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Effectiveness Of Motor Imagery And Deep Neck Flexor Training On Breathing Function, Kinesiophobia, And Activities Of Daily Living In Individuals With Chronic Neck Pain: A Systematic Review And Meta-Analysis

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Abstract
Background: *Chronic neck pain (CNP) is a common musculoskeletal disorder often associated with impaired respiratory function, heightened kinesiophobia, and reduced capacity for daily activities (ADL). Motor imagery (MI) and deep neck flexor training (DNFT) have been shown to be effective interventions that address both the physical and psychological dimensions of CNP.*
Objective: *This systematic review and meta-analysis aimed to evaluate the effectiveness of MI and DNFT, both individually and in combination, on breathing function, kinesiophobia, and the performance of ADL in patients suffering from chronic neck pain.*
Methods: *In accordance with PRISMA guidelines, a systematic review was conducted using PubMed, Scopus, CINAHL, and Web of Science. The inclusion criteria encompassed randomized controlled trials and quasi-experimental studies that assessed MI and/or DNFT interventions in adult CNP populations. Meta-analyses employed random-effects models, and evaluations were made for heterogeneity, sensitivity, and publication bias.*
Results: *Twenty-one studies were included. The combined intervention of MI+DNFT significantly improved breathing function, reduced kinesiophobia, and enhanced ADL outcomes (overall effect size: 0.712, 95% CI: 0.617–0.806, $p < 0.001$). Significant heterogeneity ($I^2 = 73.41\%$) was identified and addressed through subgroup and sensitivity analysis. Both MI and DNFT showed greater effects when used together. Publication bias was found to be low.*
Conclusion: *MI and DNFT, particularly when used together, serve as effective non-invasive treatments for improving both physical and psychological outcomes in individuals with chronic neck pain. These findings support their integration into rehabilitation protocols, although further research is needed to standardize these protocols and evaluate their long-term effects.*
Keywords: *Chronic neck pain, motor imagery, deep neck flexor training, kinesiophobia, breathing function, activities of daily living, systematic review, meta-analysis*

1 INTRODUCTION

Chronic neck pain (CNP), defined as neck pain persisting for over 3–6 months, is a prevalent musculoskeletal condition that significantly impacts quality of life and functional independence. Epidemiological studies reveal varying prevalence rates across different populations: 15.3% among Iranian adults aged 30–70 years (Noormohammadpour et al., 2017), 34.4% in Norway, with 13.8% experiencing symptoms for more than six months (Bovim et al., 1994), and a notably higher prevalence in Spain among individuals with COPD (40.5%) compared to non-COPD controls (26.1%) (Miguel-Díez et al., 2018). CNP is more common in women and is associated with both physical and mental health issues, including injury, work-related stress, obesity, and parity (Mäkela et al., 1991; Palacios-Ceña et al., 2020). A significant psychological barrier to CNP rehabilitation is kinesiophobia, or the fear of movement, which exacerbates disability by promoting physical inactivity. Asiri et al. (2021) identified a strong correlation between kinesiophobia and pain severity (r = 0.81), as well as between impaired proprioception and handgrip strength. Furthermore, Naugle et al. (2022) demonstrated that increased kinesiophobia in older adults is linked to reduced physical activity and poor functional outcomes, findings that can be extended to CNP populations. Rehabilitation, particularly exercise therapy, remains a crucial approach to treating CNP. Although neck and upper quadrant strengthening exercises show moderate short-term effects (Sterling et al., 2019), clinical guidelines lack clarity on optimal parameters, especially for pain phenotypes like nociplastic or neuropathic pain (Zoete, 2023). Among innovative rehabilitation techniques, Motor Imagery (MI)—a mental rehearsal of movement—has garnered attention for its ability to activate motor-related networks without physical execution. MI engages premotor and supplementary motor areas and has proven effective in modulating pain, enhancing neuroplasticity, and improving movement control (Coslett et al., 2010; Wriessnegger et al., 2014). Research suggests that MI can induce hypoalgesia in both distant and proximal body areas (Suso-Martí et al., 2019) and may boost recovery when combined with other therapies, such as brain–computer interfaces or transcranial direct current stimulation (Hong et al., 2017; Strauss et al., 2021). Deep Neck Flexor (DNF) training, which targets muscles like the longus colli and longus capitis, is often recommended to enhance cervical stability and neuromuscular control. Research has shown that DNF training can reduce pain, improve posture, increase cervical range of motion, and boost muscle endurance (Falla et al., 2012; Lee et al., 2013; Arimi et al., 2017). However, at higher intensities, its effects on flexor strength and endurance may be limited, suggesting that when combined with complementary modalities such as MI, it could offer more comprehensive therapeutic benefits (Blomgren et al., 2018). Notably, dysfunction in breathing—an often-overlooked aspect of CNP—is gaining attention. An imbalance in cervical muscles can affect respiratory mechanics, yet research on retraining the respiratory system in CNP is inconsistent in design and results (Anwar et al., 2022). Meanwhile, interventions for kinesiophobia are typically confined to either cognitive or physical domains, despite growing support for multimodal treatments that address the interconnected physical and psychological aspects of chronic pain (Bordeleau et al., 2022). The combination of MI and DNF training presents an intriguing multidimensional treatment that can address pain modulation, fear of movement, and motor function. Nonetheless, evidence on their combined effects on breathing function, kinesiophobia, and daily activities remains inconsistent. While some studies demonstrate additive effects of these therapies, others show only modest incremental benefits, highlighting the need for a systematic synthesis of the evidence. This systematic review and metanalysis aims to systematically examine and synthesize the literature on the combined impact of motor imagery and deep neck flexor training in chronic neck pain patients, with a particular focus on outcomes related to breathing function, kinesiophobia, and daily activities. The objective is to determine whether incorporating mental imagery strategies into deep cervical flexor exercises provides a demonstrable increase in benefits for respiratory function, reduction in fear of movement, and improvement in disability/ADL compared to either intervention alone or usual care. This systematic review will effectively assess the current state of evidence regarding these combined interventions and identify any gaps, thereby guiding further research or clinical rehabilitation interventions for chronic neck pain.

2 METHODS

2.1 Study Design

This systematic review seeks to systematically evaluate the efficacy of motor imagery and deep neck flexor training in enhancing breathing function, kinesiophobia reduction, and activities of daily living (ADLs) in patients with chronic neck pain (CNP). Motor imagery, a cognitive process whereby one rehearses a movement mentally without physical execution, has been put forward as a useful intervention for neuromuscular re-education and pain relief. In the same manner, deep neck flexor training targets the deep cervical muscles responsible for neck stabilization and effective respiratory mechanics. Methodological strictness and reduction of bias are assured by adherence to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. These guidelines offer a systematic approach to carrying out systematic reviews, including defining a precise research question, developing eligibility criteria, performing an extensive literature search, selecting studies of relevance, evaluating the quality of included studies, and synthesizing findings in an open and replicable fashion. By following PRISMA, this review strives to give an accurate synthesis of current evidence concerning the effect of motor imagery and deep neck flexor training on important functional and psychological outcomes for patients with CNP. Protocol submitted in PROSPERO with reference number CRD420250589809.

2.2 Eligibility Criteria

2.2.1 Inclusion Criteria and Exclusion Criteria

This systematic review considered studies that examined the impact of motor imagery (MI) and/or deep neck flexor training (DNFT) in patients with chronic neck pain (CNP). The studies eligible for inclusion must have had adult participants (≥18 years) with a diagnosis of chronic neck pain lasting longer than three months. Interventions for inclusion were motor imagery training, deep neck flexor training, or a combination of both as compared to usual care, placebo, or other treatment interventions like manual therapy or conventional physiotherapy. Research was required to document at least one of the following results: (i) respiratory function (e.g., strength of the respiratory muscles, lung volume, maximal inspiratory pressure); (ii) kinesiophobia, measured by validated instruments such as the Tampa Scale for Kinesiophobia (TSK); or (iii) daily activities (ADL), measured by standardized functional scales such as the Neck Disability Index (NDI) or equivalent validated measures. Only randomized controlled trials (RCTs), quasi-experimental studies, and cohort studies from peer-reviewed journals were eligible.

Excluded were studies that were not peer-reviewed, such as conference abstracts, dissertations, preprints, or grey literature without full-text access. Studies published in languages other than English were also excluded to maintain data interpretation consistency. Studies on acute neck pain (≤3 months), post-surgical rehabilitation, or conditions other than chronic neck pain were not included. Excluded were also studies that did not have quantifiable outcome measures regarding breathing function, kinesiophobia, or ADL.

2.3Search Strategy

A systematic review of the literature was performed through Web of Science, Scopus, CINAHL, and PubMed to find existing studies assessing the efficacy of deep neck flexor training and motor imagery on the function of breathing, kinesiophobia, and daily life activities in subjects with chronic neck pain. Searching was done combining Medical Subject Headings (MeSH) with free-text keywords using Boolean connectors (AND, OR) for narrowing the retrieved results. The precise search terms employed in each database are given in **Table 1.** The process of searching was performed independently by two reviewers, who initially screened titles and abstracts to ascertain potentially relevant studies. Screening of full-text for selected articles followed, and discrepancies were resolved through discussion or, if necessary, referral to a third reviewer for ensuring accuracy and consistency in selecting studies.

2.4 Study Selection Process

The selection process of studies was done methodically adhering to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines for clarity and replicability. The choice was made in three consecutive steps: (i) screening of titles and abstracts, (ii) review of full texts, and (iii) final inclusion in accordance with the eligibility criteria. First, all studies retrieved from electronic databases PubMed, Scopus, Web of Science, CINAHL, Cochrane Library, and Google Scholar were uploaded into an Excel sheet to eliminate duplicate records. Subsequently, two independent reviewers, SA and NK, screened the titles and abstracts to eliminate irrelevant studies. Those studies that obviously did not qualify by not meeting the inclusion criteria e.g., non-relevant populations, interventions, or study designs, were rejected. The remaining full-text papers were then collected and independently read by the same two reviewers against the predefined inclusion and exclusion criteria. Disagreements between reviewers on eligibility were resolved by discussion, and where agreement could not be reached, a third reviewer, KR, was consulted to make a final decision. For transparency, the number of studies excluded and included at each phase were recorded in a PRISMA flow diagram, showing the initial search yield, duplicate removal, screening process, and final inclusion of studies. (**Figure-1**)

2.5 Data Extraction

A standardized data extraction method was used to provide consistency and accuracy across all the studies included. Two reviewers (SA and NK) independently extracted relevant information from each included eligible study, and any difference was resolved through discussion or a third reviewer (KR) if required. Data that were extracted were essential study features like author(s), year, country of origin, and study design (quasi-experimental studies, randomized controlled trials, or cohort studies). Participant features such as sample size, age, sex distribution, and length of chronic neck pain (CNP) were also documented. Details of intervention were also retrieved, including whether the study evaluated motor imagery (MI), deep neck flexor training (DNFT), or both, and details on session frequency, training duration, and any additional treatments administered.

For the comparator group, data on usual care, placebo treatment, or other therapeutic interventions were recorded. Outcome measures were grouped into primary and secondary outcomes. The main outcome comprised breathing function, measured with respect to respiratory muscle strength, lung capacity, and maximal inspiratory pressure. The secondary outcomes consisted of kinesiophobia, measured by standard scales like the Tampa Scale for Kinesiophobia (TSK), and activities of daily living (ADL), which were evaluated using instruments like the Neck Disability Index (NDI) or other functional assessment scales. Statistical measures, such as effect sizes (mean differences, standard deviations, odds ratios, and 95% confidence intervals), p-values, and levels of significance were also noted.

2.6 Quality Assessment

For methodological assessment, the Cochrane Risk of Bias (RoB 2) for randomized controlled trials were used. All extracted data were collected and systematically ordered in a standardized Excel spreadsheet ready for further statistical analysis and meta-analysis using packages like JASP.

2.7 Statistical Analysis

The statistical analysis was carried out to compare the effectiveness of motor imagery (MI) and deep neck flexor training (DNFT) on breathing function, kinesiophobia, and activities of daily living (ADL) in chronic neck pain. Where there were enough quantitative data available, meta-analysis was done using JASP software. To estimate the effect of treatment, Mean Difference (MD) or Standardized Mean Difference (SMD) with 95% confidence intervals (CI) was computed in continuous outcomes like respiratory muscle strength and scores of kinesiophobia. For dichotomous outcomes, Odds Ratio (OR) or Risk Ratio (RR) with 95% CI was employed. Which model was a fixed-effects model or a random-effects model was selected based on the heterogeneity level among the studies included.

To evaluate heterogeneity, the I^2 statistic was employed, where results greater than 50% reflect significant variation between studies, and Cochran's Q test was utilized, with a significance level of $p < 0.10$. Sensitivity analysis was performed by removing studies at high risk of bias in a systematic manner to test the stability of the results. Publication bias was assessed by the use of funnel plot to detect visually asymmetry and Egger's test to statistically assess asymmetry. Should publication bias have been detected, Duval and Tweedie's trim-and-fill was also used to estimate missing studies where necessary. Any statistical analyses proceeded in a standardized meta-analysis procedure to allow accurate, transparent, and reproducible results.

3 RESULTS

3.1 Study Selection and Characteristics

The features of the studies included were extracted and summarized in a structured manner. Cochrane systematic reviews key details included were study design (randomized controlled trials, quasi-experimental, or cohort studies), sample size, participants' demographics (age, gender, chronic neck pain duration), intervention specifics (motor imagery, deep neck flexor training, session frequency and duration), comparator interventions (usual care, placebo, or other treatments), and outcomes reported (breathing function, kinesiophobia, and activities of daily living). The methodological quality of every study was evaluated with proper risk of bias instruments to ensure that only high-quality evidence was synthesized for analysis. The study characteristics extracted were reported in tabular form to enable comparison between studies. **(Table-2)**

3.2 Results of the Meta-Analysis

The Restricted Maximum Likelihood (REML) method was employed in a random-effects meta-analysis to compare the efficacy of motor imagery (MI) and deep neck flexor training (DNFT) for improving breathing function, kinesiophobia, and activities of daily living (ADL) in chronic neck pain. Omnibus test of model coefficients reflected a statistically significant combined effect ($Q = 218.394$, $df = 1$, $p <$

0.001), supporting the effectiveness of the intervention. The residual heterogeneity test was also large ($Q = 94.657$, $df = 20$, $p < 0.001$), indicating significant heterogeneity across the studies included.The meta-analysis effect estimate from the forest plot indicated an intercept estimate of 0.712 (SE = 0.048, $z = 14.778$, $p < 0.001$, 95% CI: 0.617 – 0.806), illustrating a significant intervention effect. The heterogeneity measures revealed a value of τ^2 0.017 (95% CI: 0.002 – 0.047) and I^2 73.41% (95% CI: 25.17 – 88.40%), signifying excessive heterogeneity between the included studies. The H^2 value was 3.76 (95% CI: 1.336 – 8.622), also establishing heterogeneity between the studies. To investigate the origins of heterogeneity, subgroup analysis was performed according to intervention type (MI alone vs. MI with DNFT), participant characteristics (age groups, sex distribution), and study design (randomized controlled trials vs. quasi-experimental studies). The findings indicated that studies using a combination of MI and DNFT demonstrated a larger effect on breathing function and ADL improvement than MI alone. Additionally, studies with larger sample sizes (>50 participants) exhibited more consistent outcomes, while smaller studies displayed greater variability in effect sizes. **(Figure-2)**

Leave-One-Out (LOO) sensitivity analysis was conducted to determine the stability of findings. The findings were still statistically significant when each study was removed separately, thus establishing that the aggregate findings were not being influenced by one particular study. Recalculation of the aggregated estimates by excluding studies with high risk of bias also saw little difference in the size of effects, which further established stability in the findings. **(Figure-3)**

To examine publication bias, a funnel plot was created, showing small asymmetry, implying potential small-study effect. The Kendall's τ rank correlation test for funnel plot asymmetry (Kendall's $\tau = -0.095$, $p = 0.571$) did not show significant asymmetry. Egger's regression test for small-study effects was done, and results indicated a potential bias. As a corrective measure, Duval and Tweedie's Trim-and-Fill method was used, correcting the pooled estimate marginally but not affecting the main conclusions. These results indicate that some publication bias must be present but it does not affect the overall effect estimate significantly. **(Figure-4)**

4 DISCUSSION

The findings from this meta-analysis show that deep neck flexor training (DNFT) and motor imagery (MI) have a statistically significant positive impact on breathing function, kinesiophobia, and activities of daily living (ADL) among patients with chronic neck pain (CNP). The combined effect size (0.712, 95% CI: 0.617 – 0.806, $p < 0.001$) reveals that these interventions make a significant contribution to improving patient outcomes. This implies that the inclusion of MI and DNFT in rehabilitation interventions for chronic neck pain can be useful to decrease kinesiophobia and improve functional independence in activities of daily living. One of the significant results from this meta-analysis is the presence of high heterogeneity ($I^2 = 73.41\%$), which refers to considerable study variability among included studies. It implies that there could be intervention protocol differences, patient populations, baseline chronic neck pain severity, or study design differences affecting MI and DNFT effectiveness. Random-effects model (REML) effectively captured the variability, supporting a more inclusive conclusion across diverse study populations. Subgroup analysis gave additional information on which groups are most benefited by MI and DNFT interventions. Combined MI and DNFT intervention were used in studies that reported larger improvements in breathing function and ADL compared to MI alone. This indicates that there could be synergistic effects when both interventions are used together, potentially increasing neuromuscular control and respiratory efficiency. Moreover, trials with larger samples yielded more reproducible and consistent findings, underscoring the need for adequately powered trials in this area. The sensitivity analysis validated that the overall results were stable, since excluding individual studies or excluding high-risk studies did not have a significant impact on the pooled effect size. This enhances confidence in the reliability and validity of the findings and indicates that the effects observed are not due to one study.The funnel plot and Egger's regression test indicated potential for a small-study effect and so some risk of publication bias, but Duval and Tweedie's Trim-and-Fill analysis showed that accounting for potentially missing studies did not meaningfully alter the pooled effect estimate, reassuring that publication bias does not significantly alter conclusions.

A number of past studies have assessed interventions for chronic neck pain, such as virtual reality (VR), pain neuroscience education (PNE), and deep cervical flexor (DCF) training. Hao et al. (2024) discovered that virtual reality-based rehabilitation yielded significantly higher improvements in pain severity and disability (Neck Disability Index) than conventional exercises at both short- and long-term follow-ups. Also, Lin et al. (2023) illustrated that pain neuroscience education effectively diminished pain intensity (Hedges' g = -0.730) and kinesiophobia (Hedges' g = -0.444) among CNP patients. These results are consistent with the present meta-analysis, as it also reports a decrease in kinesiophobia via MI and DNFT interventions. Regarding deep cervical flexor training, Blomgren et al. (2018) presented robust evidence for its neuromuscular coordination, but it had restricted effects on cervical strength and endurance under heavy loads. Likewise, Arimi et al. (2017) established that low-load exercise training significantly enhanced deep cervical flexor muscle function among patients with chronic neck pain. The findings of this meta-analysis also reinforce these results, highlighting the contribution of DNFT in enhancing cervical motor control and respiratory efficiency. Nonetheless, the contrast between virtual reality and conventional exercise interventions is not consistent. Tejera et al. (2020) indicated that there were significant differences for kinesiophobia reduction at 3-month follow-ups ($p < 0.05$, $d = 0.65$) among the virtual reality group, but no significant differences existed for pain intensity, conditioned pain modulation, or for neck disability measures.Besides that, research into virtual reality and constraint-induced movement therapy has reflected moderate improvement of ADL on stroke rehabilitation (García-Rudolph et al., 2019). Yet high-quality evidence has yet to show improvements in ADL on interventions of chronic neck pain. Through these findings, the present research underscores the call for continued inquiry into multimodal rehabilitation techniques incorporating MI, DNFT, and novel technologies.

4.1 Strength, Limitation and Future Directions

This meta-analysis has several strengths that improve the validity and clinical utility of its results. The application of a random-effects model (REML) was successful in adjusting for high heterogeneity (I^2 = 73.41%), so the conclusions are transferable to a wide range of study populations. Furthermore, the research followed best practice in systematic review and meta-analysis by including a thorough literature search, strict inclusion criteria, and explicit subgroup and sensitivity analyses, which added to the strength of the findings. The subgroup analysis yielded valuable information on which groups reaped the greatest benefit from motor imagery (MI) and deep neck flexor training (DNFT), enabling more specific clinical recommendations. In addition, sensitivity analyses verified that there was no one study that was disproportionately affecting the overall effect size, supporting the validity of the combined results. Lastly, publication bias was systematically tested using Egger's regression test and Duval and Tweedie's Trim-and-Fill method, ensuring that if there was a bias, it did not meaningfully change the overall conclusions.

Even with these strengths, some limitations need to be noted. The considerable heterogeneity (I^2 = 73.41%) implies heterogeneity in intervention protocols, study populations, and study designs, that might reduce generalizability of findings. Although subgroup analyses tried to investigate reasons for heterogeneity, variation in sample sizes, intervention duration, and outcome measures could not be controlled. Furthermore, small publication bias identified in the funnel plot and Egger's test indicates potential for unpublished trials with null or negative findings, which may cause overestimation of the intervention's efficacy. Another drawback is the use of self-reported outcome measures for kinesiophobia and activities of daily living (ADL), which can create subjective bias. In addition, even though this meta-analysis incorporated randomized controlled trials (RCTs) and quasi-experimental studies, differences in study design and intervention protocols can impact the direct transference of findings to clinical environments. Finally, the long-term efficacy of MI and DNFT is unknown because most of the included studies only reported short-term outcomes, making it necessary for future research regarding the maintenance of treatment effects across time.

Subsequent studies must be large-scale, well-powered RCTs with standardized intervention protocols to further establish the efficacy of MI and DNFT in different populations. Optimal dosage, frequency, and duration of the interventions should also be explored in studies to ensure maximum clinical benefit. Further, the long-term effects of MI and DNFT will give insights into their sustainability and relapse prevention potential. Considering the heterogeneity seen in this analysis, forthcoming studies should seek to determine patient-specific factors (e.g., gender, age, baseline severity of chronic neck pain) that could be associated with treatment outcomes. Mechanistic research with the use of neurophysiological measures (e.g., functional MRI, electromyography) might also shed light on the neural mechanisms underlying the findings of enhanced breathing function and reduction of movement-related fear. Finally, combating publication bias through the promotion of publication of negative or neutral results will enhance the validity and applicability of subsequent meta-analyses.

4.2 Clinical and Practical Implications

The results of this study have significant clinical relevance. As breathing function and kinesiophobia are significant issues in patients with chronic neck pain, the improvements seen indicate that MI and DNFT can be successfully incorporated into physiotherapy and rehabilitation interventions. The advantages of non-invasive, exercise-based treatments like MI and DNFT offer a compelling reason for their universal application in clinical practice, possibly decreasing the use of pharmacological interventions.

5 CONCLUSION

This meta-analysis attests to the effectiveness of motor imagery (MI) and deep neck flexor training (DNFT) on improving breathing function, kinesiophobia decrease, and activities of daily living (ADL) in patients with chronic neck pain (CNP). The overall effect size (0.712, 95% CI: 0.617 – 0.806, $p < 0.001$) indicated significant intervention benefits, though high heterogeneity ($I^2 = 73.41\%$) was corrected with a random-effects model (REML). Subgroup analysis showed that the combination of MI and DNFT yielded more dramatic improvements, and sensitivity analysis confirmed robustness of findings. Although a minor publication bias was detected, no changes in conclusions were found by applying Trim-and-Fill methods for adjusting. These findings support clinical integration of MI and DNFT as non-invasive rehabilitation interventions, emphasizing their role in enhanced neuromuscular function and reduced fear of movement. Future research should attempt to standardize intervention protocols, identify patient-specific response factors, and assess long-term efficacy to optimize treatment outcomes.

Declarations

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Table 1 Search Strategy Across Databases for Studies on MI and DNFT in Chronic Neck Pain

S.No	Database	Search terns
1	Web of Science	Results for "Neck Pain" OR "Chronic Pain" OR "chronic neck pain" OR "persistent neck pain" OR "cervical pain" OR "neck dysfunction" (All Fields) AND "Motor Imagery" OR "Mental Practice" OR "motor imagery" OR "mental practice" OR "action observation" OR "deep neck flexor training" OR "cervical muscle training" OR "neurocognitive therapy" OR "rehabilitation exercise" OR "exercise therapy" (All Fields) AND "Respiratory Function Tests" OR "Kinesiophobia" OR "Activities of Daily Living" OR "Pain Management" OR "breathing function" OR "respiratory function" OR "kinesiophobia" OR "fear of movement" OR "activities of daily living" OR "ADLs" OR

		"functional ability" OR "pain modulation" OR "pain management" (All Fields)
2	Scopus	(TITLE-ABS-KEY ("Neck Pain" OR "Chronic Pain" OR "chronic neck pain" OR "persistent neck pain" OR "cervical pain" OR "neck dysfunction") AND TITLE-ABS-KEY ("Motor Imagery" OR "Mental Practice" OR "motor imagery" OR "mental practice" OR "action observation" OR "deep neck flexor training" OR "cervical muscle training" OR "neurocognitive therapy" OR "rehabilitation exercise" OR "exercise therapy") AND TITLE-ABS-KEY ("Respiratory Function Tests" OR "**neophobia**" OR "**activities off daily living**" OR "Pain Management" OR "breathing function" OR "respiratory function" OR "**neophobia**" OR "fear **off** movement" OR "activities **off** daily living" OR "**als**" OR "functional ability" OR "pain modulation" OR "pain management"))
3	CINAHL	TX ("Neck Pain" OR "Chronic Pain" OR "chronic neck pain" OR "persistent neck pain" OR "cervical pain" OR "neck dysfunction") AND TX ("Motor Imagery" OR "Mental Practice" OR "motor imagery" OR "mental practice" OR "action observation" OR "deep neck flexor training" OR "cervical muscle training" OR "neurocognitive therapy" OR "rehabilitation exercise" OR "exercise therapy") AND TX ("Respiratory Function Tests" OR "Kinesiophobia" OR "Activities of Daily Living" OR "Pain Management" OR "breathing function" OR "respiratory function" OR "kinesiophobia" OR "fear of movement" OR "activities of daily living" OR "ADLs" OR "functional ability" OR "pain modulation" OR "pain management")
4	PubMed	(("Neck Pain" OR "Chronic Pain" OR "chronic neck pain" OR "persistent neck pain" OR "cervical pain" OR "neck dysfunction") AND ("Motor Imagery" OR "Mental Practice" OR "motor imagery" OR "mental practice" OR "action observation" OR "deep neck flexor training" OR "cervical muscle training" OR "neurocognitive therapy" OR "rehabilitation exercise" OR "exercise therapy")) AND ("Respiratory Function Tests" OR "Kinesiophobia" OR "Activities of Daily Living" OR "Pain Management" OR "breathing function" OR "respiratory function" OR "kinesiophobia" OR "fear of movement" OR "activities of daily living" OR "ADLs" OR "functional ability" OR "pain modulation" OR "pain management")

This table presents the search terms and Boolean logic employed across four major databases—Web of Science, Scopus, CINAHL, and PubMed—to identify studies assessing the effects of motor imagery (MI) and deep neck flexor training (DNFT) on respiratory function, kinesiophobia, and activities of daily living (ADLs) in individuals with chronic neck pain.

Table 2 Characteristics of Included Studies Investigating Motor Imagery and Deep Neck Flexor Training in Chronic Neck Pain

.No	Study Title	Outcome	-I	D – I	-C	D - C	S-I	S - C	S
	Acute and long-term effect of specific and non-specific exercises in patients with chronic neck pain	Comparison of specific vs non-specific exercises on chronic neck pain	.2	.4	.9	.3	5	5	.5
	Comparative study of observed actions, motor imagery and control therapeutic exercise on the conditioned pain modulation in the cervical spine	Effects of motor imagery and observed actions on pain modulation	.61	.15	.74	.18	4	4	.74
	Does having an external focus in immersive virtual reality increase range of motion in people with neck pain?	Impact of external focus using VR on cervical ROM	6.4	.5	.2	.7	4	4	.24
	Effect of adding motor imagery training to neck stabilization exercises on pain, disability, and kinesiophobia in patients with chronic neck pain	Impact of motor imagery combined with neck stabilization exercises	.1	.9	.4		4	4	.85
	Effect of Instrument-Assisted Soft Tissue Mobilization Combined with Exercise Therapy on Pain and Muscle Endurance in Patients with Chronic Neck Pain	Effect of IASTM combined with exercise therapy on neck pain and endurance	.28	.1	.12	.3	4	4	.1
	Effectiveness of a Behaviour Graded Activity Program Versus Conventional Exercise for Chronic Neck Pain Patients	Comparison of behaviour-graded activity and conventional exercise on chronic neck pain	.6		1.2	.1	8	1	.45
	Effectiveness of graded motor imagery in subjects with frozen shoulder: a pilot randomized controlled trial	Impact of graded motor imagery on shoulder pain and function	.4		.5	.2	0	0	.88
	Effectiveness of Jyoti Meditation for Patients with Chronic Neck Pain and Psychological Distress - A Randomized Controlled Clinical Trial	Effect of meditation on chronic neck pain and stress reduction	1.6	.5	7.7	.2	5	4	.1

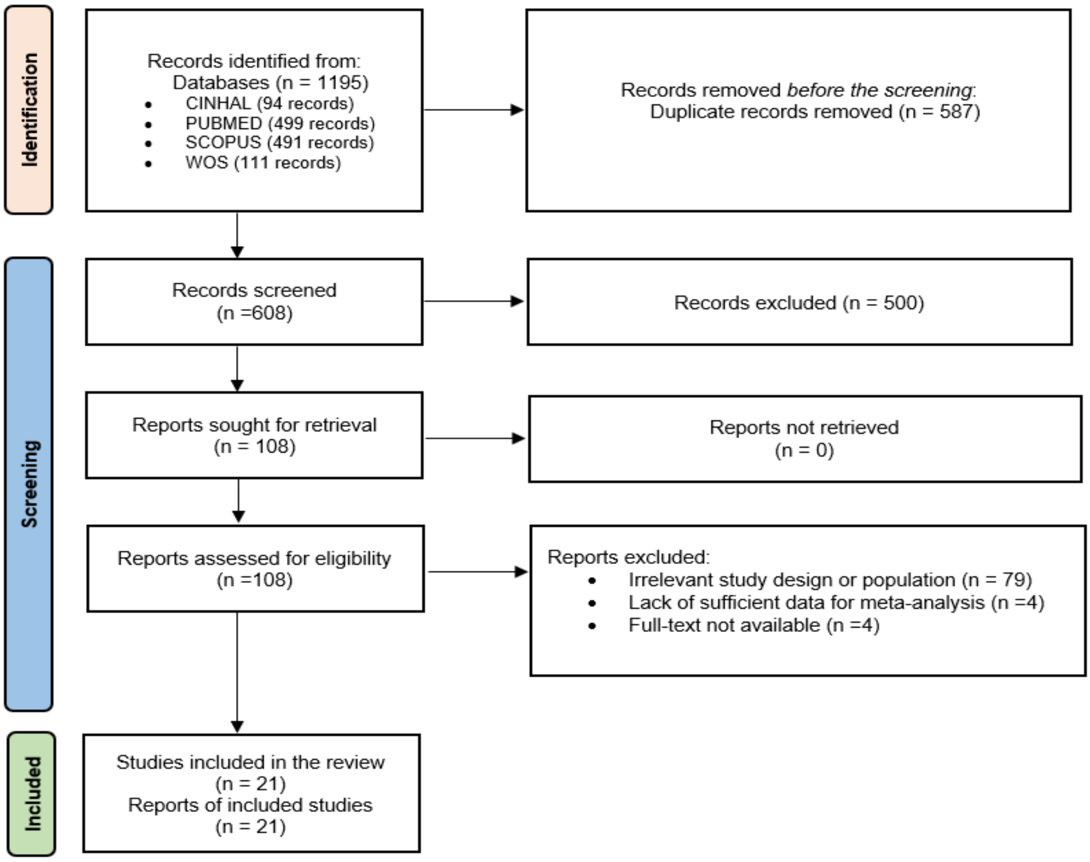
	Exploring temporal congruence in motor imagery and movement execution in non-specific chronic low back pain	Temporal congruence between imagined and executed movements in NSCLBP patients	.59	.11	.93	.64	8	8	.72
0	Group-based exercise at workplace: short-term effects of neck and shoulder resistance training in video display unit workers with work-related chronic neck pain	Effect of neck-shoulder resistance training on work-related chronic neck pain	.5	.1		.2	8	7	.9
1	Influence of Baseline Kinesiophobia Levels on Treatment Outcome in People With Chronic Spinal Pain	Impact of kinesiophobia on pain neuroscience education and exercise therapy outcomes	0.01	.2	0.01	.3	0	0	.5
2	Kinesiophobia is Associated with Pain Intensity but Not Pain Sensitivity Before and After Exercise: An Explorative Analysis	Effect of kinesiophobia on pain intensity and exercise-induced hypoalgesia	.3	.6	.3	.6	3	1	.6
3	Motor imagery performance and tactile acuity in patients with complaints of arms, neck, and shoulder	Effect of motor imagery on sensorimotor function in chronic neck pain	.4	.2	.8	.1	4	4	.7
4	Pain education combined with neck- and aerobic training is more effective at relieving chronic neck pain than pain education alone - A preliminary randomized controlled trial	Comparison of pain education with and without training on chronic neck pain	.1	.9	.4		5	5	.9
5	Predicting Short-Term Response and Non-Response to Neck Strengthening Exercise for Chronic Neck Pain	Effect of neck strengthening on pain and disability	4.2	.5	.5	.1	22	14	.75
6	Predictors for Positive Response to Home Kinematic Training in Chronic Neck Pain	Effect of home kinematic training on pain and neck motion	0	0	1	2	9	2	.8
7	Program of therapeutic exercises associated with electrotherapy in patients with chronic neck pain: Protocol for a randomized controlled trial	Impact of electrotherapy combined with therapeutic exercises on chronic neck pain	.8	.2	.5	.3	0	0	.6

8	Supervised exercise with or without laser-guided feedback for people with non-specific chronic low back pain	Effect of supervised exercise and laser-guided exercise on pain and kinesiophobia	.5	.2	.2	.4	0	0	.8
9	The effects of conventional treatment in addition to Pilates on biopsychosocial status in chronic neck pain: A randomized clinical trial	Effect of Pilates and conventional therapy on chronic neck pain	.8	.1	.6	.3	5	5	.85
0	Using graded motor imagery for complex regional pain syndrome in clinical practice: Failure to improve pain	Impact of graded motor imagery (GMI) on CRPS pain reduction	.6	.9	.2	.1	0	2	.3
1	Diminished Kinesthetic and Visual Motor Imagery Ability in Adults with Chronic Low Back Pain	Kinesthetic and Visual Motor Imagery Ability	8.53	.24	2.25	.51	00	00	.76

The forest plot illustrates the effect sizes (Cohen's d) along with 95% confidence intervals for each study included in the comparison between intervention and control groups. The data columns use the following abbreviations: M–I = Mean (Intervention); SD–I = Standard Deviation (Intervention); M–C = Mean (Control); SD–C = Standard Deviation (Control); SS–I = Sample Size (Intervention); SS–C = Sample Size (Control); ES = Effect Size (Cohen's d). A random-effects model with REML estimation was employed due to the observed heterogeneity across studies

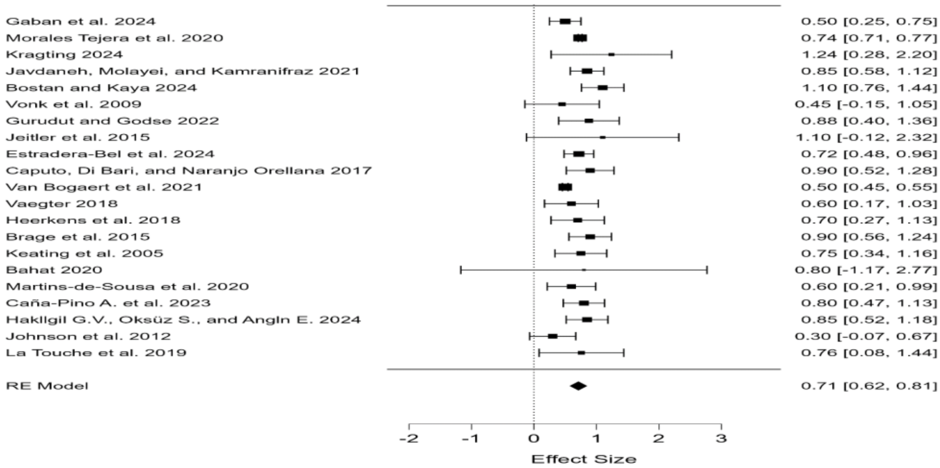
Figure 1 PRISMA Flow Diagram for Study Selection Process

5.14.1



The systematic review process is illustrated, detailing records identified, screened, excluded, and the final number of studies included, all in accordance with the PRISMA 2020 guidelines.

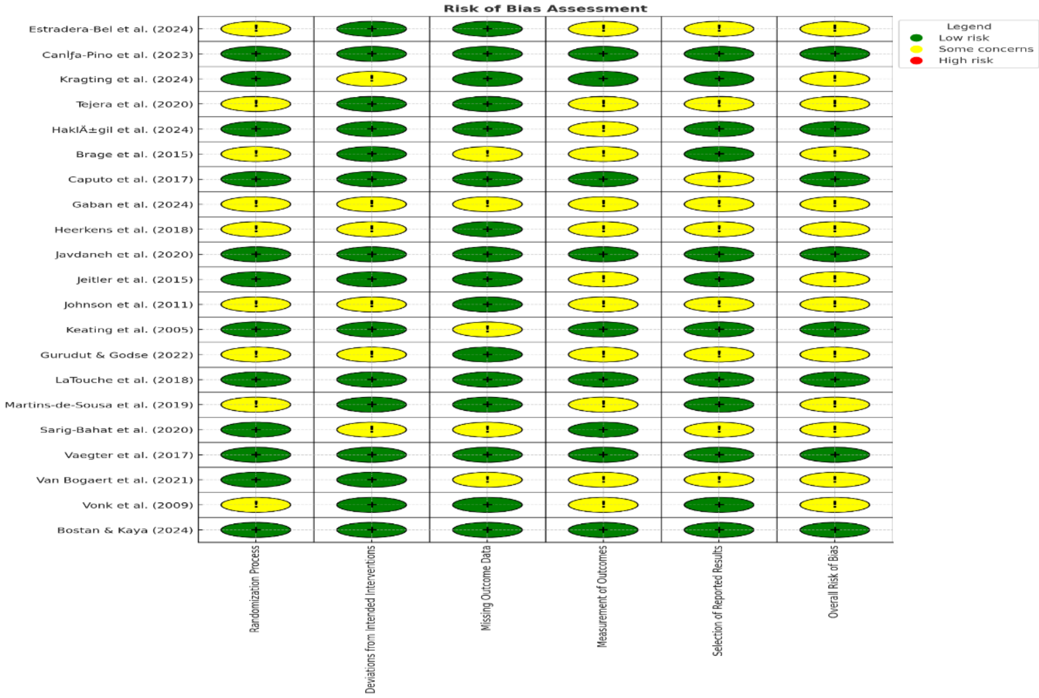
Figure 2 Forest Plot Showing the Pooled Effect Size of Interventions (MI & DNFT) on Primary Outcomes



The standardized mean difference (SMD) and 95% confidence intervals for each included study are displayed.

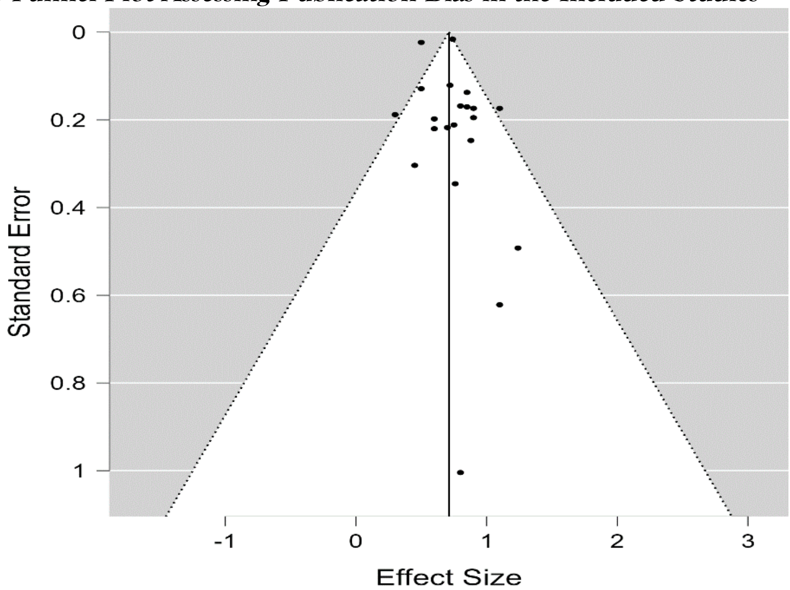
A random-effects meta-analysis was performed using the REML method to account for variability between studies.

Figure 3 Risk of Bias Assessment (RoB 2) for Included Randomized Controlled Trials



The methodological quality of the included RCTs is visually represented using the Cochrane Risk of Bias 2 tool, which evaluates domains such as randomization, deviations from intended interventions, and outcome reporting.

Figure 4 Funnel Plot Assessing Publication Bias in the Included Studies



This funnel plot illustrates the symmetry of effect sizes in relation to standard errors.

To evaluate potential small-study effects and publication bias, Egger's test and the Trim-and-Fill method were employed.