; Smartphone Usage; Cervical Posture; Scapular Stability; Postural Rehabilitation; Physiotherapy Intervention; Forward Head Posture; Young Adults; Musculoskeletal Dysfunction

Introduction

Background and Public Health Significance

The global proliferation of smartphone technology has created an unprecedented public health challenge, with young adults spending an average of 2–4 hours daily in sustained cervical flexion postures [1]. This chronic postural deviation has precipitated a predictable epidemic of smartphone-associated musculoskeletal disorders, characterized by forward head posture, scapular dyskinesis, thoracic kyphosis, and associated neck and shoulder pain [2, 3].

Cross-sectional epidemiological studies document that 60–87% of young adults demonstrate forward head posture (craniovertebral angle <48°), with severity correlating directly with daily smartphone usage duration [4]. Beyond immediate postural deviations, smartphone-induced dysfunction carries substantial long-term consequences: prospective longitudinal investigations reveal that asymptomatic individuals with forward head posture progress to clinically symptomatic cervical pathology within 12–24 months, requiring medical intervention and contributing to healthcare burden [5, 6].

The economic impact is substantial. In India alone, smartphone-related neck and shoulder pain accounts for an estimated 2.3 million physician visits annually, with 18–25% of young adults reporting functional disability necessitating activity restriction [7]. This growing burden motivates urgent investigation of evidence-based preventive and therapeutic interventions.

Current State of Evidence and Intervention Rationale

Recent systematic reviews and meta-analyses confirm that exercise interventions targeting cervical stabilization, scapular motor control, and thoracic mobility produce clinically meaningful improvements in forward head posture (craniovertebral angle improvements of 6–10°), neck pain reduction (2.5–4.5 points on Visual Analog Scale), and functional disability improvements (50% reduction in Neck Disability Index scores) [8, 9, 10]. However, three critical gaps persist:

Gap 1—Limited Integration: Most prior interventions examine cervical stabilization exercises in isolation. No randomized controlled trial has systematically evaluated combined cervico-scapular-thoracic interventions addressing the integrated kinetic chain dysfunction characteristic of smartphone users.

Gap 2—Smartphone-Specific Ergonomics: While general postural education has proven modestly effective, smartphone-specific ergonomic guidance integrating proper device positioning, micro-break protocols, and behavioral modification remains underutilized in treatment protocols.

Gap 3—Postural Biomarker Outcome Measures: Prior trials predominantly measure isolated cervical outcomes (craniovertebral angle) without incorporating integrated postural metrics (occipital protuberance–C7 distance, phonoion–sternal angle distance, Scapulothoracic Index) that characterize multidimensional postural dysfunction.

Theoretical Basis for Intervention Design

The proposed intervention integrates evidence from contemporary neuromuscular, biomechanical, and behavioral frameworks:

Neuromuscular Control Mechanism: Forward head posture precipitates disruption of deep cervical flexor motor control, with excessive superficial cervical muscle activation (sternocleidomastoid, anterior scalene) dominating proprioceptive mechanisms. Targeted cranio-cervical flexion exercises restore motor control sequence, re-establishing deep flexor recruitment while inhibiting superficial dominance, thereby normalizing cervical proprioception and postural stability [11, 12].

Kinetic Chain Mechanism: Progressive cervical flexion necessitates compensatory thoracic kyphosis and scapular protraction to maintain visual orientation. Integrating thoracic extension exercises and scapular retraction/depression training addresses this compensatory cascade, mechanically restoring cervico-scapulothoracic alignment [13]. Combined stabilization and proprioceptive training produce synergistic neuromuscular adaptations exceeding isolated exercise modalities [14].

Behavioral Modification Mechanism: Smartphone ergonomics education combined with behavior change coaching (identifying usage triggers, establishing device-positioning habits, integrating micro-break routines) addresses behavioral reinforcement mechanisms underlying postural dysfunction. This biopsychosocial approach produces superior adherence and sustained behavioral change compared to exercise-only interventions [15].

Study Significance and Impact

This Level 1 evidence randomized controlled trial addresses a critical evidence gap by establishing the efficacy of an integrated cervico-scapular-thoracic intervention specifically designed for smartphone users. Findings will:

1. **Establish Clinical Efficacy:** Provide quantitative evidence on intervention effectiveness across multiple integrated postural biomarkers and functional outcomes.

2. **Inform Clinical Practice Guidelines:** Enable development of evidence-based physiotherapy protocols for smartphone-related musculoskeletal dysfunction.

3. **Guide Prevention Strategy Development:** Establish whether early intervention in asymptomatic individuals prevents symptom progression.

4. **Optimize Rehabilitation Design:** Identify which intervention components produce greatest benefit, enabling targeted resource allocation in clinical settings.

Research Questions and Hypotheses

Primary Research Questions

RQ1: Does a structured 8-week targeted cervico-scapular physiotherapy intervention produce significantly greater improvements in forward head posture magnitude (occipital protuberance–C7 distance, craniovertebral angle) compared to standard care in smartphone-dependent young adults?

RQ2: Does the intervention significantly improve integrated postural alignment (head–thorax positioning via phonoion–sternal angle distance and scapular symmetry via Scapulothoracic Index) compared to control group?

RQ3: What is the magnitude of intervention effect on functional disability (Neck Disability Index, Shoulder Pain and Disability Index), pain intensity (Numeric Pain Rating Scale), and patient-reported symptom improvement?

RQ4: What is the intervention adherence rate, and which baseline participant characteristics (age, sex, body mass index, baseline postural severity, pain intensity, depression/anxiety, device addiction severity) predict superior treatment response?

Specific Hypotheses

H1: The intervention group will demonstrate significantly greater reductions in occipital protuberance–C7 distance (primary postural measure), defined as:

- Mean reduction of ≥0.6 cm in intervention group vs. ≤0.2 cm in control group ($p<0.05$)
- Corresponding craniovertebral angle improvement ≥8° in intervention vs. <3° in control ($p<0.05$)
- Large effect size (Cohen's d ≥0.8)

H2: Intervention participants will exhibit significantly greater improvements in integrated postural metrics:

- Phonoion–sternal angle distance improvement ≥1.5 cm in intervention vs. ≤0.5 cm in control ($p<0.05$)
- Scapulothoracic Index reduction ≥0.08 in intervention vs. ≤0.03 in control ($p<0.05$)
- Combined effect size (Mahalanobis distance) reflecting integrated postural change ($p<0.05$)

H3: Intervention will produce clinically meaningful functional improvements:

- Neck Disability Index reduction ≥10 points in intervention vs. ≤3 points in control ($p<0.05$)
- Shoulder Pain and Disability Index improvement ≥13.2 points in intervention vs. ≤5 points in control ($p<0.05$)
- Neck pain intensity reduction ≥2.0 points on NPRS (established MCID) in intervention ($p<0.05$)
- Shoulder pain intensity reduction ≥1.5 points in intervention ($p<0.05$)

H4:

- Intervention adherence ≥75% (defined as ≥12 of 16 treatment sessions attended, ≥4 days/week home exercise compliance)
- Baseline craniovertebral angle <45° (more severe FHP)

predicts 1.8× greater functional improvement in intervention group

- Baseline NDI score ≥15 predicts superior disability reduction in intervention group

Methodology

Study Design and Registration

Design: Prospective, parallel-group, single-blind (assessor-blinded) randomized controlled trial.

Theoretical Framework: This trial adheres to:

- CONSORT 2010 guidelines for randomized controlled trial reporting [16]
- Consolidated Standards of Reporting Trials (CONSORT) 2010 Checklist for intervention trials
- Template for Intervention Description and Replication (TIDieR) for detailed intervention specification

Ethical Approval: Institutional Ethics Committee approval obtained [Reference: IEC/PT/APPROVAL-XXX]. Trial registered prospectively with ClinicalTrials.gov [NCT XXXXXXXX].

Study Location: University-based physiotherapy clinic and research facility, Tiruchirappalli, Tamil Nadu, India.

Study Duration: 12 months (8 weeks intervention + 4 weeks post-intervention follow-up per participant).

Participant Selection and Randomization

Inclusion Criteria:

- Age 18–35 years.
- Daily smartphone usage ≥3 hours/day (verified via device screen-time statistics).
- Forward head posture confirmed by craniovertebral angle <48°.
- Asymptomatic or minimally symptomatic status (Neck Disability Index <15, indicating no moderate disability).
- Able to attend bi-weekly treatment sessions for 8 weeks.
- Fluent in English or Tamil language.
- Able to provide written informed consent.

Exclusion Criteria:

- Current significant neck or shoulder pain (pain ≥5/10 on Numeric Pain Rating Scale) requiring urgent medical management.
- History of cervical spine trauma, whiplash injury, or cervical spine surgery.
- Diagnosed cervical spondylosis, herniated intervertebral disc, myelopathy, or other structural cervical pathology requiring medical management.
- Diagnosed shoulder pathology (rotator cuff tear, labral tear, adhesive capsulitis, glenohumeral instability).
- Contraindications to exercise (cardiovascular disease, uncontrolled hypertension, severe osteoporosis).
- Neuromuscular disorders (Parkinson's disease, cerebral palsy, multiple sclerosis).
- Rheumatological diseases (rheumatoid arthritis, ankylosing spondylitis, systemic lupus erythematosus).
- Recent physiotherapy or postural training intervention (past 6 months).
- Habitual participation in overhead sports (volleyball, badminton, swimming) or occupations involving sustained abnormal cervical positioning.
- Pregnancy or current postpartum status (past 3 months).
- Depression or anxiety disorder with ongoing pharmacological treatment (due to potential neuromotor effects).
- Smartphone addiction severity score >50 on Smartphone Addiction Scale (indicating severe addiction requiring specialized treatment).

Sample Size Calculation:

Preliminary Data: Based on published studies [17, 18], we anticipated:

- Intervention group OP-C7 distance reduction: 0.6 cm (SD = 0.4 cm).
- Control group OP-C7 distance reduction: 0.2 cm (SD = 0.4 cm).
- Effect size (Cohen's d): 1.0 (large effect).

Statistical Parameters:

- $\alpha = 0.05$ (two-tailed).
- $\beta = 0.20$ (80% statistical power).
- Anticipated dropout rate: 15%.

Calculation:

$n=2[\sigma^2(Z_{\alpha/2}+Z_{\beta})/d]^2$

$n=2[(0.4)^2\ (1.96+0.84)/0.4]^2=2\times31.36=63$ per group

Final Sample Size: 80 per group (160 total), accounting for 15% anticipated attrition.

Randomization and Allocation Concealment:

Randomization Method: Computer-generated randomization using permuted block randomization (block size = 4).

Allocation Sequence Generation: Randomization performed by statistician not involved in participant enrollment or outcome assessment. Allocation sequence concealed in sequentially numbered, opaque, sealed envelopes maintained by research coordinator.

Allocation Concealment: Sealed envelopes opened only after baseline assessment completion, ensuring concealment throughout enrollment process.

Blinding: Outcome assessors blinded to group allocation. Treating physiotherapists not blinded (impractical for behavioral intervention). Participants not explicitly blinded but instructed not to discuss group assignment with assessors.

Demographic Assessment

Participants completed structured questionnaire capturing:

- Age, sex, body mass index (BMI = weight[kg]/height[m²]).
- Smartphone usage: daily duration (verified via device), frequency (episodes/day), primary activities (social media, texting, work, entertainment).
- Device characteristics (screen size, brand model).
- Sleep quality (Pittsburgh Sleep Quality Index).
- Physical activity level (International Physical Activity Questionnaire—Short Form).
- Smartphone Addiction Scale—Short Version (SAS-SV; 10-item, 0–40 scale).
- Depression/anxiety screening (Patient Health Questionnaire—4).
- Prior physiotherapy history.

Primary Postural Assessments

All assessments conducted in standardized environmental conditions (24–26°C, neutral lighting, quiet setting) by trained assessors blinded to group allocation.

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

Instrument: Flexible anthropometric measuring tape.

Procedure: Participants positioned in standing posture, bilateral feet shoulder-width apart, eyes focused on fixed horizontal target at eye level (to prevent gaze-induced posture compensation). Assessor identified and marked occipital protuberance (most prominent occipital point) and C7 spinous process using adhesive markers. Measuring tape positioned perpendicular to both landmarks in sagittal plane, measuring shortest distance (linear measurement, in cm).

Reliability: Established intra-rater ICC = 0.87, inter-rater ICC = 0.84 [19].

Measurement Protocol: Three measurements performed; mean value calculated. Values documented to 0.1 cm precision.

Phonoion–Sternal Angle Distance (PSA):

Instrument: Flexible anthropometric measuring tape.

Procedure: Phonoion (most anterior mandibular symphysis point) and sternal notch (manubrio-sternal junction) marked with adhesive markers with participant in standing posture. Measuring tape measured straight-line distance (cm) from phonoion to sternal notch. This linear metric captures head–trunk spatial relationship.

Reliability: Intra-rater ICC = 0.86, inter-rater ICC = 0.82 [19].

Measurement Protocol: Three measurements performed; mean calculated. Values documented to 0.1 cm precision.

Scapulothoracic Index (STI):

Instrument: Flexible measuring tape, standardized postural position.

Procedure: With participant standing, bilateral medial scapular borders and thoracic spinous process identified and marked. Measuring tape measured distance from medial border of right scapula to nearest spinous process (D-right) and from medial border of left scapula to nearest spinous process (D-left).

Calculation: STI = (D-asymmetric side / D-symmetric side), where asymmetric side = greater distance, symmetric side = reference. STI = 1.0 indicates perfect symmetry; STI >1.07 indicates clinically significant asymmetry.

Reliability: Intra-rater ICC = 0.88, inter-rater ICC = 0.85 [19].

Measurement Protocol: Three measurements performed; mean STI calculated. Values documented to 0.01 unit precision.

Craniovertebral Angle (CVA):

Instrument: Digital photogrammetry with standardized positioning device.

Procedure: Lateral-view photographic image captured with participant in standing posture using fixed camera mounted at 150 cm height, positioned 75 cm perpendicular distance from participant, with standardized background. Anatomical landmarks (tragus of ear, C7 spinous process) marked with adhesive dots. Angle formed between horizontal line through C7 and line connecting tragus to C7 measured using computer-based image analysis software (ImageJ, NIH).

Reliability: Intra-rater ICC = 0.92, inter-rater ICC = 0.89 [19].

Normal Reference: CVA ≥48–50° indicates normal cervical posture; <48° indicates forward head posture.

Measurement Protocol: Single photograph per assessment, with three replicate measurements performed on image. Mean CVA calculated. Values documented to 0.1° precision.

Secondary Outcome Assessments

Neck Disability Index (NDI):

Instrument: 10-item self-report questionnaire, established outcome measure for cervical pathology [20].

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

Scoring: Each item scored 0–5 points (0 = no disability, 5 = complete disability); total score range 0–50 points. Higher scores indicate greater disability. NDI score ≤4 = minimal, 5–14 = mild, 15–24 = moderate, 25–34 = severe, ≥35 = complete disability.

Reliability: Cronbach's α = 0.92; test-retest ICC = 0.91 [20].

Minimal Clinically Important Difference (MCID): ≥10 points [21].

Shoulder Pain and Disability Index (SPADI):

Instrument: 13-item self-report questionnaire measuring shoulder-specific pain and disability [22].

Structure:

- Pain subscale: 5 items assessing shoulder pain severity in various positions
- Disability subscale: 8 items assessing functional limitations

Scoring: Each item rated 0–10 points. Pain subscale total: 0–50 points. Disability subscale total: 0–80 points. SPADI total score: [(pain + disability) / 130] × 100 = 0–100% with higher scores indicating greater disability.

Reliability: ICC = 0.89–0.95; Cronbach's α = 0.86–0.96 [22].

MCID: 13.2 points on SPADI total score [23].

Neck and Shoulder Pain Intensity:

Instrument: 11-point Numeric Pain Rating Scale (NPRS, 0–10), with separate administration for neck and shoulder regions.

Administration: Participants rated pain intensity at present moment and average over past week. 0 = "no pain," 10 = "worst pain imaginable."

Reliability: Test-retest ICC = 0.89 [24].

MCID for Neck Pain: ≥2 points established in mechanical neck pain populations [25].

Exercise Adherence Assessment:

Home Exercise Compliance: Participants maintained daily log documenting exercise frequency (days/week), session duration (minutes), and perceived exertion (Borg Rating of Perceived Exertion, 0–10). Weekly compliance calculated as (days completed / 7) × 100%.

Treatment Session Attendance: Documented session-by-session with excused/unexcused absences recorded.

Adherence Definition: ≥75% adherence defined as ≥12 of 16 treatment sessions attended AND ≥4 days/week home exercise compliance averaged across intervention period.

Patient-Reported Satisfaction and Perceived Benefit:

Global Perceived Effect (GPE) Scale: 7-point scale assessing perceived improvement ("completely recovered" to "significantly worse") [26].

Patient Satisfaction: 5-item satisfaction questionnaire (1–5 scale) assessing treatment effectiveness, therapist competence, scheduling convenience, education quality, overall satisfaction.

Intervention Components (Experimental Group)

Intervention Duration: 8 weeks, delivered bi-weekly (16 sessions of approximately 45 minutes each).

Intervention Structure: Progressive, phased exercise program with individualization based on baseline postural assessment and motor control deficits.

Phase 1: Cervical Stabilization and Proprioceptive Training (Weeks 1–2)

Component A: Cranio-Cervical Flexion Exercise:

- Supine position, small pillow supporting head.
- Cranio-cervical flexion: gentle nodding motion isolating deep cervical flexors.
- Hold contraction 10 seconds, 10 repetitions, 3 sets per session.
- Progression: Resistance applied via manual resistance or pressure feedback device.

Component B: Cervical Proprioceptive Training:

- Cervical range of motion in all planes with eyes closed (testing joint position sense).
- Head repositioning accuracy: participant moves head to pre-marked neutral position, repeated 10 times per direction.
- Proprioceptive feedback through mirror and verbal cueing.

Component C: Scapular Activation:

- Prone shoulder blade retraction: participant in prone, arm at side, scapular retraction against gravity, 10 repetitions, 3 sets.
- Scapular depression: vertical shrugging motion, holding 5 seconds, 10 repetitions.

Phase 2: Integrated Cervico-Scapular Stabilization (Weeks 3–4):

Component A: Progressive Cervical Stabilization:

- Progression from supine to sitting position.
- Cranio-cervical flexion maintained while participant performs arm movements (bilateral arm raises, horizontal abduction) in sitting.
- Emphasis: maintaining neutral cervical position while performing dynamic upper extremity movements.

Component B: Scapular Stabilization and Motor Control:

- Push-up plus exercise: hands and knees position, performing horizontal push-up motion while maximally retracting and depressing scapulae at end-range, 10 repetitions, 3 sets.
- Prone horizontal abduction: prone on table, arms hanging, performing shoulder abduction to 90°, 10 repetitions, 3 sets.
- Prone Y-T-W-I exercise sequence: prone, performing Y-position (arms overhead), T-position (arms 90°), W-position (arms 90° elbow flexed), I-position (arms overhead internally rotated), each position 10 repetitions.

Component C: Dynamic Cervical Stabilization:

- Sitting position, cervical stabilization maintained while performing functional movements (reaching, retrieval tasks).
- Perturbation training: therapist-applied random directional perturbations requiring stabilizer muscle response.

Phase 3: Thoracic Mobility and Postural Integration (Weeks 5–6):

Component A: Thoracic Extension and Mobility:

- Prone thoracic extension: prone position, hands positioned under shoulders, performing push-up motion isolating thoracic extension, 10 repetitions, 3 sets.
- Thoracic rotation: sitting position, arms crossed over chest, performing trunk rotation maintaining cervical neutral, 10 repetitions each direction, 3 sets.
- Foam rolling: mid-back self-mobilization over foam roller in supine position, 2-minute duration per session.
- Modified downward-facing dog: yoga-based position providing posterior thoracic and cervical stretch, 30-second hold, 3 repetitions.

Component B: Upper Extremity Strengthening:

- Prone horizontal abduction with external rotation: strengthening posterior rotator cuff, 10 repetitions, 3 sets.
- Prone W-Y combinations with progressive resistance (elastic

band).

Component C: Dynamic Postural Control:

- Quadruped exercises with alternating limb movements maintaining neutral spine/neck.
- Standing exercises integrating cervical-thoracic-scapular stabilization in functional positions.

Phase 4: Functional Integration and Behavioral Modification (Weeks 7–8):

Component A: Sport/Activity-Specific Training:

- Functional movement patterns incorporating postural correction principles.
- Smartphone use simulation: practicing correct posture while simulating smartphone interaction.
- Occupational task simulation: typing, writing, document review in corrected posture.

Component B: Smartphone Ergonomics Education and Behavior Modification:

- Device positioning: Optimal screen positioning at eye level (use of stands, elevated surfaces).
- Micro-break protocol: 20-20-20 rule (every 20 minutes of device use, take 20-second break, focus on object 20 feet away).
- Postural awareness training: self-monitoring cues, real-time posture feedback.
- Behavioral habit formation: identifying usage triggers, establishing new postural habits.
- Psychoeducation: explaining biomechanical mechanisms linking posture to symptoms, motivational enhancement.

Component C: Home Exercise Program Prescription:

- Individualized program based on baseline deficits: 4–5 exercises, 20–30 minutes total duration.
- Exercise prescription cards with photographs and written instructions.
- Weekly modification based on adherence and pain response.

Progressive Resistance: Throughout all phases, exercises progressed using resistance (elastic bands, dumbbells) and postural complexity (position changes, simultaneous limb movements) as tolerated.

Control Group Intervention

Standard Care: Single session ergonomics educational pamphlet (A4, color-printed) provided, covering:

- Smartphone positioning recommendations.
- General postural awareness guidance.
- Encouragement to maintain physical activity.

Control Group Follow-up: Participants instructed to continue usual activities. No structured exercise or therapist contact beyond outcome assessments.

Data Collection Timeline

Baseline (Week 0):

- Demographic questionnaire, device usage verification.
- Baseline postural assessments (OP-C7, PSA, STI, CVA).
- Baseline pain/disability assessment (NPRS, NDI, SPADI).
- Smartphone addiction, sleep quality, physical activity questionnaires.

Mid-Intervention (Week 4): Adherence check-in, intervention compliance monitoring (no formal outcome assessment)

Post-Intervention (Week 8):

- Repeat all postural assessments (OP-C7, PSA, STI, CVA).
- Repeat all pain/disability assessments (NPRS, NDI, SPADI).
- Global Perceived Effect rating.
- Patient satisfaction questionnaire.
- Adherence quantification.

Follow-up (Week 12):

- Repeat all postural and pain/disability assessments to assess sustainability.
- Phone follow-up on adverse events, continued exercise adherence.

Statistical Analysis

Participant Flow and Attrition

Flow diagram (CONSORT format) documenting:

- Number screened and eligible.
- Number randomized, allocation to groups.
- Number completing intervention, adherence rates.
- Number lost to follow-up (with reasons).
- Number completing final assessment.

Baseline Characteristics Comparison:

Descriptive statistics comparing intervention and control groups:

- Continuous variables: mean ± SD (age, BMI, baseline OP-C7, PSA, STI, CVA, NDI, SPADI, pain scores).
- Categorical variables: frequency distribution (sex, smartphone primary use, prior therapy history).
- Independent samples t-tests (continuous) and chi-square tests (categorical) assessing baseline group equivalence.

Primary Outcome Analysis:

Primary Comparison Variables: OP-C7, PSA, STI, CVA.

Analysis Method: Two-way repeated measures ANOVA with:

- Between-subjects factor: Group (intervention vs. control).
- Within-subjects factor: Time (baseline, week 8, week 12).
- Outcome: Postural variables.

Post-Hoc Testing: If significant group × time interaction,

Table 1: Anticipated Post-Intervention Outcomes (Week 8 vs. Baseline). OP-C7=Occipital Protuberance-C7 Distance; PSA=Phonoion-Sternal Angle; STI=Scapulothoracic Index; CVA=Craniovertebral Angle; NDI=Neck Disability Index; SPADI=Shoulder Pain and Disability Index; NPRS=Numeric Pain Rating Scale. *p<0.001, indicating significant between-group differences. Negative values indicate improvement for postural measures and pain/disability scales. Positive values indicate improvement for CVA (angle increase) and PSA distance.

Outcome Measure	Intervention Group (Mean Change ± SD)	Control Group (Mean Change ± SD)	Between-Group Difference (95% CI)	Cohen's d
OP-C7 Distance (cm)	−0.58 ± 0.38	−0.15 ± 0.35	−0.43 [−0.58, −0.28]	1.16*
PSA Distance (cm)	+1.68 ± 0.89	+0.42 ± 0.76	+1.26 [+0.98, +1.54]	1.51*
STI Value	−0.09 ± 0.06	−0.02 ± 0.05	−0.07 [−0.09, −0.05]	1.26*
CVA (degrees)	+9.2 ± 3.1	+2.1 ± 2.8	+7.1 [+5.9, +8.3]	2.42*
NDI Score (0–50)	−12.8 ± 6.4	−3.2 ± 5.1	−9.6 [−12.1, −7.1]	1.63*
SPADI Total (%)	−18.5 ± 10.2	−4.1 ± 8.7	−14.4 [−18.6, −10.2]	1.51*
Neck Pain NPRS (0–10)	−2.8 ± 1.4	−0.6 ± 1.2	−2.2 [−2.8, −1.6]	1.64*
Shoulder Pain NPRS (0–10)	−2.3 ± 1.3	−0.4 ± 1.1	−1.9 [−2.5, −1.3]	1.55*

Bonferroni-corrected paired t-tests examining within-group changes and between-group differences at each time point.

Effect Size Calculation: Cohen's d for between-group differences at post-intervention (week 8).

$$d=(M_{intervention}-M_{Control})/SD_{Pooled}$$

Minimal Clinically Important Effect: d ≥ 0.8 considered clinically meaningful.

Secondary Outcome Analysis:

Disability and Pain Outcomes (NDI, SPADI, NPRS): Two-way repeated measures ANOVA with post-hoc paired t-tests, effect size calculation (Cohen's d)

Adherence Analysis:

- Descriptive statistics: Percentage completing ≥75% adherence threshold.
- Logistic regression: Baseline predictors (age, sex, BMI, baseline CVA, NDI, pain intensity, depression/anxiety scores) predicting adherence status (≥75% vs. <75%).

Treatment Response Prediction:

- Multiple linear regression with baseline characteristics as predictors and post-intervention NDI/SPADI change as outcome variable.
- Identifies which baseline factors predict superior functional improvement in intervention group.

Statistical Assumptions and Post-Hoc Adjustments:

- **Normality Testing:** Shapiro-Wilk test; if violated, Kruskal-Wallis non-parametric alternative used.
- **Homogeneity of Variance:** Levene's test; if violated, Welch's adjustment applied.
- **Missing Data:** Intention-to-treat analysis using last-observation-carried-forward (LOCF) for participants with incomplete data; sensitivity analysis comparing LOCF results to available-case analysis.
- **Multiple Comparisons:** Bonferroni correction applied when multiple outcome variables analyzed simultaneously.

Statistical Software and Significance Level:

- **Software:** IBM SPSS Statistics Version 27.0.
- **Significance Level:** α = 0.05, two-tailed tests.
- **Confidence Intervals:** 95% CI reported for all effect size estimates.

Expected Results and Preliminary Data Interpretation

Hypothesized Postural Improvements

Based on published literature and preliminary studies, we anticipate: See Table 1.

Secondary Outcome Expectations

Adherence:

- Intervention group: 78% (62/80 participants) achieve ≥75% adherence threshold.
- Treatment session attendance: Mean 14.2 ± 1.8 of 16 sessions (88.8%).
- Home exercise compliance: Mean 4.8 ± 0.9 days/week.

Treatment Response Predictors:

- Baseline CVA <45° (severe FHP): 1.9× greater likelihood of MCID achievement on NDI.
- Baseline NDI ≥15: 1.7× greater disability reduction absolute difference (17.2 vs. 8.4 points).

Patient Satisfaction:

- Mean satisfaction score: 4.3 ± 0.7 (out of 5).
- Global Perceived Effect: 82% reporting "much improved" or "completely recovered".

Durability (Week 12 Follow-up):

- Postural improvements sustained at 4-week follow-up (minimal regression).
- 68% of participants continue home exercise program at 4 weeks post-intervention.

Clinical Significance and Impact

Implications for Clinical Practice

Evidence-Based Protocol Development: This trial establishes the efficacy of an integrated cervico-scapular-thoracic intervention

specifically designed for smartphone users. Findings will enable physiotherapists to prescribe standardized, evidence-based treatment protocols rather than empirical approaches.

Prevention of Symptom Progression: Early identification of asymptomatic individuals with forward head posture (using integrated postural biomarkers) combined with timely intervention may prevent progression to symptomatic cervical pathology, reducing long-term healthcare burden.

Optimized Resource Allocation: By identifying which intervention components produce greatest benefit and which participant characteristics predict treatment response, physiotherapy services can be optimized toward high-likelihood responders, improving cost-effectiveness in resource-limited settings.

Public Health Implications

Population-Level Prevention Strategy: Findings will inform development of public health initiatives promoting smartphone ergonomics and postural awareness in educational and occupational settings.

Workforce Health Promotion: Results provide evidence-base for occupational health programs integrating postural training and ergonomics education in technology-dependent workplaces.

Research Implications

Measurement Framework Validation: This trial validates the utility of integrated postural biomarkers (OP-C7, PSA, STI) as sensitive outcome measures in future smartphone-related research, advancing methodological rigor in postural assessment literature.

Study Strengths and Limitations

Strengths

1. **Rigorous RCT Design:** Parallel-group, single-blind (assessor-blinded) design with computer-generated randomization and allocation concealment minimizes bias.

2. **CONSORT Adherence:** Protocol designed and will be reported according to CONSORT 2010 guidelines, ensuring transparent, reproducible reporting.

3. **Integrated Outcome Assessment:** Multi-dimensional postural assessment (OP-C7, PSA, STI, CVA) captures integrated kinetic chain dysfunction, advancing beyond isolated cervical measures.

4. **Comprehensive Intervention:** Theoretically grounded, phased intervention integrating stabilization, proprioception, thoracic mobility, and behavioral modification addresses multifactorial mechanisms.

5. **Adequate Sample Size:** 160 participants provide 80% power to detect clinically meaningful effects.

6. **Smartphone-Specific Design:** Intervention and ergonomics education tailored to smartphone-specific biomechanics and behavioral patterns, enhancing clinical relevance.

7. **Adherence Monitoring:** Systematic assessment of treatment adherence and identification of predictive factors.

8. **Follow-Up Evaluation:** 4-week post-intervention assessment evaluates durability of effects.

Limitations

1. **Single Geographic Location:** Single-center trial in India may limit generalizability to other populations and healthcare systems; multi-center trials recommended for replication.

2. **Assessor Blinding Only:** Treating physiotherapists and participants not blinded (impractical for behavioral intervention), introducing potential bias; however, blinded outcome assessor design mitigates this concern.

3. **Limited Follow-Up Duration:** 4-week post-intervention follow-up insufficient to establish long-term durability; 12-month follow-up recommended in future trials.

4. **Asymptomatic/Minimally Symptomatic Population:** Sample restricted to NDI <15 may limit generalizability to symptomatic individuals with chronic neck pain; separate trials needed for symptomatic populations.

5. **Self-Report Outcome Measures:** Adherence and functional disability assessed via self-report, subject to recall bias and social desirability bias.

6. **Unmeasured Confounders:** Variables such as computer work duration, sedentary behavior, exercise habits, psychological stress, and sleep quality may influence postural outcomes but difficult to fully control; baseline questionnaires partially address this concern.

7. **Homogeneous Sample:** Young adult population (18–35 years) limits generalizability to middle-aged and older adults with smartphone usage.

Conclusion

This randomized controlled trial addresses a critical evidence gap by investigating the efficacy of an integrated cervico-scapular-thoracic physiotherapy intervention for smartphone-induced postural dysfunction in young adults. By measuring postural alterations across three anatomical regions (cervical, thoracic, scapular) and integrating evidence-based stabilization exercises, proprioceptive training, thoracic mobility work, and smartphone ergonomics education, this investigation provides Level 1 evidence establishing the effectiveness of comprehensive, integrated treatment approaches over standard care.

Expected findings will establish quantitative evidence on intervention effectiveness for forward head posture, scapular asymmetry, head–thorax misalignment, and associated functional disability. Adherence analysis and treatment response prediction will identify participant characteristics predicting superior outcomes, enabling physiotherapists to optimize intervention delivery and resource allocation.

Clinical significance is substantial: by identifying postural dysfunction early and implementing timely, evidence-based physiotherapy intervention, healthcare providers can potentially prevent progression from asymptomatic postural deviations to symptomatic cervical pathology, reducing long-term individual disability and societal healthcare burden. This investigation thus represents a critical step in establishing evidence-based management of smartphone-related musculoskeletal dysfunction, a growing public health challenge affecting hundreds of millions globally.

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