Mobile-Related Musculoskeletal Abnormalities in Long-Term Smartphone Users: Physical Examination Findings and Physiotherapy Effectiveness of Stretching and Strengthening Exercise Interventions

P.Muthukrishnan, PT, PhD[1] · Dr,Rajadurai, MS, (Ortho)[2] · Dr.D.Basil Jebaslin Durai [3]. Dr.A.Sam Thamburaj[4]. Dr.Pradeepa Mani[5]

[1]Department of Physiotherapy, Meenakshi higher education and reserch center, chennai,tamilnadu,india.
[2]Department of Orthopedic and Rehabilitation Medicine, meenakshi higher education and reserch center, chennai,tamilnadu,india
[3]Principal, Christian College of Physiotherapy,Colachel,Kanyakumari, Affiliated to The Tamilnadu Dr.M.G.R Medical University,Tamilnadu,India
[4]Professor/Principal,Vinayaka Mission's College of Physiotherapy,Vinayaka Mission's Research Foundation(DU),Salem,Tamilnadu,India
[5]Vice principal,PPG College of physiotherapy, Affiliated to The Tamilnadu Dr.M.G.R Medical University,Coimbatore,Tamilnadu,India.

Corresponding Author: **P. Muthukrishnan**, PT, PhD(Scholar) | Email: muthukrishnanptet@svuniversity.ac.in] | Tel: [+91-7373721004]

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ABSTRACT

Background: The epidemic-scale adoption of smartphones globally has created a distinct and growing clinical entity — mobile-related musculoskeletal disorder (MRMD) — characterized by posture-driven cervical, thoracic, scapular, and upper-limb dysfunction. Despite the enormous public health burden, no validated, comprehensive physical examination framework has been proposed exclusively for this population, and evidence on exercise-based interventions remains fragmented.

Objective: To document the spectrum of musculoskeletal abnormalities detected by systematic physical examination in long-term smartphone users and to evaluate the effectiveness of a structured 12-week stretching and strengthening exercise program in correcting postural, strength, and pain parameters.

Methods: A prospective, single-blind randomized controlled trial enrolled 120 adults aged 18–45 years who reported smartphone use exceeding 6 hours per day for more than 2 years. Participants were randomized into an intervention group ($n = 60$) receiving a supervised progressive stretching and strengthening protocol and a control group ($n = 60$) continuing habitual activity. Standardized postural photographic assessment quantified the Craniovertebral Angle (CVA), Scapular Index (SI), and Thoracic Kyphosis Index (TKI). Additional clinical measures included cervical range of motion (CROM), grip strength dynamometry, neck disability index (NDI), visual analogue scale for pain (VAS), and upper trapezius and deep cervical flexor endurance testing. Assessments were performed at baseline, 6 weeks, and 12 weeks.

Results: Physical examination revealed forward head posture (CVA < 50°) in 88.3% of participants, protracted scapulae in 74.2%, and moderate-to-severe thoracic kyphosis in 61.7%. Cervical flexion strength deficits and upper trapezius hypertonicity were near-universal findings. At 12 weeks, the intervention group demonstrated clinically meaningful improvements in CVA ($+8.4° \pm 2.1°$; $p < 0.001$), SI ($p = 0.003$), TKI ($p = 0.001$), NDI score reduction ($p < 0.001$), and VAS pain score ($p < 0.001$). Control group parameters showed minimal change. No adverse events were recorded.

Conclusion: Long-term smartphone use produces a consistent and clinically recognizable constellation of musculoskeletal abnormalities. A progressive 12-week stretching and strengthening program produces statistically significant and clinically meaningful improvements across postural, functional, and pain outcomes. These findings establish a reproducible examination framework for this population and support structured physiotherapy as a first-line intervention for mobile-related musculoskeletal disorders.

Keywords: *Smartphone musculoskeletal disorders; Forward head posture; Cervical dysfunction; Scapular dyskinesis; Thoracic kyphosis; Stretching exercise; Strengthening exercise; Physiotherapy; Text neck; Craniovertebral angle; Digital health; Postural rehabilitation*

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1.

INTRODUCTION

The smartphone has become arguably the most transformative personal technology device of the twenty-first century. With more than 6.8 billion smartphone subscriptions active globally as of 2024, and average daily usage time escalating to 4–7 hours across demographic groups, the human body is now subjected to postural loading patterns for which it was not evolutionarily prepared. What began as convenience has quietly become a public health problem that physiotherapists and musculoskeletal clinicians encounter daily, yet which has received disproportionately little systematic clinical attention.

The term "text neck" was coined to describe the forward head posture (FHP) adopted during downward gaze at a handheld screen. When the head is held in a neutral position, it exerts approximately 4.5–5.5 kilograms of load on the cervical spine. At 15 degrees of flexion — a common angle during smartphone use — this load rises to approximately 12 kg. At 45 degrees of flexion, it increases to approximately 22 kg. These biomechanical realities translate, over months and years of habitual use, into profound structural and functional consequences: lengthening and weakening of the deep cervical flexors, shortening and hypertonicity of the suboccipital musculature and upper trapezius, protraction of the scapulae, loss of thoracic mobility, and acceleration of cervical degenerative changes.

Despite the breadth and depth of emerging evidence on individual components of mobile-related musculoskeletal dysfunction, no comprehensive, validated physical examination framework has been proposed specifically for this clinical population. Clinicians encounter these patients regularly but lack standardized guidance on which assessments to prioritize and how to interpret findings within the specific context of prolonged smartphone use. This clinical gap creates inconsistency in diagnosis and management.

Equally important is the question of treatment. While physiotherapy is widely recommended, the specific dose, content, and progression of exercise protocols remain areas of active debate. Stretching programs targeting shortened anterior chain structures (pectoralis minor, sternocleidomastoid, scalenes) and strengthening programs targeting weakened posterior chain structures (deep cervical flexors, lower trapezius, serratus anterior, rhomboids) represent the two broad therapeutic pillars — but their combined effectiveness in a standardized, progressive format has not been rigorously evaluated in populations defined explicitly by long-term smartphone use.

The present study therefore pursues two interrelated objectives. First, it documents the spectrum and prevalence of musculoskeletal abnormalities detected through a systematic, reproducible physical examination protocol applied to confirmed long-term smartphone users. Second, it evaluates the effectiveness of a 12-week progressive stretching and strengthening exercise program in correcting the identified abnormalities across postural, functional, and pain-related outcome domains.

2. LITERATURE REVIEW

2.1 Epidemiology of Smartphone-Related Musculoskeletal Complaints

The association between prolonged smartphone use and musculoskeletal pain has been documented across multiple geographic contexts and occupational groups. Systematic reviews and meta-analyses published between 2018 and 2024 consistently report prevalence rates of neck pain between 57% and 74% in populations using smartphones for more than 4 hours daily. Shoulder pain prevalence ranges from 35% to 52%, thumb and wrist pain from 28% to 44%, and upper back discomfort from 40% to 61%. The dose-response relationship between daily usage duration and symptom severity has been confirmed in cross-sectional studies employing objective usage tracking, with a statistically significant inflection point emerging around 4–6 hours of daily use.

Adolescents and young adults represent the highest-risk demographic, with several longitudinal studies demonstrating that individuals who adopted high smartphone use during adolescence exhibit measurably greater cervical muscle fatigue, reduced cervical ROM, and accelerated radiographic degenerative changes compared to age-matched controls with restricted usage. The occupational dimension is equally significant: studies in office workers and university students — populations combining computer work with smartphone use — demonstrate synergistic musculoskeletal loading that compounds postural risk beyond either modality alone.

2.2 Biomechanical Mechanisms of Cervical and Thoracic Dysfunction

The primary biomechanical pathway through which smartphone use induces cervical dysfunction is sustained anterior weight-bearing beyond the neutral cervical spine position. When flexed to accommodate downward gaze at a phone screen, the cervical spine operates at a chronic mechanical disadvantage. Sustained loading in this position activates a cascade: progressive lengthening and inhibition of the deep cervical flexors (longus colli, longus capitis), compensatory recruitment and subsequent hypertonicity of the superficial cervical flexors (sternocleidomastoid) and upper trapezius, and progressive anterior translation of the head relative to the thoracic reference axis.

Simultaneously, the thoracic spine adopts an increased kyphotic curvature as the thorax rounds forward to support the flexed neck. This thoracic hyperkyphosis reduces the available range of cervical extension and rotation, compounds the mechanical load at the cervicothoracic junction, and drives the scapulae into a protracted, anteriorly tilted position. Scapular protraction diminishes the subacromial space, alters the force-couple balance of the rotator cuff, and reduces shoulder elevation strength — creating a biomechanical pathway from cervical to shoulder dysfunction that explains the high co-prevalence of neck and shoulder pain in this population.

2.3 Clinical Assessment of Postural Abnormalities

Photographic postural analysis has emerged as the reference standard for quantifying postural deviations in clinical research settings. The craniovertebral angle (CVA) — measured between a horizontal line through C7 and a line connecting C7 to the tragus of the ear — provides a reliable and reproducible index of forward head posture. Values below 50 degrees are widely accepted as indicative of clinically significant forward head posture. Interrater reliability for CVA measurement using photographic analysis with software assistance has been reported in the range of ICC 0.87–0.95 in multiple validation studies.

The Scapular Index provides a normalized ratio-based measure of scapular position relative to body size, avoiding the anthropometric confounding that affects absolute distance measurements. Thoracic kyphosis assessment using surface landmark-based angle measurement offers a practical alternative to full-spine radiography for longitudinal clinical monitoring, with demonstrated moderate-to-good correlation with radiographic kyphosis angle.

2.4 Exercise Interventions for Postural Correction

Two broad categories of exercise intervention have been evaluated for postural correction in forward head posture and related cervical dysfunction: stretching protocols targeting shortened anterior and lateral cervical, chest, and shoulder structures, and strengthening protocols targeting the weakened or inhibited cervical stabilizers and scapular retractors. Both modalities have demonstrated independent efficacy in randomized trials, with combined approaches generally producing larger and more sustained improvements than either modality alone.

Cervical deep flexor training, popularized through the Jull cranio-cervical flexion test rehabilitation model, has demonstrated robust evidence for reducing neck pain, improving cervical neuromuscular control, and increasing deep flexor endurance. Scapular retraction and depression exercises targeting the lower trapezius and serratus anterior have demonstrated efficacy in correcting protracted scapular posture and reducing shoulder pain in office workers. However, a comprehensive progressive protocol combining all relevant muscle groups within a single standardized framework, specifically validated in a smartphone-defined population, has not previously been reported.

3. MATERIALS AND METHODS

3.1 Study Design

This study was conducted as a prospective, single-blind randomized controlled trial following the CONSORT 2010 reporting guidelines. Ethical approval was obtained from the Institutional Ethics Committee of Meenakshi Institute of Higher Education and Research (IEC/PHD/10/2023/22). All participants provided written informed consent prior to enrollment.

3.2 Participants

Participants were recruited through campus-based poster advertisement and department-level word-of-mouth at three institutions in Chennai, Tamil Nadu, India. Inclusion criteria required: age 18–45 years, self-reported smartphone use $\geq$ 6 hours per day confirmed by objective screen time logging for a minimum of 7 days prior to enrollment, duration of smartphone use $\geq$ 2 years, presence of at least one musculoskeletal symptom (neck pain, shoulder pain, upper back pain, or upper limb discomfort) with Numeric Pain Rating Scale $\geq$ 2/10, and willingness to attend supervised sessions.

Exclusion criteria included: any prior cervical or thoracic spine surgery, diagnosed inflammatory arthritis or systemic connective tissue disease, active cervical radiculopathy confirmed by neurological examination, severe scoliosis (Cobb angle > 25°) or other structural spinal deformity, neurological disorders affecting motor control, pregnancy, and participation in any formal physiotherapy program within the preceding 6 months. All participants underwent a standardized 15-minute structured clinical interview and physical screening prior to enrollment.

3.3 Sample Size Calculation

Sample size was calculated using G*Power 3.1 software based on the primary outcome of CVA change. Using a two-tailed independent samples t-test model, a minimum detectable difference of 4 degrees in CVA, a standard deviation of 6.2 degrees derived from pilot data, an alpha of 0.05, and a desired power of 80%, the calculated sample size was 48 participants per group. Accounting for an anticipated 20% attrition rate, 60 participants were enrolled per group, yielding a total enrollment of 120 participants.

3.4 Randomization and Allocation Concealment

Randomization was performed using a computer-generated random number sequence produced by a biostatistician not involved in participant assessment or treatment delivery. Allocation was concealed using sequentially numbered sealed opaque envelopes. Group assignment was disclosed to the treating physiotherapist only after baseline assessment was complete. The assessing physiotherapist remained blinded to group allocation throughout the study.

3.5 Physical Examination Protocol

3.5.1 Postural Photographic Assessment

Standardized postural photographic assessment was performed in a dedicated examination room with controlled environmental conditions (standardized lighting, room temperature 22–25°C, white background). A tripod-mounted high-resolution digital camera (Sony Alpha ILCE, 24.2-megapixel sensor) was positioned at a fixed height of 1.2 meters from the ground, at 1.5 meters perpendicular distance from the participant, and at right angles to the participant's sagittal plane.

Participants wore standardized fitted clothing (black fitted t-shirt and elastic waist trousers) to facilitate clear visualization of anatomical landmarks. Self-adhesive reflective markers (8 mm diameter, high-contrast white) were placed at the following landmarks: C7 spinous process, tragus of the ear (anterior aspect), sternal notch, coracoid process, posterolateral scapular angle (inferior scapular angle), and T3–T4 thoracic spine reference point.

Prior to photography, all participants completed a 5-minute standing habituation period with instructions to stand upright with arms at sides, feet hip-width apart, and eyes directed to a fixed point at eye level. Three sequential photographs were captured from each participant (two right lateral, one left lateral) at 5760 × 3840 pixel resolution. Photographic images were imported into CorelDRAW Graphics Suite (version 2024) and Kinovea motion analysis software (version 0.9.3) for angle measurement.

3.5.2 Outcome Measures

Primary Outcome Measures:

- Craniovertebral Angle (CVA): Angle between a horizontal line through C7 and the C7-to-tragus line. CVA < 50° was classified as clinically significant forward head posture.
- Scapular Index (SI): Ratio of sternal notch-to-coracoid process distance divided by posterolateral scapular angle-to-T3/T4 distance. Provides body-size-normalized scapular position measurement.
- Thoracic Kyphosis Index (TKI): Semi-quantitative surface landmark-based kyphosis angle. Categorized as: normal 20–40°, moderate 41–55°, severe > 55°.

Secondary Outcome Measures:

- Cervical Range of Motion (CROM): Measured using a calibrated digital goniometer across six planes (flexion, extension, bilateral lateral flexion, bilateral rotation).
- Deep Cervical Flexor (DCF) Endurance: Cranio-cervical flexion test (CCFT) using pressure biofeedback unit (Stabilizer, Chattanooga). Performance index derived from highest activation level sustained for 10 seconds without superficial muscle substitution.
- Upper Trapezius Pressure Pain Threshold (PPT): Algometer-based PPT measurement at the midpoint of the upper trapezius belly bilaterally.
- Grip Strength: Dominant and non-dominant hand grip strength measured using a calibrated Jamar hydraulic hand dynamometer (three trials, average recorded).
- Neck Disability Index (NDI): Validated 10-item self-report questionnaire (0–100 scale); higher scores indicate greater disability.
- Visual Analogue Scale for Pain (VAS): 100 mm horizontal scale for current worst neck/shoulder/upper back pain intensity.
- Smartphone Usage Duration: Objective daily screen time data extracted from device settings at each assessment.

3.6 Intervention Protocol

3.6.1 Intervention Group: Structured Stretching and Strengthening Program

The intervention group received a supervised, progressive 12-week exercise program combining cervical and thoracic stretching with targeted strengthening of cervical stabilizers and scapulothoracic musculature. Sessions were conducted three times weekly under physiotherapist supervision, with two additional home-based sessions per week using a pictorial exercise diary. Total weekly exercise volume was approximately 75–90 minutes.

The program was structured in three 4-week phases:

Phase 1 (Weeks 1–4): Foundation — Mobility and Activation

This phase prioritized pain-free restoration of cervical and thoracic mobility and activation of inhibited deep stabilizers. The initial focus was on reducing tissue sensitivity and establishing neuromuscular awareness before progressive loading. Participants performed cervical retraction and chin tuck exercises in supine and sitting positions, suboccipital soft tissue self-release, upper trapezius and levator scapulae stretches, pectoralis minor doorway stretches, thoracic self-mobilization over a foam roller, and seated scapular retraction exercises with elastic resistance band (light resistance).

Phase 2 (Weeks 5–8): Load Progression — Endurance and Coordination

Resistance and volume were progressively increased. Deep cervical flexor endurance training advanced through CCFT performance levels. Exercises added included: prone cervical retraction with head lift against gravity, prone Y-T-W scapular exercises with light dumbbell resistance (0.5–1 kg), serratus anterior wall slides, lower trapezius strengthening in prone with arm elevation, rhomboid exercises with resistance band, and thoracic extension over rolled towel progressing to prone thoracic extension.

Phase 3 (Weeks 9–12): Functional Integration and Maintenance

Exercises were progressed to functional and sport-specific loading. Participants were educated on ergonomic phone positioning, posture breaks during sustained phone use, and a maintenance home exercise program for post-trial continuation. Exercises included: resistance band face-pulls, single-arm cable row variations, thoracic rotation with lunge, cervical stabilization with perturbation training, and plank progressions targeting global stabilization.

3.6.2 Control Group

The control group received no structured exercise intervention. Participants were asked to continue their habitual daily activities without modification. No ergonomic advice or posture education was provided to the control group during the study period. A delayed intervention was offered to control participants following completion of the 12-week assessment.

3.7 Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics (version 27.0). Normality of distribution was confirmed using the Shapiro-Wilk test. Baseline between-group comparability was assessed using independent samples t-tests for continuous variables and chi-square tests for categorical variables. The primary analysis was conducted using repeated measures analysis of variance (RMANOVA) with a between-subjects factor (group: intervention vs. control) and a within-subjects factor (time: baseline, 6 weeks, 12 weeks). Post-hoc pairwise comparisons were conducted using Bonferroni correction. Effect sizes are reported as Cohen's d and partial eta-squared (η^2p). Statistical significance was defined as $p < 0.05$. Data are presented as mean ± standard deviation unless otherwise specified.

4. RESULTS

4.1 Participant Flow and Baseline Characteristics

One hundred and twenty participants were enrolled and randomized. Seven participants withdrew during the 12-week period (4 from the intervention group: 2 relocation, 1 personal commitment, 1 unrelated illness; 3 from the control group: 2 lost to follow-up, 1 initiated independent physiotherapy). Final analysis included 56 intervention and 57 control participants (total n = 113). All withdrawals occurred before the 6-week assessment and are accounted for in the reported analysis.

Characteristic	Intervention (n=56)	Control (n=57)
Age, years (mean ± SD)	27.4 ± 6.1	26.9 ± 5.8
Female (%)	58.9%	61.4%
BMI (kg/m²)	23.1 ± 3.2	22.8 ± 3.0
Daily smartphone use (hours)	7.8 ± 1.6	7.5 ± 1.7
Duration of use (years)	5.3 ± 2.1	5.1 ± 1.9
CVA, degrees	43.2 ± 5.4	43.8 ± 4.9
VAS Pain Score (0-100 mm)	48.6 ± 14.2	47.3 ± 13.8
NDI Score (0-100)	32.4 ± 8.6	31.9 ± 9.1

Table 1. Baseline demographic and clinical characteristics of study participants (no significant between-group differences, p > 0.05 for all comparisons)

4.2 Prevalence of Musculoskeletal Abnormalities at Baseline

Physical examination findings at baseline revealed a consistent and clinically coherent pattern of musculoskeletal dysfunction across the enrolled population. The most prevalent single finding was forward head posture, defined as CVA below 50 degrees, present in 88.3% of the total enrolled sample. This was closely followed by upper trapezius hypertonicity, identified by palpation and confirmed by reduced pressure pain threshold bilaterally, present in 91.7% of participants.

Musculoskeletal Finding	Prevalence (%)	Severity (Mean ± SD)
Forward Head Posture (CVA < 50°)	88.3%	43.5 ± 5.1°
Upper Trapezius Hypertonicity	91.7%	PPT: 182 ± 41 kPa
Scapular Protraction (SI > 0.9)	74.2%	SI: 1.06 ± 0.14
Reduced DCF Endurance	83.6%	CCFT Level 22 ± 4 mmHg
Moderate-Severe Thoracic Kyphosis (TKI > 40°)	61.7%	TKI: 46.3 ± 7.8°
Reduced Cervical Flexion ROM	72.5%	42.3 ± 8.6°
Reduced Cervical Extension ROM	68.3%	48.2 ± 9.1°
Grip Strength Deficit (≥15% below norm)	55.8%	24.1 ± 6.3 kg
Pectoralis Minor Shortening (clinical)	69.2%	N/A (categorical)
Temporomandibular Tenderness	38.3%	N/A (categorical)

Table 2. Prevalence and severity of musculoskeletal abnormalities on baseline physical examination (n = 120)

4.3 Primary Outcome: Postural Parameters

The craniovertebral angle demonstrated a statistically significant group-by-time interaction ($F(2,222) = 47.3$, $p < 0.001$, $\eta^2p = 0.299$). Within the intervention group, CVA improved from a baseline mean of 43.2 ± 5.4 degrees to 48.3 ± 4.8 degrees at 6 weeks and 51.6 ± 4.2 degrees at 12 weeks, representing a total mean improvement of 8.4 degrees (95% CI: 7.2–9.6°; Cohen's d = 1.72). The control group demonstrated no clinically or statistically meaningful change in CVA across the same period (43.8 ± 4.9° to 43.6 ± 5.1°; p = 0.71).

The proportion of intervention group participants classified as having clinically significant FHP (CVA < 50°) decreased from 89.3% at baseline to 48.2% at 12 weeks. In the control group, this proportion remained stable at 87.7% at baseline and 86.0% at 12 weeks.

Outcome Measure	Group	Baseline	6 Weeks	12 Weeks
CVA (°)	Intervention	43.2 ± 5.4	48.3 ± 4.8*	51.6 ± 4.2*
CVA (°)	Control	43.8 ± 4.9	43.5 ± 5.0	43.6 ± 5.1
SI (ratio)	Intervention	1.06 ± 0.14	0.97 ± 0.12*	0.91 ± 0.10*
SI (ratio)	Control	1.04 ± 0.13	1.05 ± 0.14	1.05 ± 0.13
TKI (°)	Intervention	46.3 ± 7.8	42.1 ± 6.9*	38.7 ± 6.2*
TKI (°)	Control	45.9 ± 7.5	46.2 ± 7.6	46.5 ± 7.8
NDI (0-100)	Intervention	32.4 ± 8.6	22.1 ± 7.4*	14.8 ± 6.2*
NDI (0-100)	Control	31.9 ± 9.1	31.2 ± 8.9	30.8 ± 9.3
VAS (mm)	Intervention	48.6 ± 14.2	31.4 ± 11.8*	19.2 ± 10.1*
VAS (mm)	Control	47.3 ± 13.8	46.8 ± 14.1	47.1 ± 13.6

*Table 3. Primary and secondary outcome measures at baseline, 6 weeks, and 12 weeks. *p < 0.001 vs. baseline within-group and vs. control at same time point.*

4.4 Secondary Outcomes

Cervical range of motion improved significantly across all six planes in the intervention group (all p < 0.001) with the greatest relative gains in flexion (+14.2° ± 3.8°) and extension (+16.7° ± 4.1°). Deep cervical flexor endurance assessed via CCFT performance level improved from a baseline mean of 22.3 ± 4.1 mmHg activation level to 28.6 ± 3.4 mmHg at 12 weeks in the intervention group (p < 0.001), indicating improved capacity to recruit deeper cervical stabilizers without superficial muscle substitution.

Upper trapezius pressure pain threshold improved bilaterally in the intervention group (right: +38 ± 12 kPa; left: +34 ± 11 kPa; p < 0.001 for both), consistent with reduction in muscle hypertonicity and sensitization. Grip strength showed modest but statistically significant improvements in the intervention group (dominant: +2.8 ± 1.2 kg; p = 0.003), likely attributable to improved proximal shoulder and scapular stability enabling more efficient forearm and hand muscle recruitment.

No adverse events or serious adverse events were recorded in either group throughout the 12-week study period.

5. DISCUSSION

5.1 Characterization of Mobile-Related Musculoskeletal Syndrome

The findings of the present study confirm and extend previous research by establishing that long-term smartphone users present with a clinically consistent and reproducible constellation of musculoskeletal abnormalities. The near-universal prevalence of forward head posture (88.3%), upper trapezius hypertonicity (91.7%), and deep cervical flexor endurance deficits (83.6%) observed in this cohort represents more than a collection of incidental findings. These features form a coherent clinical syndrome — what we propose terming Mobile-Related Musculoskeletal Syndrome (MRMS) — with consistent biomechanical logic, predictable examination findings, and demonstrable response to targeted exercise intervention.

The high prevalence of temporomandibular tenderness (38.3%) in this cohort is a finding that deserves particular clinical attention. While the relationship between forward head posture and temporomandibular dysfunction has been described in the literature, its prevalence in a smartphone-using population has not previously been systematically documented. The mandibular repositioning that accompanies sustained forward head posture — posterior and inferior displacement of the mandible relative to the glenoid fossa — generates sustained pressure on the posterior capsule of the temporomandibular joint, a mechanism that may explain the observed co-prevalence. Clinicians assessing smartphone-using patients with neck pain should routinely screen for temporomandibular symptoms as part of the examination.

The pattern of grip strength deficits observed (55.8% of participants demonstrating ≥ 15% reduction below age-sex-matched normative values) is similarly clinically important. The commonly overlooked pathway from cervical posture to hand function — mediated through thoracic outlet compromise, brachial plexus tension, and altered scapulohumeral rhythm — means that distal upper limb symptoms in smartphone users should not be reflexively attributed to local wrist and hand pathology before thorough proximal assessment.

5.2 Effectiveness of the Exercise Intervention

The 12-week progressive stretching and strengthening program produced clinically meaningful improvements across all primary and secondary outcome measures in the intervention group. The magnitude of CVA improvement (+8.4°) is not only statistically significant but clinically meaningful — it corresponds to a shift from a population mean falling firmly in the pathological range below 50° to a population mean exceeding 51°, which lies within the normal reference range. The large effect size (Cohen's d = 1.72) further underscores the robust responsiveness of forward head posture to the applied exercise protocol.

The three-phase progressive structure of the protocol — beginning with mobility restoration and neuromuscular activation, advancing to endurance and coordination loading, and culminating in functional integration — reflects established principles of musculoskeletal rehabilitation. The early-phase emphasis on deep cervical flexor activation addresses the foundational neuromuscular deficit that perpetuates forward head posture irrespective of conscious correction attempts. Without reactivating and strengthening the longus colli and longus capitis, surface-level postural correction cues are unlikely to produce sustained structural change.

The observed improvements in NDI and VAS pain scores parallel and are consistent with the postural improvements. This temporal and mechanistic concordance supports the view that pain reduction in this population is primarily mediated through reduction in abnormal mechanical loading rather than through central pain modulation. The clinical implication is that exercise programs should be designed and monitored with postural correction, not pain relief alone, as the primary therapeutic target.

5.3 Clinical Implications and Unique Contributions

This study makes several contributions that are, to our knowledge, novel in the published literature. First, it proposes and operationalizes a comprehensive multi-domain physical examination framework specifically designed for long-term smartphone users. Prior studies have examined individual components of this examination in isolation; the integrated framework presented here — encompassing postural photography, cervical ROM, deep flexor endurance, trapezius PPT, grip strength, and validated self-report questionnaires — provides a replicable clinical template.

Second, the study demonstrates that exercise-induced postural improvements are achievable within a 12-week timeframe using a relatively modest intervention volume (approximately 75–90 minutes per week including home exercise). This finding has significant practical implications: a physiotherapy program of this duration and intensity is feasible within typical outpatient appointment structures and does not impose prohibitive time demands on participants who are, by definition, already time-burdened by extensive digital device use.

Third, the inclusion of a 5-minute habituation period prior to postural photography, and the use of three sequential photographs per participant, addresses the reproducibility challenges that have limited photographic postural assessment in previous studies. The bilateral photographic capture additionally permitted detection of asymmetric postural patterns that single-view assessment would have missed.

5.4 Limitations

The present study is not without limitations. The single-centre design limits the generalizability of findings to populations differing demographically or culturally in smartphone use patterns. The 12-week assessment period, while sufficient to demonstrate significant change, does not permit conclusions about the durability of benefits beyond this timeframe. The absence of radiographic outcome measures means that improvements in surface-landmark-based postural indices cannot be directly correlated with skeletal structural change. The blinding of participants to group allocation was not feasible given the nature of the intervention, introducing potential performance bias. Future studies should incorporate 6-month and 12-month follow-up assessments and should include radiographic sub-studies to quantify the relationship between surface-based and skeletal postural parameters.

6. CONCLUSION

Long-term smartphone use produces a consistent, reproducible, and clinically significant constellation of musculoskeletal abnormalities centered on forward head posture, scapular protraction, thoracic hyperkyphosis, deep cervical flexor inhibition, and upper trapezius hypertonicity. Physical examination using a standardized multi-domain framework reliably identifies this syndrome and provides quantitative baseline data for treatment monitoring.

A structured, progressive 12-week exercise program combining targeted stretching of shortened anterior chain structures with progressive strengthening of inhibited posterior chain stabilizers produces statistically significant and clinically meaningful improvements across all examined postural, functional, and pain-related outcome domains. The program is safe, feasible, and effective within realistic outpatient physiotherapy parameters.

These findings collectively establish the foundations for a dedicated clinical pathway for Mobile-Related Musculoskeletal Syndrome — from systematic physical examination to evidence-based exercise prescription. As smartphone use continues to increase across populations worldwide, the demand for effective physiotherapy assessment and management strategies for this condition will only grow. Physiotherapists are uniquely positioned to address this emerging epidemic through skilled examination, targeted exercise prescription, and patient education on ergonomic phone use habits.

DECLARATIONS

Conflict of Interest: The authors declare no conflict of interest.

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Ethical Approval: Approved by the Institutional Ethics Committee, Meenakshi Institute of Higher Education and Research (IEC/PHD/10/2023/22).

Data Availability: Dataset available from the corresponding author upon reasonable request.

Author Contributions: RD: Conceptualization, Methodology, Supervision, Writing – Original Draft. MK: Data Collection, Physical Examination, Writing. MK: Clinical Supervision, Data Analysis. MK: Statistical Analysis, Review & Editing. MK: Investigation, Writing – Review & Editing.

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