# Interventions of Exercise Therapy for Chronic Non-Specific Low Back Pain: A Comprehensive Systematic Review and Comparative Study of Effects

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# Abstract

**Background:** The cost of medical care for low back pain is a heavy financial burden for patients and has become a common social health issue that affects people of all ages and professions.

**Objective**To comprehensively evaluate the effectiveness of different types of exercise therapy in treating chronic non-specific low back pain, and provide decision support for patients, medical professionals, and decision-makers to choose the most suitable exercise therapy to reduce pain, improve function, and reduce medical expenses.

**Methods:** Data was sourced from electronic databases including PubMed, China Knowledge Network (CNKI), China Biomedical Literature Database (CBM), and Wanfang Data (WD). The search targeted studies focused on exercise therapy as a treatment for chronic non-specific low back pain (CNLBP) conducted within the timeframe spanning five years, from 2018 to 2022. The selection process encompassed published literature, excluding studies deemed of low relevance, ultimately culminating in the inclusion of 26 pertinent papers.

**Results:** Different exercise modalities have shown clinical effectiveness for lumbopelvic stability exercise spinal stabilization exercise training, etc., with superior efficacy for increasing muscle strength, enhancing spinal or lumbar stability, and increasing the thickness of core stabilising muscles. However, exercise therapies like McKenzie therapy (MDT), Motor Control Exercise MCE , Sling Exercise Therapy SET , and physical education (PE) are more helpful in restoring posture and function, improving neuromuscular control, and correcting delayed muscle activation than they are in increasing muscle thickness. Second, yoga activities have been found to help with pain management, emotional regulation, psychological control, and sleep problems.

**Conclusions:** Although there are differences in the clinical effectiveness of various exercise therapies for the management of CNLBP, yet all of these exercise interventions have significant efficacy for managing low back pain and are safe, simple to use, and affordable. This is crucial for reducing medical costs and warrants widespread promotion.The potential of exercise therapy in the treatment of CNLBP, healthcare professionals and patients choose appropriate exercise modalities based on individual needs to improve quality of life and reduce pain


# Introduction

The prevalence of chronic low back painis steadily rising in today's aging population, making the need for health advices in this area even more urgent [1]. Low back pain (LBP) has long been a common condition in contemporary society [2] and is one of the most prevalent public health problems worldwide[3, 4], affecting people of all ages and posing a significant financial burden for those who suffer from it [5]. People who lead healthy lifestyles and experience non-specific low back pain (NLBP) may experience pain, loss of physical function, and other adverse effects on their physical and emotional health [6]. In contrast, chronic non-specific low back pain (CNLBP), which excludes specific conditions like tumours, fractures, herniated discs, cauda equina syndrome, neuropathic pain, and imaging manifestations, is described as pain and discomfort in the low back, lumbosacral region, or hip region that lasts longer than three months [7]. In persons aged 20 to 64 who engage in at least one to three 20-minute exercise sessions each week, physical activity is linked to a lower incidence of chronic pain, which is as low as 10–12% [8]. Therefore, independent physical exercise is crucial for the management of chronic pain. Exercise therapy is preferred over untreated natural healing for persons with CNLBP[9]. The majority of the existing research on exercise treatment for CNLBP compares the effects of one or more various exercise therapies, focusing in different ways on each therapy's clinical efficacy[10]. Studies of several exercise regimens provide indirect evidence that one therapy is necessarily superior to the others. However, due to a variety of circumstances, various exercise regimens have their own unique benefits and clinical implications for CNLBP. Patients with low back pain can select the best form of exercise treatment for their needs [10] .

CNLBP refers to pain or discomfort in the lower back, usually without a clear structural lesion or specific joint injury as the cause. This pain can be related to a variety of factors, such as postural problems, muscle strain, and spinal problems.[7, 10]that affects adults in different occupations [61, 81] and professions and has emerged as a widespread health issue in society. The root causes of its severity are a combination of biological, psychological, and social factors [11]. Conversely, low back pain may also be accompanied by joint degeneration, damage to the articular surfaces and soft tissues surrounding the sacroiliac joint, and decreased muscle strength. Consequently, patients may experience a range of issues, such as low back instability, reduced control over daily activities, limb dysfunction, and improper movement patterns, all of which can lead to low back pain [12, 13]. Moreover, the development of low back pain makes the patient somewhat fearful of sports[6].When pain is treated solely with medication, it may result in recurring symptoms, treatment of the symptoms rather than the cause, and incurrence of excessive treatment costs [11]. Exercise is used to treat low back pain symptoms, as well as to improve the patient's exercise capacity and intervene in controllable factors that promote a healthy condition, such as trunk stability, strong neuromuscular control, and psychological factors, in order to prevent pain recurrence, promote physical function, and alleviate symptoms. Exercise therapy is more widely used in the treatment of sports injuries and pain, and as the name suggests, it is the use of exercise to improve sports injuries and pain.. To determine whether various trainings or protocols of exercise therapy can reduce pain, increase muscle thickness in core muscle groups, improve abnormal posture, improve neuromuscular control, and regulate depressive and fearful psychological states, this paper conducts a systematic review of recent research on the various exercise therapies for low back pain. It is believed that this would provide patients with low back pain with a clear understanding of the best exercise therapy to choose, as well as theoretical support for enhancing physical function and strength, controlling depression and movement anxiety, and regaining their health.

# Material And Methods

# Search Strategy

The electronic databases PubMed and CNKI CBM WD were searched for "chronic nonspecific low back pain, exercise therapy, core stability training, aerobic training, Pilates, yoga, exercise control training, suspension exercise, and McKenzie therapy" as search terms for the selection of literature, and the search period was based on the years 2018 to 2022. The different database retrieval methods are shown in Table 1.

Table 1
Different database retrieval methods

| Database | Retrievable |
| --- | --- |
| English literature search(PubMed) | ((Chronic nonspecific low back pain) OR (nonspecific low back pain)) AND (Exercise therapy)<br><br>((Chronic nonspecific low back pain) OR (nonspecific low back pain)) AND ((Exercise control training) ((Chronic nonspecific low back pain) OR (nonspecific low back pain)) AND (Aerobic training)) ((Chronic nonspecific low back pain) OR (nonspecific low back pain)) AND (Pilates)) ((Chronic nonspecific low back pain) OR (nonspecific low back pain)) AND (Yoga) ((Chronic nonspecific low back pain) OR (nonspecific low back pain)) AND (Mckenzie therapy) ((Chronic nonspecific low back pain) OR (nonspecific low back pain)) AND (Core stability training) |
| Chinese literature search(CNKI CBM WD) | (Chronic nonspecific low back pain, Exercise therapy); (Chronic nonspecific low back pain, Exercise control training); (Chronic nonspecific low back pain, Aerobic training); (Chronic nonspecific low back pain, Core stability training); (Chronic nonspecific low back pain, Pilates); (Chronic nonspecific low back pain, Yoga); (Chronic nonspecific low back pain, Mckenzie therapy) |

# Inclusion/Exclusion Criteria

The screening of the literature included in this study and the quality analysis of the literature were done using the software Review Manager 5.4, which includes the following tasks: importing the literature; importing the information of the literature in English and Chinese, screening the literature; and screening the literature one by one according to the set inclusion criteria and exclusion criteria.The specific inclusion and exclusion criteria are shown in Table 2.

Table 2
Inclusion and exclusion criteria

| Inclusion criteria | | Exclusion criteria | |
| --- | --- | --- | --- |
| **Standard** | **Specific requirements** | **Standard** | **Specific requirements** |
| Study Type | Including peer-reviewed original research, such as randomized controlled trials (RCTs), cohort studies, clinical trials, | Study Type | Exclude case reports, expert opinions, books, and other non-original research sources. |
| Study Participants | Inclusion criteria encompass patients aged 18 years and older suffering from chronic non-specific low back pain, with no gender restrictions. | Study Participants | Exclude patients under the age of 18. |
| Intervention Type | Studies eligible for inclusion must focus on exercise therapy as the primary treatment modality. Intervention measures in the studies must involve exercise regimens, such as exercise courses, workout plans, or rehabilitation training. | Intervention Type | Exclude studies that do not involve exercise therapy or studies involving other primary treatment interventions, such as drug therapy or surgical treatments. |
| Reported Symptoms | Only studies pertaining to chronic non-specific low back pain will be considered. | Reported Symptoms | Exclude studies focused on specific types of back pain. |
| Publication Year Limit | Relevant literature published within the last five years will be included. | Publication Year Limit | Exclude randomized controlled trial studies published prior to 2018. |
| Study Outcomes | Studies must report key clinical outcomes related to chronic non-specific low back pain, such as pain intensity, functional improvement, quality of life, recurrence rate, and so forth. Results must be presented using numerical values or statistical indicators, such as effect sizes and confidence intervals. | Study Outcomes | Exclude studies that do not report key clinical outcomes related to chronic non-specific low back pain. |
| Intervention Period | In randomized controlled trials investigating exercise therapy for CNLBP, the intervention duration should be at least two weeks." | Intervention Period | In randomized controlled trial studies investigating exercise therapy for chronic non-specific low back pain, the intervention duration should be less than two weeks. |

# Quality Assessment

Literature data extraction and literature quality assessment for the study in this paper was done solely by the first author.The quality assessment of the included literature in this study was done using Review Manager's built-in Cochrane Risk of Bias tool for assessing the quality of randomized controlled trials. The tool includes assessments of the following aspects: randomized sequence generation, allocation concealment, blinding, completeness and selective reporting, and other biases, resulting in the inclusion of 26 randomized controlled trials.The article quality evaluation is shown in Figs. 1 and 2.

# Summary of included Studies

Through preliminary advanced search of all search terms in the literature, 1802 English articles and 415 Chinese papers were obtained. After screening the article titles and conducting a self-examination of the reading abstracts, the articles were selected based on inclusion and exclusion criteria, and ultimately 81 articles, including 12 Chinese articles and 69 English articles, were included. 26 randomized controlled trial type studies were selected from the 81 articles for literature review. The flowchart for article screening is shown in Fig. 3.

## Results

## Study Characteristics

In this study, exercise therapy is categorized into two main groups for review: "Different Training Modes" and "Different Exercise Programs."In total, 26 randomized controlled trials were included, encompassing a total of 1,716 clinical participants.

## Exercise Therapy for Different Training Modes

"Different Training Modes" refer to the use of various training methods and strategies to enhance athletes' skills, strength, endurance, and other abilities in specific sports or physical activities. The different training modes included in this research encompass core stability training, exercise control training, breathing exercises, suspension training, and aerobic training. A total of 18 studies involving 1,145 clinical participants were included in this review (see Table 3).

Table 3
Randomised controlled trial of exercise therapy with different training modalities

| Study | Time | Region | Age | Patient | Intervention/control | Intervention | Research results | | | Co |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Pain | Function | Perform | |
| Sipavicien | 2019 | U.S.A | 38.3 ± 5.1 | 70 | Lumbar spine stabilization training / muscle strength strengthening training | 20Weeks | VAS(1–10) | ODI | LM area | Th ex gr ex in lu m m th re re lu fu re lu sy |
| Hlaing | 2021 | Thailand | 34.78 ± 9.07 | 36 | Core stability training/strength training | 4Weeks | VAS(3–7) | MODQ | TSK/TrA\LM thickness | Th in ef in th th m ab m er pr ar ar cc al ar fe m |
| Khodadad | 2019 | Iran | 44.3 ± 2.46 | 52 | Lumbar spine stabilization intervention/cognitive function intervention | 8Weeks | VAS(1–10) | LMC | LST | W wa si di pa im be tw in gr ex gr de ar er in sp |
| Salik | 2021 | Türkiye | - | 37 | Stability Training / Routine Training | 6Weeks | VAS(1–10) | ODI | Trunk strength | St tra to to cc tra im pa er fu in er ar cc |

**Notes;***VAS, Visual analog scale ;ODI, Oswestry disability index MODQ,Modified Oswestry disability questionnaire TrA;Transverse abdominal muscle;LM, Lumb multifidus;TSK,Tampa Scale for Kinesiophobia; LST, Lumbar Stabilisation Treatment; NPRS, Numerical Pain Rating Scale; R-M, Roland-Morris; MRS, Modified Scale; CMS-HS, Zebris CMS-HS; PSLRT, passive straight leg raising test; TTT, The toe-touch test; MTT, The modified Thomas test; QVAS, Quadruple visual ana ODI-k, Oswestry Disability Index-Korean version; PSFS, Patient Specific Functional Scale; OI, obliquus internus; OE, obliquus externus; COS, core outcome set; F Avoidance Belief Questionnaire; HADS, Hospital Anxiety and Depression Scale; CES-D 10-, Centre for Epidemiologic Studies Depression Scale; NPRS, numerica scale; NHP, Notting-152 ham Health Profile.*

| Study | Time | Region | Age | Patient | Intervention/control | Intervention | Research results | | | Co |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Pain | Function | Perform | |
| Thomas | 2020 | France | 25 ± 6.2 | 162 | Chiropractic / Spinal Joint Release | 3Weeks | NPRS(0–10 | R-M(0–24) | - | Bc in m nc yi re in wi m CI |
| Schulz | 2019 | U.S.A | 65≤ | 241 | Home fitness combined with spinal manipulative therapy/rehabilitation exercises | 12Weeks | 11-BS(0–10) | MRS | CMS-HS | Ne de si im in fu ei sh lo |
| Chen Lei | 2018 | China | 19–22 | 30 | Core plyometric training/traditional plyometric training | 12Weeks | VAS(1–10) | - | LM thickness | Fc st tra w im in re in lu ba st ar th of st m gr |
| Aboufazeli | 2021 | Iran | 20–45 | 24 | Stability training / Hip abduction strengthening training | 8Weeks | VAS(1–10) | ODI | LM thickness | Bc gr sh si in th th m m cc th st of st |
| Ahmadnezhad | 2020 | Korea | 18–25 | 47 | Respiratory training (inspiratory muscle strength)/none | 8Weeks | VAS(1–10) | ODI(0–60) | PSLRT/TTT/MTT | Im re fu re ar st m re ab ar ab m ob |

**Notes**;*VAS, Visual analog scale ;ODI, Oswestry disability index MODQ,Modified Oswestry disability questionnaire TrA;Transverse abdominal muscle;LM, Lumb multifidus;TSK,Tampa Scale for Kinesiophobia; LST, Lumbar Stabilisation Treatment; NPRS, Numerical Pain Rating Scale; R-M, Roland-Morris; MRS, Modified Scale; CMS-HS, Zebris CMS-HS; PSLRT, passive straight leg raising test; TTT, The toe-touch test; MTT, The modified Thomas test; QVAS, Quadruple visual anal ODI-k, Oswestry Disability Index-Korean version; PSFS, Patient Specific Functional Scale; OI, obliquus internus; OE, obliquus externus; COS, core outcome set; F Avoidance Belief Questionnaire; HADS, Hospital Anxiety and Depression Scale; CES-D 10-, Centre for Epidemiologic Studies Depression Scale; NPRS, numerica scale; NHP, Notting-152 ham Health Profile.*

| Study | Time | Region | Age | Patient | Intervention/control | Intervention | Research results | | | Co |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | | | | | | Pain | Function | Perform | |
| Finta1 | 2018 | Hungary | | 52 | Respiratory training (diaphragm training)/ | | VAS(1–10) | - | TrA/LMthickness | Th of m tra ab m in lea im in sp |
| Oh YJ | 2020 | Korea | 40–49 | 44 | Breathing resistance lumbar spine stabilization training / breathing resistance training | 4Weeks | QVAS | ODI-K(0–5) | TrA thickness | Th co of re tra lu st tra sig im ar fu ar th st co gr |
| Halliday | 2019 | Australia | 18–70 | 70 | Motor Control Training/McKenzie Therapy | 8Weeks | - | PSFS(3–30) | TrA OE\OI thickness | Bo de sir ef te m th fu se re pa wi m re ab wi im m th th m |
| Van Baal | 2020 | Germany | 18< | 34 | Movement therapy (motor control + tactile sensitivity / traditional movement) | 6Treatments | COS | ODI | FABQ/HADS | Ex th er ne co re sig im in fu in es wl co lo ex co tra m in tra tra al po ef de |

**Notes**;*VAS, Visual analog scale ;ODI, Oswestry disability index MODQ,Modified Oswestry disability questionnaire TrA;Transverse abdominal muscle;LM, Lumb multifidus;TSK,Tampa Scale for Kinesiophobia; LST, Lumbar Stabilisation Treatment; NPRS, Numerical Pain Rating Scale; R-M, Roland-Morris; MRS, Modified Scale; CMS-HS, Zebris CMS-HS; PSLRT, passive straight leg raising test; TTT, The toe-touch test; MTT, The modified Thomas test; QVAS, Quadruple visual anal ODI-k, Oswestry Disability Index-Korean version; PSFS, Patient Specific Functional Scale; OI, obliquus internus; OE, obliquus externus; COS, core outcome set; F Avoidance Belief Questionnaire; HADS, Hospital Anxiety and Depression Scale; CES-D 10-, Centre for Epidemiologic Studies Depression Scale; NPRS, numerica scale; NHP, Notting-152 ham Health Profile.*

| Study | Time | Region | Age | Patient | Intervention/control | Intervention | Research results | | | Co |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Pain | Function | Perform | |
| Teychenne | 2019 | Australia | 35Average | 40 | Motor control training combined with manual therapy/traditional training (medium intensity) | 6 Months | VAS(0–100) | | CES-D(0–30) | Lo ex co tra co wi th m in tra tra im pa de |
| Li Xin | 2020 | China | 20–45 | 20 | Suspension training (low back pain group)/health group | 2Weeks | NPRS | ODI | Balance ability | Su tra no im ar fu ar po re ac ch pa co ne |
| Niu Kun | 2019 | China | 30.82 ± 5.2 | 42 | Suspension training combined with vine moxibustion liquid / lumbar abdominal muscle training | 8Weeks | VAS(1–10) | ODI | 5-HT β-EP | Th co of tra he m th sig im ef of pa m ar ef pr re |
| Wang | 2019 | China | 30.45 ± 5.55 | 60 | Lumbar oblique plate manipulation combined with suspension training/simple suspension training | 4Weeks | VAS(1–10) | ODI | Maximum muscle strength of waist and back | In pa fu in co in th ou pu su tra |
| Wang X | 2019 | China | 41.45 ± 10.23 | 84 | Acupuncture treatment combined with suspension training/simple suspension training | 12Weeks | VAS(1–10) | ODI | - | Fo fu in ac th co su tra m th su tra |

**Notes**;*VAS, Visual analog scale ;ODI, Oswestry disability index MODQ,Modified Oswestry disability questionnaire TrA;Transverse abdominal muscle;LM, Lumb multifidus;TSK,Tampa Scale for Kinesiophobia; LST, Lumbar Stabilisation Treatment; NPRS, Numerical Pain Rating Scale; R-M, Roland-Morris; MRS, Modified Scale; CMS-HS, Zebris CMS-HS; PSLRT, passive straight leg raising test; TTT, The toe-touch test; MTT, The modified Thomas test; QVAS, Quadruple visual anal ODI-k, Oswestry Disability Index-Korean version; PSFS, Patient Specific Functional Scale; OI, obliquus internus; OE, obliquus externus; COS, core outcome set; F Avoidance Belief Questionnaire; HADS, Hospital Anxiety and Depression Scale; CES-D 10-, Centre for Epidemiologic Studies Depression Scale; NPRS, numerica scale; NHP, Notting-152 ham Health Profile.*

# Exercise Therapy for Different Programs

"Different Sports Programs" refers to various sports or physical activities, each with its unique set of rules, technical requirements, and competition formats. In this study, different sports programs refer to the McKenzie method, Pilates, and yoga. A total of 8 studies were included, involving 571 clinical participants (see

Table 4). Two included studies provided descriptions of patient baseline characteristics, intervention measures, timing, and primary outcome measures.

Table 4
Randomised controlled trials of exercise therapy for different programs

| Study | Time | Region | Age | Patient | Intervention/control | Intervention | Research results | | | Conclusion |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Pain | Function | Perform | |
| Valenza | 2018 | Spain | 37.62 ± 12.14 | 54 | Pilates/Cognitive Education | 8weeks | VAS(0–10) | ODI(0–24) | LM/FTFT/SLST | Pilates has demonstrated significant therapeutic efficacy in improving pain and disability indices, posture control, and enhancing flexibility and balance. |
| Batıbay | 2020 | Türkiye | 18–60 | 60 | Mat Pilates / Home Fitness | 8weeks | VAS(0–10) | ODI | BDQ/LM thickness | Pilates is effective in addressing pain, functional levels, and depression intervention, but it does not have an impact on the thickness of the core muscle group. |
| Castro | 2022 | Brazil | - | 22 | Elastic resistance Pilates/non-elastic resistance Pilates | 8weeks | VAS(0–10) | ODI | ADM strength | Both approaches have a relatively low impact on pain and functional impairments but significantly increase lumbar strength. |
| Yalfani | 2020 | Iran | 24.92–4.03 | 24 | Pilates in water / Pilates on mat | 8weeks | VAS(0–10) | ODI(0-100) | BBS | Both interventions have a positive impact on treating lower back pain, but neither has a substantial effect on patients' balance. |
| Yang | 2021 | Taiwan, China | 30–70 | 39 | Mat Pilates / Medicated Rehabilitation Care | 8weeks | VAS(0–10) | RMDQ(0–24) | EQ-5D | A core training program involving mat Pilates significantly improves pain, enhances overall health, and regulates psychological states. |

**Notes**; *VAS, Visual analog scale; ODI, Oswestry disability index; BDQ, Beck Depression Questionnaire; BBS, Biodex Balance System Biodex; RMDQ, Roland-Morris Disability Index; EQ-5D, EuroQol-5D; SF-12, health-related quality of life Short Form 12; NRS, numerical rating scale; DVPRS, Defense and Veterans Pain Rating Scale; FTFT, Fingertip-to-floor test; SLST, Single-limb stance test; ADM, Abdominal-dorsal muscle.*

| Study | Time | Region | Age | Patient | Intervention/control | Intervention | Research results | | | Conclusion |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Pain | Function | Perform | |
| Michalsen | 2021 | Germany | 18–70 | 274 | Yoga/Eurythmy Therapy/Standard Physical Therapy | 8weeks | VAS | RMDQ | SF-12 | Yoga and Eurythmy therapy can improve lower back pain, but their impact on disability indices does not reach clinical significance. |
| CuiBowen | 2022 | China | - | 28 | Yoga stabilisation training combined with health education / plyometrics | 4weeks | NRS | ODI | ADM endurance | The yoga group can provide long-term pain relief and significantly improve lumbar and back muscle endurance. |
| Neyaz | 2019 | India | 18–35 | 70 | Hatha Yoga / Traditional Movement Therapy | 12weeks | DVPRS(0–10) | RDQ(0–24) | - | Both therapies exhibit similar effectiveness, leading to a notable improvement in lower back pain and functionality. |

**Notes**; *VAS, Visual analog scale; ODI, Oswestry disability index; BDQ, Beck Depression Questionnaire; BBS, Biodex Balance System Biodex; RMDQ, Roland-Morris Disability Index; EQ-5D, EuroQol-5D; SF-12, health-related quality of life Short Form 12; NRS, numerical rating scale; DVPRS, Defense and Veterans Pain Rating Scale; FTFT, Fingertip-to-floor test; SLST, Single-limb stance test; ADM, Abdominal-dorsal muscle.*

## Outcome Measures

A forest plot was presented in a study that included 26 research studies, displaying results on pain and physical function using different scales (see Fig. 4 and5). Additionally, due to variations in the scales of the questionnaires used, standardised mean differences (SMD) were employed across all included studies.

## Pain

A total of 26 studies (with 1,479 participants) were included, of which only 23 studies (with 1,209 participants) reported the effects of different interventions on pain outcomes (VAS, QVAS, NPRS, DVPRS, NRS). The pooled data demonstrated that the TCE group showed a significant reduction in pain compared to the control group (SMD=-0.16; 95% CI: -0.65, 0.33; $p < 0.001$), and significant heterogeneity was observed in the overall results ($I^2 = 91\%$). Therefore, a random-effects model was used to combine these studies.

The findings suggest that interventions collectively referred to as TCE (which encompasses various treatments) have a demonstrable impact on alleviating pain among individuals with the conditions under investigation. This conclusion is underscored by the statistically significant reduction in pain scores. However, the high degree of heterogeneity observed across the studies should not be overlooked.

The heterogeneity, indicated by the $I^2 = 91\%$, highlights the diversity in the study designs, patient populations, and methodologies employed across the 23 studies. Several factors may contribute to this heterogeneity, such as variations in intervention duration, patient demographics, the specific type of interventions administered, and the severity of the condition being treated. Therefore, while the overall effect size suggests a benefit of TCE interventions in managing pain, it's important to interpret this result with caution due to the substantial variability among the studies.

## Physical Function

A total of 26 studies (with 1,479 participants) were included, of which only 22 studies (with 1,178 participants) reported the effects of various interventions on the outcomes of physical function assessment (VMODQ, ODI, Roland-Morris, RMDQ). The pooled data indicated that the TCE group had a greater advantage in improving physical function compared to the control/comparison group (SMD = -1.56; 95% CI: -0.38, -0.71; $p < 0.001$), and significant heterogeneity was present in the overall result ($I^2 = 98\%$). Therefore, a random-effects model was used to combine these studies.

The results of the analysis of the forest map showed that interventions collectively referred to as TCE (encompassing various treatment modalities) are associated with a notable improvement in physical function among individuals with the conditions under investigation. This conclusion is underpinned by the statistically significant effect size, highlighting the potential benefits of these interventions in enhancing physical functionality.

Despite All This, the substantial heterogeneity observed across the studies warrants careful consideration. The high level of heterogeneity, indicated by an I^2 value of 98%, underscores the variability in study designs, patient characteristics, and methodological approaches employed among the 22 studies. Diverse factors, including differences in the type and duration of interventions, the demographic profiles of participants, and variations in the severity of the conditions being treated, could contribute to this observed heterogeneity. Therefore, while the overall effect size indicates a favorable impact of TCE interventions on physical function, it is essential to interpret these findings cautiously, given the considerable variability among the studies.

## Discussion

# Exercise Therapy for Different Training Modes

# Core Stability Training

The majority of exercise therapies utilise specialised exercises that specifically target the patient's core stability, encompassing both lumbar and spinal stability. The aim is to enhance the strength of the core muscle groups, including the deep trunk muscles, erector spinae, and multifidus, in order to achieve a balance of muscle tone around the lumbar spine and spine, ultimately leading to trunk stability [14]. For patients suffering from CNLBP who exhibit inadequate core muscular strength in the trunk, such as those who engage in occasional sports or lead a sedentary lifestyle, the elderly, and women who have recently given birth, various stabilisation or muscle strength training exercises can be employed as part of their treatment plan.

# Increase in Lumbar Spine Stability Training

One of the key risk factors for CNLBP is believed to be deficiencies in lumbar segmental stability [15, 16]. Limitations in muscle power, stamina, flexibility, and range of motion caused by lumbar instability can lead to reduced active range of motion (AROM) in patients with CNLBP who have had the condition for longer than six months. However, this can weaken the paravertebral and multifidus muscles [17], increasing the risk of lumbar instability and the likelihood of low back pain recurrence. This is true even though restricting mobility may prevent pain in the lumbosacral area or legs. In contrast, core stability exercise (CSE) strengthens deep trunk muscles, enhances muscle motor control, and engages dormant muscle groups, improving lumbar spine stability and preventing low back pain. Abdominal and spinal extensors are necessary to increase lumbar spine stability [13]. Rehabilitative ultrasonography and surface electromyography monitoring have shown that CSE successfully promotes lumbar spine stability by stimulating local stabilising muscles [18]. Similarly, lumbopelvic stability exercise (LSE) is a core training method intended to increase the thickness of the abdominal muscles, enhance spinal stability, and enhance core activation as a mechanism of action. Both exercise regimens improve lumbar spine strength by increasing the cross-sectional area of the multifidus muscle. The study showed[19] that both training protocols improved the structural integrity of the lumbar spine and increased the cross-sectional area of the multifidus muscle in 70 patients with chronic lumbar disc herniation, reducing their Oswestry disability index (ODI) scores [20]. In the LSE group, the improvement in lumbar strength persisted for 12 weeks following the intervention, whereas it only did so for 4 weeks in the lumbar strengthening group, demonstrating that the LSE treatment was more durable. [21] discovered that while both conventional strength training and CSE improved patient pain, there was variability in efficacy, with CSE significantly outperforming conventional strength training in terms of enhancing proprioception, balancing, and increasing the thickness of the rectus abdominis and multifidus muscles, as well as lowering functional impairment and exercise phobia in patients with subacute low back pain. Khodadad et al.[22] discovered that both cognitive function therapy and LSE intervention improved motor control scores and decreased pain in 52 patients.

# Strengthening Spinal Stability Training

Deficits in lumbar spine stability have been identified as a significant contributor to CNLBP [23]. Spinal stabilisation exercise (SSE) is a strengthening exercise that focuses on specific deep trunk muscles that are weak in CNLBP function and improves lumbar spine stability. In the majority of randomised controlled studies, exercises designed to increase spinal stability were performed on the muscles that stabilise the spine. According to Salik et al [24] stabilisation exercises were superior to traditional exercises for minimising pain while exercising, enhancing the endurance and function of the core muscles, and improving spinal stability.

There has been a debate about the effectiveness of spinal stabilisation exercises versus spine manipulative therapy (SMT). Thomas et al[23] found that in various SMT randomised clinical trials, spine manipulation and spinal mobility therapy did not appear to be effective treatments for patients with mild to moderate CNLBP. However, Evans et al [25] found that SMT in addition to exercise was more efficient than exercise alone over a 1-year period in adolescents with CNLBP. Schulz et al [26]found that for older persons with CNLBP, combining SMT or supervised rehabilitation activities with home exercise alone did not seem to enhance pain or disability indices in the short or long term.

Overall, decreases in stabilising muscle strength appear to play a more substantial role in spinal control and the alleviation of low back pain than relaxation of the soft tissues around the spine, which is significantly less effective than spinal stabilising muscle group workouts.

# Strengthening Core Muscle Group Strength Training

There is a high correlation between CNLBP and deficits in the paravertebral muscles that maintain the stability of the lumbar spine, and active strengthening of the lumbar muscles such as the multifidus, transversus abdominis and erector spinae muscles is the main focus of core muscle training for CNLBP, and good results are achieved [27]. Due to the multifidus' increased function as the foundation of the paravertebral muscles, which improves spinal stability and restores the spine's natural physiological curvature, as well as spinal mechanics and intervertebral joint stability, the effect of the core musculature on CNLBP appears to have become undeniable [28]. In a study by Chen et al[29], 30 patients with CNLBP as dragon boat athletes underwent a 12-week randomised controlled intervention of core plyometric training versus traditional plyometric training. The findings revealed that the core group experienced significantly less pain than the traditional group did compared to the control group, and that core plyometric training at 12 weeks significantly increased patients' pain at rest and during sleep. The multifidus muscle's thickness in the systolic state was much increased, and spinal stability was greatly enhanced. These improvements helped to successfully control the spine's natural curvature and allow spine to move over a wider range of motion. To avoid experiencing pain when exercising, the choice of training activities for the core muscles is essential. The use of hip abduction exercises had a significant strengthening effect on the multifidus. According to Aboufazeli et al[30], the strengthening of the multifidus training movements, which are mostly concentrated in the dorsolumbar region and are difficult, is not always better for women with poor strength and athletic ability to perform the target movements. The degree of connectivity between hip motion and body stability is high, and the two factors support each other in terms of movement and postural maintenance. Kim and Yim [31] discovered that the interventions in the hip stretching and hip strength strengthening groups were significantly better than the manipulative therapy groups in terms of pain level, ODI, balance, and quality of life, with the hip stretching and hip strength strengthening groups having the greatest benefits. It is clear that the stability of the human body's core is intimately related to the strength and functionality of the hip. It appears that active interventions in the hip can be carried out first for patients with low back pain who struggle to complete the movements associated with core stability training. This would promote the development of the core stability muscle group or allow patients to more successfully complete core stabilisation training, which would ultimately result in pain relief.

# Breathing Training

The benefits of respiratory exercise have been widely recognised in contemporary rehabilitation medicine. Stronger respiratory muscles not only improve thoracic activity to promote cardiorespiratory function but also facilitate trunk stability. Ahmadnezhad et al [32] investigated the effects of respiratory training on core muscle activity in patients with CNLBP using spinal electromyography, multifidus, transversus abdominis, and lung function parameters. They found that breathing training enhanced respiratory function and increased core muscle activity, which reduced pain intensity in athletes with CNLBP. Finta1 et al [33] discovered that diaphragmatic training also had an impact on the thickness of muscle groups that stabilise the lumbar spine in studies examining the relationship between respiratory training and lumbar stability (transversus abdominis, multifidus). Oh et al [34] demonstrated that therapies focusing on respiratory strength training for lumbar stabilisation and respiratory strength training alone both improved CNLBP discomfort and functional impairment and enhanced respiratory support muscles' muscular thickness and contraction rate. Therefore, it is evident that breathing-focused training seems to engage deep stabilising muscles, strengthening not only the delayed activation muscle groups but also increasing respiratory strength, expanding thoracic volume, and raising intra-abdominal pressure, which in turn contributes to greater stability in the lumbar region. It is crucial to promote respiratory training therapy as a viable option for treating CNLBP because it is non-invasive, painless, simple to use, and inexpensive.

# Motion Control Training

The human body engages in proprioceptive afferent input during various movements, where central system information is integrated and then expressed through motor feedback. The interaction between nerves and muscles is a subconscious act, which may produce flawed movement patterns and increase the risk of motor injury and pain, particularly when the body has neuromuscular control impairments. Impaired motor function is considered a key contributor to the emergence of CNLBP [35]. The primary goal of motor control exercise (MCE )primary is to provide patients with the opportunity to practice specific motions to achieve optimal control over their spine movements. This exercise is often performed under close supervision, and ultrasound imaging is used to track muscle activation recruitment and offer instructive feedback during muscle contraction [36]. The transversus abdominis, multifidus, diaphragm, and pelvic floor muscle groups are the primary muscle groups engaged in improving the function of specific trunk muscles that are thought to govern movement across spinal segments, as demonstrated through several randomised controlled trials [37]. According to Gutknecht et al [38], MCE was associated with CNLBP patients in a controlled experiment comparing MCE to normal exercise. However, Halliday et al [39] found that changes in muscle thickness may be less significant for clinical results in CNLBP, as demonstrated in a controlled experiment comparing MCE with McKenzie therapy. Patients in both groups saw improved ODI. A randomised experiment of motor control therapy and general exercise (GE) was conducted by Van et al [40], which demonstrated that GE in combination with motor control therapy improved clinical results in CNLBP. Not only did CNLBP strengthen muscles more effectively than other treatments, but it also greatly improved postural movement control. Additionally, Teychenne et al [41] found in a controlled trial comparing MCE with manual therapy to conventional strength training that lower intensity MCE and manual therapy were clinically effective in modulating depressive states in adults with CNLBP, leading to a shift in perspective, improved body control, and a decrease in pain. In conclusion, MCE is a safer and more generalisable supplement to other treatments that may result in better clinical outcomes, even though it has little impact on stabilising muscle thickness. MCE plays a role in muscle activation recruitment, improving neuromuscular coordination and control, and correcting improper movements. It is more widely applicable, safer, and can be used in conjunction with other therapies as an adjuvant therapy.

# Sling Exercise Therapy

Sling exercise therapy (SET) is a systematic approach to treating CNLBP that aims to improve coordinated neuromuscular control and the stability of the core muscles in the lumbar region. The main objective of SET is to correct the improper movement patterns caused by atypical neuromuscular control. The closed-chain action with an open-chain motor effect is designed to engage the inferior muscle groups that have been inactive in order to participate in movement and improve proprioception, which has the effect of locally stabilising the structure. Li et al [43] discovered that SET improved the neural regulation of movement and reversed the adaptive changes in the motor cortex neural network in CNLBP patients, supporting the efficacy of the treatment. Similarly, Sun et al [42]validated this finding by demonstrating that surface electromyography showed that static postural maintenance training was superior to dynamic supination training in CNLBP and that multi-point multi-axis SET had enhanced activation of the core lumbar muscles.

Most recent SET studies tend to prefer combining SET with other physiotherapy techniques to improve CNLBP, possibly to make it more accessible to patients. In studies of combined physical manipulation co-treatment, Niu et al [44]found that a combination of tui na manipulation plus external rubbing with vine moxibustion liquid combined with SET therapy was effective and long-lasting for CNLBP, significantly reducing neuromuscular control imbalances and successfully preventing the onset of low back pain. A lumbar ramp adjustment along with SET therapy intervention was effective, according to Wang et al[45], for patients with CNLBP. Xie [46]demonstrated that SET was superior to jogging exercise for clinical CNLBP patients. Wang et al [47] also demonstrated that the efficacy of SET in conjunction with acupuncture was prolonged and superior to acupuncture alone in the treatment of CNLBP. Jiang [48] conducted a controlled experiment comparing SET to standard care and found that while both intervention groups saw symptom reduction, SET was much more effective than electrotherapy and had a greater safety profile.

In conclusion, although SET has no effect on muscle thickness, it is significantly more effective in reversing patients' flawed neurological control patterns, significantly enhancing the maintenance of proper posture through training, and its restoration of neuromuscular control enhances patients' motor function. Acupuncture, massage, and electrotherapy are just a few of the physiotherapy procedures that SET outperforms.

## Aerobic Training

Aerobic exercise (AE) has been found to effectively reduce pain and increase exercise capacity, while also improving abs, low back, core stabilisation, coordination, and traditional muscle strength [49]. In addition to the VAS, ODI, spinal mobility, and psychological health, cardiopulmonary function and fitness are crucial indicators of the effectiveness of CNLBP treatment [50]. Regular aerobic exercise has various benefits for enhancing functional status, including reducing recurrent pain and negative mental states [51]. Later study by Maselli et al[52] demonstrated that AE had a beneficial impact on preventing low back pain, and that long-term runners had a lower prevalence and incidence of low back pain compared to the general or specific athlete population. For patients with CNLBP, Nduwimana et al [53] conducted a systematic assessment of the therapeutic effectiveness of walking exercise and mind-body treatments (MBTs). The article covered 31 randomised controlled trials (RCTs), and while the therapies' durations varied widely, 77.4% of the studies with interventions lasting 6–12 weeks were also included. The findings suggest that MBTs, particularly yoga activities among them, would be more efficient in the short run. In contrast, walking activities were more successful during the middle of the course of treatment, particularly in terms of pain reduction. Can AE be used instead of opioid medications to reduce pain in CNLBP patients? Studies have shown that AE [54], a non-pharmacological exercise therapy, has the same pain-relieving effects as moderate doses of opioid painkillers for patients with CNLBP, and that it can provide pain relief almost as similar to that of 7 mg morphine-based painkillers. This suggests that people with low back pain can use AE or a similar exercise therapy to reduce pain, contributing to reduced reliance on pain medications and avoiding adverse effects. As a result of the decreased feeling of pain, patients can more easily engage in physical activity, progressively overcoming their fear of exercise. In fact, the clinical effectiveness of AE in the treatment of chronic pain appears to reduce patients' fear of exercise, and because it only requires one type of exercise, it is the most straightforward exercise therapy to put into practice, increasing its accessibility. After conducting a systematic study, Santos et al[37]demonstrated the value of aerobic exercise for treating CNLBP patients' pain and ODI indicators, while also demonstrating the exercise's low cost and universal applicability. In a controlled trial of progressive resistance training (PRT) and progressive aerobic training (PAT), Wewege et al[55] demonstrated that, although neither intervention was clinically successful, both decreased pain levels in patients with CNLBP. A summary of a randomised controlled trial of different forms and intensities of walking exercise by Vanti et al [56] revealed that it not only reduced pain and improved function, but also dramatically increased patients' quality of life and reduced their fear of exercise. Despite the fact that adding walking to other exercise therapies did not lead to more improvement, its use in the clinical treatment of CNLBP should be encouraged due to its low exercise cost, high level of safety characteristics, and simplicity of usage.

## Exercise Therapy for Different Programs

## McKenzie Therapy

The McKenzie therapy (MDT) protocol emphasises a comprehensive assessment and examination of function, specifically focusing on pain and symptoms induced by repetitive motion of the spine or lumbar segment. Postural correction and training to restore normal spinal curvature are integral components of the MDT protocol, which also tends to enhance the mobility of the lumbar spine [57]. Alhakami et al [58]evaluated the efficacy of MDT and stability training in the treatment of pain and ODI in patients with CNLBP. According to their review, both exercise therapies proved to be efficient and clinically superior to conventional exercise training, with patients demonstrating significantly improved neural control of the lumbar segmental musculature following MDT. However, Lam et al [59]assessed the effectiveness of MDT in reducing pain and ODI in acute and chronic CNLBP, supported by high and moderate-quality trials. Their findings indicated that MDT was not more successful than other rehabilitation methods in treating acute low back pain, although it might be for treating persistent pain. In conclusion, MDT primarily involves the activation of additional muscles for movement, with minimal impact on the thickness of the deep stabilising muscles of the trunk. As a result of engaging the patient's deeper muscles, they can perform more dynamic exercises and promote the development of other muscle groups or general stabilising muscles, thus enhancing overall trunk stability. Consequently, MDT is employed as an auxiliary exercise in the treatment of CNLBP and may yield better outcomes when combined with other exercise therapies.

## Pilates

Pilates exercise, predominantly focusing on enhancing lumbar spine and pelvic stability, is a common component of physical education (PE) for improving posture. These exercises can be categorised into two main groups: core exercises and breathing exercises. During the exercise process, the involved muscles work synergistically to stabilise the lumbosacral pelvic region, necessitating greater muscle strength for movements with varying degrees of difficulty [60]. As there is minimal external load, these exercises are safe for individuals with CNLBP. Practicing stabilising postures and breathing exercises may not only ameliorate the patient's condition but also yield similar beneficial clinical effects on interventions for psychiatric disorders [61]. Moreover, the efficacy of PE appears to be somewhat superior to other treatments. Valenza et al[62]demonstrated significant clinical effectiveness of an eight-week PE intervention for individuals with CNLBP, resulting in improvements in pain, dysfunction, flexibility, and balance. Batbay et al [63]found that physical therapy (PT) and home exercise interventions for CNLBP patients had comparable effects on symptoms; however, PE interventions did not significantly contribute to muscle thickness. Nevertheless, PE interventions improved balance and postural stability without significantly impacting muscle growth. Castro et al [64] reported that PE intervention with elastic resistance was associated with a higher IGF-1/IGFBP-3 ratio, as both groups exhibited improved lumbar strength and control, reduced pain, and decreased ODI scores. Yalfani et al [65] compared the effectiveness of aquatic versus mat-based PT and found that both forms of PE interventions were equally efficacious. Yang et al [66]noted significant improvements in patients' health and quality of life following exercise therapies using core training movements in PE. Cruz-Díaz et al.[67]found that a 12-week PE programme effectively modulated psychological barriers to exercise, alleviated exercise anxiety, and enhanced postural control. Lastly, Domingues et al[81]conducted a review of 27 publications and confirmed the positive clinical effects of PT in strengthening muscle neural control, reducing pain associated with CNLBP, and overcoming motor phobia when compared to other low-intensity exercise interventions and no exercise. These studies collectively demonstrate that there is a comprehensive training system for PT interventions, resulting in a more integrated effect, safe, and controlled training model. Consequently, PT therapy has emerged as a viable option for the individuals with various forms of low back pain to improve their pain, depression, quality of life, and overall health.

## Yoga

Patients with CNLBP often experience depression and fear of exercise due to their pain, which can exacerbate their condition and hinder symptom improvement, significantly impacting their quality of life [72]. Therefore, it is essential to select appropriate activities that minimise pain during exercise and promote post-exercise well-being. Yoga interventions, which incorporate body posture alignment, breathing techniques, and meditation exercises, have been found to effectively manage both psychological and physiological aspects of individuals [68]. Moreover, yoga has demonstrated positive effects on cardiovascular health, osteo-articular therapy, exercise capacity, and muscle fibber discomfort [69]. Frequently employed as a complementary medical approach, yoga addresses emotional, stress, and sleep factors to enhance physical and psychological health and alleviate patients' symptoms, highlighting its therapeutic value. Clinical evidence supports the effectiveness of yoga in reducing pain and decreasing the reliance on psychosocial treatments for CNLBP patients. A study by Kuvai et al [70] revealed that combining yoga with education led to reduced depression, anxiety, and perceived pain in CNLBP patients. Although meditation training, a component of yoga, does not directly influence pain function and reduction, it significantly affects the psychological state of patients with chronic pain, indirectly reducing pain levels [71]. In a randomised controlled trial, Cui et al.[73] compared yoga exercise to plyometric training in patients with CNLBP, observing significant pain reduction and functional improvement within the first four weeks of intervention, but no notable effect thereafter. Another randomised controlled trial [74] comparing yoga to conventional exercise therapy found comparable clinical efficacy for CNLBP between the two modalities. In conclusion, yoga practice is a viable option for individuals with CNLBP, offering substantial benefits in pain relief and psychological adjustment. These advantages are attributed to the diverse exercise patterns of yoga, which encompass the unique integration of mind and body, motion and stillness, and the release of physical and psychological stress.

## Conclusion

CNLBP is a highly prevalent global public health issue (Van et al., 2006), causing not only physical and psychological harm to patients but also incurring significant financial costs that must be addressed [75]. Exercise treatment has been demonstrated to alleviate symptoms in individuals with CNLBP, according to several studies [76, 77, 78]. The pathophysiology of CNLBP is multifaceted, with non-specific origins and no single site of low back pain. Pain may manifest on one side of the back, in the upper vertical crest muscle region, or in the lower lumbosacral area. The patient's age and occupation are associated with the nature of the pain [79]. Although lumbar stabilisation exercises (LSE), segmental stabilisation exercises (SSE), and core strength training effectively strengthen muscles, increase the thickness of core stabilising muscles, and enhance spinal or lumbar stability, these training movements can be challenging and require a certain level of physical fitness. The clinical effects of the exercise therapies examined in this paper differ in focus and may be more suitable for older or younger individuals. In contrast, McKenzie therapy (MDT), motor control exercises (MCE), specific exercise therapy (SET), and postural education (PE) may not significantly increase muscle thickness but are more effective in restoring postural and functional function, developing robust neuromuscular control, and reversing abnormally delayed muscle activation. Consequently, these therapies are more accessible to most patients and pose fewer risks for older individuals. Furthermore, practicing yoga can assist patients in managing pain, regulating emotions, maintaining psychological control, and improving sleep quality. Promoting these exercises is highly beneficial, as they are not limited by facility equipment and are cost-effective. However, when the cause of low back pain cannot be accurately identified, it is challenging to select a targeted treatment. CNLBP symptoms vary significantly among patients, and each individual exhibits unique key manifestations of the condition. Therefore, it is crucial to adopt a personalised treatment plan tailored to each patient's specific needs, as implementing appropriate exercise regimens and enhancing patient compliance will undoubtedly amplify the therapeutic effects. In conclusion, independent exercise not only aids in the management of chronic pain but also helps prevent sports injuries, strengthens motor skills, elevates mood and mental well-being, and enhances the overall quality of life.

## Abbreviations

CNLBP
Chronic non-specific low back pain
CSE
Core stability exercise
AROM
Range of motion
LSE
Lumbopelvic Stability Exercise
ODI
Oswestry disability index
SSE
spinal Stabilisation Exercise
MCE
Motor Control Exercise
GE

General Exercise
SET
Sling Exercise Therapy
AE
Aerobic exercise
VAS
Visual Analogue Scale
MBTs
Mind-Body Therapies
PAT
Progressive Aerobic Training
PRT
Progressive Resistance Training
PE
Pilates exercise
CPE
Conventional Physiotherapy Exercises.

## Declarations


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### Author Contributions

Yang Liu came up with the initial thesis idea and topic selection, and completed the literature search, data collection and analysis, manuscript writing and revision,and was a major contributor in writing the manuscript.

Yidan Wang writing part of the manuscript content and providing critical revision of the manuscript for intellectual content and proofreading manuscript.

Kunwei Dong is responsible for the final review and revision of the paper.

Garry Kuan oversight and leadership responsibility for the research activity planning and execution.


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### Conflict Of Interest

The authors declares no conflict of interest

### Availability of data and materials

The dataset used and/or analyzed during the current research period can be obtained from the first author upon reasonable request: 784389072@qq.com

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## Figures

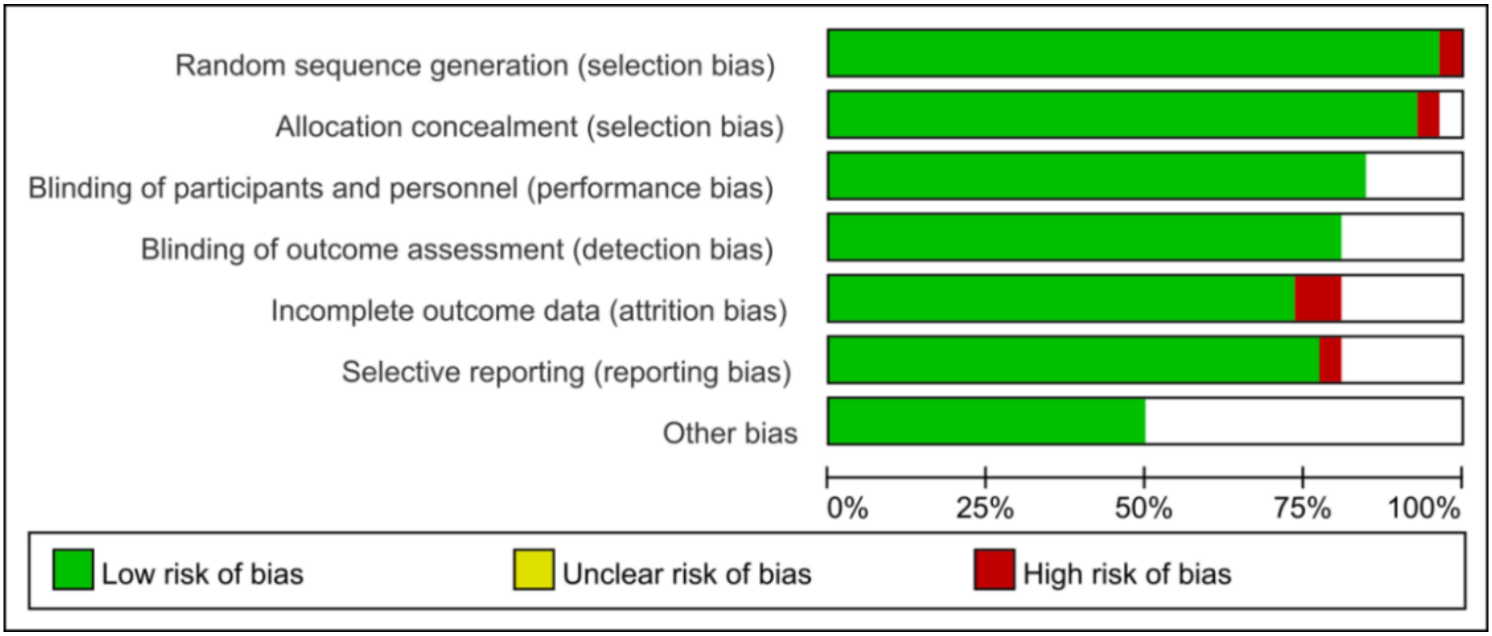



**Figure 1**

Risk of bias graph

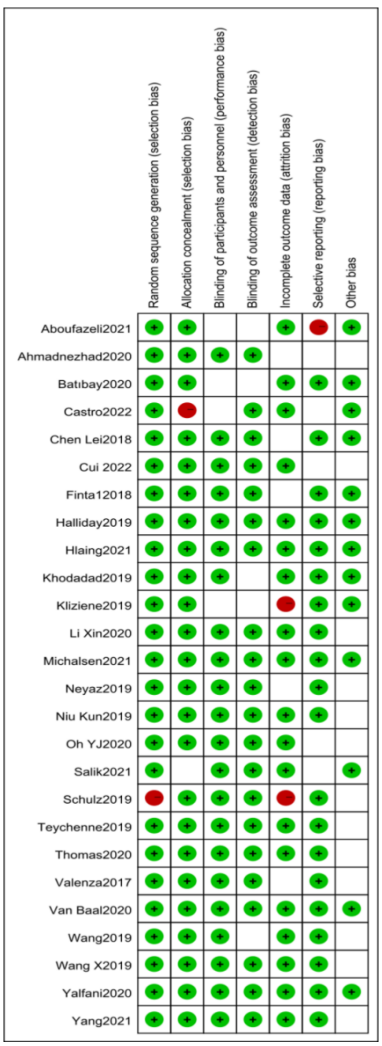



**Figure 2**

Risk of bias summary

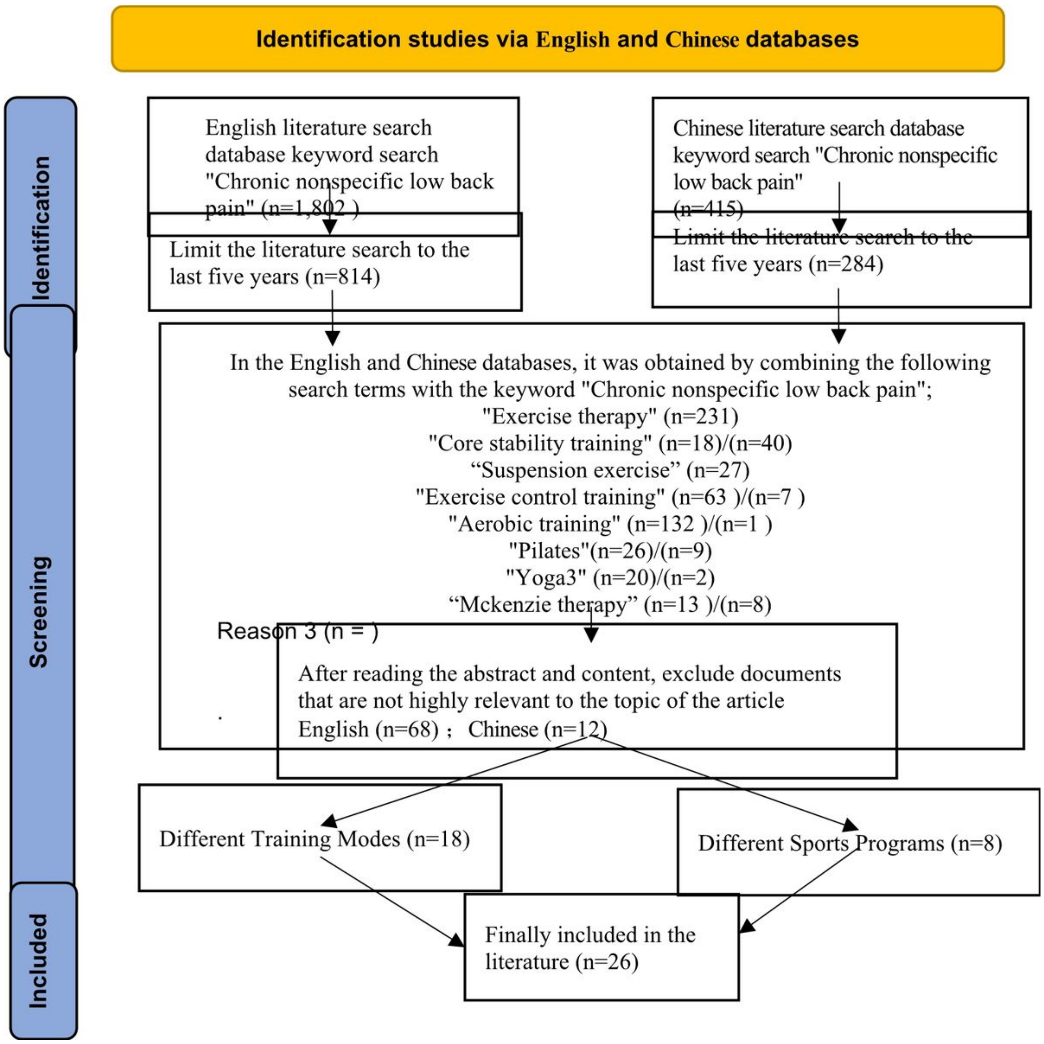



**Figure 3**

Flow chart of literature screening

| Study or Subgroup | Experimental Mean | Experimental SD | Experimental Total | Control Mean | Control SD | Control Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Aboufazeli2021 | 4.76 | 1.06 | 12 | 6.76 | 2.01 | 12 | 4.1% | -2.00 [-3.29, -0.71] |
| Ahmadnezhad2020 | 6.12 | 1.02 | 22 | 5.85 | 1.16 | 20 | 5.2% | 0.27 [-0.39, 0.93] |
| Batıbay2020 | 3 | 1.5 | 28 | 4.6 | 1.8 | 25 | 4.8% | -1.60 [-2.50, -0.70] |
| Castro2022 | 3.35 | 1.64 | 8 | 3.87 | 1.32 | 11 | 3.9% | -0.52 [-1.90, 0.86] |
| Chen Lei2018 | 2.38 | 1.09 | 15 | 4.23 | 1.33 | 15 | 4.8% | -1.85 [-2.72, -0.98] |
| Cui 2022 | 1.89 | 1.24 | 14 | 3.43 | 2.88 | 14 | 3.5% | -1.54 [-3.18, 0.10] |
| Finta12018 | 2.4 | 2.4 | 21 | 2.1 | 2.4 | 26 | 3.9% | 0.30 [-1.08, 1.68] |
| Halliday2019 | 0 | 0 | 35 | 0 | 0 | 35 | | Not estimable |
| Hlaing2021 | 4.28 | 1.13 | 18 | 4.61 | 1.2 | 18 | 5.0% | -0.33 [-1.09, 0.43] |
| Khodadad2019 | 5.8 | 1.87 | 18 | 3.3 | 1.26 | 17 | 4.5% | 2.50 [1.45, 3.55] |
| Kliziene2019 | 4.2 | 0.1 | 35 | 5.3 | 0.7 | 35 | 5.7% | -1.10 [-1.33, -0.87] |
| Li Xin2020 | 4.7 | 1.3 | 20 | 1.65 | 0.88 | 10 | 5.0% | 3.05 [2.26, 3.84] |
| Michalsen2021 | 50.6 | 12 | 100 | 48.2 | 12.5 | 82 | 1.4% | 2.40 [-1.18, 5.98] |
| Neyaz2019 | 4 | 2.2 | 35 | 4 | 2 | 35 | 4.6% | 0.00 [-0.99, 0.99] |
| Niu Kun2019 | 2.71 | 0.92 | 21 | 1.83 | 0.97 | 21 | 5.3% | 0.88 [0.31, 1.45] |
| Oh YJ2020 | 4.58 | 0.46 | 22 | 4.45 | 0.42 | 22 | 5.6% | 0.13 [-0.13, 0.39] |
| Salik2021 | 3.87 | 1.23 | 19 | 4.32 | 1.2 | 18 | 5.0% | -0.45 [-1.23, 0.33] |
| Schulz2019 | 3.8 | 0 | 81 | 2.6 | 0 | 80 | | Not estimable |
| Teychenne2019 | 3.69 | 1.47 | 20 | 4.76 | 0.54 | 20 | 5.1% | -1.07 [-1.76, -0.38] |
| Thomas2020 | 4.2 | 2.4 | 52 | 4.1 | 2.4 | 52 | 4.8% | 0.10 [-0.82, 1.02] |
| Valenza2017 | 1 | 2.1 | 27 | 0.2 | 2.1 | 27 | 4.4% | 0.80 [-0.32, 1.92] |
| Van Baal2020 | 1.13 | 3.44 | 18 | 2 | 3 | 16 | 2.7% | -0.87 [-3.03, 1.29] |
| Wang2019 | 1.02 | 0.75 | 42 | 2.33 | 0.93 | 42 | 5.6% | -1.31 [-1.67, -0.95] |
| Wang X2019 | 5.07 | 1.75 | 30 | 4.93 | 1.62 | 30 | 4.9% | 0.14 [-0.71, 0.99] |
| Yalfani2020 | 29 | 12.18 | 12 | 34.42 | 14.31 | 12 | 0.2% | -5.42 [-16.05, 5.21] |
| Yang2021 | 50.7 | 0 | 20 | 44.2 | 26.5 | 19 | | Not estimable |
| **Total (95% CI)** | | | **745** | | | **714** | **100.0%** | **-0.16 [-0.65, 0.33]** |

Heterogeneity: Tau² = 1.08; Chi² = 241.52, df = 22 (P < 0.00001); I² = 91%
Test for overall effect: Z = 0.65 (P = 0.52)

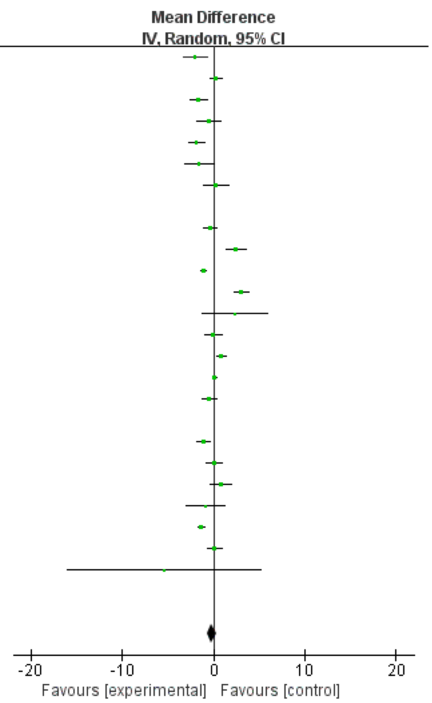
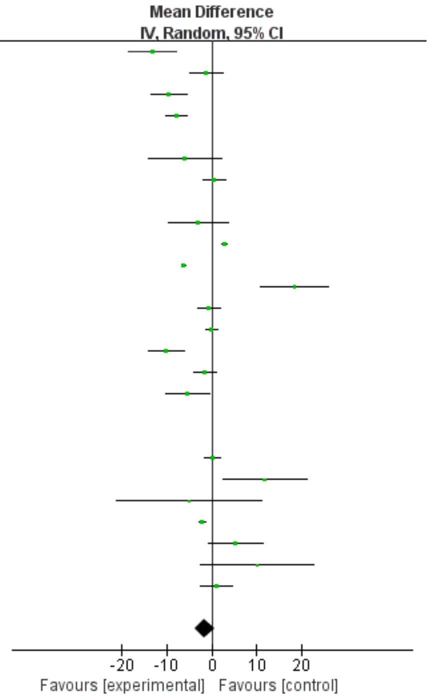



**Figure 4**

*Forest plots showing standardised mean differences in changes in pain scores (VAS, QVAS, NPRS, DVPRS, NRS) between the main TCE group and the control group. CI: Confidence interval; VAS, Visual analog scale; NRS, numerical rating scale; DVPRS, Defense and Veterans Pain Rating Scale; QVAS, Quadruple visual analogue scale; NPRS, Numerical Pain Rating Scale.*

| | Experimental | | | Control | | | | Mean Difference |
|---|---|---|---|---|---|---|---|---|
| **Study or Subgroup** | **Mean** | **SD** | **Total** | **Mean** | **SD** | **Total** | **Weight** | **IV, Random, 95% CI** |
| Aboufazeli2021 | 53.23 | 7.1 | 12 | 66.37 | 6.35 | 12 | 4.4% | -13.14 [-18.53, -7.75] |
| Ahmadnezhad2020 | 56.91 | 6.92 | 22 | 58.2 | 5.27 | 20 | 5.0% | -1.29 [-4.99, 2.41] |
| Batıbay2020 | 21.4 | 5.9 | 28 | 30.9 | 8.8 | 25 | 4.9% | -9.50 [-13.58, -5.42] |
| Castro2022 | 46.5 | 3.2 | 8 | 54.3 | 1.2 | 11 | 5.4% | -7.80 [-10.13, -5.47] |
| Chen Lei2018 | 0 | 0 | 15 | 0 | 0 | 15 | | Not estimable |
| Cui 2022 | 39.04 | 9.21 | 14 | 45.01 | 12.35 | 14 | 3.3% | -5.97 [-14.04, 2.10] |
| Finta12018 | 23 | 5.3 | 31 | 22.4 | 4.6 | 36 | 5.4% | 0.60 [-1.80, 3.00] |
| Halliday2019 | 0 | 0 | 35 | 0 | 0 | 35 | | Not estimable |
| Hlaing2021 | 39.89 | 10.48 | 18 | 42.89 | 10.25 | 18 | 3.8% | -3.00 [-9.77, 3.77] |
| Khodadad2019 | 4.3 | 1.07 | 18 | 1.5 | 0.74 | 17 | 5.7% | 2.80 [2.19, 3.41] |
| Kliziene2019 | 11.4 | 0.5 | 35 | 17.6 | 0.9 | 35 | 5.8% | -6.20 [-6.54, -5.86] |
| Li Xin2020 | 24.3 | 17.18 | 20 | 5.75 | 1.29 | 10 | 3.5% | 18.55 [10.98, 26.12] |
| Michalsen2021 | 38.4 | 8.6 | 100 | 39 | 8.1 | 82 | 5.4% | -0.60 [-3.03, 1.83] |
| Neyaz2019 | 6 | 3.5 | 35 | 6 | 1 | 35 | 5.7% | 0.00 [-1.21, 1.21] |
| Niu Kun2019 | 43.22 | 7.1 | 21 | 53.34 | 6.23 | 21 | 4.9% | -10.12 [-14.16, -6.08] |
| Oh YJ2020 | 9.45 | 3.92 | 22 | 10.95 | 4.36 | 22 | 5.4% | -1.50 [-3.95, 0.95] |
| Salik2021 | 40.3 | 5.3 | 19 | 45.7 | 9.2 | 18 | 4.6% | -5.40 [-10.27, -0.53] |
| Schulz2019 | 1.9 | 0 | 81 | 0.04 | 0 | 80 | | Not estimable |
| Teychenne2019 | 0 | 0 | 20 | 0 | 0 | 20 | | Not estimable |
| Thomas2020 | 10.1 | 4.5 | 52 | 10 | 4.5 | 52 | 5.6% | 0.10 [-1.63, 1.83] |
| Valenza2017 | 16.35 | 14.07 | 27 | 4.5 | 20.52 | 27 | 2.9% | 11.85 [2.47, 21.23] |
| Van Baal2020 | 11 | 26.5 | 18 | 16 | 21.67 | 16 | 1.5% | -5.00 [-21.21, 11.21] |
| Wang2019 | 8.95 | 1.7 | 42 | 11.05 | 2.3 | 42 | 5.7% | -2.10 [-2.96, -1.24] |
| Wang X2019 | 19.26 | 16 | 30 | 13.9 | 5.25 | 30 | 4.1% | 5.36 [-0.67, 11.39] |
| Yalfani2020 | 29.67 | 18.46 | 12 | 19.5 | 12.68 | 12 | 2.1% | 10.17 [-2.50, 22.84] |
| Yang2021 | 6.5 | 5.7 | 20 | 5.4 | 5.7 | 19 | 5.0% | 1.10 [-2.48, 4.68] |
| **Total (95% CI)** | | | **755** | | | **724** | **100.0%** | **-1.56 [-3.83, 0.71]** |

Heterogeneity: $Tau^2 = 23.31$; $Chi^2 = 841.59$, df = 21 ($P < 0.00001$); $I^2 = 98\%$
Test for overall effect: Z = 1.34 (P = 0.18)




## Figure 5

*Forest plot showing standardised mean differences in changes in physical functioning scores (MODQ, ODI, Roland-Morris, RMDQ) between the TCE and control/control groups. CI: confidence interval; Oswestry disability index; MODQ, Modified Oswestry disability questionnaire Oswestry; R-M, Roland-Morris; RMDQ, Roland-Morris Disability Index.*