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Human Kinetics
META-ANALYSIS

The Efficiency of Respiratory Exercises in Rehabilitation of Low Back Pain: A Systematic Review and Meta-Analysis

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Background: Low back pain (LBP) is a common musculoskeletal disorder, and respiratory exercise is considered a nonsurgical management method. Therefore, this systematic review and meta-analysis aims to estimate the results of randomized controlled trials on the effect of respiratory training in reducing LBP and its dose relationship. ***Methods:*** The present study was conducted from January 2020 to January 2022, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (2020). Relevant studies were searched in multiple databases including PubMed, Web of Science, the Cochrane Library, EBSCO, Scopus, ScienceDirect, Wan Fang and China Knowledge Network, ClinicalTrials.gov, and Google Scholar, using a combination of MeSH/Emtree terms and free-text words. The heterogeneity of the studies was assessed using the I^2 statistic. ***Results:*** A total of 14 publications were included in the meta-analysis, with a total sample size of 698 individuals, aged 60–80 years. Respiratory exercise was effective in relieving LBP (standardized mean difference = −0.87, $P < .00001$) and improving physical disability (standardized mean difference = −0.79, $P < .00001$). The type of breathing and the total duration of breathing exercises were found to be the source of heterogeneity in this study by subgroup analysis. Subgroup analysis revealed that the most significant effect sizes of breathing resistance exercise to reduce LBP and the most significant effect sizes of breathing relaxation techniques to alleviate physical disability were performed 3 to 5 times per week and period >4 weeks. Respiratory exercise reducing LBP and improving functional disability was most effective when the total duration of the intervention was >500 minutes. Funnel plots showed that the results of the 2 overall studies were reliable without publication bias. ***Conclusions:*** Respiratory exercise can effectively reduce LBP and improve physical disability. Therefore, these exercises can be regarded as a part of a LBP management plan. We recommend an exercise program with 30 to 50 minutes, 3 to 5 times per week, and >4 weeks of breathing resistance exercise program as the most effective for treating LBP.

Keywords: breathing exercise, respiratory resistance, functional disability, health management

Low back pain (LBP) is a representative musculoskeletal disorder that is defined by the location of the pain, typically between the low border of the rib cage and the gluteal groove.[1] LBP can be confined solely or can radiate to the buttocks or low-extremities, usually presenting as soreness, swelling, or tingling.[2] Patients are unable to sit for long periods, and the pain decreases with standing or activity, but worsens with more walking or standing for too long.[3] More than 80% of people will experience LBP at least once in their lifetime, and the specific cause of most LBP cannot be identified and is, therefore defined as nonspecific LBP (NLBP), of which about 15% is from chronic LBP,[4] and is distributed across different age groups.[5–7] Significantly, LBP is a prevalent health concern not only among the general population, but also among athletes, and sports enthusiasts.[8,9] This condition can restrict their physical abilities and daily routines, ultimately affecting their overall quality of life. Athletes who engage in intense training and participate in contact and combative sports are particularly vulnerable to experiencing back pain due to the increased strain on their lower backs.[10,11] Consequently, this not only hampers their athletic performance but can also result in training disruptions and even absence from competitions, thereby significantly impacting their professional careers.

Lower back pain can occur when the muscles in this area weaken or experience chronic stress.[12] This issue is not limited to the general population; it is particularly relevant for athletes and those actively involved in sports.[13] Chronic LBP often arises due to structural and histomorphological changes in the lumbar muscles. Muscle fiber weakening and atrophy are more common in the muscles that stabilize the lower back.[14] Furthermore, muscle pain can result in reduced muscle strength and stiffness in ligaments and joints, leading to decreased mobility.[15,16] This not only affects daily activities but also impacts athletic performance. Therefore, it is crucial for everyone to focus on preventing muscle weakness, maintaining the mechanical integrity of trunk muscles, and ensuring trunk stability. Breathing exercises play a significant role in achieving these goals. They help relax overworked muscles, restore normal breathing patterns, and improve respiratory muscle function.[17–19] Additionally, these exercises increase intra-abdominal pressure, which is essential for enhancing lumbar stability. As a result, they offer significant benefits for both the general public and athletes.

Currently, nonpharmacological treatments for LBP include acupuncture, massage, yoga, and cognitive functional therapy.[20–23] In recent years, respiratory exercises have gained popularity as a form of exercise therapy not only for the rehabilitation of respiratory diseases but also for the treatment of acute and chronic LBP in both the general public and athletes.[24,25] The methods of respiratory exercise mainly consist of abdominal breathing, resistance breathing, and breathing relaxation techniques.[26] However, previous reviews have not fully considered the diagnostic triage categories for chronic LBP, and some potentially relevant trials were excluded.[24] It is important for clinicians to understand how

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different types of breathing exercises impact pain and functional disability in order to assist the general public, active individuals, and athletes. Given the inconsistent results from these studies, conducting a systematic review and meta-analysis to assess the combined effect of these findings is crucial. Therefore, this systematic review and meta-analysis aim to compile and summarize the results of randomized controlled trials (RCTs) on the effectiveness of respiratory exercises in reducing LBP and explore the dose–response relationship. The findings of this study will provide valuable insights and guidance for the health management of the general public, active individuals, and athletes.

Methods

Data Sources and Searches

Articles were searched from January 2000 to June 2023. A systematic literature review was conducted in the Persian databases of SID (https://www.sid.ir) and MagIran (https://www.magiran.com) and the databases of Embase, PubMed, Scopus, ScienceDirect, Wan Fang and China Knowledge Network databases, ClinicalTrials.gov, and Web of Science to identify relevant publications. The searches included the combinations of the following MeSH for PubMed/Emtree for Embase and free-text words: "Respiratory Exercises," "Breathing exercise," "Breath therapy," "Diaphragm training," "Inspiratory muscle training," "Respiratory resistance," "Breathing training," "Respiratory training," "Low back pain," "Lumbar instability," and "Chronic low back pain." We included publications in English and Chinese. To enhance the comprehensiveness of the search, we also conducted a search on the Google Scholar search engine. In addition to reviewing the references of all included articles, we also manually reviewed the studies that cited the included articles. For example, the PubMed search strategy was defined as follows: (((((((("Respiratory Exercises"[Title/Abstract]) OR ("Breathing exercise"[Title/Abstract])) OR ("Breath therapy"[Title/Abstract])) OR (Diaphragm training [Title/Abstract])) OR ("Inspiratory muscle training"[Title/Abstract])) OR ("Respiratory resistance"[Title/Abstract])) OR ("Breathing training"[Title/Abstract])) OR ("Respiratory training"[MeSH Terms])) AND (((("Low back pain"[Title/Abstract]) OR ("Lumbar instability"[Title/Abstract])) OR ("Back Pain"[MeSH Terms])) OR ("Chronic low back pain"[MeSH Terms])). The retrieved literature from each database was imported into EndNote X 9 (Clarivate Analytics) for further primary screening and inclusion according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 guidelines for systematic reviews and meta-analysis. Prior to search, a review protocol was completed and registered at PROSPERO (CRD42023493894).

Inclusion Criteria

The inclusion criteria for this study included original scientific research articles that focused on randomized controlled trials (RCTs). In these trials, the control group received routine lower back pain treatments, while the intervention group received routine lower back pain treatments along with respiratory exercises. Additionally, only studies that provided access to the full text of the article were considered. The main objective of these studies was to examine the effect of respiratory exercises on reducing the intensity of lower back pain. Finally, the studies needed to have adequate data, specifically reporting the mean (standard deviation) of lower back pain intensity before and after the intervention in both the intervention and control groups, see Table 1.

Table 1 Inclusion Criteria

Design	Randomized Trials
Population	Low back pain
Intervention	Respiratory exercises
Outcomes	Degree of lower back pain (QVAS or NRS) Functional disability (ODI or RMQ)
Comparison	Control group (stabilization exercise, physical therapy, traditional exercise, and other types of exercise), pre-exercise, and postexercise

Abbreviations: NRS, Numerical Rating Scale; ODI, Oswestry Disability Index; QVAS, Quadruple Visual Analog Scale; RMQ, Roland–Morris questionnaire.

Exclusion Criteria

The exclusion criteria included the non-RCTs; samples comprised of people with any serious primary diseases, such as heart, brain, kidney, liver, and hematopoietic diseases, psychiatric diseases, and serious skin diseases; samples with disc herniation; unhealed spinal fractures; ankylosing spondylitis, with nerve involvement, or previous history of spinal surgery; nonapplication of respiratory exercises; literature not in Chinese or English; age under 18 years old or over 55 years old; literature that is not available in full text and not accessible by other means; outcomes assessed in this study not included the degree of pain and functional dysfunction; lack of sufficient data (failure to report mean [standard deviation] of LBP intensity before and after intervention in both case and control groups); and lack of control group.

Literature Data Extraction

All articles obtained from various databases were imported into EndNote X9 software. After eliminating duplicates, the titles and abstracts of the studies were thoroughly screened by 2 authors (Zhai and Xia). The full text of the remaining articles was carefully assessed by Zhai and Xia to remove studies that did not meet the inclusion criteria. Finally, a quality assessment was conducted for all studies included in the systematic review and meta-analysis. The relevant indicators for the final included study literature were extracted and entered by Zhai and Xia. Entries were made for: author and publication date, sample size, gender, age, intervention content, and intervention protocol (exercise duration, weekly exercise frequency, and exercise cycle). Using an independent double-blind approach to exclude irrelevant studies. Disagreements were resolved through centralized discussion. The data selection and extraction process conducted from May 10, 2023 to May 25, 2023.

Literature Quality Assessment

Fourteen papers were assessed for quality using the Cochrane risk of bias assessment.[27] Seven items were assessed: random assignment method (1), allocation protocol concealment (2), subject and investigator blinding (3), assessor blinding (4), outcome data completeness (5), selective reporting of study results (6), and other biases (7). Each article was scored with "yes," "no," and "unclear," with "yes" being scored as 1 and "unclear" or "unclear" as 2. The score of "yes" was 1, and "unclear" or "no" was 0. A total score of <3 is considered low-quality literature, 3-4 is considered medium-quality literature, and 5 or more is considered high-quality literature.

Data Synthesis and Analysis

Meta-analysis was performed using Review Manager (version 5.3, Cochrane Collaboration). In this study, a continuous variable was used, and mean and SD before and after the intervention in both intervention and control groups were used to combine the results of different studies. Standardized mean difference (SMD) was used as the effect size because of the differences in the rating scales between studies, which led to a large difference in the means of the outcome indicators. According to Cohen's interpretation, $SMD < 0.2$ is a small effect size, $0.2 \le SMD < 0.5$ is a small effect size, $0.5 \le SMD < 0.8$ is a medium effect size, and ≥ 0.8 is a large effect size. I^2 was used to determine the magnitude of heterogeneity between studies, using a fixed effects model if $I^2 < 50\%$ and a random variables model if $I^2 \ge 50\%$.[28] Subgroup analysis was performed to find sources of heterogeneity. Publication bias was tested using funnel plots.

Results

Literature Search Results

2061 publications were obtained by searching various databases and other means, and 837 remained after removing duplicates, duplicate records, and records removed for other reasons. According to the inclusion and exclusion criteria, 262 articles were obtained after the initial screening of the literature that was obviously incompatible by reading the text title and abstract, and 43 articles remained by excluding the review literature, non-RCTs, nonhuman experimental literature and reading the full text, excluding incomplete data, poor quality literature and inconsistent literature on outcome indicators, a total of 11 articles were included after identifying new studies through databases and registers, 2 articles were selected from previous studies, 1 article was obtained through other methods. Fourteen articles were finally included in the Systematic Review and Meta-analysis, followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 flow diagram, see Figure 1.

Basic Information on the Inclusion of the literature

A total of 14 RCTs were included in the meta-analysis through strict inclusion and exclusion criteria.[25,29–40] Basic information on the inclusion of the literature can be found in Table 2. Subjects were aged 20–60 years, with a total sample size of 698. Subjects involved the general population, athletes. Respiratory exercise involved abdominal breathing, respiratory resistance, respiratory combined with core stability exercises, respiratory combined with trunk stability exercises, and respiratory combined with core strength exercises. Exercise range time 10 to 60 minutes per session, exercise range frequency: 2 to 6 times per week, exercise period: 2 to 8 weeks.

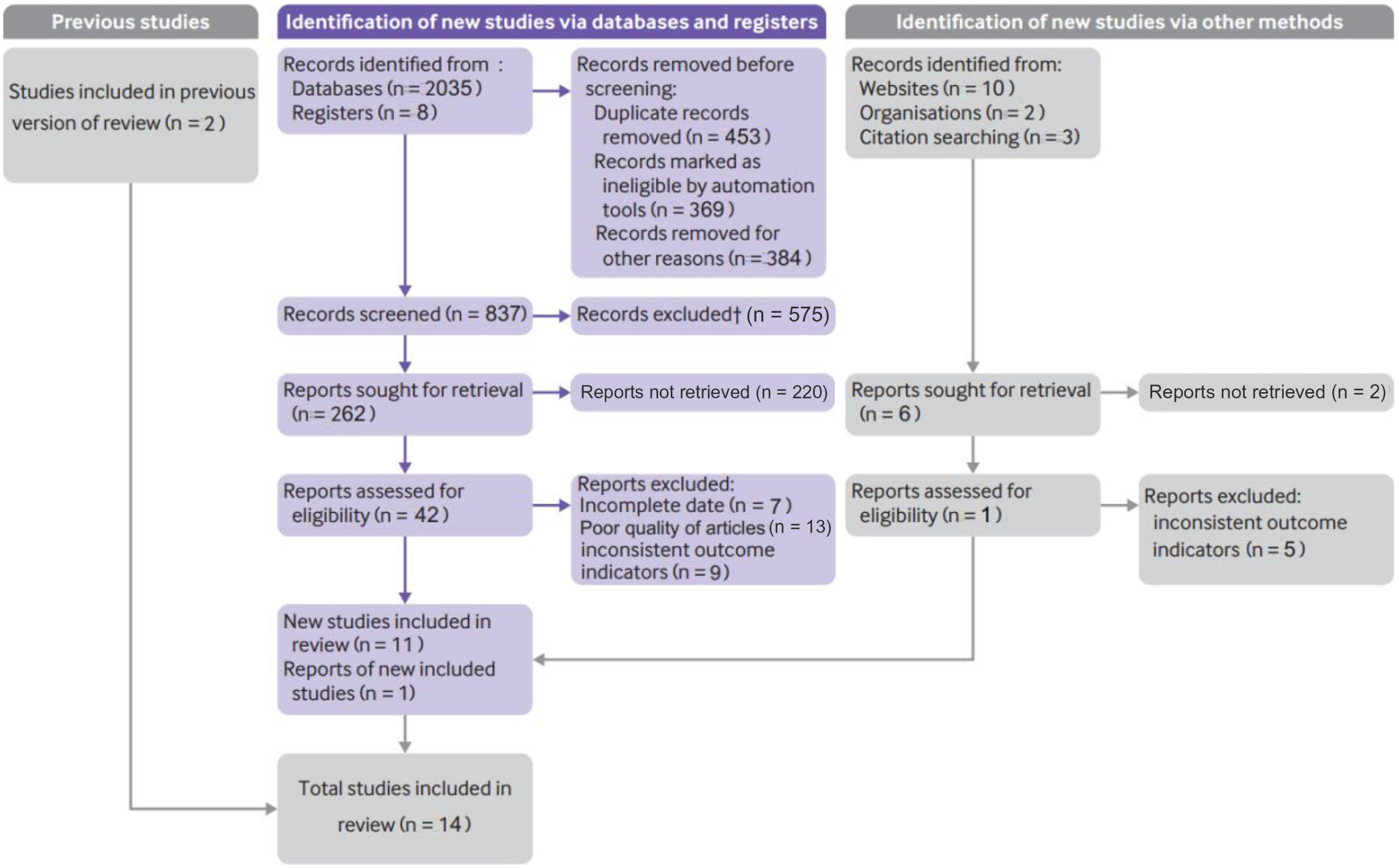


Figure 1 — Flow diagram of study selection.

Table 2 Basic Characteristics of Included Studies

Author, y	Populations	Sample EG/CG	Age	Sex	Interventions	Dose–response	Outcome
Youn et al,[40] 2020	GP	22/22	EG: 46.14 (2.5) CG: 44.4 (2.5)	NA	EG: Abdominal draw-in lumbar stabilization exercises + respiratory resistance exercise CG: Abdominal draw-in lumbar stabilization exercises	40 min, 3 times/wk, 4 wk	QVAS, ODI
Park et al,[37] 2022	GP	15/14	EG: 31.07 (6.82) CG: 30.29 (5.34)	NA	EG: Stabilization exercise program + respiratory resistance CG: Stabilization exercise	60 min, 3 times/wk, 5 wk	QVAS, RMQ
Park and Lee,[36] 2019	GP	20/23	EG: 30.9 (4.53) CG: 30.70 (6.32)	NA	EG: Progressive lumbar stabilization exercises + respiratory resistance CG: Progressive lumbar stabilization exercises	40 min, 3 times/wk, 4 wk	NRS, ODI
Khadijeh et al,[25] 2021	AP	12/12	EG: 36.2 (8.9) CG: 34.2 (10.8)	12 women, 12 men	EG: Diaphragm exercise + transcutaneous electrical nerve stimulation CG: Transcutaneous electrical nerve stimulation	12 sessions, 4 wk	NRS
Janssens et al,[33] 2015	GP	14/14	EG: 32 (9) CG: 33 (7)	18 women, 10 men	EG: High-intensity inspiratory muscle exercise CG: Low-intensity inspiratory muscle exercise	8 wk	NRS
Ahmadnezhad et al,[34] 2020	AP	23/24	EG: 21.43 (2.15) CG: 22.33 (1.41)	EG:12 male, 12 female CG:12 male, 12 female	EG: Inspiratory muscle exercise + traditional exercise CG: Traditional training	30 min, 7 times/wk, 8 wk	QVAS
Mireia,[35] 2018	GP	33/33	EG: 43.4 (10.8) CG: 41.7 (10.3)	EG:16 male, 17 female CG:13 male, 20 female	EG: Including specific diaphragm techniques CG: Sham-diaphragm intervention	20 min, 5 times/wk, 4 wk	QVAS, ODI
Mehling et al,[38] 2005	GP	16/12	EG: 49.7 (12.1) CG: 48.7 (12.5)	NA	EG: Breath therapy vs physical therapy CG: Physical therapy	20 – 30 min, 2 times/wk, 6 – 8 wk	QVAS
Atilgan and Tuncer,[29] 2021	MP	23/20	EG: 32.08 (7.15) CG: 37.7 (5.80)	NA	EG: Breathing exercises with core stabilization exercises CG: Core stabilization exercises	3 times/wk, 8 wk	QVAS
Zhang and Zang,[41] 2019	GP	33/33	EG: 39.43 (3.65) CG: 40.18 (4.01)	EG:18 male, 15 female CG:20 male, 13 female	EG: Breathing exercises with core stabilization exercises CG: Core stabilization exercises	10 min, 5 times/wk, 4 wk	QVAS, RMQ
Fan et al,[30] 2018	GP	30/30	EG: 40.87 (9.56) CG: 38.53 (11.19)	EG:17 male, 13 female CG:15 male, 15 female	EG: Breathing exercises with core stabilization exercises CG: Core stabilization exercises	20 min, 5 times/wk, 4 wk	QVAS, ODI
Fei et al,[31] 2018	GP	13/14	EG: 25.69 (4.44) CG: 25.78 (5.39)	EG:5 male, 8 female CG:5 male, 9 female	EG: Breathing exercises with sling exercise training CG: Sling exercise training	30⊠40 min, 3times/wk, 8 wk	QVAS, ODI
Guo et al,[32] 2020	GP	70/70	EG: 31 (6) CG: 30 (6)	140 male	EG: Breathing exercises with core exercises CG: Core exercises	40 min, 4 times/wk, 4 wk	QVAS, ODI
Ye et al,[39] 2021	GP	25/28	EG: 40.31 (7.59) CG: 38.98 (8.27)	EG:10 male, 15 female CG:15 male, 13 female	EG: Expiratory training CG: Expiratory training + routine rehabilitation	30 min, 5 times/wk, 4 wk	QVAS, ODI

Abbreviations: AP, athlete populations; CG, control group; EG, experimental group; GP, general population; MP, mothers of children with special health care needs; NRS, Numerical Rating Scale; ODI, Oswestry Disability Index; QVAS, Quadruple Visual Analog Scale; RMQ, Roland–Morris questionnaire.

Literature Quality Evaluation Results

All 14 papers included in this study were RCTs; 6 were randomized by number, lottery, or district group (low risk), and the remaining 8 did not mention how the randomized sequence was generated (unclear); none of the 14 mentioned allocation concealment (unclear); 14 did not specify assessor blinding (unclear); 6 papers had complete data results (low risk), and 8 had incomplete data results (high risk); and 14 had no selective reporting and no other bias (low risk). Four of the included studies were of high-quality and 10 of medium-quality literature are shown in Table 3, and the bias results for each study are shown in Figures 2 and 3.

Results

Testing the Effect of Breathing Training on Pain Degree in Patients With LBP

The outcomes in the included articles used the Quadruple Visual Analog Scale (QVAS) and Numerical Rating Scale (NRS) to assess the effect of BT on pain degree in patients with LBP. QVAS and NRS are commonly used single-dimensional measurements of pain intensity in clinical settings. These tools are used to assess the level of pain experienced by patients, monitor changes in pain over time, and compare pain levels before and after treatment. The QVAS involves drawing a 10 cm horizontal line on a piece of paper, where the 0 mm end represents "complete absence of pain" and the 10 mm end represents "pain to the extreme." The degree of pain is measured by marking a point on the line, with higher scores indicating more severe pain. On the other hand, the NRS is a scale consisting of 11 numbers ranging from 0 to 10, which allows individuals to describe their pain level in a stepwise and increasing manner. The overall effect test was performed on the 13 included RCTs with a total of 558 subjects, see Figure 4. The results showed an effect size SMD = –0.87, (95% CI, –1.18 to –0.56; $Z = 5.53$; $P < .00001$), indicating that LBP could be effectively reduced by breathing exercises. Heterogeneity testing of the included studies ($I^2 = 66\%$; $P < .0005$) indicated moderate heterogeneity among studies. Therefore, a random effects model was used.

Table 3 Literature Quality Evaluation Form of Cochrane

	A	B	C	D	E	F	G	Total scores
Atilgan and Tuncer,[29] 2021	1	0	0	0	0	1	1	3
Fan et al,[30] 2018	1	1	0	0	1	1	1	5
Fei et al,[31] 2018	1	1	0	0	1	1	1	5
Guo et al,[32] 2020	1	1	0	0	1	1	1	5
Janssens et al,[33] 2015	1	0	0	0	0	1	1	3
Ahmadnezhad et al,[34] 2020	1	0	0	0	0	1	1	3
Mireia,[35] 2018	1	0	0	0	1	1	1	4
Khadijeh et al,[25] 2021	1	0	0	0	0	1	1	3
Park and Lee,[36] 2019	1	0	0	0	0	1	1	3
Park et al,[37] 2022	1	0	0	0	0	1	1	3
Mehling et al,[38] 2005	1	1	0	0	0	1	1	4
Ye et al,[39] 2021	1	1	0	0	0	1	1	4
Youn et al,[40] 2020	1	0	0	0	1	1	1	4
Zhang and Zang,[41] 2019	1	1	0	0	1	1	1	5

Testing the Effect of BT on Function in Disability Patients With LBP

The outcomes in the included articles used the Oswestry Disability Index (ODI) and Roland–Morris questionnaire (RMQ) to assess the effect of BT on function in disability patients with LBP. ODI and RMQ scales were utilized to evaluate dysfunction in patients with LBP. The ODI scale comprises of 10 items, with each item having a minimum score of 0 and a maximum score of 5. A higher score on this scale indicates a more severe degree of dysfunction. The ODI was calculated by summing the scores of all 10 items, resulting in a maximum score of 50. A higher ODI score indicates a greater level of disability. On the other hand, the RMQ scale consists of 24 items, with each question being assigned 1 point. A "yes" response is also assigned 1 point, while a "no" response is assigned 0 points. The final score on the RMQ scale is the sum of the selected items, ranging from 0 to 24. Higher scores on the RMQ scale indicate a higher level of dysfunction. The overall effect test was performed on the 10 included RCTs with a total of 594 subjects, see Figure 5. The results showed an effect size SMD = –0.79, (95% CI, –1.09 to –0.50; $Z = 5.27$; $P < .00001$), indicating that the mobility function of patients with LBP could be improved by breathing exercises. Heterogeneity testing of the included studies ($I^2 = 62\%$ $P < .00001$) indicated moderate heterogeneity among studies. Therefore, a random effects model was used.

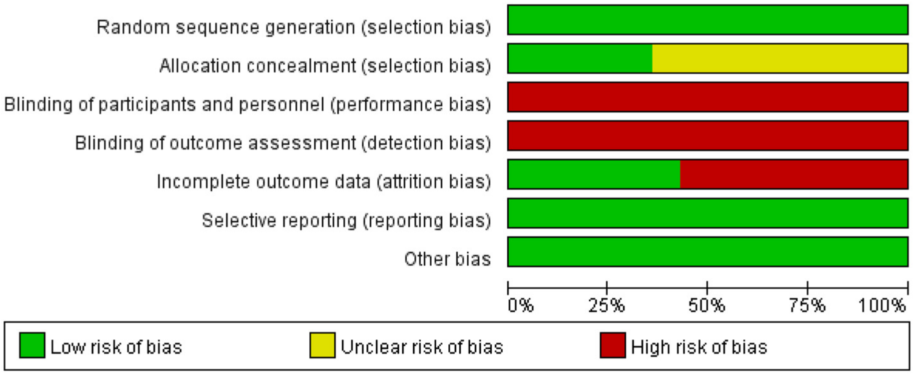
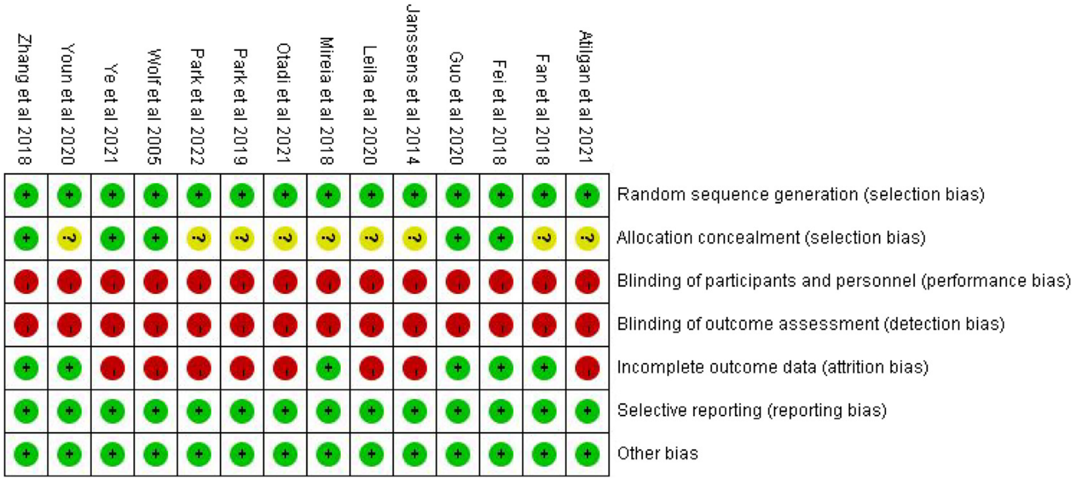
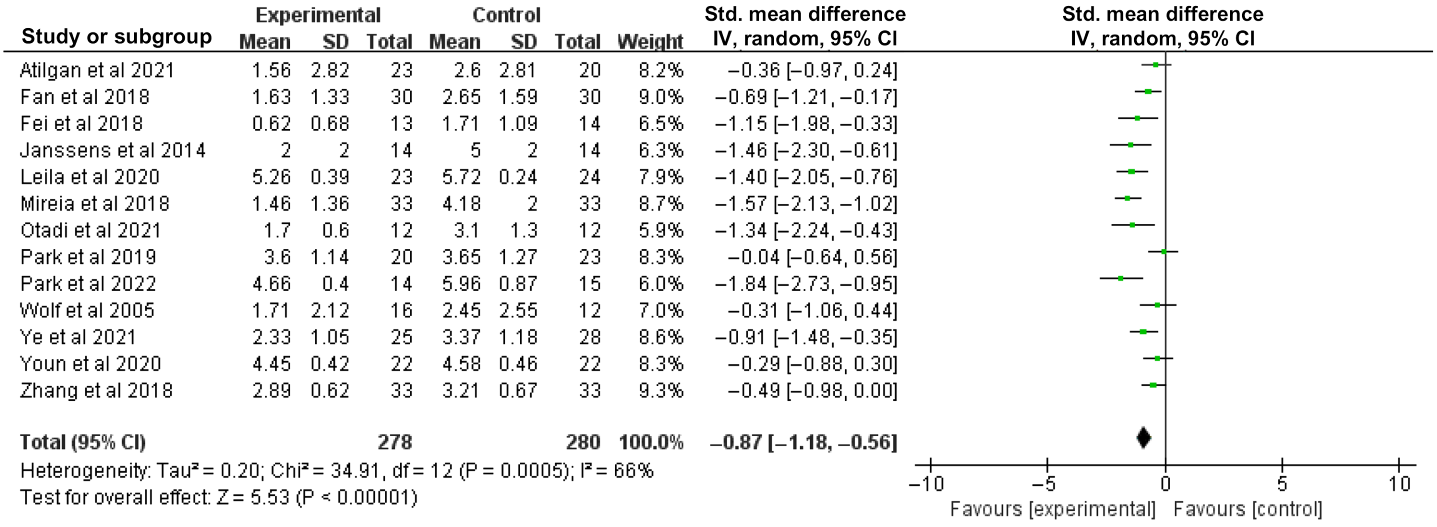


Figure 2 — Diagram of the included literature with quality assessment.



	Zhang et al 2018	Youn et al 2020	Ye et al 2021	Wolf et al 2005	Park et al 2022	Park et al 2019	Otadi et al 2021	Mireia et al 2018	Leila et al 2020	Janssens et al 2014	Guo et al 2020	Fei et al 2018	Fan et al 2018	Atilgan et al 2021
Random sequence generation (selection bias)	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Allocation concealment (selection bias)	+	?	+	+	?	?	?	?	?	?	+	+	?	?
Blinding of participants and personnel (performance bias)	−	−	−	−	−	−	−	−	−	−	−	−	−	−
Blinding of outcome assessment (detection bias)	−	−	−	−	−	−	−	−	−	−	−	−	−	−
Incomplete outcome data (attrition bias)	+	+	−	−	−	−	−	+	−	−	+	+	+	−
Selective reporting (reporting bias)	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Other bias	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Figure 3 — Summary diagram of the included literature with quality assessment.

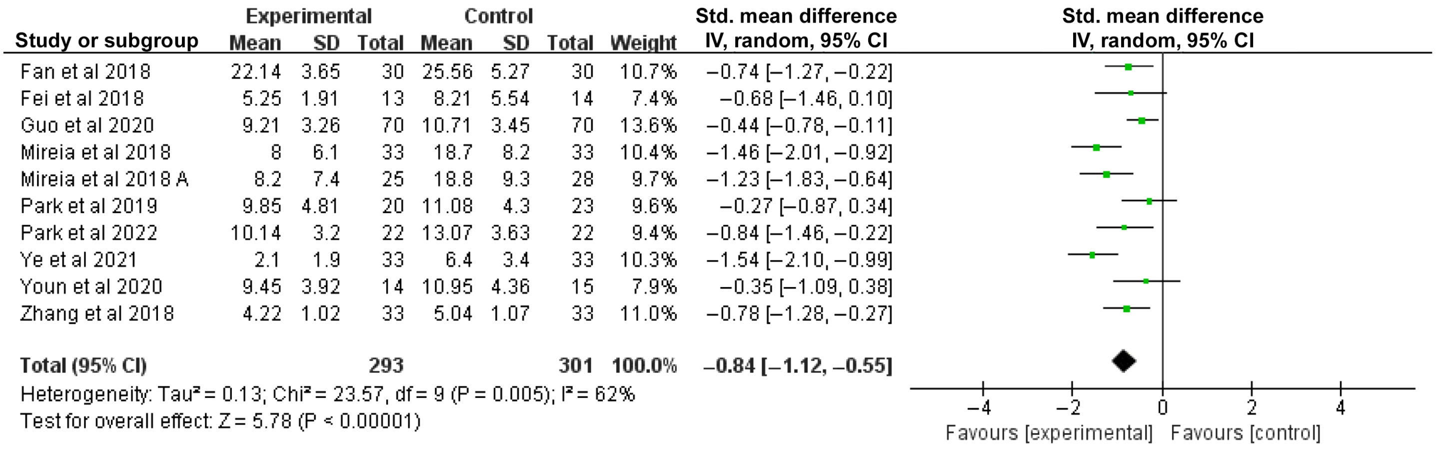


Study or subgroup	Experimental			Control			Weight	Std. mean difference IV, random, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Atilgan et al 2021	1.56	2.82	23	2.6	2.81	20	8.2%	−0.36 [−0.97, 0.24]
Fan et al 2018	1.63	1.33	30	2.65	1.59	30	9.0%	−0.69 [−1.21, −0.17]
Fei et al 2018	0.62	0.68	13	1.71	1.09	14	6.5%	−1.15 [−1.98, −0.33]
Janssens et al 2014	2	2	14	5	2	14	6.3%	−1.46 [−2.30, −0.61]
Leila et al 2020	5.26	0.39	23	5.72	0.24	24	7.9%	−1.40 [−2.05, −0.76]
Mireia et al 2018	1.46	1.36	33	4.18	2	33	8.7%	−1.57 [−2.13, −1.02]
Otadi et al 2021	1.7	0.6	12	3.1	1.3	12	5.9%	−1.34 [−2.24, −0.43]
Park et al 2019	3.6	1.14	20	3.65	1.27	23	8.3%	−0.04 [−0.64, 0.56]
Park et al 2022	4.66	0.4	14	5.96	0.87	15	6.0%	−1.84 [−2.73, −0.95]
Wolf et al 2005	1.71	2.12	16	2.45	2.55	12	7.0%	−0.31 [−1.06, 0.44]
Ye et al 2021	2.33	1.05	25	3.37	1.18	28	8.6%	−0.91 [−1.48, −0.35]
Youn et al 2020	4.45	0.42	22	4.58	0.46	22	8.3%	−0.29 [−0.88, 0.30]
Zhang et al 2018	2.89	0.62	33	3.21	0.67	33	9.3%	−0.49 [−0.98, 0.00]
Total (95% CI)			**278**			**280**	**100.0%**	**−0.87 [−1.18, −0.56]**

Heterogeneity: Tau² = 0.20; Chi² = 34.91, df = 12 (P = 0.0005); I² = 66%

Test for overall effect: Z = 5.53 (P < 0.00001)

Figure 4 — Respiratory exercise on the degree of lower back pain: meta-analysis.



Study or subgroup	Experimental			Control			Weight	Std. mean difference IV, random, 95% CI
	Mean	SD	Total	Mean	SD	Total		
Fan et al 2018	22.14	3.65	30	25.56	5.27	30	10.7%	−0.74 [−1.27, −0.22]
Fei et al 2018	5.25	1.91	13	8.21	5.54	14	7.4%	−0.68 [−1.46, 0.10]
Guo et al 2020	9.21	3.26	70	10.71	3.45	70	13.6%	−0.44 [−0.78, −0.11]
Mireia et al 2018	8	6.1	33	18.7	8.2	33	10.4%	−1.46 [−2.01, −0.92]
Mireia et al 2018 A	8.2	7.4	25	18.8	9.3	28	9.7%	−1.23 [−1.83, −0.64]
Park et al 2019	9.85	4.81	20	11.08	4.3	23	9.6%	−0.27 [−0.87, 0.34]
Park et al 2022	10.14	3.2	22	13.07	3.63	22	9.4%	−0.84 [−1.46, −0.22]
Ye et al 2021	2.1	1.9	33	6.4	3.4	33	10.3%	−1.54 [−2.10, −0.99]
Youn et al 2020	9.45	3.92	14	10.95	4.36	15	7.9%	−0.35 [−1.09, 0.38]
Zhang et al 2018	4.22	1.02	33	5.04	1.07	33	11.0%	−0.78 [−1.28, −0.27]
Total (95% CI)			**293**			**301**	**100.0%**	**−0.84 [−1.12, −0.55]**

Heterogeneity: Tau² = 0.13; Chi² = 23.57, df = 9 (P = 0.005); I² = 62%

Test for overall effect: Z = 5.78 (P < 0.00001)

Figure 5 — Breathing exercise on Oswestry Disability Index of low back pain: meta-analysis.

Subgroup Analysis Results

Subgroup Analysis of Breathing Exercises on Pain Degree in Patients With LBP

Subject population: a subgroup analysis was performed on 13 included papers with a total of 558 subjects, see Table 4. The results showed moderate heterogeneity among the 3 groups ($I^2 = 66\%$). Since there was only one study in the mothers of children with special health care needs group, the effect sizes were not representative, and the effect sizes in both the athlete and general population groups were statistically significant ($P < .01$), indicating that breathing exercises were effective in relieving pain degree in different subject populations. There was a significant difference in the effect sizes between the 3 groups ($P < .00001$).

Type of respiration: subgroup analysis was performed on the 13 included papers with a total of 558 subjects, see Table 4. The results showed moderate heterogeneity among the 3 groups ($I^2 = 61\%$). The effect sizes for the breathing combined with core exercises group, the breathing resistance group, and the breathing relaxation technique group were all statistically significant ($P < .0001$; $P = .007$; $P = .008$), indicating that different types of breathing relieved pain degree in patients with LBP. There was a significant difference in the amount of effect between the 3 groups ($P < .00001$). The effect size was most significant in the respiratory resistance group SMD = –0.96 (95% CI, –1.66 to –0.27; $Z = 2.71$; $P = .007$).

Total duration of intervention: a subgroup analysis was performed on 13 included papers with a total of 558 subjects, see Table 4. The results showed moderate heterogeneity between the 2 groups ($I^2 = 66\%$) and homogeneity within both groups ($I^2 = 0$), indicating that the total duration of the intervention was the source of heterogeneity. The effect sizes within both groups were statistically significant ($P = .001$; $P < .00001$), suggesting that breathing exercises with >2 weeks of intervention and a total duration of >200 minutes can reduce the pain level of LBP. There was a significant difference in the amount of effect between the 2 groups ($P < .00001$). The >500 minutes group had the most significant effect size SMD = −1.35 (95% CI,–1.61 to −1.08; $Z = 9.91$; $P < .00001$), indicating that breathing exercises performed 3 to 5 times per week for at least 4 weeks with a total intervention duration >500 minutes were effective in reducing LBP.

Outcome indicators: subgroup analysis was performed on 13 included papers with a total of 558 subjects, see Table 4. The results showed moderate heterogeneity between the 2 groups ($I^2 = 66\%$), with statistically significant intra-group effect sizes in the QVAS group ($P < .00001$) and not in the NRS group ($P = .07$). This indicates that QVAS as an outcome indicator better reflects the effect of breathing exercise on the relief of LBP. There was a significant difference in the between-group effect size ($P < .00001$).

Subgroup Analysis of Breathing Exercises on Functional Disability in Patients With LBP

Respiratory type

A subgroup analysis was performed on the 10 included papers with a total of 541 subjects (Table 5). The results showed moderate heterogeneity between the 3 groups ($I^2 = 62\%$) and homogeneity within all 3 groups ($I^2 = 0$), indicating that breathing type was the source of heterogeneity. The effect sizes for the breathing combined with the core exercises group, the breathing resistance group, and the breathing relaxation group were all statistically significant ($P < .00001$; $P = .009$; $P < .00001$), indicating that different types of breathing improved disability in patients with LBP. There was a significant difference in the amount of effect between the 3 groups ($P < .0001$). The effect size was most significant in the respiratory relaxation group SMD = −1.42 (95% CI, −1.75 to −1.10; $Z = 8.57$; $P < .0001$).

Total duration of intervention

Total duration of intervention: Ten included papers with a total of 541 subjects were analyzed in subgroups, and the total duration of the intervention was divided into a 200 to 500 minutes group and a >500 minutes group (Table 5). The results showed that the effect sizes within both groups were statistically significant ($P = .0003$; $P < .0001$), indicating that breathing exercises with >2 weeks of intervention and a total duration of >200 minutes improved functional disability in patients with LBP. There was no significant difference in effect size between the 2 groups ($P = .54$). The >500 minutes group had the most significant effect size SMD = –0.84 (95% CI,–1.39 to –0.49; $Z = 4.08$; $P < .0001$), indicating that breathing exercises performed 3 to 5 times per week for at least 4 weeks with a total duration of intervention >500 minutes are more effective in improving physical function in patients with LBP.

Table 4 Results of Subgroup Analysis on the Degree of Low Back Pain

Subgroup	Heterogeneity test			Group	Effect size and 95% CI	Two-tailed test		Numbers of studies	Sample size
		I^2	P			Z	P		
		19	.29	Breathing + core	–0.69 (–1.00 to –0.38)	4.34	<.0001	5	220
Respiratory type	61	80	.0005	Respiratory resistance	–0.96 (–1.66 to –0.27)	2.71	.007	5	191
		55	.11	Breathing and relaxation	–0.90 (–1.42 to –0.37)	3.34	.008	3	147
Duration	66	0	.72	≤500 min	–0.39 (–0.63 to –0.16)	3.25	.001	6	284
		0	.63	>500	–1.35 (–1.61 to –1.08)	9.91	<.00001	7	274
		0	.9	Athlete	–1.38 (–1.90 to –0.86)	5.16	<.00001	2	71
Person type	66	68	.0009	General	–0.83 (–1.19 to –0.48)	4.57	<.00001	10	444
		NA	NA	Mothers	–0.36 (–0.97 to 0.24)	1.18	.24	1	43
Outcome	66	79	.008	NRS	–0.90 (–1.88 to 0.08)	1.8	.07	3	95
		64	.003	QVAS	–0.87 (–1.20 to –0.54)	5.19	<.00001	10	463

Abbreviations: NRS, Numerical Rating Scale; QVAS, Quadruple Visual Analog Scale.

Outcome indicators

Ten included papers with a total of 541 subjects were analyzed in subgroups, and the outcome indicators were divided into RMQ and ODI groups (Table 5). The results showed moderate heterogeneity between the 2 groups ($I^2 = 62\%$) and statistically significant within-group effect sizes in both groups ($P < .00001$; $P < .00001$). This indicates that both the ODI and RMQ can be used as an assessment of functional disability in patients with LBP. There was a significant difference in effect size between groups ($P < .00001$).

Publication Bias Test

Meta-analysis funnel plots of the effects of interventions on pain degree and low back disability in LBP through breathing exercises showed that most of the scatter distributions were skewed upward and symmetrical to each other, indicating that there was no significant publication bias between studies and that the findings were reliable, see Figure 6.

Discussion

Analysis of the Effect of Respiratory Exercises on Pain Degree and Physical Function in Patients With LBP

Chronic lower back pain is a prevalent musculoskeletal pain syndrome among the general population, affecting approximately 60% to 80% of individuals at some point in their lives. Sports enthusiasts and athletes face an even higher risk of experiencing chronic lower back pain. This condition presents significant challenges to their regular training and competitive activities, and in severe cases, it may even force them to prematurely end their sports careers.[42] While previous recommendations for the treatment of LBP included health education, analgesic medication, or bed rest, modern philosophy prefers to keep patients active and actively involved in treatment to prevent recurrence of LBP.[43] Most scholars believe that patients with NLBP have varying degrees of restricted core recruitment, as evidenced by reduced lumbar stability and poor core strength, which may be the main pathogenesis of NLBP. However, in the past, core strength training has mainly targeted the outer muscles of the lumbar and abdominal walls, without paying attention to the role of the diaphragm in maintaining trunk stability, especially for postural control. The diaphragm has a stable function in addition to its respiratory function, and activating both functions simultaneously is one of the key factors in the maintenance of core stability, some studies have shown that diaphragmatic dysfunction increases the risk of LBP.[44] Ahmadnezhad et al[34] suggest that Inspiratory Muscle Training can increase the activity of the local trunk muscles and enhance respiratory function in athletes with chronic low back pain, thereby reducing the pain intensity in these individuals and enhancing their functional activities. Improving deep lumbar and abdominal muscle strength should be achieved through a

Table 5 Results of Subgroup Analysis on ODI of Low Back Pain

	Heterogeneity test					Two-tailed test			
Subgroup		I^2 (%)	P	Group	Effect size and 95% CI	Z	P	Numbers	Sample size
		0	.65	Breathing + core	−0.60 (−0.83 to −0.36)	5.0	<.00001	4	293
Respiratory type	62	0	.39	Respiratory resistance	−0.50 (−0.87 to −0.12)	2.61	.009	3	116
		0	.74	Breathing and relaxation	−1.42 (−1.75 to −1.10)	8.57	<.00001	3	132
Duration	62	60	.04	≤500 min	−0.75 (−1.15 to −0.34)	3.58	.0003	5	264
		70	.01	>500	−0.94 (−1.39 to −0.49)	4.08	<.0001	5	277
Outcome	62	65	.005	ODI	−0.92 (−1.25 to −0.58)	5.35	<.00001	8	432
		38	.20	RMQ	−0.55 (−1.05 to −0.05)	2.17	<.00001	2	109

Abbreviations: ODI, Oswestry Disability Index; RMQ, Roland–Morris questionnaire.

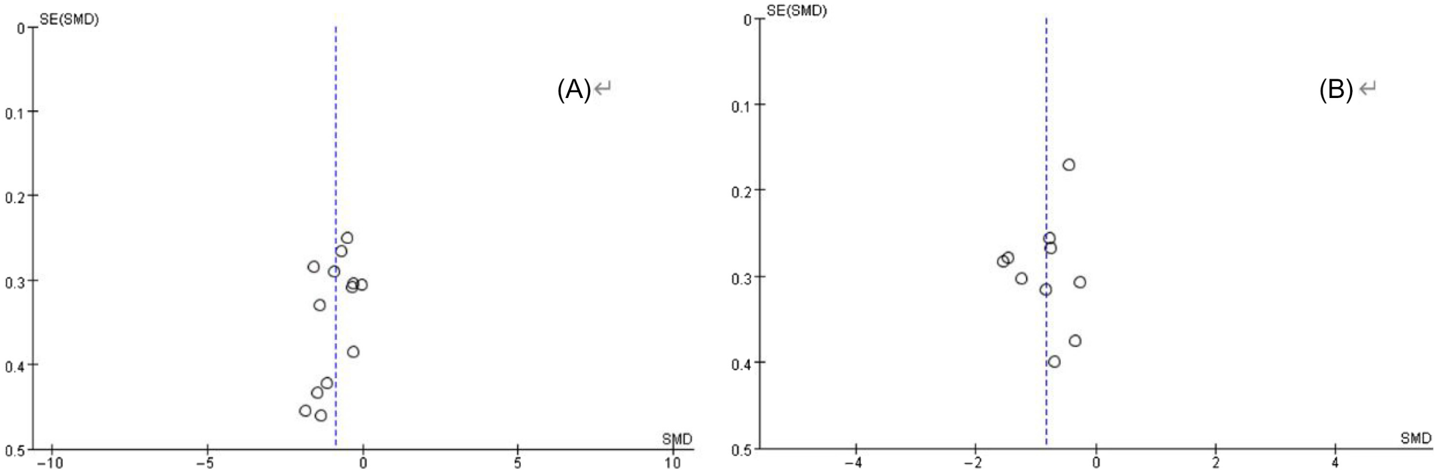


Figure 6 — Funnel plots of pain degree (A) and Oswestry Disability (B). SMD indicates standardized mean difference.

combination of respiratory and stabilization training, rather than just core stabilization training alone. Guo et al[32] pointed out that submarine officers live and work in a small space, are sedentary, perform long voyage missions, are confined to a small space for a long time, and maintain the same posture for a long time, resulting in the posture of the spine not being corrected in a timely manner, resulting in a decrease in the coordinated movement ability of the trunk muscle groups and a decrease in spinal stability, which leads to the recurrence of LBP that is difficult to cured. The treatment of chronic nonspecific LBP in submarine officers and soldiers through core strength and breathing exercises has a good therapeutic effect. Wong et al[45] suggested that diaphragmatic and respiratory dysfunction is closely associated with chronic LBP and that there are adverse effects of respiratory muscle fatigue and breathing abnormalities on postural stability. The deep lumbar and abdominal muscles are trained using a combination of stabilizing exercises and respiratory exercise, not just stabilizing exercises. Breathing exercises activate the diaphragm and its associated core muscles, close the functional anatomical connection between the diaphragm and the spine, and establish an appropriate intra-abdominal pressure, thus stabilizing the lumbar spine, while also improving the blood supply to the associated muscles, enhancing proprioceptive sensitivity of the back, and achieving good proprioceptive use. In addition, some studies have found that breathing exercise is also beneficial to the body's cardiovascular and nervous system, not only by increasing the output of healthy hearts but also by reducing blood pressure and left ventricular afterload, promoting venous return, reducing the sensitivity of the chemical reflex, enhancing the central inhibitory rhythm, and reducing sympathetic nerve activity.[24] Current research confirms that through breathing exercise, the abdominal muscles are made to alternate between relaxation and tension, which can contract and stretch the capillaries within the muscles, speed up local blood circulation, increase the supply of oxygen, and promote the discharge of metabolites from the body, thus adjusting the tissues within the organism.[46] In addition, breathing exercises can enhance lung compliance and target the problem of hyperventilation caused by shallow and rapid breathing due to pain, which can effectively improve the anxiety symptoms caused by pain, provide good prerequisites for the body to relax, and reduce stress and promote pain relief.[47] This meta-analysis was conducted to explore the therapeutic effect of breathing exercise in patients with LBP. The results were statistically significant ($P < .05$) in terms of improvement in QVAS and ODI scores compared with the control group. This indicates that LBP ($\text{SMD} = -0.87$, $P < .00001$) and physical functional capacity ($\text{SMD} = -0.79$, $P < .00001$) can be relieved by breathing exercises. For athletes or sports enthusiasts, it is recommended that sports therapists, rehabilitation nurses, physicians, and trainers incorporate these simple and easy-to-perform exercises into their pretraining routine. This can help improve respiratory function, enhance core stability, and reduce pain intensity, ultimately leading to increased training efficiency.

Subgroup Analysis of Breathing Exercises on Moderating Variables in Patients With LBP

Studies showed that this type of breathing may be a moderating variable affecting the level of pain in patients with LBP from breathing exercise, with the variables presenting a better intervention effect for breathing resistance than for breathing combined with core exercises and breathing techniques. The 4 studies that included respiratory resistance focused on training with assistive devices during inhalation or breathing. Respiratory exercise methods varied, including Janssens et al[33] and Ahmadnezhad et al[34] enhancing inspiratory muscle strength by using the Power-Breathe KH1 device (HaB Direct), performing resistance breathing exercises and measuring maximal inspiratory pressure. Park and Lee[36] and Young et al[40] used a resolution reading device (Expand-a-Lung), which is composed of a silicon south piece and a valve that controls differentiation, the respiration-resisting device controls the utilization amount during inflation, and results in resistance of air—ow for respiratory muscle strengthening. The control group of the 4 studies carried out traditional core strength training, mainly through strength training for the core muscles of the waist and buttocks, such as transverse abdominis, gluteus, latissimus dorsi muscle, and multifidus, to improve the ability to control trunk posture and stabilize the core muscles by improving the movement and sensory stimulation of core muscles. The experimental group performed respiratory resistance exercises on this basis. In contrast to natural breathing with core exercises, the use of this assisted device allowed for the full activation of the muscles involved in breathing with each breath. This type of breathing resistance exercise differs from abdominal and thoracic breathing in which the diaphragm is only pushed downward from the posterior side, but promotes the movement of the diaphragm in a 3-dimensional direction. Edwards et al[48] concluded that diaphragmatic breathing exercise makes full use of the abdominal muscles and diaphragm, reduces the movement of muscles such as the sternocleidomastoid and oblique muscles, and low energy consumption produces greater exercise efficiency. Patients in the experimental group used core muscle training combined with respiratory exercise to make the diaphragm, pelvic floor muscles, and transverse abdominal muscles work together for abdominal pressure regulation, thus contributing to the restoration of lumbosacral stability, reducing the pressure on the lumbar region, and relieving painful conditions. Yildirim and Sahin[49] investigated the mechanism of respiratory resistance combined with core training to improve NLBP symptoms in terms of inflammatory mechanisms, and their study showed that serum inflammatory factor degree was significantly lower after treatment than before treatment, reflecting that respiratory resistance combined with core strength exercises improved local blood and lymphatic circulation and promoted the dissipation of inflammatory substances to improve pain symptoms. The experimental group in this study showed significant improvement in QVAS and ODI scores after treatment ($P < .05$), which also confirmed its reliable efficacy. These findings provide valuable insights for sports rehabilitation professionals, helping them to develop more effective treatment strategies, especially for those who frequently participate in sports activities.

Noteworthy, the breathing technique was shown to have a large effect size ($\text{SMD} = -0.90$, $P = .0008$) in terms of pain relief in the low back, in addition to improving physical function ($\text{SMD} = -1.42$, $P < .00001$). Previous studies have demonstrated that engaging in a single core exercise can effectively alleviate LBP and enhance physical function in athletes.[50] However, it is important to note that during acute episodes of NLBP, patients often experience intense pain, making it challenging for them to actively engage in treatment. At this point, breathing techniques are easier to perform, softer, safer, and more reliable than other exercise therapies, making them more accessible to patients with high pain indices, and providing better pain relief, and improved low back function. Mireia[35] used osteopathic manipulative treatment that includes diaphragm techniques, and this breathing technique is widely used to relieve musculoskeletal pain originating in the skeletal system, soft tissues, and nervous system, providing significant and clinically relevant improvements in pain and disability in patients with NLBP. The traditional Chinese breathing technique known as "Liu Zi Jue" (6 Healing Sounds) has been found to have unique value in the field of sports rehabilitation, particularly in improving core stability of the lumbar spine in athletes. In a study conducted by Ye et al,[39] it was observed that the "Liu Zi Jue" breathing technique and lumbar spine core stability training are closely connected and can complement each other. This technique involves reverse abdominal breathing, which not only expands the lower thoracic cavity and improves ventilation, but also activates the multifidus and rectus abdominis muscles through movements such as abdominal suction, abdominal tension, and anterior pelvic tilt. As a result, it improves perception control and stability of the spine. Furthermore, this breathing method enhances lumbar stability and ventilation function, and has a beneficial effect on regulating the autonomic nervous system, leading to physical and mental relaxation. Another study by Kang et al[51] utilized a biofeedback system to train participants to maintain a specific pressure level by bending their knees at a 90° hip flexion. Breathing techniques were used to increase the pressure, followed by rapid abdominal muscle contraction to maintain it. The aim of this method was to help participants feel the expansion of the trunk muscles while maintaining relaxed breathing. The study showed that regardless of the specific breathing technique used, activating the respiratory muscles to maintain lumbar stability can effectively alleviate pain and enhance lumbar mobility, which is significant for the rehabilitation of athletes and sports enthusiasts.

The study showed that the total duration of the respiratory exercise intervention may be a moderating variable affecting the degree of pain and physical function in patients with LBP, and the variables showed that the total duration of the respiratory exercise intervention >500 minutes was superior to the intervention effect of ≤500 minutes. The total duration of respiratory exercise >500 minutes showed large effect sizes in terms of pain relief ($\text{SMD} = -1.35$, $P < .00001$) and improvement in physical function ($\text{SMD} = -0.94$, $P < .0001$). Noteworthy, the number of weeks of the intervention included in the study was >4 weeks for both the total intervention length >500 minutes group and the ≤500 minutes group. However, there were differences in the number of sessions per week and the duration of each exercise. Although different types of respiratory exercise modalities were effective in the treatment of LBP, the exact training dose could not be known for the same type of respiratory exercise because the intensity of the load could not be determined; and in the studies included in the total duration of respiratory exercise >500 minutes group, Park et al[37] achieved good results in patients with 60 minutes per session, 3 times per week, for a period 5 weeks of respiratory resistance combined with core stabilization training; and Ahmadnezhad et al[34] subjected 23 athletes with LBP to an intervention program of 30 minutes per session, 7 times per week, for a total of 8 weeks to significantly improve the subjects' low back disability. In a study by Fei et al,[31] suspension training combined with respiratory exercise for 30 to 40 minutes per session, 3 times per week, for a total of 8 weeks, in an experimental group of 13 subjects reduced pain degree and functional disability in patients with nonspecific LBP. Therefore, this study recommends a range of loading doses for respiratory exercise arrangement: 30 to 50 minutes per session, 3 to 5 times per week during at least 4 weeks. Although only 2 studies involving athletes were included in the literature, our study examined the mechanism of chronic LBP and found that this training program is suitable for both athletes and individuals who regularly participate in sports activities. Our findings demonstrate that the prescribed dose of respiratory training effectively treats LBP and enhances the rehabilitation efficiency and quality of life for these individuals.

Our research findings suggest that the selection of participants plays a significant role in the level of pain reduction and physical function improvement in patients with LBP. Specifically, our data indicate that breathing exercises are particularly effective in alleviating LBP in athletes, compared with other demographic groups. However, it is important to note that our analysis is based on a limited data set, comprising only 2 studies focusing on athlete groups and a single study involving mothers. This limitation highlights the need for further research with a larger sample size to validate our initial findings. To strengthen these findings, future studies should aim to include a wider range of athletes, allowing for a more comprehensive evaluation of the differential effects of breathing exercises on LBP in diverse populations. In this study, a subgroup analysis of outcome indicators was performed, and there was no statistical significance in the NRS group regarding the degree of pain ($P = .07$), which may be related to the number of included literature, with only 3 studies with NRS as an outcome indicator, and a large number of future studies are needed to validate the validity of NRS as an assessment of the degree of pain. In terms of functional disability, statistical significance existed within both the ODI and RMQ groups ($P < .05$), but the number of publications on RMQ was only 2. Therefore, the results of the outcome indicator as a moderating variable also need to be interpreted with caution.

Research Limitations and Future Prospects

There are some limitations of this study. First, in order to enhance the rigor of this study, some of the less common outcome indicator studies responding to pain indices or disability indices were excluded, resulting in an insufficient number of studies included in the literature. In addition, there existed literature in which the same author included 2 articles, which may somewhat increase risk bias. Second, the age of the included individuals was too broad, and there may be differences in the mechanisms of LBP in different age states. Third, the difficulty of exercise content and intervals may also be moderating variables, but most of the 2 studies did not mention, and therefore, this study failed to conduct more subgroup analysis to explore their effects.

Future Applications

Based on a meta-analysis of 14 RCTs, this paper found that breathing exercises were effective in reducing pain scores and improving patient-related functional disability in patients with NLBP. A variety of treatment options are available for patients with NLBP. Regardless of the treatment, the goal of treatment is to address the pain and improve physical function. Not only can respiratory exercise be used at any point in treatment, studies have also shown that it is effective in combination with conventional training, physical therapy, and other treatments, as well as in the ability to resolve disability after the disease. Our study emphasizes the significance of incorporating respiratory training in exercise rehabilitation and presents compelling evidence for clinicians to enhance their decision-making process while treating patients with NLBP. Subsequent studies should delve deeper into the application of breathing training in various athlete populations, soldiers, and physically active individuals, as well as investigate its role in long-term rehabilitation.

Conclusions

1. Breathing exercises can effectively reduce LBP and improve physical disability.
2. A exercise program with 30 to 50 minutes per session, 3 to 5 times per week, and >4 weeks of breathing resistance exercise program is more effective in the treatment of LBP.

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