

The Effectiveness of Manual Therapy on Musculoskeletal and Respiratory Parameters in Patients with Chronic Low Back Pain: A Systematic Review

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ABSTRACT: Patients with chronic low back pain (CLBP) exhibit respiratory dysfunction. Dysfunction in motor control of trunk muscles (diaphragm included) negatively affects the mechanics and biochemistry of breathing. The aim of this systematic review was to analyze evidence from randomized controlled trials (RCTs) investigating the effect of manual therapy on musculoskeletal and respiratory parameters in patients with CLBP. Systematic search and selection of RCTs was performed using specific keywords in three scientific databases (Medline, Scopus, and the Physiotherapy Evidence Database, or PEDro) from inception to March 2021. Relevant studies published in English were extracted, evaluated, and independently rated for methodological quality by two assessors using the PEDro scale. Data extraction and methodological ratings were inspected by a third assessor. Out of 943 initially collected studies, 922 were excluded (did not meet inclusion criteria or were duplicates). Twenty-one clinical trials were finally included, though they were characterized by moderate methodological quality (PEDro scale). Meta-analysis was not performed due to differences in techniques utilized (targeting spinal joints or trunk or respiratory muscles) and the outcomes were assessed across studies. Overall, there was evidence, of moderate methodological quality, that manual therapy on the low back joints or trunk stabilization exercises, diaphragmatic release techniques, and respiratory exercises significantly improve musculoskeletal as well as respiratory parameters in patients with CLBP. More and higher-quality RCTs are required, especially those that will utilize respiratory reeducation and exercise of the respiratory muscles as therapeutic interventions contributing to the holistic management of patients with CLBP.

KEY WORDS: chronic low back pain, manual therapy, breathing exercises, respiratory dysfunction, breathing education, randomized controlled trials

I. INTRODUCTION

Low back pain (LBP) is a highly prevalent health condition worldwide, resulting in disability that affects function, occupational performance and well-being. Socioeconomic

impacts are considerable in terms of work loss. In industrialized countries, the lifetime prevalence of non-specific low back pain is estimated at 60–70%.¹

LBP is defined as pain and discomfort localized below the costal margin and above the inferior gluteal folds, with or without referred leg pain. The pain in most cases cannot be attributed to any specific or serious pathology.^{1,2} The pain may begin suddenly or gradually. Chronic low back pain (CLBP) is defined as low back pain persisting for longer than 7–12 weeks or after the period of healing, or recurring back pain that intermittently affects an individual over a long period of time.¹ The main source of the pain could be the intervertebral disc, the facet joints, or the soft tissues of the area. The main symptoms are pain and decreased function.³

Although CLBP has conventionally been treated by traditional physiotherapy or manual therapy, the majority of patients do not completely recover from their symptoms. A dual-morbidity perspective of troublesome CLBP has been highlighted in relation to spondylarthritis and respiratory disorders. The core muscles and the diaphragm contribute to respiratory function and spinal stability. Respiratory disorders affect diaphragmatic function, subsequently compromising the role of the diaphragm in spinal stability. Interestingly, the management of CLBP usually takes into consideration only the neuromusculoskeletal system, although there are many indications of decreased respiratory function.⁴

Respiratory function disorder signs and symptoms commonly present in patients with CLBP. Asthma and/or chronic obstructive pulmonary disease increases the risk of developing serious CLBP.⁴ This line of research also highlights the importance of considering the overall health of people at risk of CLBP and approaching CLBP from a multimorbidity perspective. Beeckmans et al.⁵ provided an overview of literature on the relationship between CLBP and respiratory disorders, concluding that the link between the two pathologies might be explained by immunological, biomechanical, psychosocial, and socioeconomic factors.⁵ Under a biomechanical premise, Janssens et al.⁶ determined postural stability and proprioceptive postural control strategies of healthy subjects and subjects with recurrent low back pain during acute fatigue of the inspiratory muscles. They reported that after inspiratory muscle fatigue (IMF) provocation, their control subjects, like their subjects with LBP, used a rigid proprioceptive postural control strategy rather than normal “multisegmental” control. This resulted in decreased postural stability and suggests that IMF might be a factor in the high rate of LBP recurrence.⁶ Similarly, Ostwal and Wani⁷ observed the breathing pattern in individuals with LBP both at rest and during motor control tasks; they reported around 71% patients having abnormal breathing patterns during motor control tests.⁷

Dysfunctional breathing has been defined as inappropriate, unhelpful, or inefficient in relation to the requirements of the individual at that time.⁸ Expiration is disturbed when it prematurely stops, when typical changes in respiratory pattern reflect increased breathing effort (upper chest breathing in combination with decreased lateral expansion of the lower chest wall), and a tendency for asynchronous and paradoxical breath is present. There is a developing interest in the impact of dysfunctional breathing in common musculoskeletal pathologies.⁸

The diaphragm is the primary muscle of respiration and of key importance to the function of the other respiratory muscles.^{8,9} Tonic and phasic contraction of abdominal muscles during inhalation aids diaphragmatic downward excursion and flattening in parallel lifting and widening of the lower six ribs, while during exhalation the diaphragmatic dome returns to its starting position, increasing its length and curvature for a more efficient contraction during the upcoming inhalation.⁸ If the diaphragm is dysfunctional, the other respiratory muscles will alter their function, often becoming overloaded. Typically in the case of a dysfunctional diaphragm the abdominal muscles will alter their pattern of respiratory activity (usually paradoxical or asynchronous motion of the abdomen, where the dimensions of the abdominal muscles decrease during inspiration). Conversely, weakness of the abdominal muscles exacerbates diaphragmatic dysfunction.^{8,9}

Until recently, rehabilitation specialists had not considered the impact of respiratory function on the neuromusculoskeletal system. CLBP management must focus on rehabilitation of dysfunctional postural as well as motor control patterns,¹⁰ including dysfunctional respiratory patterns.⁹ It was for this reason that this systematic review, aimed to clarify in particular the following questions:

- Are there any evidence-based studies regarding the effectiveness of manual therapy in the form of mobilization, manipulation, or core stability exercises, including respiratory exercises, on musculoskeletal and respiratory parameters in patients with CLBP?
- Are there any evidence-based studies regarding the inclusion of the diaphragm and the other respiratory muscles in rehabilitation exercise programs for patients with CLBP?
- Which form of manual therapy, according to the definition of the International Federation of Orthopaedic Manipulative Physical Therapists (IFOMPT),¹¹ can serve as a more appropriate intervention for musculoskeletal and respiratory parameter improvement in patients with CLBP?

II. METHODS

This systematic review was conducted according to revised Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines¹² and the methodological quality assessment of clinical trials according to the PEDro scale.^{13,14} It has been registered in the PROSPERO database (Registration No.: CRD42021234032).

A. Inclusion and Exclusion Criteria

The present systematic review included randomized controlled trials (RCTs), published in English, that (1) were relevant to intervention with manual therapy, consisting of mobilization or manipulation techniques and/or exercises, in combination with or without other interventions in musculoskeletal and/or respiratory parameters applied in patients with CLBP, and (2) included individuals aged 18–65 years.

Excluded were nonrandomized controlled clinical trials, studies without control or other interventional groups, trials that were relevant to the effectiveness of manual therapy only in musculoskeletal parameters and without respiratory exercises. Also, studies were excluded if they included individuals with any of the following conditions: low back pain of less than six weeks duration, vertebral column operations, fibromyalgia, systemic diseases, neurological disorders, tumors, cancer, COPD, dyspnea, and spinal cord injuries.

B. Search Strategy

An electronic database search of Medline (via PubMed), PEDro (Physiotherapy Evidence Database), and Scopus was undertaken from inception to March 2021. Supplementary searches were carried out by hand-searching the references of included studies. Key words were used in the Scopus and PEDro databases (advanced search) in different combinations and according to the PICO Model for Clinical Questions (Table 1). The algorithm used in the PubMed database (Advanced Search) is shown in the Appendix.

A total of 321 clinical trials were collected from PubMed, 232 from Scopus, and 386 from PEDro. Four clinical trials were selected from the references of the included studies.

Two of the authors (PIT and GK) independently screened all titles and/or abstracts and reviewed the studies identified for inclusion. Disagreements were resolved by consensus between the two screeners or by a third author (PK) when required.

C. Assessment of Methodological Quality

Two authors (PIT and GK) assessed methodological quality using the PEDro scale.¹³ A third author (PK) reassessed the results and disagreements. The PEDro scale is a reliable and useful tool for assessing the quality of physical therapy and rehabilitation trials.^{13–15} Eight items on the PEDro scale are related to internal validity and two items are

TABLE 1: PICO model applied to the systematic review

Patient/client group	“low back pain” OR “chronic low back pain” OR “lumbar pain” OR “nonspecific low back pain” AND
Intervention	“manual therapy” OR “respiratory exercises” OR “breathing retraining” OR “mobilization” OR “manipulation” OR “respiratory muscle endurance” OR “diaphragm exercises” AND
Comparison	“control group” OR “traditional physical therapy” OR “exercise” AND
Outcomes	“pain” OR “function” OR “respiratory parameters” OR “respiratory dysfunction” OR “breathing evaluation” AND
Study	“randomized clinical trial” OR “systematic review”

related to the adequacy of statistical requirements. Each item satisfied contributes one point to the total PEDro score (0–10 points). However, for items that were unclear no points were awarded. Overall¹³ as well as individual^{14,15} scores on the PEDro scale were presented for all studies alongside the effectiveness of studies individually addressing each question of this review.

D. Data Extraction and Data Synthesis

One author (PIT) assessed titles and abstracts of the extracted studies. In the case of insufficient data in the abstract, the whole article was studied. Two authors (PIT and GK), extracted data that related to year of publication, inclusion-exclusion criteria of individuals, demographic characteristics of participants (sample size, study population, sex, age), type and duration of each intervention, outcomes measures of pain, function, psychology, proprioception, outcomes of respiratory parameters, follow-up, and results of each included study, according to the revised PRISMA.¹²

III. RESULTS

A. Identification of Studies

The electronic search identified 939 studies. Four additional studies were identified through hand-searching of references. Initially excluded were 594 because 215 were duplicates, 8 were in another language, and 371 from the title; 349 studies were screened and 215 excluded after studying the abstract. The remaining 134 articles were left for full-text inspection, and another 113 were excluded based on the inclusion and exclusion criteria, leaving 21 articles to be included in the present systematic review. A detailed flowchart is provided in Fig. 1.

B. Methodological Quality

On average, the methodological quality score of the included studies^{16–36} rated with the PEDro scale (Table 2) was 5.28/10. Specifically, only one study was rated 9/10²⁴; two 7/10^{27,34}; 6/10^{16,17,28,31}; seven 5/10^{21–23,25,26,35,36}; five 4/10^{19,20,29,30,32}; and one 3/10.¹⁸

Analysis of each of the 10 items of the PEDro scale showed that risk of bias mainly arose from the following five categories: concealed allocation, blinding of subjects, therapists, assessors, and as planned/intention-to-treat analysis. Fifty percent or more of the studies failed to address these sources of bias (Fig. 2).

C. Study Characteristics

The characteristics of the included studies are provided in Table 3. All but five mentioned the exact number of individuals allocated in each group and their age and sex.^{18,25,28,30,32} All but five provided BMI,^{16,19,26,28,33} and the duration of interventions and symptoms.

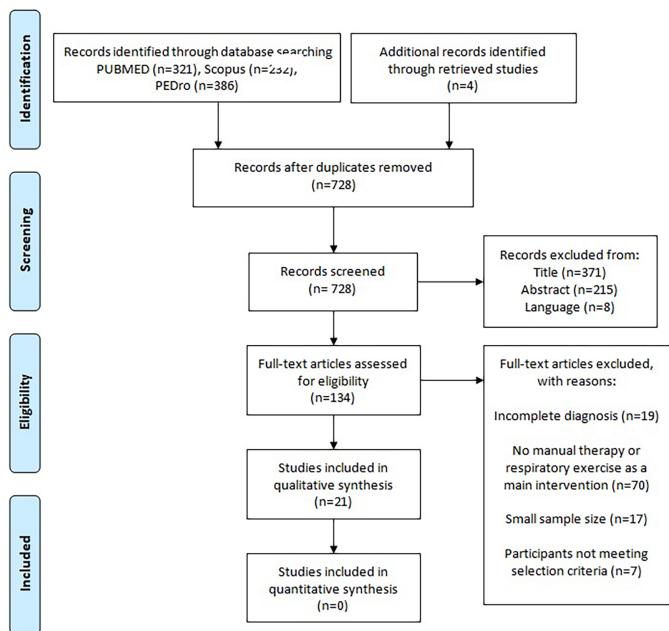


FIG. 1: PRISMA flowchart showing the selection procedure for the studies in this systematic review

Additionally, only 11 of the 21 included studies had performed an *a priori* sample size calculation to achieve a power level of at least 80% at a significance level $\alpha = 0.05$ for one of their main outcome measures.^{16,17,21,22,24,26,27,29,31,35,36}

1. Interventions

In all included studies, the experimental group included manual therapy as an intervention in the form of joint or/and soft tissue mobilization/manipulation (at the thoracic or lumbar spine) or in the form of individualized, analytically specified exercise of the respiratory muscles that contribute to spinal stabilization. That intervention was compared with other therapeutic approaches (traditional physiotherapy, exercise) or a control group. Duration of interventions ranged 2–12 weeks (Table 3).

2. Outcome Measures

Pain outcome measures included the visual analogue scale (VAS),^{16,21,22,24,25,27,28,31} the quadruple visual analogue scale (QVAS),²⁹ the numerical pain rating scale (NPRS),^{17,26,33,35,36} and the short-form McGill pain questionnaire (SF-MPQ).²⁴ Disability/functional outcomes were measured by the Korean Oswestry Disability Index (K-ODI),^{19,26,29} the Oswestry Disability Index (ODI)^{20–24,28} or the ODI-2,¹⁷ the

TABLE 2: Methodological quality of included studies according to met (Y) and unmet (N) PEDro criteria

Study	Items										Total Score
	1	2	3	4	5	6	7	8	9	10	
Mehling et al. 2005 ¹⁶	Y	Y	Y	N	N	N	Y	Y	Y	Y	6/10
Janssens et al. 2014 ¹⁷	Y	N	Y	N	N	Y	Y	Y	Y	Y	6/10
Ki et al. 2016 ¹⁸	Y	N	Y	N	N	N	N	N	N	Y	3/10
Kang et al. 2016 ¹⁹	Y	N	Y	N	N	N	N	N	Y	Y	4/10
Babina et al. 2016 ²⁰	Y	N	N	N	Y	N	N	Y	Y	Y	4/10
Tamer et al. 2017 ²¹	Y	Y	N	N	N	N	N	N	Y	Y	4/10
Ulger et al. 2017 ²²	Y	N	Y	N	N	Y	N	N	Y	Y	5/10
Waseem et al. 2018 ²³	Y	Y	N	N	N	Y	N	Y	N	N	5/10
Marti-Salvador et al. 2018 ²⁴	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	9/10
Finta et al. 2018 ²⁵	Y	N	Y	N	N	Y	N	Y	Y	Y	5/10
Park and Lee 2019 ²⁶	Y	N	Y	N	N	Y	N	Y	Y	Y	5/10
Gholami Borujeni and Yalfani 2019 ²⁷	Y	N	Y	N	N	Y	Y	Y	Y	Y	7/10
Kavya and Dhanesh Kumar 2020 ²⁸	Y	Y	N	N	Y	N	N	Y	Y	Y	6/10
Oh et al. 2020 ²⁹	Y	N	Y	N	N	N	N	Y	Y	Y	4/10
Park et al. 2020 ³⁰	Y	N	Y	N	N	N	N	N	Y	Y	4/10
Ahmadvazhad et al. 2020 ³¹	Y	N	Y	N	Y	Y	N	Y	Y	Y	6/10
Finta et al. 2020 ³²	Y	N	Y	N	N	N	N	Y	Y	Y	4/10
Shah et al. 2020 ³³	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Lim et al. 2020 ³⁴	Y	Y	N	N	Y	Y	N	Y	Y	Y	7/10
Mohan et al. 2020 ³⁵	Y	N	Y	N	N	N	Y	N	Y	Y	5/10
Ohtadi et al. 2021 ³⁶	Y	N	Y	N	N	N	Y	N	Y	Y	5/10

1, random allocation; 2, concealed allocation; 3, baseline comparability; 4, blind subjects; 5, blind therapists; 6, adequate follow up; 8, management as planned or intention-to-treat analysis; 9, between-group comparisons; 10, point estimates and variability; Y, yes (criteria met); N, no (criteria unmet).

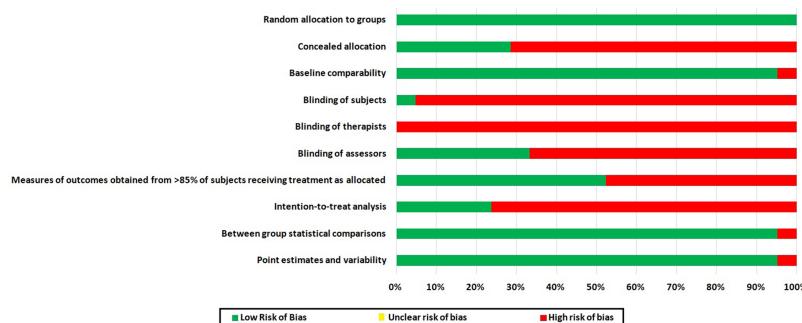


FIG. 2: Resulting risk of bias per methodological quality item assessed via PEDro

Roland-Morris Disability Questionnaire (RMQ),^{16,24} the Modified Oswestry Disability Questionnaire (MODQ),³³ the Athletes Disability Index Questionnaire (ADIQ),²⁷ and the Core Outcome Measures Index (COMI).³⁶ Spinal core stability outcomes were measured with the spinal mouse analyzer,¹⁸ pressure biofeedback,^{28,33,35} the modified Functional Reach Test (mFRT),³² the modified Lateral Reach Test (mLRT),³² the Limits of Stability (LoS) test,³² and the Unilateral Hip Bridge Endurance test (UHBE).³⁶ Satisfaction with treatment was measured with the Treatment Satisfaction Scale (TSS).^{17,24} Quality-of-life outcomes were measured with the Short Form Health Survey (SF36)^{16,21,22} and the Patient Health Questionnaire (PHQ4).²⁷ Psychological health outcomes were measured with the Fear-Avoidance Belief Questionnaire (FAB-Q),^{17,24,26} the Pain Catastrophizing Scale (PCS),²⁴ the Hospital Anxiety and Depression Scale (HADS),²⁴ and the Tampa Scale of Kinesiophobia (TSK).¹⁷ Proprioception outcomes were measured with center of pressure displacement during local muscle vibration (ankle, back, and ankle-back),¹⁷ the sensory organization test (SOT),¹⁶ the Kistler force plate,¹⁶ cervical joint position sense,³⁴ and the plantar pressure measurement device.²⁷ Static balance was tested with the Wii balance board²⁶ and dynamic balance was measured with the Star Excursion Balance test (SEBT).³⁶ Muscle activity of the trunk muscles was measured with surface EMG.^{19,31} Thickness of the diaphragm and the other stabilizer muscles of the lumbar spine were measured with ultrasound.^{25,29} Chest wall expansion (CWE) was measured with a tape measure.^{20,32,34,35} Respiratory patterns were measured with the Total Faulty Breathing Scale (TFBS)³⁵ and the Nijmegen Questionnaire (NQ).³⁴ Respiratory parameters were measured with an electronic pressure transducer,¹⁷ capnography,³⁴ an expiratory flow meter (PICO-6),²⁰ a POWERbreathe device,^{17,27,31,32} or spirometer.^{18,26,29,31,35} Respiratory parameters measured were vital capacity (VC),³¹ forced vital capacity (FVC),^{20,26,29,30,31} forced expiratory volume in 1 second (FEV1),^{26,29,30,31} maximum expiratory pressure (MEP),^{30,35} maximum inspiratory pressure (MIP),^{17,20,30,32,35} peak inspiratory flow (PIF),³² end tidal CO₂ (ETCO₂),³⁴ maximum voluntary ventilation (MVV),^{26,29,31,35} respiratory rate (RR),³⁴ breathing holding time (BHT),³⁴ and sustained maximal inspiratory pressure (SMIP).²⁰

TABLE 3: Characteristics of randomized controlled trials in the systematic review

Study	Methodology	Criteria	Interventions	Outcome measures	Main results
Otadi et al. 2021³⁶ Aim: Evaluate the effectiveness of combining diaphragm training with electrical stimulation in athletes with nonspecific LBP	Participants: Number: 24 (female: 12, male: 12) Age: 20–50 BMI: 25.4 ± 4.4 Duration: 4 weeks (3 days/ week)	Inclusion criteria: (1) Intermittent nonspecific CLBP ≥ 12 weeks (2) VAS: 3–7 Exclusion criteria: (1) Lumbar surgery experience (2) Inflammatory spinal disease (3) Spinal deformities (4) Neurologic radiating pain (5) Unable to perform exercises	Intervention group (<i>n</i> = 12): Diaphragm training + TENS Control group (<i>n</i> = 12): TENS only	Pain: NPRS Function: COMI Static stability: UHBE Dynamic balance: SEBT All outcomes evaluated at baseline and 4 weeks <i>A priori</i> sample size calculation performed for pain (primary outcome) to detect between-group significant difference ($\alpha = 0.05$), power of 80%, and medium effect size ($d = 0.5$)	Pain, function, static stability, and dynamic balance improvement in both groups More significant improvement ($p < 0.05$) in pain, static stability, dynamic balance in intervention group
Mohan et al. 2020³⁵ Aim: To evaluate effectiveness of combined ball and balloon exercise on respiratory variables in patients with nonspecific LBP	Participants: Number: 40 (female: 28, male: 12) Age: 18–55 BMI: 23 ± 4.5 Duration: 8 weeks (3 days/ week)	Inclusion criteria: (1) CLBP between last ribs and gluteal sulcus ≥ 6 months (2) ≥ 3 LBP episodes in previous 6 months (3) Intensity ranging 2–5/10 in NRS and FEV1% $> 80\%$ Exclusion criteria: (1) Respiratory disease (2) Lumbar spine surgery (3) Leg numbness/neural signs (4) Pregnancy	Intervention group (<i>n</i> = 20): Combined ball and balloon exercises with routine physiotherapy, progression core stability exercises Control group (<i>n</i> = 20): Routine physiotherapy, ultrasound, spinal flexion/extension exercises	Respiratory variables: MIP, MVV, with spirometer Chest expansion: Cloth tape Pain: NRS Faulty breathing pattern: TFBS Lumbo-pelvic stability: Pressure biofeedback All outcomes evaluated at baseline and at 8 weeks of treatment <i>A priori</i> sample size calculation performed for MIP (primary outcome) to detect between-group significant difference ($\alpha = 0.05$) and power of 80%	Significant reduction in pain and MVV for both groups ($p < 0.05$) MIP increased significantly in experimental group compared to control group ($p < 0.05$) MEP, TFBs, chest expansion and core stability showed no changes in either group

TABLE 3: (continued)

Study	Methodology	Criteria	Interventions	Outcome measures	Main results
Lim et al. 2020³⁴ Aim: Compare the effects of joint mobilization, gym ball exercises, and breathing exercises, on breathing pattern disorders and joint position sense in persons with CLBP	Participants: Number: 36 (female: 22, male: 14) Age: 35–50 BMI: 23 ± 1.13 Duration: 12 weeks (40 min/day, 2 days/week)	Inclusion criteria: (1) Nonspecific and mechanical CLBP (2) Patients with thoracic breathing method Exclusion criteria: (1) Previous orthopedic, neurosurgical experience (2) Cardiovascular disease, high risk of falls (3) Other chronic pain (4) Participation in other exercise programs (abdominal muscle training within 1 year) (5) Pregnancy within 2 years (6) Malignant tumor (7) Radiating pain at two sites	Intervention group A (n = 12): Joint, soft-tissue mobilization according to Kaltenborn Intervention group B (n = 12): Core stability exercises with/without gym ball Intervention group C (n = 12): Breathing exercises, retraining breathing pattern through relaxed diaphragm breathing, diaphragm manual doming technique, relaxing jaws, upper chest, shoulders, accessory respiratory muscles	Respiratory parameters: ETCO ₂ , respiratory rate (RR), breathing holding time (BHT), chest expansion Breathing pattern: NQ Proprioception: Cervical JPE All outcomes evaluated at baseline and 12 weeks of treatment	All three interventions had significant impact on biomechanical changes, respiratory variables, joint position ($p < 0.05$) Between-group differences significant in favor of Intervention groups B and C for ETCO ₂ and RR ($p < 0.05$) Between-group differences significant in favor of Intervention group C for NQ and chest expansion ($p < 0.05$)
Shah et al. 2020³³ Aim: To compare the effectiveness of core stability and diaphragmatic breathing exercises (DBEx) vs. core stability alone on pain and function in mechanical nonspecific LBP patients	Participants: Number: 46 (female: 37, male: 9) Age: 33–55 BMI: not reported Duration: 4 weeks	Inclusion criteria: (1) CLBP (> 12 weeks) without respiratory pathology (2) CLBP with respiratory pathology Exclusion criteria: (1) Age < 35 and > 55 (2) Any previous abdominal and/or thoracic surgery (3) Smoking (4) Traumatic LBP	Intervention group (n = 23): Core stability exercises + diaphragmatic exercises Control group (n = 23): Core stability exercises only	Pain: NPRS Function: MODQ Core stability: Pressure biofeedback Abdominal pressure: Pressure biofeedback All outcomes evaluated at baseline and at 4 weeks of treatment	Significant between-group differences for pain ($p < 0.05$) and all other outcome measures for intervention group

Finta et al. 2020³² Aim: Evaluate the effects of diaphragm-strengthening exercises on stability limits of trunk and inspiratory function in CLBP	<p>Participants: Number: 52 (female/male: not reported) Age (mean): 21.5 BMI: 23.5 Duration: 8 weeks (60 min/day, 2 days/week)</p> <p>Inclusion criteria: (1) LBP history at least 3 months Exclusion criteria: (1) Specific cause of LBP diagnosed (2) Balance problems of neurological origin (3) Malignant tumor (4) Severe organ disease (5) Respiratory disease (6) Previous surgical intervention affecting trunk or extremities (5) Lack of cooperation</p>	<p>Intervention group (n = 26): Conventional exercise program (strengthening, mobilizing, stretching exercises of trunk muscles, balance exercises) + inspiratory muscle strengthening (POWERbreathe KH2 device)</p> <p>Control group (n = 21): Conventional exercise program only</p> <p>Chest wall expansion: Inelastic tape at nipple height Respiratory parameters: MIP, PIF Core stability: mFRT, mLRT, LOS in sitting position All outcomes evaluated at baseline and 8 weeks of treatment</p> <p>MIP, LOS tests (mFRT, mLRT) showed statistically significant between-group differences with improvements in favor of Intervention group ($p < 0.05$) Chest excursion and peak inspiratory flow (PIF) tests showed statistically significant improvements in both groups ($p < 0.05$); improvement was greater in intervention group No statistically significant change in respiratory parameters for either group</p>
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TABLE 3: (continued)

Study	Methodology	Criteria	Interventions	Outcome measures	Main results
Ahmadvazhad et al. 2020³¹ Aim: To investigate the effect of inspiratory muscle training (IMT) on core muscle activity, pulmonary parameters, and pain intensity in athletes with CLBP	Participants: Number: 47 (female: 24, male: 23) Inclusion criteria: (1) Powerlifting, weightlifting exercises 3 sessions/week, ≥ 75 min/session over last 3 years (2) Age 18–25 (3) LBP persisting ~ 6 months without severe pain (VAS: < 6) Exclusion criteria: (1) Spine deformity (2) Neck pain (3) Orthopedic/neurological disease (4) Head/spinal surgeries (5) Rheumatic, respiratory disease (6) Normal spine curvature (7) Acute musculoskeletal inflammation (8) Pregnancy (9) Severe pain (10) Injury during intervention (11) Pain-relieving medications/physical treatment	Intervention group (<i>n</i> = 23): Inspiratory strengthening, muscle training (POWERbreath KHI) Control group (<i>n</i> = 24): Weightlifting, powerlifting training	Muscle activity: Surface EMG muscle activity of erector spinae, multifidus, transverse abdominis, rectus abdominis Pain: VAS Respiratory parameters: Spirometer VC, FVC, FEV1, FEV/VC	Muscle activity: Surface EMG muscle activity of erector spinae, multifidus, transverse abdominis, rectus abdominis Pain: VAS Respiratory parameters: Spirometer VC, FVC, FEV1, FEV/VC	Multifidus, transverse abdominis activity and respiratory parameters increased significantly only in IMT group ($p < 0.05$) Decreasing VAS score in intervention group ($p < 0.05$) <i>A priori</i> sample size calculation performed to detect between-group significant difference ($\alpha = 0.05$), power of 95%, and large effect size ($d = 0.8$)

TABLE 3: (continued)

Park et al. 2020³⁰ Aim: Identify the effectiveness of breathing exercises and lumbar stabilization exercises on respiratory parameters of lumbar instability patients with chronic back pain	Participants: Number: 59 (female/male: not reported) Age: 30–53 BMI: 23.5 ± 4.85 Duration: 6 weeks (40 min/day, 5 days/week)	Inclusion criteria: (1) Lumbar instability index (author-defined) ≥ 5 points (2) No history of spinal surgery (3) No neurosurgical/orthopedic restrictions (4) No visual/vestibular abnormalities (5) No infections/tumors (6) No spinal cord idiopathic disorder/other skeletal disease (7) No history of central nervous system disease (e.g., stroke, Parkinson's), spinal cord injury	Intervention group A (n = 20): Respiratory, core stability exercises, electrotherapy for 40 min Intervention group B (n = 20): Core stability exercises, electrotherapy for 40 min Intervention group C (n = 19): Electrotherapy	Respiratory parameters: Spirometer FVC, FEV1, MIP, MEP All outcomes evaluated at baseline and 6 weeks of treatment Intervention groups A and B showed statistically significant change in FVC, FEV1, MIP, MEP at pre- and postintervention ($p < 0.05$) and among all groups ($p < 0.05$). Significant difference in FEV1 for each group ($p < 0.05$) but was not significant among groups ($p > 0.05$)
Oh et al. 2020³⁹ Aim: To identify the effectiveness of abdominal draw-in lumbar stabilization exercises (ADIM) with respiratory resistance on women ages 40–49 years with chronic low back pain	Participants: Number: 44 (female) Age: 40–49 BMI: 22.1 ± 1.5 Duration: 4 weeks (50 min/day, 3 days/week)	Inclusion criteria: (1) LBP at least within past 6 weeks (2) ≥ 3 QVAS, 3 ≥ positives among 5 lumbar instability tests (3) No history of back surgery Exclusion criteria: (1) Difficulties in motor performance due to pain (2) Participation in less than 85% of sessions (3) Systemic/respiratory diseases (e.g., cancer)	Intervention group (n = 22): Abdominal draw-in maneuver, lumbar spine stabilization exercises + respiratory with resistance exercises Control group (n = 22): Abdominal draw-in maneuver, lumbar spine stabilization exercises	Pain: QVAS Function: ODI-K Respiratory parameters: Diaphragm thickness with ultrasound and spriometer for FVC, FEV1, FEV1%, MVV All outcomes evaluated at baseline and 4 weeks of treatment <i>A priori</i> sample size calculation performed to detect between-group significant difference ($\alpha = 0.05$), power of 80%, and large effect size ($d = 0.8$) Both groups showed significant differences in QVAS, ODI-K, MVV, diaphragm thickness, contraction rate ($p < 0.05$) Intervention group showed better improvement in ODI-K, FVC, FEV1, MVV, and diaphragm thickness, contraction rate than control group ($p < 0.05$)

TABLE 3: (continued)

Study	Methodology	Criteria	Interventions	Outcome measures	Main results
Kavya and Dhanesh Kumar 2020²⁸ Aim: To identify and compare the effect of inspiratory and expiratory exercises with lumbar stabilization in patients with CLBP	Participants: Number: 36 (female/male: not reported) Age: 20–50 BMI: not reported Exclusion criteria: (1) Respiratory, cardiovascular pathology (2) Mental disorder (3) Acute LBP (4) Tumor (5) Fracture (6) Radiating LBP Duration: 3 weeks (7 days/week)	Intervention group A (n = 12): Inspiratory training + using respirometer + lumbar stabilization exercise Intervention group B (n = 12): Expiratory training using balloon and ball + lumbar stabilization exercise Intervention group C (n = 12): Lumbar stabilization exercise	Pain: VAS Function: ODI Muscle core strength: Stabilizer pressure biofeedback All outcomes evaluated at baseline and 3 weeks of treatment	All three groups demonstrated clinically significant improvements Pain in Group A showed statistically significant improvement compared to other groups	
Gholami Borujeni and Yalfani 2019²⁷ Aim: Determine the effects of inspiratory muscle training on postural sway in athletes with CLBP	Participants: Number: 47 (female: 25, male: 22) Age: 18–25 BMI: 17.19 ± 2.6 Duration: 8 weeks (twice/day, 7 days/week)	Inclusion criteria: (1) No surgery, fractures, burns, neuromuscular problems, spine/lower extremity injury (2) No artificial limbs in thighs, knees, ankles (3) No malalignments in cervical, thoracic, lumbar, pelvic region, lower limbs (4) No smoking history (5) No cardiovascular/pulmonary history (6) No pain-relieving medications (7) No steroid/other doping medication history	Intervention group (n = 24): Inspiratory muscle training protocol with POWERbreath KHI handheld device Control group (n = 23): Weightlifting/powerlifting training	Postural sway variables: Plantar pressure measurement device Pain: VAS Function: ADIQ Depression/anxiety: PHQ4 All outcomes evaluated at baseline and 8 weeks of treatment <i>A priori</i> sample size calculation performed to detect between-group significant difference ($\alpha = 0.05$), power of 95%, and large effect size ($d = 0.8$)	Intervention group postural sway indices in overhead squat test, single leg squat test, and pain decreased significantly ($p < 0.05$)

TABLE 3: (continued)

Park and Lee 2019²⁶ Aim: To investigate the effectiveness of a progressive stabilization exercise program carried out with respiratory resistance in patients with lumbar instability and chronic low back pain, in clinical and respiratory parameters	Participants: Number: 43 (female: 19, male: 24) Age: 18–65 Weight: 70 ± 17.9 kg BMI: not reported Duration: 4 weeks (40 min/session, 3 sessions/week)	Inclusion criteria: <ul style="list-style-type: none"> (1) 18–65 with LBP in last 6 weeks (2) NRS: ≥ 3 (3) Positive in ≥ 3 of 5 items in lumbar instability test (Hicks et al., 2003) (4) Able to stand on 1 leg for 30 s Exclusion criteria: <ul style="list-style-type: none"> (1) Compression fracture (2) Systemic disease (e.g., cancer) (3) Difficulties in participating due to neurological conditions (4) Participation rate lower than 80% of program schedule 	Intervention group (<i>n</i> = 20): Progressive lumbar stabilization exercises + respiratory resistance exercises	Pain: NRS Function: (K-ODI)	Both groups showed significant differences in NRS, K-ODI, balance ability, FABQ ($p < 0.05$)
Finta et al. 2018²⁵ Aim: Assess effects of diaphragm training on CLBP and thickness of stabilizer muscles of lumbar spine	Participants: Number: 52, (female/male: not reported) Age: 21.8 ± 4.94 BMI: 23.5 ± 4.8 Duration: 8 weeks (60 min/session, 2 sessions/week)	Inclusion criteria: <ul style="list-style-type: none"> (1) LBP lasting ≥ 3 months (2) No other treatment during training period (3) Ability to learn diaphragm trainer (4) Able to attend training Exclusion criteria: <ul style="list-style-type: none"> (1) Specific causes of LBP diagnosed (2) Balance problems of neurological origin (3) Malignant tumors (4) Serious organ diseases (5) Respiratory diseases (6) Previous surgical interventions affecting trunk/limbs (7) Lack of cooperation 	Intervention group (<i>n</i> = 26): Complex training program + diaphragm training (POWERbreath device)	Thickness of core stability muscles: Ultrasound Pain: VAS	Both groups improved significantly in severity of pain Diaphragm training affected transversus abdominis, lumbar multifidus thickness

TABLE 3: (continued)

Study	Methodology	Criteria	Interventions	Outcome measures	Main results
Marti-Salvador et al. 2018²⁴ Aim: Compare effects of OMT with diaphragm intervention and OMT with sham diaphragm intervention in NS-CLBP	Participants: Number: 66 (male: 29, female: 37) Age: 42.55 ± 10.5 BMI: 26 ± 4.45 Duration: 2 weeks (45 min/session, 2 sessions/week); 1 session after 1 month Inclusion criteria: (1) Age: 18–60 with NS-CLBP lasting ≥ 3 months Exclusion criteria: (1) Pregnancy (2) Spinal tumor or infection (3) Spinal fracture (4) Previous spine surgery (5) Systemic disease (6) Musculoskeletal injuries of lower limbs (7) Contraindications for OMT (8) ODI score < 16% (9) Previous OMT or history of LBP rehabilitation in previous 2 months	Intervention group (n = 33): Complex manipulation/ mobilization program for lumbar spine, diaphragm Control group (n = 33): Complex manipulation/ mobilization program for lumbar spine, sham techniques for diaphragm	Pain: SF-MPQ, VAS Disability: RMQ, ODI Psychology: FABQ, HADS, PSC, TSS All outcomes evaluated at baseline, 4, and 12 weeks of treatment <i>A priori</i> sample size calculation performed for pain (primary outcome) to detect between-group significant difference ($\alpha = 0.05$) and power of 90%		Statistically significant reduction in intervention group compared to sham group in all variables assessed at 4 and 12 weeks
Waseem et al. 2018²³ Aim: Compare effects of core musculature workout and routine physical therapy for disability caused by CLBP	Participants: Number: 108 (male: 71, female: 37) Age: 46 ± 7 BMI: 24.5 ± 2.6 Duration: 6 weeks (1 session/week)	Inclusion criteria: (1) LBP ≥ 3 months (2) Age: 20–60 Exclusion criteria: (1) Disc pathology, radicular pain (2) Acute LBP (3) History of spinal fracture/ spinal surgery (4) Spondyloolisthesis (5) Systemic disease/TB of spine (6) Physical therapy for LBP in last 6 months	Intervention group (n = 53): Complex core stability exercise program + diaphragm-strengthening exercises Control group (n = 55): Core stability exercises for local muscles of lumbar spine Both groups: Ultrasound, TENS, home exercises twice/week	Disability: ODI All outcomes evaluated at baseline and 2, 4, and 6 weeks of treatment Intervention group showed statistically significant improvement in disability ($p < 0.05$) compared to control group	Both groups showed significant reduction in disability at 2, 4, 6 weeks of treatment ($p < 0.05$)

TABLE 3: (continued)

Ulger et al. 2017 ²²	Participants: Number: 113 (male: 46, female: 67) Aim: Evaluate effectiveness of spinal stabilization exercises and manual therapy on pain, function, quality of life in patients with CLBP	Inclusion criteria: (1) Pain for ≥ 3 months (2) VAS: > 3 (3) Age: 20–73 Exclusion criteria: (1) Previous spine surgery/ failed back surgery (2) Scoliosis (3) Spinal neoplasm/ metastatic disease (4) Progressive neuropathy/ progressive lumbosacral radiculopathy (5) Rheumatoid arthritis with advanced joint involvement (6) Ongoing pharmaceutical medication (7) Neurologic + CLBP or systemic diseases, bladder disinfection	Intervention group A (n = 57): Complex core stability exercises + diaphragm exercises + cocontraction exercises between diaphragm and other local muscles of lumbar spine Intervention group B (n = 56): Complex individualized mobilization + manipulation techniques for joints, soft tissue	Pain: VAS Disability: ODI Quality of life: SF-36 All outcomes evaluated at baseline and 6 weeks of treatment <i>A priori</i> sample size calculation to detect between-group significant difference ($\alpha = 0.05$) and power of 80%	Within groups both treatments were effective in pain, function, quality of life ($p < 0.05$) Between groups there was significant ($p < 0.05$) reduction in pain and improvement in functional status in favor of Intervention group B
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TABLE 3: (continued)

Study	Methodology	Criteria	Interventions	Outcome measures	Main results
Tamer et al. 2017 ²¹ Aim: Determine effectiveness of visceral osteopathic manual therapy on NS-CLBP	Participants: Number: 39 (male: 18, female: 21) Exclusion criteria: (1) Spinal/abdominal surgery in last 6 months (2) Systemic diseases (3) Infections, tumors (4) Severe scoliosis (5) Radicular symptoms (6) Motor, sensory deficits	Inclusion criteria: (1) Age: 20–40 (2) Pain lasting > 3 months	Intervention group A (n = 19): Individualized soft-tissue mobilization, muscle-energy techniques, manipulation, mobilization for lumbar spine; spinal stabilization, strengthening, stretching exercises	Pain: VAS Disability: ODI Quality of life: SF-36 All outcomes evaluated at baseline and 6 weeks of treatment <i>A priori</i> sample size calculation performed for SF-36-Physical (primary outcome) to detect between-group significant difference ($\alpha = 0.05$) and power of 80%	Within groups, statistically significant improvements ($p < 0.05$) in all outcomes Between groups, significant improvement in quality of life ($p < 0.05$) in favor of Intervention group B

TABLE 3: (continued)

Babina et al. 2016²⁰	Participants: Number: 62 (male: 50, female: 12) Age: 40.75 ± 0.8 BMI: 20.75 ± 0.8 Duration: 2 weeks (5 sessions/week, 10 sessions total)	Inclusion criteria: (1) Age: 30–60 (2) Nonspecific LBP with/ without leg pain (3) LBP duration > 3 months (4) VAS: ≥ 4 Exclusion criteria: (1) Respiratory/cardiac disease (2) Previous rib fracture, dislocation, osteochondral, osteosternal, interchondral joint sprains (3) General contraindications for mobilization (primary, secondary neoplastic lesions of spine and/or ribs), obvious advanced spinal deformity (e.g., kyphoscoliosis), healing fracture, dislocation, infections, (e.g., TB), nonneoplastic bone diseases (e.g., osteoporosis), inflammation (e.g., acute RA, AS), gross segmental instability) (4) Spinal/ LL surgery (5) Any cervical pathology, LBP due to any pelvic, abdominal, systemic pathology (6) Signs of nerve root compromise (i.e., diminished DTRs, sensory loss, motor deficits) (7) Spinal cord compression (8) Vascular diseases of extremities (9) Pregnancy (10) Smoking	Intervention group (n = 31): Complex core stability program + respiratory, home exercises, and mobilization technique for thoracic, lumbar spine according to Maitland Control group (n = 31): Same core stability exercises without mobilization techniques	Respiratory parameters: FVC, SMIP, CWE Function: ODI All outcome measures evaluated at baseline and 2 weeks of treatment	Within groups statistically significant improvements ($p <$ 0.05) in all outcome measures Between groups significant improvement ($p <$ 0.05) in CWE, FVC, SMIP, ODI in favor of intervention group
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TABLE 3: (continued)

Study	Methodology	Criteria	Interventions	Outcome measures	Main results
Kang et al. 2016¹⁹ Aim: Determine effectiveness of exhalation exercises on trunk muscle activity, ODI in CLBP	Participants: Number: 20 (male) Age: 31–45 Weight: 65 ± 9 kg BMI: not reported Duration: 6 weeks (30-min session, 4 sessions/week)	Inclusion criteria: (1) Age: 31–45 (2) LBP > 3 months Exclusion criteria: (1) Acute pain (2) Continuous severe pain (3) Spondylosis/spondylolisthesis (4) Paresthesia, myopathy (5) Psychological problems (6) Difficulty performing exercise due to lack of comprehension	Intervention group A (n = 10): Exhalation exercise Control group (n = 10): Spinal stabilization exercise	Trunk muscle activities: Surface EMG (rectus abdominis, transversus abdominis, external oblique, erector spine muscles) Disability: ODI Korean version All outcomes evaluated at baseline and 6 weeks of treatment	Intervention group improved significantly ($p < 0.05$) in transversus abdominis muscle activity only and ODI
Ki et al. 2016¹⁸ Aim: Determine effects of forced breathing exercise on trunk functions in CLBP	Participants: Number: 24 (male/female: not reported) Age: 27.6 ± 1.5 BMI: 20.7 ± 0.8 Duration: 6 weeks (45 min/session, 3 sessions/week)	Inclusion criteria: (1) Age: 20–40 Exclusion criteria: (1) Intermittent chronic lumboago (VAS: < 4) without previous lumbar surgery (2) Inflammatory spinal disease, spinal deformities, neurologic radiating pain (3) Inability to perform muscular movements of trunk or cardiopulmonary exercise within 1 month of study and without pathological diagnosis involving respiratory system	Intervention group A (n = 12): Forced breathing exercise plus trunk stabilization exercise with SPIRO TIGER Control group (n = 12): Same trunk stability exercises without breathing exercises	Thoracic and Lumbar spine stabilization: Spinal mouse analyzer All outcome measures evaluated at baseline and 6 weeks of treatment	Statistically significant improvements in both groups ($p < 0.05$) No significant differences between groups

TABLE 3: (continued)

Janssens et al. 2014¹⁷	Participants: Number: 28 (male: 10, female: 18) Aim: Determine whether inspiratory muscle training affects proprioceptive use during postural control in LBP	Inclusion criteria: (1) At least three episodes of nonspecific LBP in last 6 months (2) $\geq 10\%$ in ODI-2 (3) Specific medical diagnosis of nonspecific mechanical LBP Exclusion criteria: (1) Previous spinal surgery (2) Specific balance problems (e.g., vestibular, neurological disorder) (3) Respiratory disorders (4) Lower-limb problems, neck pain (5) Pain-relieving medication or physical treatment	Intervention group (n = 14): High- intensity inspiratory muscle strength exercises with POWERbreath device Control group (n = 14): Low- intensity inspiratory muscle strength exercises with POWERbreath	Postural sway characteristics: 6-channel force plate CoP (Berotec, Columbus, OH) Disability: NRS, ODI-2 Psychology: FABQ, TSK Respiratory parameters: MIP All outcome measures evaluated at baseline, and 8 weeks of treatment <i>A priori</i> sample size calculation performed for CoP (primary outcome) to detect between-group significant difference ($\alpha =$ 0.05) and power of 80%	Intervention group showed statistically significant improvement ($p <$ 0.05), less responsive to ankle muscle vibration, more responsive to back muscle vibration, higher inspiratory muscle strength, reduced LBP severity ($p < 0.05$) These changes not seen in control ($p <$ 0.05) No changes in disability in either group ($p > 0.05$)
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TABLE 3: (continued)

Study	Methodology	Criteria	Interventions	Outcome measures	Main results
Mehling et al. 2005⁴⁶ Aim: Evaluate effectiveness of breathing exercises CLBP	Participants: Number: 28 (male: 36.5%, female: 63.5%) Age: 49.3 ± 12.3 BMI: not reported Duration: 6–8 weeks (45 min/session, 7 days/week, 12 sessions total)	Inclusion criteria: (1) Age: 20–70 (2) CLBP lasting 3–24 months (3) Seeking primary care help for LBP (4) Fluent in English (5) Sciatica/pain radiating below knee, only if no motor deficits	Intervention group A (n = 16): Breath therapy with mind-body therapy (body awareness, breathing, meditation, movement) Control group (n = 12): Soft-tissue mobilization, joint mobilization, exercises for postural righting, flexibility, pain relief, stabilization, strengthening, functional task performance, back-related education	Pain: VAS Function: RMQ General health: SF-36 Proprioception and body awareness: SOT, Kistler force plate All outcomes evaluated at baseline and 6 or 8 weeks of treatment <i>A priori</i> sample size calculation performed for pain and disability (primary outcomes) to detect between-group significant difference ($\alpha = 0.05$) and power of 80% No significant differences in proprioception between groups No difference in average improvements between groups	Both intervention groups showed statistically significant improvement ($p < 0.05$) in pain, function, general health

All BMI in kg/m².

ADIQ, Athletes Disability Index Questionnaire; BHT, Breathing holding time; CWE, Chest wall expansion; EMG, electromyographic; ETCO₂, End Tidal CO₂; FAB-Q, Fear-Avoidance Belief Questionnaire; FEV1, Forced Expiratory Volume in 1 second; FVC, Forced Vital Capacity; HADS, Hospital Anxiety and Depression Scale; K-ODI, Korean Oswestry Disability Index; LOS, Limits of Stability; MIP, maximum inspiratory pressure; MEP, maximum expiratory pressure; mFRT, modified Functional Reach Test; mLRT, modified Lateral Reach Test; MODQ, Modified Oswestry Disability Questionnaire; MVV, Maximum Voluntary Ventilation; NPRS, numerical pain rating scale; NRS, numeric rating scale; NQ, Nijmegen Questionnaire; PIF, Peak Inspiratory Flow; PCS, Pain Catastrophizing Scale; PHQ4, Patient Health Questionnaire; PSFS, Patient Specific Functional Scale; QVAS, Quadruple Visual Analogue Scale; RMQ, Roland-Morris Disability Questionnaire; RR, Respiratory Rate; SF-36, Short Form Health Survey; SF-MPQ, Short-form McGill Pain Questionnaire; SMIP, Sustained Maximal Inspiratory Pressure; SOT, sensory organization test; TFBS, Total Faulty Breathing Scale; TSK, Tampa Scale of Kinesiophobia; TSS, Treatment Satisfaction Scale; VAS, visual analogue scale; VC, Vital Capacity.

3. Intervention Comparability

All the included studies were randomized, with control groups and most had an adequate number of subjects. Five studies, however, had a relatively small number of individuals, two of which had three interventional groups with 12 individuals per interventional group,^{28,34} one had 10 individuals per intervention group,¹⁹ and the other two studies had 12 individuals per interventional group.^{18,36}

Meta-analysis was not performed due to differences in techniques targeting the spinal joints, trunk, or respiratory muscles; variability in intervention duration; and differences in outcomes assessed.

IV. DISCUSSION

The present systematic review analyzed the efficacy of mobilization/manipulation of diaphragm and lumbar spine, central posteroanterior pressure of thoracic vertebrae T1–T8 according to Maitland, core stability exercises, respiratory exercises under resistance, reeducation exercises of the diaphragm, inspiratory and expiratory exercises, high- and low-intensity respiratory exercises, and postural exercises in patients with CLBP. The interventions were applied with different combinations in comparison with other interventions or sham techniques. The experimental groups received different mobilization/manipulation techniques with different combinations, method of application, and techniques applied at different vertebral segments (lumbar or thoracic) and/or the diaphragm.

Mobilization/manipulation techniques were applied as the only intervention in two studies^{22,34}; in one of those these techniques were applied in another group in combination with respiratory exercises (Group C).³⁴ In one study, mobilization/manipulation techniques were combined with diaphragmatic techniques and in another group they were combined with sham diaphragmatic techniques (Group B).²⁴ In two studies, mobilization/manipulation techniques were combined with core stability exercises,^{16,21} and in one, in another group (Group B) they were combined with visceral mobilization techniques including diaphragmatic techniques.²¹

Respiratory exercises were delivered in different combinations: in 6 studies as the only intervention^{16,17,19,27,31,36} and in 11 studies combined with core stability exercises.^{18,22,23,25,26,28–30,32,33,35} One study combined respiratory exercises with mobilization/manipulation techniques of the lumbar or thoracic spine and core stability exercises.²⁰ Respiratory exercises were applied as strengthening exercises of the inspiratory,^{17,23,25,27,31,32} expiratory,¹⁹ or both muscle groups^{18,26,28,29,34,35,36} and as diaphragmatic breathing reeducation.^{16,22,30,32,33,34,36} Respiratory exercises with resistance were applied in 5 studies with the POWERbreathe device^{17,25,27,31,32}; in 2 studies, with a balloon^{28,35}; in 2 studies, with the Expand-a-Lung device^{26,29}; and in two studies, with a respirometer.^{18,28} Two studies did not mention the exact respiratory training methodology used.^{20,23}

The following paragraphs discuss the results of the current systematic review.

When respiratory exercises were applied as the only intervention in six studies,^{16,17,19,27,31,36} results were superior to weightlifting exercises for pain (VAS),^{27,31}

postural sway indices,²⁷ deep-muscle activity (EMG),³¹ and respiratory parameters (VC, FVC, FEV1, FEV/VC).³¹ They were superior to core stability exercises¹⁹ for transversus abdominis activity (EMG) and disability (ODI). They were also superior to low-intensity inspiratory exercises¹⁷ for postural sway characteristics, inspiratory muscle strength (MIP), and LBP severity (NRS), but not for function (ODI-2). Furthermore, respiratory exercises as a sole intervention were superior to transcutaneous electrical nerve stimulation (TENS) for pain (NRS), static stability (UHBE), and dynamic balance (SEBT), but not for function (COMI).³⁶ Finally, they were equally effective compared to joint and soft tissue mobilization techniques combined with exercises for pain (VAS), function (RMQ), general health (SF-36), proprioception, and body awareness (SOT, Kistler force plate).¹⁶ The six studies had on average a total PEDro score of 5.67/10 (one study had a score of 4; one, a score of 5; three, a score of 6; and one, a score of 7). The resulting risk of bias per methodological quality item is shown in Fig. 3A.

When respiratory exercises were combined with core stability exercises in 11 studies,^{18,22,23,25,26,28–30,32,33,35} results were in general superior to traditional physiotherapy in respiratory parameters (FVC, FEV1, MIP).^{30,35} Also, they were superior to core stability exercises only in disability (ODI,²³ ODI-K,²⁹ and MODQ³³), pain (VAS²⁸ and NPRS³³), static balance ability (Wii balance board),²⁶ core stability measures (LOS test³² and pressure biofeedback³³), psychology (FABQ),²⁶ thickness of transversus abdominis and lumbar multifidus muscles (ultrasound),²⁵ and respiratory parameters (FVC,^{26,29} FEV1,²⁹ MIP,³² and MVV^{26,29}). In contrast, compared to core stability exercises only in three studies, both intervention groups equally improved in thoracic-lumbar spine stabilization (spinal mouse analyzer),¹⁸ pain (NRS),³⁵ and respiratory parameters (FVC, FEV1, MIP,

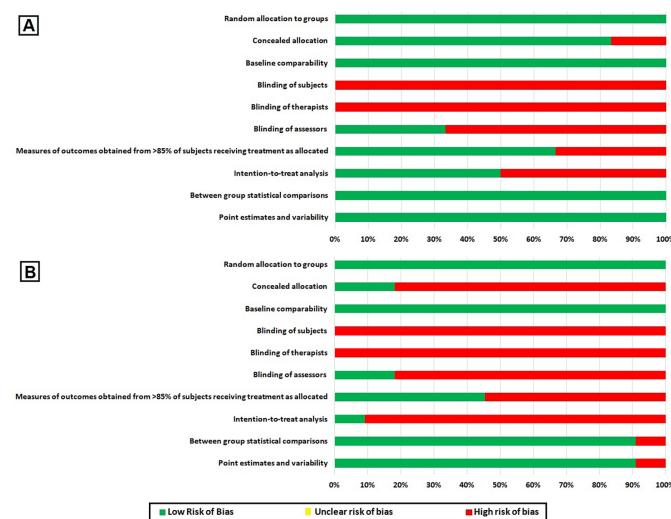


FIG. 3: Resulting risk of bias per methodological quality item assessed via PEDro for the intervention group having (A) respiratory exercises only and (B) respiratory exercises combined with core stability exercises

MEP,³⁰ and MVV³⁵), with no between-group differences present ($p < 0.05$). Conversely, in one study, mobilization/manipulation techniques demonstrated statistically significant superior improvement in pain (VAS) and function (ODI) compared to the combination of respiratory and core stability exercises ($p < 0.05$), but both interventions led to similar improvements in quality of life (SF-36).²² The 11 studies had on average a total PEDro score of 4.72/10 (one study, a score of 3; three, a score of 4; five, a score of 5; and two, a score of 6). The resulting risk of bias per methodological quality item is shown in Fig. 3B.

When respiratory exercises were combined with mobilization techniques of the lumbar spine,³⁴ the results were superior compared to joint mobilization techniques alone for respiratory parameters (ETCO₂, RR, chest expansion) and respiratory pattern (NQ), but they were equally effective with the core stability exercises, both having a significant impact on biomechanical changes, respiratory variables, and cervical joint position sense. This study had an overall PEDro score of 7, with risk of bias present due to lack of subjects and therapist blinding and lack of intention-to-treat analysis.

When respiratory exercises were combined with core stability exercises and mobilization techniques of the lumbar and thoracic spine,²⁰ the results were superior to core stability exercises in combination with respiratory exercises for respiratory parameters (FVC, SMIP, CWE), and for function (ODI). However, this particular study had an overall PEDro score of 4, meaning it was susceptible to a very high risk of bias.

When mobilization/manipulation techniques were combined with diaphragm mobilization techniques,²⁴ the results were superior to mobilization/manipulation techniques combined with sham diaphragm mobilization techniques in pain (SF-MPQ, VAS), disability (RMQ, ODI), and psychology (FABQ, HADS, PSC, TSS). This particular study had a total PEDro score of 9 (no blinding of therapists), thus having a low risk of bias.

When mobilization/manipulation techniques were combined with core stability exercises,²¹ the results were equally effective to mobilization/manipulation techniques combined with visceral applications in pain (VAS) and function (ODI) but not in quality of life (SF-36). However, this particular study had an overall PEDro score of 5, thus being susceptible to a high risk of bias.

Although many systematic reviews have reported the effectiveness of core stability exercises in patients with CLBP,^{37,38} they have not included specific diaphragmatic exercises alongside core stability exercises mainly directed to the deep abdominals and paraspinal muscles. In many research studies, core stability muscles are separated in a local (pelvic floor, transversus abdominis, multifidus, and diaphragm)³⁹ and global muscle system. The special feature of the present systematic review was the examination of all clinical trials that referred to motor control exercises of the local muscle system as an intervention and whether they included respiratory exercises alone or as part of the main intervention.

The present systematic review is the only review that has been carried out with manual therapy considered according to the IFOMPT definition (therapeutic mobilization techniques and individualized specific exercise),¹¹ but specifically focusing on

respiratory core stability exercises and diaphragmatic release mobilization techniques, and on the impact of the above interventions in musculoskeletal and respiratory clinical parameters in patients with CLBP. Most systematic reviews consider manual therapy in the form of joint or soft-tissue mobilization techniques or core stability exercises with emphasis on the pelvic floor, transversus abdominis, and multifidus muscles and their impact in musculoskeletal and not respiratory parameters in patients with CLBP. The systematic review by Anderson and Bliven⁴⁰ examined the effectiveness of respiratory exercises in patients with nonspecific chronic low back pain (NS-CLBP).⁴⁰ Three RCTs were included, two of which were analyzed in the present review; the third did not meet the inclusion criteria (yoga and meditation were not included as interventions). The results of the present systematic review are in agreement with results of this previous systematic review.⁴⁰

Core stability of the spine depends on the tone of the diaphragm and transversus abdominis. However, it has been noted that, if there is a load challenge to the low back combined with a breathing challenge, the support offered to the spine by the core stability muscles is reduced. It has been demonstrated that, after approximately 60 seconds of hypercapnoea, the postural (tonic) and phasic functions of both the diaphragm and the transversus abdominis are reduced or absent.⁹ Smooth muscle cells, now known to be widely embedded in connective tissues (including spinal discs and lumbar fascia) constrict during periods of respiratory alkalosis, with as yet undetermined effects on joint stability and fascial tone.⁹ Breathing rehabilitation offers the potential for reducing negative influences resulting from breathing pattern disorders.⁹ There are many studies that confirm the participation of the diaphragm in the local core stability muscle group to the efficient motor control of the spine.^{7,9,10,39} Disruption of motor control leads to insufficient control of the joints, mainly because of inadequate cocontraction and coordination of core muscles. Other central pain control mechanisms may be involved in pain reduction associated with breathing therapy. It has been previously reported that slow relaxed diaphragmatic breathing endogenously stimulates the vagus nerve, which has a central role in the transmission and mediation of sensory information between the brain and the peripheral tissues. Vagus nerve stimulation has been shown to strongly reduce peripheral inflammatory cytokines, decrease sympathetic tone by modulating descending serotonergic and noradrenergic neurons, decrease malondialdehyde (a biological marker of oxidative stress), reverse pain-related brain activity patterns by reducing hippocampal and amygdala activity and increasing insular cortical and left prefrontal cortex activity, and drive the antinociceptive effects of opioids and their derivatives.⁴¹

This systematic review aimed to identify the complex manual therapy interventions provided to patients with CLBP in studies that have addressed, apart from the musculoskeletal aspect, the respiratory aspect either as a therapeutic intervention or as an outcome. Among the limitations of this review were language restrictions (only studies written in English were included), the lack of meta-analysis (due to the diversity of therapeutic schemes and outcomes), and the inclusion of studies of a wide range of methodological quality and sample size.

V. CONCLUSIONS

We conclude that there is some emerging evidence that manual therapy in the form of joint, soft tissue, and diaphragm mobilization/manipulation techniques, core stability exercises augmented with respiratory exercises, and reeducation of diaphragmatic breathing, improve musculoskeletal, respiratory clinical parameters, and respiratory function in patients with CLBP. However, in many of the included studies, several methodological quality items were not fulfilled, making the results of the current review susceptible to risk of bias. Also, because interventions and outcomes presented great variability, an initial categorization of these studies was presented.

It seems that there is a significant therapeutic benefit to respiratory exercises in CLBP, possibly because breathing disorders co-exist or directly compromise motor control of all muscles surrounding the spine and should be taken into account in clinical reasoning and exercise prescription in this patient group. Further research of high methodological quality are required that focus on the effectiveness of diaphragmatic mobilization/manipulation techniques and respiratory exercises in musculoskeletal and respiratory parameters.

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APPENDIX: PUBMED ALGORITHM USED IN THE CURRENT STUDY

Search number, Query, Sort By, Filters, Search Details, Results, Time

24,#3 AND #12 AND #16 AND #23,,,”chronic low back pain””[Title/Abstract] OR ”low back pain””[Title/Abstract]) AND (“Mobilization””[Title/Abstract] OR ”Manipulation””[Title/Abstract] OR ”osteopathic””[Title/Abstract] OR (“Respiratory””[All Fields] AND ”resistance exercise””[Title/Abstract]) OR ”breathing exercise””[Title/Abstract] OR ”breath therapy””[Title/Abstract] OR ”Diaphragm””[Title/Abstract] OR ”inspiratory muscle training””[Title/Abstract]) AND (“control group””[Title/Abstract] OR ”exercise””[Title/Abstract] OR ”core stability””[Title/Abstract]) AND (“respiratory parameters””[Title/Abstract] OR ”clinical parameters””[Title/Abstract] OR ”neck disability index””[Title/Abstract] OR

““Pain””[Title/Abstract] OR ““maximum voluntary ventilation””[Title/Abstract] OR
 ““active range of motion””[Title/Abstract]”,321,09:15:19
 23, #17 OR #18 OR #19 OR #20 OR #21 OR #22,““respiratory parameters””[Title/
 Abstract] OR ““clinical parameters””[Title/Abstract] OR ““neck disability index””[Title/
 Abstract] OR ““Pain””[Title/Abstract] OR ““maximum voluntary ventilation””[Title/
 Abstract] OR ““active range of motion””[Title/Abstract]”,688,123”,09:14:29
 22, Active range of motion [Title/Abstract],““active range of motion””[Title/
 Abstract]”,1,759”,09:14:01
 21, Maximum voluntary ventilation [Title/Abstract],““maximum voluntary
 ventilation””[Title/Abstract]”,356,09:13:50
 20, Pain [Title/Abstract],““Pain””[Title/Abstract]”,658,460”,09:13:41
 19, Neck disability index [Title/Abstract],““neck disability index””[Title/
 Abstract]”,2,235”,09:13:32
 18, clinical parameters [Title/Abstract],““clinical parameters””[Title/Abstract]”,
 ”26,938”,09:13:24
 17, respiratory parameters [Title/Abstract],““respiratory parameters””[Title/
 Abstract]”,2,408”,09:13:15
 16, #13 OR #14 OR #15,““control group””[Title/Abstract] OR ““exercise””[Title/
 Abstract] OR ““core stability””[Title/Abstract]”,690,089”,09:13:01
 15, core stability [Title/Abstract],““core stability””[Title/Abstract]”,507,09:12:33
 14, exercise [Title/Abstract],““exercise””[Title/Abstract]”,278,009”,09:12:25
 13, control group [Title/Abstract],““control group””[Title/Abstract]”,428,523”,
 09:12:17
 12, #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11,““Mobilization””[Title/
 Abstract] OR ““Manipulation””[Title/Abstract] OR ““osteopathic””[Title/Abstract]
 OR (““Respiratory””[All Fields] AND ““resistance exercise””[Title/Abstract])
 OR (““breathing exercise””[Title/Abstract] OR ““breath therapy””[Title/Abstract]
 OR (““Diaphragm””[Title/Abstract] OR ““inspiratory muscle training””[Title/
 Abstract]”,185,343”,09:11:56
 11, Inspiratory muscle training [Title/Abstract],““inspiratory muscle
 training””[Title/Abstract]”,765,09:11:11
 10,Diaphragm[Title/Abstract],““Diaphragm””[Title/Abstract]”,29,284”,09:11:03
 9, Breath therapy [Title/Abstract],““breath therapy””[Title/Abstract]”,9,09:10:57
 8, Breathing exercise [Title/Abstract],““breathing exercise””[Title/Abstract]”,297,
 09:10:49
 7, Respiratory resistance exercise [Title/Abstract],““Respiratory””[All Fields]
 AND ““resistance exercise””[Title/Abstract]”,143,09:10:34
 6, osteopathic [Title/Abstract],““osteopathic””[Title/Abstract]”,3,441”,09:10:22
 5, Manipulation [Title/Abstract],““Manipulation””[Title/Abstract]”,99,465”,09:
 10:14
 4, Mobilization [Title/Abstract],““Mobilization””[Title/Abstract]”,53,504”,09:
 10:06

3, #1 OR #2, "chronic low back pain" [Title/Abstract] OR "low back pain" [Title/Abstract]" , "29,122", 09:09:49

2, Low back pain [Title/Abstract], "low back pain" [Title/Abstract]" , "29,122", 09:09:34

1, Chronic low-back pain [Title/Abstract], "chronic low back pain" [Title/Abstract]" , "6,925", 09:09:19

