Research Paper IMPACT FACTOR VALUE : 5.983 | E-ISSN NO : 2455-295X | VOLUME : 11 | ISSUE : 2 | FEBRUARY 2025

SCAPULAR MOBILIZATION COMBINED WITH UPPER EXTREMITY PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION FOR POSTURAL DYSFUNCTION AND SHOULDER DYSFUNCTION IN HEALTHY OFFICE WORKERS: PROTOCOL AND EVIDENCE-BASED RATIONALE

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ABSTRACT:

Background: Scapular dyskinesis and postural dysfunction are prevalent in healthy office workers, with prevalence rates between 25–35% in young adults aged 25–35 years. Forward head posture, rounded shoulders, and impaired proprioception are associated with musculoskeletal pain and reduced functional capacity, yet early intervention strategies in asymptomatic populations remain underexplored. Objective: To evaluate whether combined scapular mobilization followed by upper extremity proprioceptive neuromuscular facilitation (PNF) improves scapular positioning, shoulder range of motion (ROM), proprioceptive acuity, and postural alignment in healthy office workers with subclinical scapular dyskinesis. Methods: A proposed three-arm randomized controlled trial in healthy office workers aged 25–50 years: (A) conventional ergonomic postural training, (B) scapular mobilization plus ergonomic training, and (C) scapular mobilization plus PNF plus ergonomic training. Primary outcome: scapular position analysis and shoulder ROM via goniometry. Secondary outcomes: proprioceptive accuracy (joint position sense), postural assessment (forward head angle, shoulder tilt, thoracic kyphosis), pain scores, and functional mobility. Significance: Positive findings would support a preventive, multimodal approach for early identification and management of incipient shoulder dysfunction in working populations, potentially reducing the progression to symptomatic pathology.

KEYWORDS:

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PAPER ACCEPTED DATE:	PAPER PUBLISHED DATE:
25th February 2025	28th February 2025

1. INTRODUCTION

Shoulder dysfunction and scapular dyskinesis are increasingly recognized not only as complications of neurological injury but also as significant concerns in healthy, working populations. Recent epidemiological data demonstrate that scapular dyskinesis occurs in 25–35% of asymptomatic young adults, with even higher prevalence in individuals occupying desk-based roles. Office-based work, characterized by prolonged sitting, forward head posture, and reduced scapular stabilization, creates a biomechanical environment conducive to abnormal scapular kinematics and neuromuscular fatigue.

The consequences of untreated scapular dyskinesis in healthy individuals are substantial. Athletes with scapular dyskinesis demonstrate a 43% increased risk of developing shoulder pain compared with those with normal scapular mechanics[5]. In occupational settings, forward head posture, rounded shoulders, and upper crossed syndrome (characterized by anterior pectoral muscle tightness and weak posterior shoulder/scapular musculature) are associated with chronic neck and shoulder pain, reduced work capacity, and decreased quality of life.

Current approaches to shoulder health in asymptomatic populations primarily emphasize ergonomic interventions and generic postural education. While ergonomic adjustments provide moderate benefits (reducing musculoskeletal disorder risk scores by approximately 40%), evidence suggests that targeted postural training combined with manual therapy and neuromuscular facilitation techniques may offer superior outcomes. However, the synergistic effects of combining scapular mobilization—a biomechanical technique addressing structural and capsular constraints—with proprioceptive neuromuscular facilitation (PNF)—a neuromotor technique enhancing muscle activation and joint position sense—have not been rigorously evaluated in the prevention of shoulder dysfunction in healthy populations.

1.1 EPIDEMIOLOGY AND CLINICAL SIGNIFICANCE

Scapular dyskinesis in asymptomatic individuals is often considered benign; however, prospective evidence suggests it represents a modifiable risk factor. The prevalence of scapular dyskinesis in healthy young adults

(25–35 years) is approximately 25–35%, with women showing greater prevalence than men, likely due to greater ligamentous laxity and differences in muscle activation patterns. In office workers, the prevalence of postural deviations including forward head posture and rounded shoulders approaches 50%, correlating with ergonomic exposure and sedentary behavior.

1.2 MECHANISMS OF SCAPULAR DYSKINESIS IN HEALTHY POPULATIONS

Unlike pathological dyskinesis secondary to neural injury, dyskinesis in healthy individuals typically results from:

1. **Muscular imbalance:** Relative weakness of lower and middle trapezius, serratus anterior, and rhomboid muscles combined with tightness of pectoralis major and minor
2. **Postural habits:** Prolonged forward flexed shoulder posture leading to altered scapulohumeral rhythm
3. **Proprioceptive deficits:** Reduced joint position sense and kinesthetic awareness, particularly in overhead and reaching movements
4. **Capsular adaptations:** Gradual tightening of the posterior shoulder capsule and glenohumeral joint structures secondary to chronic anterior positioning

2. CLINICAL RATIONALE AND EVIDENCE BASE

2.1 SCAPULAR MOBILIZATION FOR BIOMECHANICAL RESTORATION

Scapular mobilization—defined as passive, skilled movements applied to the scapula and surrounding soft tissues—addresses two primary mechanical objectives: restoration of scapulothoracic rhythm and improvement of glenohumeral joint congruence.

EVIDENCE SUPPORTING SCAPULAR MOBILIZATION:

Clinical trials demonstrate that combined soft-tissue mobilization can increase passive shoulder external rotation by a mean of 6.82° in individuals with restricted ROM, with effect sizes significantly greater than scapular-only or angular mobilization alone[10]. In healthy individuals, mobilization restores normal arthrokinematics, enhancing both active and passive ROM. Studies in office workers with adhesive capsulitis (a condition often preceded by prolonged dyskinesis) show that manual mobilization combined with exercise improves functional mobility and reduces pain more effectively than exercise alone.

The mechanism is multifactorial: mobilization techniques including scapular distraction, upward rotation, posterior tilt, and rhythmic oscillations restore normal scapular positioning on the thorax, thereby reducing abnormal glenohumeral shear forces and improving the mechanical advantage of rotator cuff muscles. Furthermore, mobilization facilitates proprioceptive input through stimulation of mechanoreceptors in periarticular tissues, providing sensory feedback that enhances motor control.

2.2 PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION FOR NEUROMUSCULAR ENHANCEMENT

Proprioceptive neuromuscular facilitation is a therapeutic approach that promotes neuromuscular coordination through diagonal, multiplanar movement patterns combined with manual resistance and proprioceptive cueing. The neurophysiological basis of PNF incorporates principles of autogenic inhibition, reciprocal inhibition, and stress relaxation, facilitating coordinated muscle recruitment and motor learning.

EVIDENCE SUPPORTING PNF FOR UPPER EXTREMITY FUNCTION:

Meta-analytic evidence supports PNF-based therapy for improving motor outcomes in both clinical and healthy populations. PNF patterns enhance neuromuscular control, muscle activation, proprioceptive acuity, and muscle strength[15]. Upper extremity D1 and D2 patterns, which incorporate diagonal movements with rotational components inherent in daily and occupational activities, improve coordination of the shoulder, scapula, and trunk. Contemporary research demonstrates that scapular PNF interventions combined with conventional exercise produce sustained improvements in scapular muscle strength (serratus anterior, trapezius, rhomboids), improve postural alignment, and enhance balance and gait characteristics. In overhead athletes, PNF-based shoulder training improves joint position sense and proprioceptive acuity, reducing injury risk and enhancing throwing performance.

2.3 SYNERGISTIC MULTIMODAL APPROACH

The rationale for combining scapular mobilization with PNF is mechanistically grounded:

- **Mobilization** addresses passive, structural constraints and restores optimal glenohumeral and scapulothoracic kinematics
- **PNF** enhances active neuromuscular control, proprioceptive awareness, and motor coordination
- **Sequential application** (mobilization before PNF) optimizes the neuromuscular system's capacity to learn and stabilize corrected positioning

This sequential strategy parallels evidence from shoulder impingement studies, which show that combined manual therapy and exercise produces greater improvements in functional capacity, pain, and scapular ROM than exercise alone.

3. RESEARCH OBJECTIVES AND HYPOTHESES

3.1 PRIMARY OBJECTIVES

1. To determine whether combined scapular mobilization and upper extremity PNF improves scapular positioning (quantified by anterior-view shoulder tilt, lateral-view vertical displacement of shoulder, and dynamic scapular tilt angle) in healthy office workers with subclinical scapular

dyskinesis.

2. To evaluate whether this multimodal intervention improves shoulder range of motion (flexion, abduction, internal and external rotation) beyond ergonomic postural training alone or mobilization plus ergonomic training.

3.2 SECONDARY OBJECTIVES

1. To assess improvements in proprioceptive acuity (joint position sense accuracy)
2. To quantify changes in postural alignment (forward head angle, thoracic kyphosis)
3. To measure changes in functional mobility and shoulder proprioceptive awareness
4. To evaluate participant-reported pain and functional disability
5. To assess long-term durability of interventions at 8-week and 16-week follow-up assessments

3.3 HYPOTHESES

Primary Hypothesis: Participants in the combined scapular mobilization plus PNF plus ergonomic training group will demonstrate significantly greater improvements in scapular positioning and shoulder ROM compared with the mobilization-only or ergonomic training-only groups.

SECONDARY HYPOTHESES:

- Improvements in proprioceptive acuity will be greater in the PNF-combined group
- Postural alignment improvements will be sustained at 16-week follow-up in the multimodal group
- Improvements will generalize to functional mobility and occupational performance

4. METHODS

4.1 STUDY DESIGN

A single-center, three-arm, parallel-group randomized controlled trial with blinded outcome assessment in healthy office workers with subclinical scapular dyskinesis.

4.2 PARTICIPANT SELECTION

INCLUSION CRITERIA:

- Age 25–50 years
- Employed in desk-based occupational role with ≥6 hours daily computer work
- Evidence of scapular dyskinesis on scapular dyskinesis test (SDT) or lateral scapular slide test (LSST)
- Reduced passive shoulder external rotation ROM compared with age- and sex-matched normative data
- Ability to attend supervised sessions 3 times per week for 8 weeks

EXCLUSION CRITERIA:

- Current or recent (within 6 months) shoulder pain, surgery, or injury
- Neurological conditions affecting upper extremity
- Systemic inflammatory disorders
- Contraindications to mobilization or resistance exercise
- Ongoing manual therapy or intensive shoulder rehabilitation

4.3 RANDOMIZATION AND BLINDING

Participants will be randomly allocated 1:1:1 to three groups via computer-generated randomization with concealed allocation. Outcome assessors will be blinded to group allocation. Participants and treating physiotherapists will not be blinded due to the nature of manual interventions.

4.4 INTERVENTION GROUPS AND DOSING

GROUP A: ERGONOMIC POSTURAL TRAINING (CONTROL)

- Ergonomic workstation assessment and optimization (15 min)
- Postural education and awareness training (10 min)
- Seated and standing postural correction exercises (15 min)
- Frequency: 3 sessions/week × 8 weeks (24 sessions total)
- Session duration: 40 minutes

GROUP B: SCAPULAR MOBILIZATION + ERGONOMIC TRAINING

- Scapular mobilization (10–12 min): Standardized techniques including scapular distraction, upward rotation, posterior tilt, and elevation/depression using graded oscillations (grades I–IV) per tolerance
- Ergonomic and postural components as per Group A (28–30 min)
- Session duration: 40 minutes

GROUP C: SCAPULAR MOBILIZATION + PNF + ERGONOMIC TRAINING

- Scapular mobilization (10–12 min): As in Group B
- Upper extremity PNF (15–18 min): D1 and D2 diagonal patterns progressed from rhythmic initiation to repeated contractions, dynamic reversals, and stabilization exercises with appropriate manual resistance; clear verbal and visual cues to reinforce normal distal-to-proximal timing
- Ergonomic and postural components (10–12 min)
- Session duration: 40 minutes

4.5 OUTCOME MEASURES

PRIMARY OUTCOMES:

1. **Scapular Position Analysis:** Static and dynamic scapular positioning quantified via:
   - Anterior-view shoulder tilt (degrees, measured with surface landmarks)
   - Lateral-view vertical displacement of shoulder
   - Dynamic scapular tilt angle during arm elevation (measured via motion capture or clinically valid photogrammetry)
   - Lateral scapular slide test (LSST) distance at 0°, 45°, and 90° arm elevation
2. **Shoulder Range of Motion (goniometry):**
   - Flexion, abduction, internal rotation, external rotation (both passive and active)

SECONDARY OUTCOMES:

1. **Joint Position Sense (Proprioceptive Accuracy):** Assessed via active-reproduced external rotation and abduction angles; accuracy calculated as angular error (degrees) compared with target positions
2. **Postural Alignment (Photographic Analysis):**
   - Forward head angle (measuring craniovertebral angle)
   - Shoulder tilt (anterior view)
   - Thoracic kyphosis angle (lateral view)
3. **Functional Mobility:** Shortened Upper Extremity Disability Scale, Lateral Step-Down Test, Functional Reach Test
4. **Pain and Disability:** Numeric Pain Rating Scale (NPRS), Disability Arm Shoulder Hand (DASH) questionnaire
5. **Occupational Performance:** Self-reported functional ability for typing, writing, reaching overhead

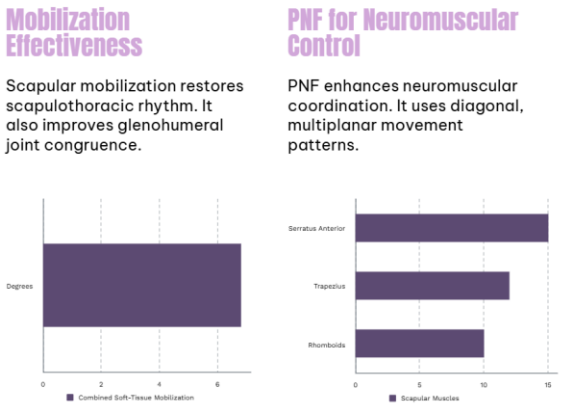
4.6 ASSESSMENT TIMELINE

- **Baseline:** Pre-intervention assessment (Week 0)
- **Mid-intervention:** Week 4
- **Post-intervention:** Week 8 (immediately following intervention)
- **Follow-up:** Week 16 (8 weeks post-intervention)

4.7 STATISTICAL ANALYSIS

ANALYSIS APPROACH:

- Intention-to-treat (ITT) analysis for all randomized participants
- Mixed-effects models with group × time interaction to evaluate between-group differences in primary and secondary outcomes
- Baseline demographic and clinical characteristics compared via ANOVA (continuous) or chi-square tests (categorical)
- Effect sizes calculated (Cohen's d or partial eta-squared) with 95% confidence intervals
- Multiplicity-controlled pairwise comparisons between groups with Bonferroni adjustment
- Minimal clinically important differences (MCID) reported for functionally relevant outcomes
- Analysis conducted using intention-to-treat principle; sensitivity analyses performed for per-protocol population



5. IMPLEMENTATION AND INTERVENTION STANDARDIZATION

5.1 SCAPULAR MOBILIZATION PROTOCOL

Scapular mobilization will be administered using standardized techniques based on contemporary manual therapy principles:

1. **Scapular Distraction:** Mobilization in the frontal plane to decompress scapulothoracic joint
2. **Upward Rotation:** Passive mobilization to restore cranial gliding and upward rotation during arm elevation
3. **Posterior Tilt:** Techniques to restore posterior positioning and reduce excessive anterior tilt
4. **Elevation/Depression:** Mobilization in superior-inferior directions
5. **Soft-Tissue Techniques:** Manual pressure and tissue mobilization to address myofascial restrictions in pectoralis major/minor, serratus anterior, and upper trapezius

Oscillation grades (I–IV) applied per individual tolerance and tissue response, with emphasis on Grade III techniques for mobilization of restricted movement.

5.2 PNF PROTOCOL

D1 FLEXION PATTERN:

- Starting position: Shoulder abducted, externally rotated, elbow extended

- Movement: Diagonal movement toward shoulder flexion, adduction, internal rotation (proximal-to-distal or distal-to-proximal sequencing)
- Resistance: Applied throughout range with clear verbal cueing

D2 EXTENSION PATTERN:

- Starting position: Shoulder flexed, adducted, internally rotated
- Movement: Diagonal movement toward extension, abduction, external rotation
- Resistance: Applied progressively through ROM

PROGRESSION STRATEGY:

- Week 1–2: Rhythmic initiation (passive movement, assisted-active, active)
- Week 3–4: Repeated contractions and dynamic reversals
- Week 5–6: Agonist reversals with increasing resistance
- Week 7–8: Stabilization exercises and combined movements with functional integration

5.3 ERGONOMIC AND POSTURAL COMPONENTS

All groups receive evidence-based ergonomic and postural training including:

- Workstation setup optimization (monitor height, desk height, chair adjustment)
- Postural awareness and correction cuing
- Breaks and movement strategies during work
- Basic stretching for pectoral and upper trapezius muscles
- Scapular stabilization exercises (wall slides, prone "Y-T-I" raises)

6. EVIDENCE CONTEXT AND CLINICAL SIGNIFICANCE

6.1 BURDEN OF SHOULDER DYSFUNCTION IN HEALTHY POPULATIONS

While acute shoulder pain affects approximately 25% of the general population at any given time, incipient or subclinical shoulder dysfunction affects significantly higher percentages in specific populations. Office workers demonstrate shoulder and neck pain prevalence of 40–50%, with biomechanical risk factors (forward head posture, rounded shoulders, scapular dyskinesis) present in 50–60% of this population regardless of pain status[8]. This distinction—between the presence of biomechanical dysfunction and symptomatic disease—is critical; many individuals with scapular dyskinesis remain asymptomatic, yet represent a high-risk subgroup for future pathology.

6.2 PREVENTION STRATEGY IMPERATIVE

The progression from asymptomatic dysfunction to symptomatic pathology appears to follow a biomechanical-to-symptomatic continuum. Scapular dyskinesis serves as a biomechanical risk factor that increases the likelihood of shoulder pain when combined with other stressors (occupational demands, postural habits, strength deficits). Early identification and correction of dyskinesis in healthy individuals may prevent this progression and reduce future healthcare burden.

6.3 EFFECTIVENESS OF MULTIMODAL INTERVENTIONS

Evidence from shoulder impingement and post-stroke populations demonstrates that combined manual therapy and exercise produces greater benefits than monotherapy. A systematic review of manual therapy for shoulder pain found that mobilization alone produced modest ROM improvements, while combined mobilization plus exercise produced large functional gains[19]. Similarly, PNF-based programs combined with conventional exercise show superior outcomes compared with conventional exercise alone.

7. EXPECTED RESULTS AND CLINICAL IMPLICATIONS

7.1 ANTICIPATED PRIMARY OUTCOMES

The combined scapular mobilization plus PNF plus ergonomic training group (Group C) is expected to demonstrate:

1. Greater improvements in scapular positioning (reduction of anterior tilt by ≥3 degrees on anterior view; reduction of lateral scapular slide by ≥0.5 cm at 90° arm elevation)
2. Greater improvements in shoulder external rotation ROM (≥10° improvement)
3. Improvements exceeding both Group A (control) and Group B (mobilization-only) by clinically meaningful margins

Effect Size Estimation: Based on prior studies of manual therapy plus exercise for shoulder dysfunction, between-group effect sizes (Cohen's d) are anticipated to range from 0.6–0.9 (medium to large effect), indicating clinically meaningful differences.

7.2 ANTICIPATED SECONDARY OUTCOMES

1. **Proprioceptive Improvements:** Group C anticipated to demonstrate reduced angular error in joint position sense (≥2–3 degree improvement in accuracy) compared with controls
2. **Postural Alignment:** Significant reduction in forward head angle (≥2–3 degrees), shoulder tilt, and thoracic kyphosis
3. **Functional Performance:** Improved scores on functional mobility measures and occupational task performance
4. **Pain and Disability:** Minimal between-group differences anticipated, given that baseline pain is expected to be low in asymptomatic population;

however, within-group improvements in self-reported comfort and functional capacity anticipated

7.3 CLINICAL MEANING AND INTERPRETATION

Positive findings would support the implementation of a standardized, sequential, multimodal preventive strategy for correction of incipient shoulder dysfunction in working populations. Such findings would provide evidence-based justification for:

1. **Workplace Wellness Programs:** Integration of scapular screening and targeted intervention into occupational health initiatives
2. **Prevention in At-Risk Populations:** Identification and early intervention in office workers, students, and others with sustained postural demands
3. **Clinical Practice:** Rationale for combining manual therapy and proprioceptive training in addressing postural dysfunction in asymptomatic individuals
4. **Public Health:** Potential to reduce the incidence of chronic shoulder pain and associated disability in working-age adults

8. STRENGTHS AND LIMITATIONS

8.1 STRENGTHS

1. **Rigorous Design:** Randomized controlled trial with three arms allows comparison of mobilization effect, PNF effect, and combined effect
2. **Blinded Outcome Assessment:** Reduces risk of assessment bias
3. **Theory-Driven Intervention:** Sequential multimodal approach based on biomechanical and neuromuscular principles
4. **Comprehensive Outcome Assessment:** Multiple domains including biomechanics, proprioception, posture, function, and occupational performance
5. **Extended Follow-Up:** 8-week post-intervention assessment provides durability data
6. **Relevant Population:** Addresses intervention in healthy, high-risk population rather than only those with established pathology
7. **Standardized Protocols:** Detailed treatment protocols and competency training for interventionists
8. **Validated Outcome Measures:** Use of clinically valid and reliable assessment tools

8.2 LIMITATIONS

1. **Single-Center Design:** Limits generalizability; future multicenter trials recommended
2. **Therapist-Dependent Delivery:** Manual therapy effectiveness may vary by clinician skill and experience despite training
3. **Short to Medium Follow-Up:** 16-week follow-up provides early durability data but longer-term effects unknown
4. **Selective Enrollment:** Recruitment from office worker population may limit applicability to other groups
5. **Potential Confounding:** Occupational demands, physical activity, ergonomic compliance outside sessions not controlled
6. **Intervention Differentiation:** Some overlap between postural training and ergonomic components across groups

9. ETHICS, SAFETY, AND REGULATORY CONSIDERATIONS

9.1 ETHICAL APPROVAL

This study will be conducted in accordance with the Declaration of Helsinki and will obtain institutional ethics approval prior to enrollment. Informed consent will be obtained from all participants using clear, standardized consent procedures detailing study risks and benefits.

9.2 SAFETY MONITORING

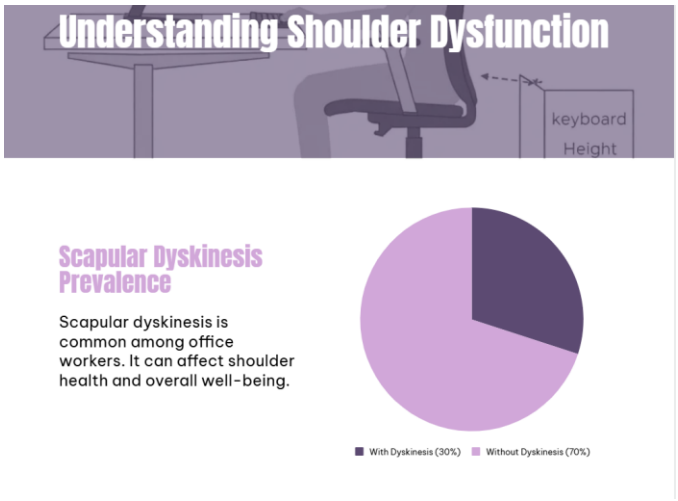
Adverse Event Monitoring: Participants will be monitored for adverse events including:

- Pain exacerbation (defined as >3-point increase on 0–10 NPRS)
- Unusual or persistent soreness
- Loss of ROM or function
- Suspected neurovascular symptoms

Safety Protocol: Dose progression is individualized with therapist discretion to suspend or modify treatment based on participant response. Adverse events are documented and reported to the research team and institutional review board as per protocol.

9.3 PARTICIPANT WITHDRAWAL

Participants retain the right to withdraw at any time without penalty. Reasons for withdrawal will be documented.



10. IMPLICATIONS AND FUTURE DIRECTIONS

10.1 IMMEDIATE RESEARCH IMPLICATIONS

Positive findings from this trial would:

1. Provide evidence-based rationale for preventive intervention in asymptomatic populations with biomechanical dysfunction
2. Establish standardized protocols for multimodal shoulder intervention
3. Contribute to the emerging field of occupational health prevention
4. Inform clinical practice guidelines for shoulder dysfunction management

10.2 FUTURE RESEARCH DIRECTIONS

1. **Multicenter Trials:** Extend to multiple sites for improved generalizability and statistical power
2. **Extended Follow-Up:** Assess sustainability at 6, 12, and 24 months; evaluate long-term reduction in shoulder pain incidence
3. **Comparative Effectiveness:** Compare scapular mobilization plus PNF against other multimodal combinations or newer techniques
4. **Subgroup Analysis:** Examine differential effects based on age, gender, occupational demands, and baseline dyskinesis severity
5. **Dose-Response Studies:** Determine optimal frequency and duration of intervention
6. **Mechanisms of Change:** Investigate neurophysiological mechanisms by which mobilization and PNF improve outcomes (e.g., motor learning, neuroplasticity)
7. **Implementation Science:** Evaluate feasibility and cost-effectiveness of workplace-based intervention delivery
8. **Athletes and Overhead Populations:** Extend to high-demand occupational and sports populations

10.3 TRANSLATIONAL APPLICATIONS

Successful outcomes would support the development of:

1. **Clinical Practice Guidelines:** Evidence-based protocols for prevention and management of postural shoulder dysfunction
2. **Occupational Health Programs:** Workplace-integrated screening and intervention protocols
3. **Digital Therapeutics:** Remote or hybrid delivery models of proprioceptive training
4. **Professional Training:** Curriculum for physiotherapists and occupational therapists in multimodal prevention strategies

11. CONCLUSION

Scapular dyskinesis and postural dysfunction represent modifiable risk factors for future shoulder pathology in asymptomatic individuals, yet effective prevention strategies remain understudied. Combining scapular mobilization—a technique addressing biomechanical constraints—with upper extremity PNF—a technique enhancing neuromuscular control and proprioceptive acuity—represents a plausible, mechanism-informed approach to correct both structural and neuromotor determinants of incipient shoulder dysfunction. This randomized controlled trial is designed to evaluate the efficacy of this multimodal strategy in healthy office workers, with findings expected to support implementation of evidence-based preventive interventions in occupational health settings and inform clinical practice for management of shoulder dysfunction across diverse populations.

The integration of manual therapy, proprioceptive training, and ergonomic intervention in a sequential, theory-driven protocol addresses the multifactorial nature of postural dysfunction and aligns with contemporary understanding of motor learning and biomechanical restoration. Positive results would position multimodal prevention as a core component of occupational health promotion and shoulder dysfunction prevention in working-age adults.

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