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CAN NECK STABILIZATION TRANSFORM TMJ REHABILITATION? EFFECTS OF CERVICAL STABILIZATION TRAINING IN INDIVIDUALS WITH TEMPOROMANDIBULAR DISORDERS: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background

Temporomandibular disorders (TMDs) are common musculoskeletal conditions associated with pain, jaw dysfunction, cervical impairment, and postural abnormalities. Increasing evidence suggests a functional relationship between the temporomandibular joint and cervical spine; however, limited randomized controlled trials have evaluated the effectiveness of cervical stabilization training in TMD rehabilitation.

Objective

To determine the effectiveness of cervical stabilization training combined with conventional TMJ rehabilitation on pain, jaw function, cervical mobility, neck disability, posture, and quality of life in individuals with temporomandibular disorders.

Methods

A single-blinded randomized controlled trial was conducted involving 60 participants diagnosed with TMD according to the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD). Participants were randomly allocated into an experimental group receiving conventional TMJ rehabilitation plus cervical stabilization training (n = 30) and a control group receiving conventional TMJ rehabilitation alone (n = 30). Interventions were administered three sessions per week for six weeks. Outcome measures included Visual Analog Scale (VAS), Jaw Functional Limitation Scale (JFLS), maximum mouth opening (MMO), cervical range of motion (CROM),

Neck Disability Index (NDI), pressure pain threshold (PPT), postural alignment, and SF-36 quality-of-life questionnaire. Repeated measures ANOVA with Bonferroni post hoc correction was used for statistical analysis, with significance set at $p < 0.05$.

Results

Both groups demonstrated significant improvement following intervention; however, the experimental group showed significantly greater improvement compared with the control group across primary and secondary outcome measures. Repeated measures ANOVA revealed significant group × time interaction effects for pain intensity ($F = 6.21$, $p = 0.003$), jaw functional limitation ($F = 5.84$, $p = 0.005$), maximum mouth opening ($F = 4.97$, $p = 0.009$), cervical range of motion ($F = 5.66$, $p = 0.004$), and Neck Disability Index scores ($F = 6.03$, $p = 0.003$). Significant improvements were maintained at 12-week follow-up assessment. No major adverse events were reported.

Conclusion

Cervical stabilization training combined with conventional TMJ rehabilitation appears to be more effective than conventional rehabilitation alone in improving pain, mandibular function, cervical mobility, posture, and quality of life in individuals with temporomandibular disorders.

keywords

Temporomandibular disorders; Cervical stabilization; TMJ rehabilitation; Neck dysfunction; Randomized controlled trial.

INTRODUCTION

Temporomandibular disorders (TMDs) represent a heterogeneous group of musculoskeletal and neuromuscular conditions affecting the temporomandibular joint (TMJ), masticatory muscles, and associated craniofacial structures. These disorders are commonly characterized by jaw pain, restricted mouth opening, joint sounds, muscular tenderness, impaired mastication, and functional limitations that negatively influence quality of life. TMD is considered one of the most prevalent chronic pain conditions of the orofacial region and is frequently associated with cervical pain, postural dysfunction, and psychosocial impairment (1, 2).

Current evidence indicates a strong anatomical, biomechanical, and neurophysiological relationship between the temporomandibular region and the cervical spine. The trigeminocervical nucleus integrates nociceptive input from both cervical and trigeminal structures, creating bidirectional interactions between neck dysfunction and TMJ symptoms. Altered cervical posture, forward head posture, reduced cervical mobility, and impaired deep cervical muscle activation have been consistently reported in individuals with TMD (3, 4).

Several observational and systematic review studies have demonstrated a significant association between TMD and cervical dysfunction. A meta-analysis by Minervini et al. reported correlations between postural alterations and TMD manifestations, suggesting that cervical and mandibular mechanics are functionally interconnected (5). Likewise, Cuenca-Martínez et al. identified increased neck disability, altered craniocervical posture, and cervical musculoskeletal impairments in patients with TMD (4). Earlier evidence from Olivo et al. also highlighted associations between head posture and temporomandibular dysfunction, although methodological heterogeneity limited definitive conclusions (6).

Conventional rehabilitation approaches for TMD generally focus on local interventions targeting the jaw and masticatory system, including relaxation exercises, manual therapy, stretching, postural education, thermotherapy, and behavioral modification. While these approaches can reduce symptoms, persistent dysfunction and recurrence remain common, particularly in individuals with associated cervical impairments (7).

Recent rehabilitation models increasingly support the concept of regional interdependence, where dysfunction in adjacent anatomical regions contributes to pain and movement impairment. Within this framework, cervical stabilization training has emerged as a potentially valuable intervention strategy. Cervical stabilization exercises aim to improve neuromuscular control, activate deep cervical flexors, enhance postural alignment, optimize cervical biomechanics, and reduce abnormal loading across the cranio-cervico-mandibular complex (7, 8).

Emerging clinical evidence suggests that cervical-focused interventions may improve TMD symptoms. Calixtre et al. demonstrated that cervical mobilization and exercise interventions improved mandibular function and reduced pain in individuals with TMD (7). Similarly, Lam et al. reported that cervical and cervico-craniomandibular manual therapy interventions improved maximal mouth opening and pain outcomes (9). More recent randomized controlled trials have explored cervical stabilization approaches in TMD populations and reported improvements in pain intensity, cervical posture, muscle performance, and functional outcomes (8, 10).

Despite growing interest in the cervical contribution to TMD, high-quality randomized controlled evidence investigating structured cervical stabilization programs remains limited. Many previous studies included small sample sizes, heterogeneous interventions, short follow-up durations, or lacked standardized stabilization protocols. Furthermore, the combined effects of conventional TMJ rehabilitation and progressive cervical stabilization training on pain, jaw function, cervical mobility, and postural control remain insufficiently explored(5, 8).

Therefore, investigating cervical stabilization training within a structured rehabilitation framework may provide important evidence for improving multidisciplinary management of TMD. Understanding the therapeutic contribution of cervical stabilization may help clinicians develop more comprehensive rehabilitation strategies targeting both local TMJ dysfunction and associated cervical impairments.

Literature Review

Temporomandibular disorders are multifactorial conditions involving musculoskeletal, biomechanical, neuromuscular, and psychosocial components. The prevalence of TMD has increased substantially over recent decades, particularly among young and middle-aged adults. Pain-related TMD conditions often coexist with cervical dysfunction, headaches, postural abnormalities, and chronic musculoskeletal pain syndromes (1, 2).

The relationship between the cervical spine and TMJ has been widely investigated due to their close anatomical and functional integration. Neurophysiological studies have demonstrated convergence between trigeminal and cervical afferents within the trigeminocervical nucleus, supporting the concept that cervical dysfunction may contribute to orofacial pain and TMJ symptoms (4).

A systematic review by Chisari et al. concluded that cervical pain and postural impairments are frequently associated with TMD, particularly in individuals presenting with chronic symptoms and muscular involvement (4, 6). Similarly, Petronis et al. reported that cervical spine abnormalities, reduced cervical range of motion, and forward head posture are strongly linked with temporomandibular dysfunction (11).

The influence of posture on TMD has gained increasing attention in rehabilitation research. Minervini et al. conducted a meta-analysis evaluating the relationship between posture and TMD and found significant correlations between craniofacial dysfunction and postural abnormalities. The authors suggested that altered cervical alignment may modify mandibular mechanics and increase muscular stress within the cranio-cervico-mandibular system (5).

Cuenca-Martínez et al. further demonstrated that patients with TMD commonly exhibit impaired cervical mobility, neck disability, muscular tenderness, and altered craniocervical posture compared with asymptomatic individuals (4).Their findings support the integration of cervical assessment and rehabilitation into TMD management protocols.

Conventional physiotherapy management for TMD typically includes jaw mobility exercises, relaxation techniques, soft tissue therapy, thermotherapy, education regarding parafunctional habits, and postural correction exercises. Although these interventions are beneficial for symptom reduction, evidence suggests that isolated TMJ-focused treatment may inadequately address associated cervical impairments contributing to persistent dysfunction (7).

Cervical stabilization training has been extensively used in patients with chronic neck pain to improve deep cervical flexor activation, cervical proprioception, postural control, and spinal stability. These exercises target neuromuscular dysfunction and motor control deficits commonly observed in cervical musculoskeletal disorders (8).

The application of cervical stabilization strategies in TMD rehabilitation has recently expanded.

Arslan et al. investigated the effects of cervical stabilization training in individuals with TMD and reported significant improvements in pain intensity, cervical posture, mobility, and muscle performance following intervention (8). Another randomized clinical trial evaluating cervical core stabilization and Rocabado exercises demonstrated improvements in musculoskeletal and psychosocial outcomes among female patients with myogenic TMD (10).

Additional studies have explored the role of scapulothoracic and cervico-craniomandibular interventions in improving jaw function and postural stability. Miçooğulları et al. reported that scapulothoracic exercises positively influenced temporomandibular and cervical joint position sense in individuals with cranio-cervico-mandibular malalignment (12).

Although current evidence supports the cervical contribution to TMD rehabilitation, methodological limitations remain evident across the literature. Variability in intervention protocols, outcome measures, treatment duration, and patient characteristics restricts generalizability. Moreover, few randomized controlled trials have specifically investigated progressive cervical stabilization programs integrated with conventional TMJ rehabilitation (8, 10).

Consequently, there remains a need for rigorously designed randomized controlled trials evaluating the effectiveness of cervical stabilization training on pain, jaw function, cervical mobility, postural alignment, and quality of life in individuals with TMD.

Objectives

Primary Objective

To determine the effectiveness of cervical stabilization training combined with conventional TMJ rehabilitation on pain intensity, jaw functional limitation, and maximum mouth opening in individuals with temporomandibular joint disorders.

Secondary Objectives

To evaluate the effects of cervical stabilization training on cervical range of motion.

To assess changes in neck disability following intervention.

To determine the effect of cervical stabilization exercises on postural alignment and cervical muscle performance.

To evaluate changes in pressure pain threshold and quality of life after rehabilitation.

To compare clinical outcomes between the experimental and control groups over time.

Hypothesis

Null Hypothesis (H_0)

There will be no significant difference between conventional TMJ rehabilitation alone and conventional TMJ rehabilitation combined with cervical stabilization training in individuals with temporomandibular joint disorders.

Alternative Hypothesis (H_1)

Conventional TMJ rehabilitation combined with cervical stabilization training will produce significantly greater improvements in pain, jaw function, cervical mobility, posture, and quality of life compared with conventional TMJ rehabilitation alone in individuals with temporomandibular joint disorders.

Methodology

Study Design

This study was a single-blinded, parallel-group randomized controlled trial conducted to investigate the effectiveness of cervical stabilization training in individuals with temporomandibular joint disorders (TMD). The study followed the CONSORT guidelines for randomized clinical trials. Participant flow throughout the study is illustrated in Figure 1

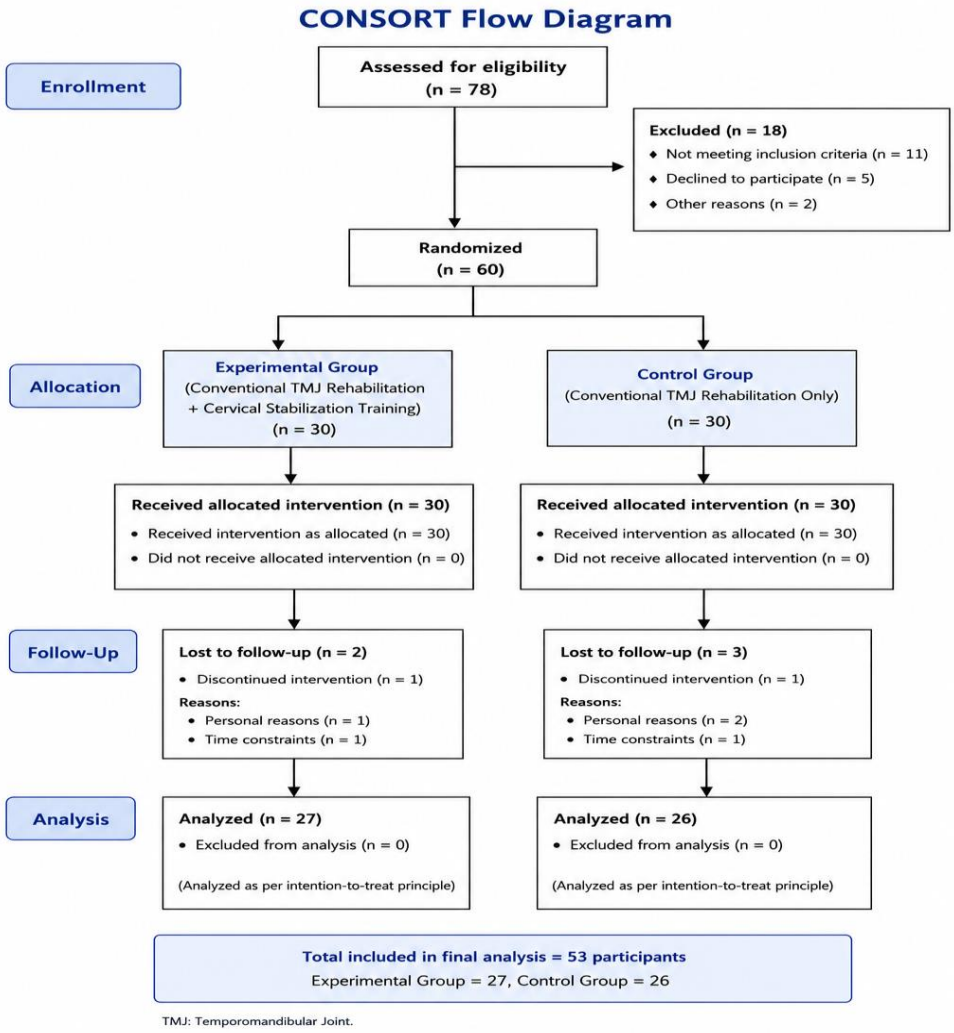


Figure 1. CONSORT Flow Diagram

Sample Size

The sample size for the present study was calculated using G*Power software version 3.1 based on repeated measures analysis of variance (ANOVA). An effect size of 0.80, alpha level of 0.05, and statistical power of 80% were considered for the calculation. The estimated effect size was determined from previous studies investigating cervical stabilization and cervical rehabilitation interventions in individuals with temporomandibular disorders. To compensate for potential participant dropout and loss to follow-up, an additional 10–15% attrition rate was included in the calculation. Consequently, a total sample of 60 participants was recruited and equally allocated into the experimental group (n = 30) and control group (n = 30).

Study Setting

The study was conducted at the Department of Physical Therapy in DHQ and Mufti Mehmood Memorial Teaching Hospital MTI Dera Ismail Khan.

Eligibility Criteria

Inclusion Criteria

Participants were included in the study if they:

Were aged between 18 and 45 years

Had a clinically diagnosed temporomandibular joint disorder according to the Diagnostic Criteria for Temporomandibular Disorders (DC/TMD)

Reported jaw pain for more than three months

Demonstrated cervical muscle tenderness or postural dysfunction

Were willing to participate and provided written informed consent

Exclusion Criteria

Participants were excluded from the study if they:
Had a history of previous temporomandibular joint or cervical spine surgery
Had neurological disorders
Had rheumatoid arthritis or other systemic inflammatory diseases
Had acute trauma involving the jaw or cervical spine
Had vestibular disorders
Were undergoing ongoing orthodontic treatment
Were pregnant

Randomization and Blinding

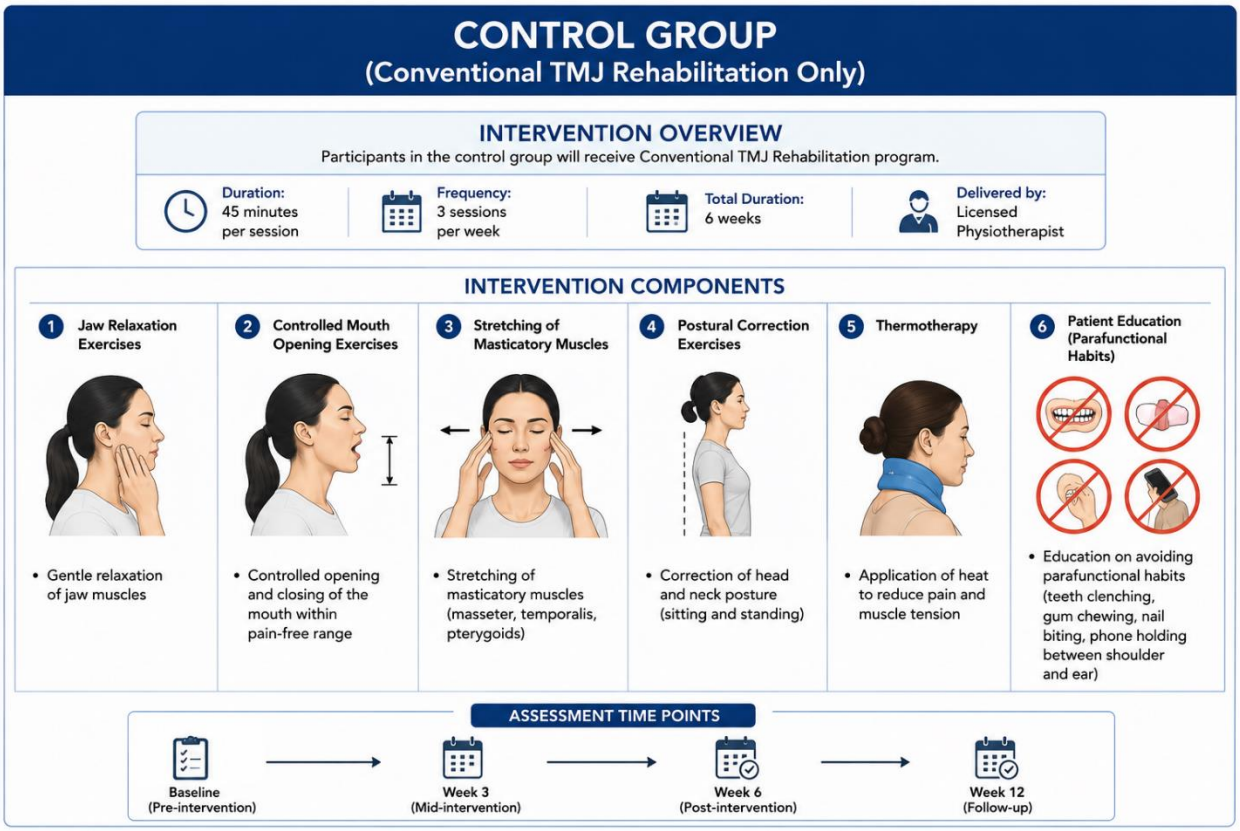
A total of 60 participants diagnosed with temporomandibular joint disorders were recruited and randomly allocated into two groups. Participants in the experimental group (n = 30) received conventional TMJ rehabilitation combined with cervical stabilization training, whereas participants in the control group (n = 30) received conventional TMJ rehabilitation alone. Randomization was performed using a computer-generated randomization method. Allocation concealment was maintained through the use of sealed opaque envelopes. The outcome assessor and data analyst remained blinded to group allocation throughout the study period to minimize assessment bias.

Intervention ProtocolControl Group

Participants in the control group received conventional temporomandibular joint (TMJ) rehabilitation. Detailed components of the intervention protocol are presented in Table 1.

Table 1. Control Group Intervention Protocol (Conventional TMJ Rehabilitation Only)

Component	Intervention	Description	Duration
1	Jaw Relaxation Exercises	Gentle relaxation of masticatory muscles to reduce muscle tension and pain	5–7 minutes
2	Controlled Mouth Opening Exercises	Repetitive controlled mouth opening and closing within pain-free range to improve mandibular mobility	5–7 minutes
3	Stretching of Masticatory Muscles	Stretching exercises targeting masseter, temporalis, and pterygoid muscles	5 minutes
4	Postural Correction Exercises	Correction of forward head posture and faulty cervical alignment during sitting and standing	5–8 minutes
5	Thermotherapy	Application of moist heat around TMJ and cervical region to decrease pain and muscle spasm	10 minutes
6	Patient Education	Education regarding avoidance of parafunctional habits such as teeth clenching, gum chewing, nail biting, and improper phone posture	Throughout session
7	Home Exercise Program	Daily self-management exercises and posture correction instructions	Daily at home



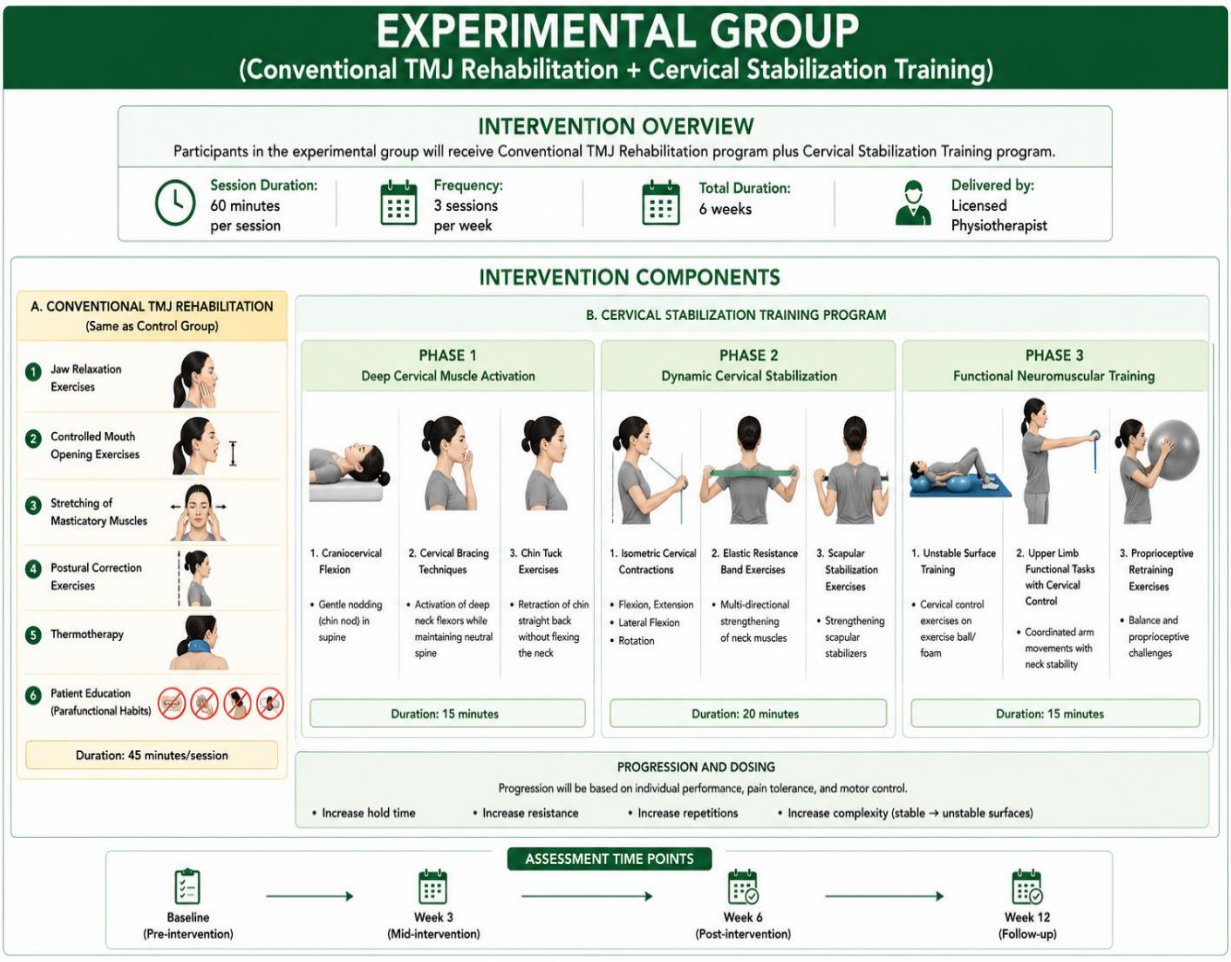
Experimental Group

Participants in the experimental group received conventional temporomandibular joint (TMJ) rehabilitation combined with a structured cervical stabilization training program. Detailed phases and components of the intervention protocol are presented in Table 2.

Table 2. Experimental Group Intervention Protocol (Conventional TMJ Rehabilitation + Cervical Stabilization Training)

Phase	Intervention Component	Description	Duration
A	Conventional TMJ Rehabilitation	Same rehabilitation protocol as control group	45 minutes
B – Phase 1	Craniocervical Flexion Exercises	Activation of deep cervical flexor muscles using gentle nodding movements in supine position	5 minutes
B – Phase 1	Cervical Bracing Techniques	Isometric cervical stabilization while maintaining neutral cervical alignment	5 minutes
B – Phase 1	Chin Tuck Exercises	Retraction of chin to improve cervical posture and deep neck flexor activation	5 minutes
B – Phase 2	Isometric Cervical Contractions	Cervical contractions in flexion, extension, lateral flexion, and rotation directions	5–7 minutes

B – Phase 2	Elastic Resistance Band Exercises	Multi-directional resisted cervical strengthening exercises using elastic bands	7–10 minutes
B – Phase 2	Scapular Stabilization Exercises	Strengthening of scapular stabilizers to improve cervico-scapular control	5 minutes
B – Phase 3	Unstable Surface Training	Cervical stabilization exercises performed on exercise balls or unstable surfaces	5 minutes
B – Phase 3	Functional Neuromuscular Training	Upper limb functional tasks integrated with cervical motor control	5 minutes
B – Phase 3	Proprioceptive Retraining Exercises	Balance and cervical joint position sense retraining exercises	5 minutes
C	Home Exercise Program	Daily cervical stabilization and TMJ self-management exercises	Daily at home



Outcome Measures

Outcome assessments were performed at baseline (pre-intervention), Week 3, Week 6 (post-intervention), and follow-up at Week 12. Primary outcome measures included pain intensity, jaw functional limitation, and maximum mouth

opening. Pain intensity was measured using the Visual Analog Scale (VAS), jaw functional limitation was assessed using the Jaw Functional Limitation Scale (JFLS), and maximum mouth opening was measured using a digital caliper. Secondary outcome measures included cervical range of motion, neck disability, postural alignment, pressure pain threshold, and quality of life. Cervical range of motion was assessed using a cervical goniometer/inclinometer, while neck disability was evaluated using the Neck Disability Index (NDI). Postural alignment was analyzed through photogrammetric assessment. Pressure pain threshold was measured using algometry over the masticatory and cervical muscles, and quality of life was assessed using the Short Form-36 (SF-36) questionnaire.

Data Collection Procedure

All baseline demographic and clinical data were recorded before intervention. Outcome measurements were collected by a trained physiotherapist blinded to treatment allocation. Participants' adherence, adverse events, and treatment progression were monitored throughout the study period.

Statistical Analysis

Data analysis was performed using Statistical Package for the Social Sciences (SPSS) version 26.0. Mean ± standard deviation was calculated for continuous variables, whereas frequencies and percentages were used for categorical variables. Data normality was assessed using the Shapiro–Wilk test. Independent t-tests and chi-square tests were used to compare baseline demographic and clinical characteristics between groups. Repeated measures analysis of variance (ANOVA) was used to analyze within-group and between-group differences across different assessment time points. Bonferroni post hoc correction was applied for multiple comparisons. Statistical significance was set at $p < 0.05$.

Results

Participant Flow

A total of 78 participants were screened for eligibility. Eighteen participants were excluded due to not meeting inclusion criteria, declining participation, or other reasons. Sixty eligible participants were randomly allocated into either the experimental group (n = 30) or the control group (n = 30). During follow-up, 2 participants from the experimental group and 3 participants from the control group were lost to follow-up. Finally, 27 participants in the experimental group and 26 participants in the control group completed the study and were included in the final analysis.

Table 3. Participant Recruitment and Retention

CONSORT Stage	Total (n)
Assessed for eligibility	78
Excluded	18
Randomized	60
Allocated to experimental group	30
Allocated to control group	30
Lost to follow-up	5
Discontinued intervention	2

Baseline Characteristics

No statistically significant differences were observed between the experimental and control groups for demographic or baseline clinical variables ($p > 0.05$), indicating that both groups were comparable prior to intervention and that randomization was successful.

Table 4. Baseline Demographic and Clinical Characteristics

Variable	Experimental Group (n = 30)	Control Group (n = 30)	p-value
Age (years)	28.63 ± 5.74	29.11 ± 5.48	0.741
Gender (Male/Female)	11 (36.7%) / 19 (63.3%)	10 (33.3%) / 20 (66.7%)	0.793
Body Mass Index (kg/m²)	24.18 ± 2.91	24.44 ± 3.07	0.728

Duration of Symptoms (months)	8.76 ± 2.83	8.41 ± 2.67	0.619

Primary Outcome Measures

Pain Intensity (VAS)

Both groups demonstrated reduction in pain intensity following intervention; however, the experimental group showed significantly greater reduction in VAS scores compared with the control group at Week 3, Week 6, and Week 12 follow-up assessments. Pain intensity outcomes are presented in Table 5.

Table 5. Comparison of Pain Intensity (VAS Scores)

Assessment Time	Experimental Group	Control Group	Between-Group p-value
Baseline	7.46 ± 1.12	7.39 ± 1.08	0.812
Week 3	4.83 ± 0.96	5.91 ± 1.02	0.021*
Week 6	2.41 ± 0.88	4.36 ± 0.94	0.003*
Week 12 Follow-up	2.08 ± 0.81	4.11 ± 0.89	0.002*

*Statistically significant at $p < 0.05$.

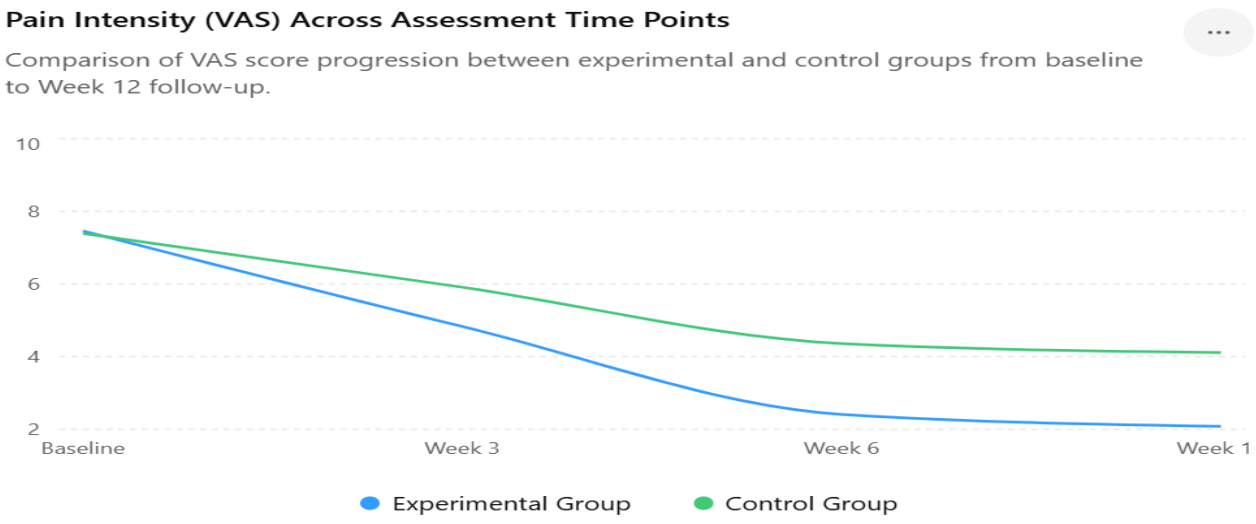


Figure 2. Changes in Pain Intensity Across Assessment Time Points

Jaw Functional Limitation (JFLS) Both groups demonstrated improvement in jaw functional limitation following intervention; however, the experimental group showed significantly greater reduction in JFLS scores compared with the control group at Week 3, Week 6, and Week 12 follow-up assessments.

Table 6. Jaw Functional Limitation Scale (JFLS) Scores

Assessment Time	Experimental Group (Mean ± SD)	Control Group (Mean ± SD)	Between-Group p-value
Baseline	52.37 ± 6.81	51.94 ± 6.56	0.791
Week 3	38.21 ± 5.74	45.16 ± 5.92	0.024*
Week 6	24.85 ± 4.63	38.72 ± 5.18	0.002*
Week 12 Follow-up	22.94 ± 4.28	37.91 ± 4.96	0.001*

*Statistically significant at $p < 0.05$.

Maximum Mouth Opening (MMO)

Both groups demonstrated improvement in maximum mouth opening following intervention; however, the experimental group exhibited significantly greater improvement compared with the control group at Week 3, Week 6, and Week 12 follow-up assessments.

Table 7. Maximum Mouth Opening (MMO)

Assessment Time	Experimental Group	Control Group	Between-Group p-value
Baseline	31.84 ± 3.26 mm	32.11 ± 3.41 mm	0.763
Week 3	36.92 ± 3.08 mm	34.15 ± 3.27 mm	0.031*
Week 6	42.76 ± 2.94 mm	36.88 ± 3.14 mm	0.002*
Week 12 Follow-up	43.28 ± 2.86 mm	37.11 ± 3.06 mm	0.001*

*Statistically significant at $p < 0.05$.

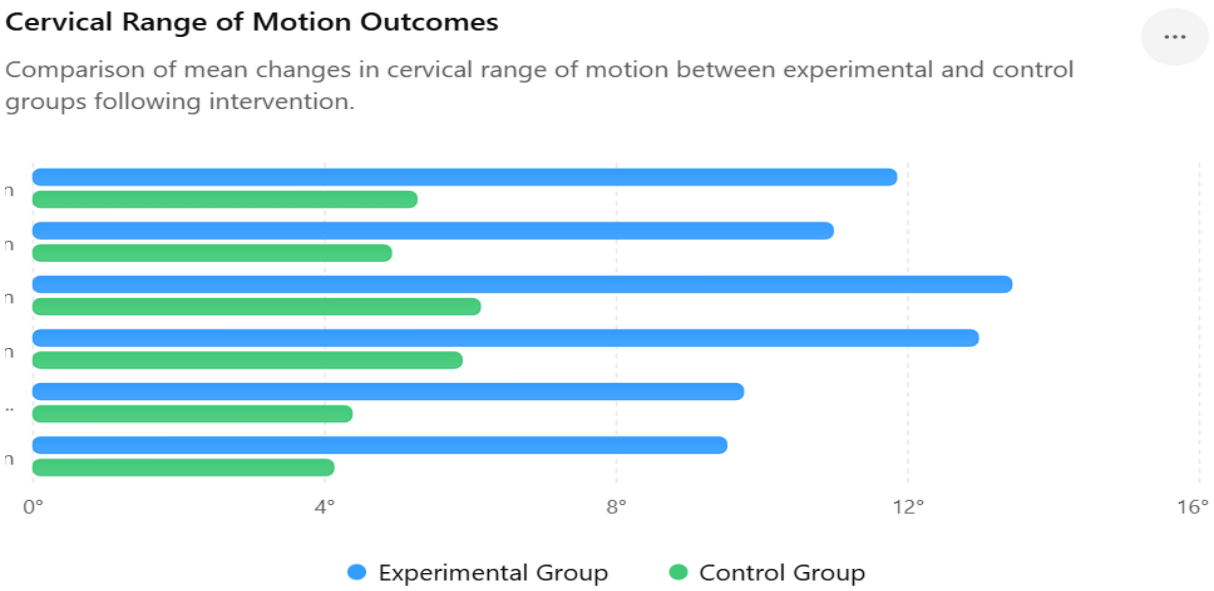
Secondary Outcome Measures

Cervical Range of Motion (CROM)

The experimental group demonstrated significantly greater improvement in all cervical range of motion parameters compared with the control group following six weeks of intervention. Cervical ROM outcomes are summarized in Table 8.

Table 8. Cervical Range of Motion Outcomes

Cervical Motion	Experimental Group (Mean Change ± SD)	Control Group (Mean Change ± SD)	Mean Difference	p-value
Flexion	11.84 ± 3.12°	5.26 ± 2.41°	6.58°	0.002*
Extension	10.97 ± 2.88°	4.91 ± 2.19°	6.06°	0.003*
Right Rotation	13.42 ± 3.56°	6.13 ± 2.67°	7.29°	0.001*
Left Rotation	12.96 ± 3.44°	5.88 ± 2.53°	7.08°	0.001*
Right Lateral Flexion	9.74 ± 2.63°	4.37 ± 1.95°	5.37°	0.004*
Left Lateral Flexion	9.51 ± 2.48°	4.12 ± 1.87°	5.39°	0.004*



*Statistically significant at $p < 0.05$.

Figure 3. Mean Changes in Cervical Range of Motion Following Intervention

Neck Disability Index (NDI)

Both groups demonstrated improvement in Neck Disability Index scores following intervention; however, the experimental group showed significantly greater reduction in neck-related disability compared with the control group at Week 3, Week 6, and Week 12 follow-up assessments.

Table 9. Neck Disability Index Scores

Assessment Time	Experimental Group (Mean ± SD)	Control Group (Mean ± SD)	Between-Group p-value
Baseline	28.74 ± 4.62	27.93 ± 4.51	0.684
Week 3	20.15 ± 3.88	24.62 ± 4.07	0.028*
Week 6	12.81 ± 3.14	20.37 ± 3.82	0.002*
Week 12 Follow-up	11.94 ± 2.96	19.76 ± 3.57	0.001*

*Statistically significant at $p < 0.05$.

Postural Alignment

Participants in the experimental group demonstrated significantly greater improvement in postural alignment compared with the control group following intervention.

Table 10. Postural Alignment Outcomes

Variable	Experimental Group (Mean Change ± SD)	Control Group (Mean Change ± SD)	Mean Difference	p-value
Craniovertebral Angle	6.82 ± 1.94°	2.97 ± 1.41°	3.85°	0.002*
Forward Head Posture	−5.74 ± 1.63°	−2.11 ± 1.26°	3.63°	0.004*

*Statistically significant at $p < 0.05$.

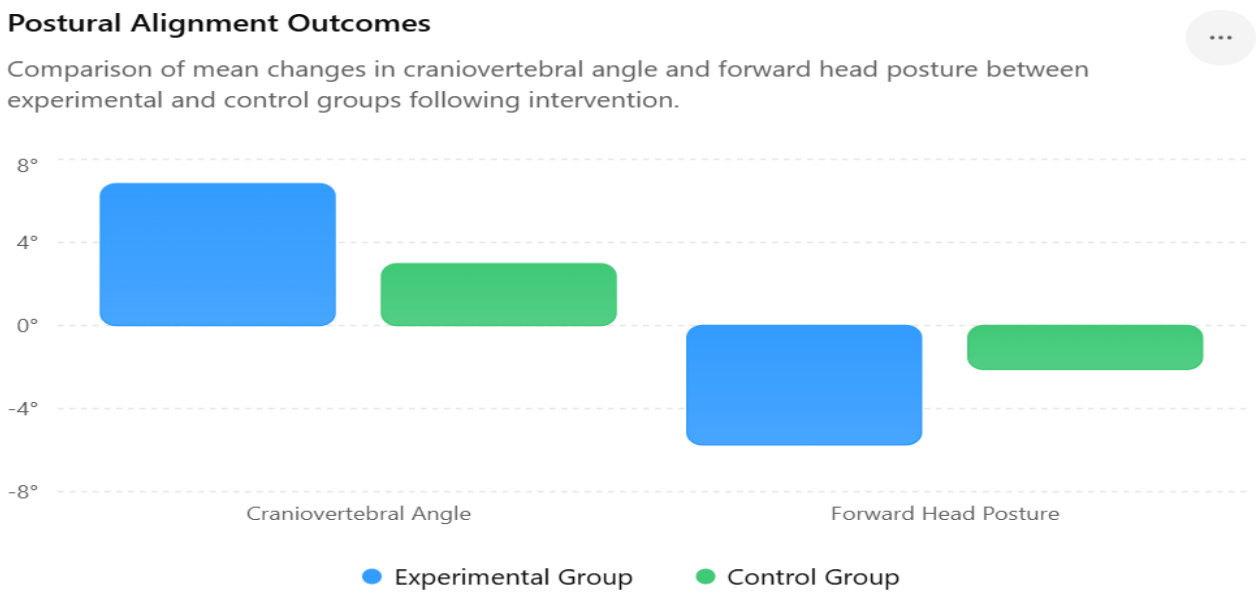


Figure 4. Postural Alignment Outcomes Following Intervention

Pressure Pain Threshold (PPT)

The experimental group demonstrated significantly greater increases in pressure pain threshold values across all assessed muscle regions compared with the control group. These findings indicate reduced muscular tenderness and decreased pain sensitivity following cervical stabilization training.

Table 11. Pressure Pain Threshold Outcomes

Muscle Region	Experimental Group (Mean Change ± SD)	Control Group (Mean Change ± SD)	Mean Difference	p-value
Masseter Muscle	1.92 ± 0.54 kg/cm²	0.83 ± 0.37 kg/cm²	1.09 kg/cm²	0.003*
Temporalis Muscle	1.76 ± 0.49 kg/cm²	0.74 ± 0.31 kg/cm²	1.02 kg/cm²	0.004*
Upper Trapezius	2.11 ± 0.58 kg/cm²	0.97 ± 0.42 kg/cm²	1.14 kg/cm²	0.002*
Sternocleidomastoid	1.84 ± 0.51 kg/cm²	0.79 ± 0.35 kg/cm²	1.05 kg/cm²	0.003*

*Statistically significant at $p < 0.05$.

Quality of Life (SF-36)

Participants in the experimental group demonstrated significantly greater improvements in physical functioning, bodily pain, vitality, and social functioning domains of the SF-36 compared with the control group following intervention. However, no statistically significant difference was observed between groups in the emotional wellbeing domain ($p > 0.05$).

Table 12. SF-36 Quality of Life Scores

Domain	Experimental Group (Mean ± SD)	Control Group (Mean ± SD)	Mean Difference	p-value
Physical Functioning	81.47 ± 7.26	68.32 ± 6.94	13.15	0.002*
Bodily Pain	78.63 ± 6.88	64.91 ± 7.11	13.72	0.003*
Vitality	75.28 ± 7.04	66.17 ± 6.52	9.11	0.004*
Social Functioning	79.14 ± 6.73	69.05 ± 6.41	10.09	0.003*
Emotional Wellbeing	71.52 ± 6.47	69.84 ± 6.15	1.68	0.087

*Statistically significant at $p < 0.05$.

Within-Group and Between-Group Analysis

Repeated measures ANOVA revealed statistically significant improvements across time in both groups for pain intensity, jaw function, cervical mobility, and neck disability. Significant group × time interaction effects were observed for most primary and secondary outcome measures, favoring the experimental group.

Bonferroni post hoc analysis demonstrated that the experimental group achieved significantly greater clinical improvement between baseline and post-treatment assessments compared with the control group.

Adverse Events

No major adverse events were reported during the intervention period. Mild transient muscular soreness was reported by a small number of participants in the experimental group during the initial phase of cervical stabilization exercises; however, symptoms resolved spontaneously without interruption of treatment.

DISCUSSION

The present randomized controlled trial investigated the effectiveness of cervical stabilization training combined with conventional temporomandibular joint (TMJ) rehabilitation in individuals with temporomandibular disorders (TMD). The findings demonstrated that both groups improved following intervention; however, participants receiving cervical stabilization training showed greater improvements in pain intensity, jaw functional limitation, maximum mouth opening, cervical mobility, neck disability, postural alignment, pressure pain threshold, and quality of life compared with conventional TMJ rehabilitation alone.

These findings support the hypothesis that dysfunction of the cervical region contributes significantly to the clinical presentation of TMD and that addressing cervical impairments through stabilization training may enhance rehabilitation outcomesOne of the primary findings of this study was the greater reduction in pain intensity observed in the experimental group. Pain reduction following cervical stabilization training

may be explained by improved neuromuscular control, reduction in cervical muscle overactivity, enhanced postural alignment, and decreased mechanical stress across the cranio-cervico-mandibular complex. The trigeminocervical nucleus is known to facilitate convergence of nociceptive input from both trigeminal and upper cervical structures, which may explain why cervical dysfunction can perpetuate temporomandibular pain symptoms. Previous studies have similarly reported reductions in pain following cervical-focused interventions in patients with TMD. Calixtre et al. demonstrated that cervical mobilization and exercise interventions improved pain and mandibular function in individuals with temporomandibular disorders (7). Likewise, Lam et al. reported improvements in pain and mouth opening following upper cervical manual therapy interventions (9).

The experimental group also demonstrated greater improvements in jaw functional limitation and maximum mouth opening compared with the control group. These findings suggest that cervical stabilization training may positively influence mandibular biomechanics and functional mobility. Improvement in cervical posture and muscular coordination may reduce abnormal tension in the masticatory system and optimize mandibular movement patterns. Previous evidence has shown that altered cervical alignment and forward head posture are associated with restricted mandibular motion and impaired TMJ function (4, 5). The present findings are therefore consistent with the concept of regional interdependence between cervical and temporomandibular structures.

Significant improvements in cervical range of motion and neck disability were also observed in the experimental group. Cervical stabilization exercises specifically target deep cervical flexor activation, neuromuscular coordination, proprioception, and postural control. These mechanisms likely contributed to improved cervical mobility and reduced disability scores observed after intervention. Similar findings were reported by Arslan et al., who demonstrated that cervical stabilization training improved cervical posture, muscle performance, and pain outcomes in individuals with TMD (8).

Postural alignment improved substantially in participants receiving cervical stabilization training. Forward head posture and altered craniocervical alignment are commonly reported in individuals with TMD and may increase mechanical loading on both cervical and temporomandibular structures (4, 5). Improvement in craniovertebral angle and postural correction observed in the present study may have contributed to reductions in muscular strain and improved mandibular mechanics. These findings further support the integration of postural rehabilitation into TMD management.

Pressure pain threshold values increased significantly in the experimental group, indicating reduced pain sensitivity in cervical and masticatory muscles. This finding may reflect reduced peripheral sensitization and improved muscular function following stabilization exercises. The reduction in muscle tenderness may also be related to normalization of cervical motor control and decreased protective muscle guarding around the cervical and temporomandibular regions.

Quality-of-life outcomes also improved more substantially in the experimental group. Improvement in pain, function, posture, and disability likely contributed to enhanced physical functioning and daily activity performance. TMD frequently affects eating, speaking, sleeping, and psychosocial wellbeing; therefore, reducing symptom severity may positively influence broader health-related quality-of-life domains.

Although both groups demonstrated clinical improvement, greater improvements observed in the experimental group indicate that conventional TMJ rehabilitation alone may insufficiently address cervical impairments contributing to TMD symptoms. Conventional rehabilitation primarily targets local jaw dysfunction, whereas cervical stabilization training addresses neuromuscular and postural dysfunction within the broader cranio-cervico-mandibular system. The present findings therefore support a more comprehensive rehabilitation approach integrating cervical interventions into TMD management protocols (5).

The maintenance of treatment effects at follow-up further suggests that cervical stabilization training may provide sustained neuromuscular and functional benefits. Improved cervical motor control and postural awareness may continue to reduce abnormal loading and mechanical stress even after supervised intervention has ended.

Despite these findings, several limitations should be acknowledged. The study sample size was relatively moderate, which may limit

generalizability of the results. Long-term follow-up beyond 12 weeks was not performed; therefore, the durability of treatment effects over extended periods remains uncertain. The study also did not stratify participants according to specific TMD subtypes, psychosocial factors, or severity levels, which may influence treatment response. Furthermore, electromyographic analysis and advanced biomechanical assessments were not included, limiting detailed evaluation of neuromuscular adaptations following cervical stabilization training.

Future research should include multicenter randomized controlled trials with larger sample sizes and longer follow-up durations. Studies investigating the effects of cervical stabilization training across different TMD classifications and psychosocial profiles may provide further insight into individualized rehabilitation strategies. Additional investigation using electromyography, motion analysis, and imaging techniques may also clarify the biomechanical and neurophysiological mechanisms underlying clinical improvement.

The findings of this study suggest that clinicians managing temporomandibular disorders should incorporate routine cervical assessment and stabilization-based rehabilitation into clinical practice due to the interconnected biomechanical and neurophysiological relationship between the cervical spine and temporomandibular region.

Overall, the findings of this study suggest that cervical stabilization training is an effective adjunct to conventional TMJ rehabilitation in individuals with temporomandibular disorders. Incorporating cervical stabilization exercises into rehabilitation programs may improve pain, jaw function, cervical mobility, posture, and quality of life more effectively than conventional TMJ rehabilitation alone.

RECOMMENDATIONS

Based on the findings of the present study, cervical assessment should be routinely incorporated into the clinical evaluation of individuals with temporomandibular disorders, as cervical dysfunction appears to contribute significantly to pain, postural abnormalities, and functional impairment associated with TMD. The addition of cervical stabilization training to conventional TMJ rehabilitation programs may enhance treatment outcomes by improving pain intensity, jaw function, cervical mobility, postural alignment, and overall functional performance. Rehabilitation strategies for temporomandibular disorders should therefore adopt a multidimensional approach addressing both temporomandibular and cervical components rather than focusing solely on local jaw dysfunction. Furthermore, clinicians should emphasize postural correction, deep cervical muscle activation, and neuromuscular control exercises during rehabilitation to reduce symptom recurrence and improve long-term clinical outcomes in patients with temporomandibular disorders.

FUTURE RESEARCH RECOMMENDATIONS

Future randomized controlled trials should include larger sample sizes to improve statistical power and enhance the external validity of findings related to cervical stabilization training in temporomandibular disorders. Long-term follow-up studies are also recommended to determine the sustainability and durability of treatment effects over extended periods. Future investigations should stratify participants according to specific TMD classifications, symptom severity, and psychosocial characteristics to better understand differential treatment responses among various patient subgroups. Multicenter studies involving diverse populations and clinical settings are necessary to improve the generalizability of results. Additionally, future research should incorporate electromyography, motion analysis, and imaging techniques to provide deeper insight into the neurophysiological and biomechanical mechanisms underlying cervical stabilization interventions. Comparative studies evaluating different cervical stabilization protocols, exercise intensities, and treatment durations are recommended to establish standardized rehabilitation guidelines for clinical practice. Further investigations should also explore the relationship between cervical stabilization training and psychosocial outcomes such as anxiety, sleep quality, stress, and pain-related disability. Finally, studies examining cost-effectiveness, patient adherence, and long-term compliance with cervical stabilization programs may provide additional clinical value for rehabilitation planning and healthcare implementation.

CONCLUSION

The findings of this randomized controlled trial demonstrate that cervical stabilization training combined with conventional temporomandibular joint rehabilitation produced greater improvements in pain intensity, jaw functional limitation, maximum mouth opening, cervical mobility, neck disability, postural alignment, pressure pain threshold, and quality of life compared with conventional TMJ rehabilitation alone in individuals with temporomandibular disorders.

The results support the concept that cervical dysfunction plays an important role in the pathophysiology and persistence of temporomandibular disorders. Addressing cervical neuromuscular impairments through stabilization training may enhance functional recovery and reduce symptom severity by improving postural control, cervical motor function, and cranio-cervico-mandibular biomechanics.

Although conventional TMJ rehabilitation alone resulted in clinical improvement, the addition of cervical stabilization exercises provided superior therapeutic outcomes and maintained benefits during follow-up assessment. These findings highlight the importance of incorporating cervical assessment and stabilization strategies into multidisciplinary rehabilitation programs for individuals with temporomandibular disorders.

Therefore, cervical stabilization training may be considered an effective adjunctive intervention for improving clinical and functional outcomes in patients with temporomandibular joint disorders. Further large-scale studies with longer follow-up durations are recommended to confirm these findings and establish standardized cervical stabilization protocols for TMD rehabilitation.

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