(ISSN: 0973-7049(P))

The Bioscan AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES 21(2): S.I (2), 21908-21917, 2026 www.thebioscan.com

Clinical Changes Following Diaphragmatic Breathing Retraining Added to Conventional Physiotherapy in Mechanical Low Back Pain: A Single-Group Prospective Study With 9-Month Follow-up

[1]Khushi Vishwakarma, [2]Dr. Jafar Khan, [3]Dr. Rahat Khan Warsi, [4]Dr. K. M. Annamali, [5]Dr Reshma Khurana, [6]Dr. Renuka Pal, [7]Dr. Vaishnavi Jayant Kania, [8]Dr. Prashant Kumar Ramawat, [9]Dr Hasnen Sheikh, [10]Ashwani Kumar

[*1]M.P.Th. scholar, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan

[2]Dean & HOD, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan

[3]Assistant Professor, Department of Pharmacology, Pacific Medical College and Hospital, Pacific medical university, Udaipur, Rajasthan

[4]Consultant Senior Physiotherapist & Director Physio Alliance Apollo Hospital, Ahmedabad, Gujarat, India

[5]Principal, Index Department of Physiotherapy and Paramedical Sciences, Malwanchal university, Indore

[6]Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan

[7]Assistant Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan

[8]Assistant Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan

[9]Assistant Professor, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan

[10]M.P.Th. scholar, Pacific college of Physiotherapy, Pacific medical university, Udaipur, Rajasthan

Corresponding author: Khushi Vishwakarma | Email: vishwakarma.eddy@gmail.com

DOI:https://doi.org/10.63001/tbs.2026.v21.i02.S.I(2).pp21908-21917

KEYWORDS

mechanical low back pain; diaphragmatic breathing; core stability; Numeric Pain Rating Scale; Modified Oswestry Disability Index; pressure biofeedback; physiotherapy

Article Info

Received: 29.05.2026

Accepted: 17.06.2026

Published: 27.06.2026

Abstract

Background: Mechanical low back pain is commonly accompanied by impaired lumbopelvic control. The diaphragm contributes to respiration and postural stabilization through coordinated regulation of intra-abdominal pressure. This study examined changes in pain, disability, and core stability after diaphragmatic breathing retraining was added to conventional physiotherapy.

Methods: A single-group prospective quasi-experimental study enrolled 30 adults aged 20-45 years with mechanical low back pain of more than 3 weeks' duration from a physiotherapy outpatient department in Udaipur, India. Participants received supervised diaphragmatic breathing retraining plus conventional physiotherapy four times weekly for 6 weeks. Outcomes were the Numeric Pain Rating Scale (NPRS), Modified Oswestry Disability Index (MODI), and a Pressure Biofeedback Unit (PBU)-derived core stability performance score, recorded at baseline, 6 weeks, and 9 months. Source master-chart data were independently re-entered. Repeated outcomes were analysed using Friedman tests with Kendall's W and exact Wilcoxon signed-rank tests with Holm adjustment.

Results: The mean age was 33.33 +/- 7.25 years and 15 participants (50.0%) were women. Mean NPRS scores declined from 6.50 +/- 1.04 at baseline to 3.50 +/- 1.04 at 6 weeks and 1.50 +/- 1.04 at 9 months. Mean MODI scores decreased from 43.70 +/- 7.32 to 25.70 +/- 7.32 and 15.70 +/- 7.32, respectively. Mean PBU-derived scores increased from 4.00 +/- 0.79 to 7.00 +/- 0.79 and 9.00 +/- 0.79. Time effects were significant for all outcomes (Friedman chi-square=60.0, df=2, p<0.001; Kendall's W=1.00), and every pairwise comparison remained significant after multiplicity adjustment (p<0.001). From baseline to 9 months, pain decreased by 76.9%, disability by 64.1%, and the PBU-derived score increased by 125.0%.

Conclusion: The combined rehabilitation programme was associated with large and sustained within-group improvements in pain, disability, and PBU-derived core stability. Because the study lacked a comparator and included co-intervention with conventional physiotherapy, the independent effect of diaphragmatic breathing retraining cannot be isolated. A randomized controlled trial with standardized treatment dosage and blinded assessment is warranted.

1. Introduction

Low back pain is the leading cause of disability worldwide and affected an estimated 619 million people in 2020; the number of affected individuals is projected to rise substantially by 2050 [1]. Contemporary guidance emphasizes person-centred, non-surgical care, including structured education, exercise, and multicomponent rehabilitation [2]. Mechanical or non-specific low back pain represents the majority of clinical presentations and commonly restricts movement, work participation, and daily activities [2,3].

The persistence and recurrence of mechanical low back pain cannot be explained by local tissue changes alone. Altered motor control, reduced endurance of local stabilizing muscles, fear-related movement patterns, and impaired coordination between active, passive, and neural subsystems may contribute to recurrent symptoms [3,4]. The deep stabilizing system includes the transversus abdominis, multifidus, pelvic floor, and diaphragm. Their coordinated activity supports intersegmental control and contributes to regulation of intra-abdominal pressure.

Although the diaphragm is primarily a respiratory muscle, experimental work has shown that it is activated during postural tasks [5]. Dynamic magnetic resonance imaging has further demonstrated its stabilizing behaviour during limb loading [6], while patients with chronic low back pain may show reduced diaphragm excursion and altered diaphragm position during postural challenges [7]. Greater diaphragm fatigability has also been observed in individuals with recurrent low back pain [8]. These findings provide a physiological rationale for incorporating breathing control into lumbopelvic rehabilitation.

Reviews published in recent years suggest that attention to breathing mechanics may augment core stabilization programmes [9-11]. Clinical trials have reported improvements in pain, disability, muscle activation, balance, and diaphragm-related measures when breathing or diaphragm training is added to stabilization exercise [12-15]. Nevertheless, intervention protocols, outcome measures, treatment doses, and follow-up periods remain heterogeneous. Evidence from longer follow-up periods is particularly limited.

The present study therefore examined changes in pain intensity, functional disability, and PBU-derived core stability after a 6-week programme of diaphragmatic breathing retraining combined with conventional physiotherapy in adults with mechanical low back pain. The study also evaluated whether observed changes were maintained at a 9-month follow-up. Because all participants received both components, the research question concerns the combined programme rather than the isolated efficacy of diaphragmatic breathing retraining.

2. Materials and Methods

2.1 Study design and setting

This was a single-group prospective quasi-experimental study with repeated measurements at baseline, immediately after a 6-week intervention, and 9 months after completion of the supervised programme. The study was conducted in the Physiotherapy Outpatient Department of Pacific Medical College and Hospital, Udaipur, Rajasthan, India.

2.2 Participants and sampling

Participants were recruited through purposive sampling from patients attending the outpatient department with a clinical diagnosis of mechanical low back pain. Adults aged 20-45 years with symptoms lasting more than 3 weeks, the ability to understand verbal instructions, and willingness to provide written informed consent were eligible. Exclusion criteria were neurological deficits such as sciatica or clinically diagnosed disc prolapse, recent spinal or abdominal surgery, cardiopulmonary disorders that limited exercise performance, and pregnancy.

The thesis reported a final sample of 30 participants based on feasibility. All 30 records in the master chart contained outcome data at baseline, 6 weeks, and 9 months; therefore, the manuscript analysis used complete cases without imputation.

2.3 Intervention

All participants received diaphragmatic breathing retraining in addition to conventional physiotherapy. Treatment was delivered four sessions per week for 6 consecutive weeks, with each session lasting approximately 20-30 minutes. Diaphragmatic breathing was initially taught in crook lying. One hand was placed over the upper chest and the other over the abdomen. Participants inhaled slowly through the nose while allowing abdominal expansion with minimal upper-chest movement, followed by controlled expiration through pursed lips.

Once the breathing pattern was performed correctly, training progressed to sitting and standing and was integrated with bridging and controlled limb movements. Conventional physiotherapy comprised stretching, strengthening, postural correction, and other routine interventions considered appropriate for mechanical low back pain. The source thesis did not provide a fully replicable exercise-by-exercise dosage schedule for the conventional physiotherapy component; this is acknowledged as a reporting limitation.

2.4 Outcome measures

Pain intensity was assessed using the 11-point Numeric Pain Rating Scale, ranging from 0 (no pain) to 10 (worst imaginable pain). A reduction of approximately 2 points is commonly considered to exceed measurement error and represent clinically meaningful improvement in patients with low back pain [21].

Functional disability was assessed using the Modified Oswestry Disability Index. Ten domains were scored from 0 to 5 and converted to a percentage, with higher scores indicating greater disability. The Oswestry instrument is widely used in spinal disorders [19], and the modified version has demonstrated reliability and responsiveness in low back pain populations [20].

Core stability was assessed with a Pressure Biofeedback Unit placed under the lumbar lordosis during abdominal drawing-in and progressive dynamic tasks. The source protocol used a 40 mmHg starting pressure, monitored the ability to maintain pressure within a target range, and recorded successful controlled repetitions. The master chart expressed performance as a discrete 0-10 score, with higher scores indicating better lumbopelvic control. Pressure biofeedback can support clinical assessment of movement control, although it should not be interpreted as a direct measure of transversus abdominis activation or diaphragm function [22].

2.5 Data management and statistical analysis

Participant-level data were independently transcribed from the thesis master chart and checked against the displayed rows. Continuous variables are presented as mean +/- standard deviation and median [interquartile range], while categorical variables are presented as frequency and percentage. The source master chart showed discrete outcome values and uniform paired change scores; consequently, paired t tests and repeated-measures analysis of variance would yield unstable or degenerate variance estimates. Repeated outcomes were therefore analysed using the Friedman test. Kendall's W was calculated as an effect-size measure. Exact Wilcoxon signed-rank tests were used for pairwise comparisons, with Holm adjustment for three comparisons per outcome. Two-sided p values below 0.05 were considered statistically significant.

2.6 Ethical considerations

The thesis states that approval was obtained from the Institutional Ethics Committee of Pacific Medical University and that written informed consent was obtained from every participant. Participation was voluntary, confidentiality was maintained, and participants could withdraw without affecting routine care. The ethics approval identifier and approval date were not available in the source document and must be inserted before journal submission.

3. Results

3.1 Participant characteristics

Thirty participants were included in the analysis. The mean age was 33.33 +/- 7.25 years (range 20-45 years), and the mean body weight was 68.13 +/- 9.40 kg. The sample included 15 men and 15 women. Office workers were the largest occupational group (33.3%). Most participants had symptoms lasting 13-24 weeks (43.3%) or more than 24 weeks (40.0%).

Table 1. Baseline demographic and clinical characteristics (n=30)

Characteristic	Value, mean +/- SD or n (%)	Range
Age, years	33.33 +/- 7.25	20-45
Weight, kg	68.13 +/- 9.40	48-85
Female sex	15 (50.0)	
Male sex	15 (50.0)	
Age 20-29 years	10 (33.3)	
Age 30-39 years	14 (46.7)	
Age 40-45 years	6 (20.0)	
Office worker	10 (33.3)	
Teacher	5 (16.7)	
Homemaker	5 (16.7)	
Student	4 (13.3)	
Labourer	3 (10.0)	
Shopkeeper	3 (10.0)	
Symptom duration 4-12 weeks	5 (16.7)	
Symptom duration 13-24 weeks	13 (43.3)	
Symptom duration >24 weeks	12 (40.0)	

SD, standard deviation.

3.2 Changes in pain, disability, and core stability

All three outcomes changed significantly over time. Mean NPRS decreased by 3.00 points at 6 weeks and by 5.00 points at 9 months relative to baseline. Mean MODI decreased by 18.00 percentage points at 6 weeks and by 28.00 percentage points at 9 months. Mean PBU-derived core stability performance increased by 3.00 points at 6 weeks and by 5.00 points at 9 months.

Friedman tests produced the same omnibus statistic for each outcome (chi-square=60.0, df=2, $p<0.001$), with Kendall's W=1.00. Exact pairwise comparisons were significant for baseline versus 6 weeks, baseline versus 9 months, and 6 weeks versus 9 months for every outcome (Holm-adjusted $p<0.001$).

Table 2. Outcome trajectories across the three assessment points

(ISSN: 0973-7049(P))

The Bioscan 21(2): S.I (2), 21908-21917, 2026 www.thebioscan.com

Outcome	Baseline	6 weeks	9 months	Friedman chi-square	p value	Kendall W
NPRS (0-10)	6.50 +/- 1.04; 6.5 [6.0-7.0]	3.50 +/- 1.04; 3.5 [3.0-4.0]	1.50 +/- 1.04; 1.5 [1.0-2.0]	60.0	<0.001	1.00
MODI (%)	43.70 +/- 7.32; 43.5 [38.0-50.0]	25.70 +/- 7.32; 25.5 [20.0-32.0]	15.70 +/- 7.32; 15.5 [10.0-22.0]	60.0	<0.001	1.00
PBU-derived score	4.00 +/- 0.79; 4.0 [3.0-5.0]	7.00 +/- 0.79; 7.0 [6.0-8.0]	9.00 +/- 0.79; 9.0 [8.0-10.0]	60.0	<0.001	1.00

Values are mean +/- SD; median [IQR]. NPRS, Numeric Pain Rating Scale; MODI, Modified Oswestry Disability Index; PBU, Pressure Biofeedback Unit; IQR, interquartile range.

Table 3. Pairwise within-participant comparisons

Outcome	Comparison	Median change	Wilcoxon W	Holm-adjusted p
NPRS	Baseline vs 6 weeks	-3.00	0.0	<0.001
NPRS	Baseline vs 9 months	-5.00	0.0	<0.001
NPRS	6 weeks vs 9 months	-2.00	0.0	<0.001
MODI	Baseline vs 6 weeks	-18.00	0.0	<0.001
MODI	Baseline vs 9 months	-28.00	0.0	<0.001
MODI	6 weeks vs 9 months	-10.00	0.0	<0.001
PBU-derived score	Baseline vs 6 weeks	+3.00	0.0	<0.001
PBU-derived score	Baseline vs 9 months	+5.00	0.0	<0.001
PBU-derived score	6 weeks vs 9 months	+2.00	0.0	<0.001

Negative change denotes improvement for NPRS and MODI; positive change denotes improvement for the PBU-derived score. Exact two-sided Wilcoxon signed-rank tests were used.

3.3 Clinical category shifts

At baseline, 15 participants had moderate pain and 15 had severe pain. At 9 months, 6 participants reported no pain and 24 reported mild pain. Severe disability was present in 18 participants at baseline, whereas 21 participants were classified as having minimal disability at 9 months. All participants reached the 'good' PBU-derived performance category at 9 months under the category definitions used in the thesis.

Table 4. Distribution of clinical categories over time, n (%)

Measure	Category	Baseline	6 weeks	9 months
NPRS	No pain	0 (0.0)	0 (0.0)	6 (20.0)
NPRS	Mild	0 (0.0)	15 (50.0)	24 (80.0)
NPRS	Moderate	15 (50.0)	15 (50.0)	0 (0.0)
NPRS	Severe	15 (50.0)	0 (0.0)	0 (0.0)
MODI	Minimal disability	0 (0.0)	9 (30.0)	21 (70.0)
MODI	Moderate disability	12 (40.0)	21 (70.0)	9 (30.0)
MODI	Severe disability	18 (60.0)	0 (0.0)	0 (0.0)

The Bioscan 21(2): S.I (2), 21908-21917, 2026 www.thebioscan.com

PBU-derived	Poor	21 (70.0)	0 (0.0)	0 (0.0)
PBU-derived	Moderate	9 (30.0)	21 (70.0)	0 (0.0)
PBU-derived	Good	0 (0.0)	9 (30.0)	30 (100.0)

Categories followed the scoring interpretations used in the source thesis and master chart.

4. Discussion

This single-group study found large, progressive improvements in pain, functional disability, and PBU-derived lumbopelvic control after diaphragmatic breathing retraining was combined with conventional physiotherapy. Improvements were evident at the end of the supervised 6-week programme and were maintained, with further numerical gains, at the 9-month assessment. The mean 5-point reduction in NPRS exceeded the commonly cited 2-point threshold for meaningful change in low back pain [21]. The 28-percentage-point reduction in MODI was also substantially larger than conventional thresholds used to interpret clinically important disability change.

The findings are biologically plausible. The diaphragm has a dual respiratory and postural role. During limb loading, diaphragm activation can precede or accompany movement and contribute to trunk control [5,6]. Patients with chronic low back pain may demonstrate smaller diaphragm excursions during postural tasks [7] and greater susceptibility to diaphragm fatigue [8]. Retraining a coordinated abdominal breathing pattern may therefore improve the timing and integration of the diaphragm with the abdominal wall, pelvic floor, and spinal extensor system. It may also reduce unnecessary accessory-muscle activity and promote more efficient movement strategies during exercise.

The present results align with earlier controlled work. Finta et al. reported reduced pain and changes in diaphragm and lumbar stabilizer muscle thickness after diaphragm training [12]. Masroor et al. found that adding diaphragmatic breathing to core stabilization improved pain, disability, muscle activity, chest expansion, and sleep-related outcomes compared with core stabilization alone [13]. Yu et al. also observed benefits when breathing training was combined with core stability training [14]. Additional trials involving hypopressive abdominal training, respiratory resistance, and stabilization exercise have reported favourable changes in pain, function, and diaphragm-related measures [15-18,23]. Systematic reviews now suggest that breathing or diaphragmatic interventions can improve pain and disability, although evidence certainty and intervention consistency vary [9-11].

The 9-month pattern is clinically interesting but should be interpreted cautiously. Continued improvement after supervised treatment may reflect ongoing self-practice, greater physical activity, improved confidence, ergonomic changes, or natural symptom fluctuation. The source thesis did not document home-exercise adherence, additional treatment, medication use, adverse events, or occupational exposure during follow-up. Consequently, the long-term values cannot be attributed exclusively to the original intervention.

The PBU-derived outcome deserves particular caution. Pressure biofeedback is useful for monitoring lumbopelvic position during abdominal drawing-in, but its concurrent validity as a surrogate for selective transversus abdominis activation is limited [22]. The score used in the master chart represented successful performance across controlled tasks rather than a direct physiological measurement of

(ISSN: 0973-7049(P))

The Bioscan AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES 21(2): S.I (2), 21908-21917, 2026 www.thebioscan.com

diaphragm excursion, muscle thickness, or intra-abdominal pressure. Future studies should include ultrasound imaging, electromyography, respiratory pressure testing, or motion analysis alongside clinically feasible performance tests.

An important methodological contribution of the present manuscript is the independent participant-level reanalysis. The thesis summary tables and master chart were not fully concordant. The manuscript therefore used the participant-level values, reported corrected means and standard deviations, and selected non-parametric repeated-measures procedures because paired change scores were uniform. This improves internal numerical consistency, but the uniformity of changes also reinforces the need for source-data verification and independent statistical review before external submission.

4.1 Strengths

- The study evaluated multiple clinically relevant domains rather than pain alone.
- Every participant had recorded data at all three assessment points, including a relatively long 9-month follow-up.
- The intervention was low-cost, non-invasive, and feasible for routine physiotherapy settings.
- Participant-level reanalysis enabled internally consistent reporting and appropriate non-parametric inference.

4.2 Limitations

- The single-group design cannot distinguish treatment effects from natural recovery, regression to the mean, attention effects, or concurrent care.
- Diaphragmatic breathing was delivered with conventional physiotherapy, so the independent contribution of breathing retraining cannot be estimated.
- The sample was small, purposively selected, and drawn from one outpatient department, limiting generalizability.
- Treatment fidelity, assessor blinding, home-practice adherence, additional care, medication use, and adverse events were not systematically reported.
- The conventional physiotherapy component was not described with sufficient detail for exact replication.
- The PBU-derived score is a clinical performance indicator and not a direct measure of diaphragm function.
- Ethics approval identifiers and exact recruitment dates were absent from the source thesis.

5. Conclusion

A 6-week programme combining diaphragmatic breathing retraining with conventional physiotherapy was associated with substantial reductions in pain and disability and improved PBU-derived lumbopelvic control in adults with mechanical low back pain. These within-group changes were maintained at 9 months. The results support further investigation of breathing retraining as one component of multimodal rehabilitation, but they do not establish a causal or independent effect. A sufficiently powered randomized controlled trial with a standardized comparator, concealed allocation, blinded outcome assessment, treatment-fidelity monitoring, adherence tracking, adverse-event reporting, and objective diaphragm measurements is required.

Declarations

Ethics approval and consent to participate: Institutional Ethics Committee approval from Pacific Medical University and written informed consent from all participants.

Consent for publication: Not applicable for anonymized aggregate data. Confirm according to the target journal's policy.

Data availability: The participant-level master chart is contained in the source dissertation. Public sharing requires institutional and participant-consent review.

Funding: No dedicated research funding was specified in the source thesis. Authors must confirm the final funding statement before submission.

Conflict of interest: None

Acknowledgements: The author acknowledges the academic guidance and clinical support provided by the Pacific College of Physiotherapy and Pacific Medical College and Hospital, Udaipur.

References

1. GBD 2021 Low Back Pain Collaborators. Global, regional, and national burden of low back pain, 1990-2020, its attributable risk factors, and projections to 2050: a systematic analysis of the Global Burden of Disease Study 2021. Lancet Rheumatol. 2023;5(6):e316-e329. doi:10.1016/S2665-9913(23)00098-X.
2. World Health Organization. WHO guideline for non-surgical management of chronic primary low back pain in adults in primary and community care settings. Geneva: World Health Organization; 2023.
3. Foster NE, Anema JR, Cherkin D, Chou R, Cohen SP, Gross DP, et al. Prevention and treatment of low back pain: evidence, challenges, and promising directions. Lancet. 2018;391(10137):2368-2383. doi:10.1016/S0140-6736(18)30489-6.
4. Panjabi MM. A hypothesis of chronic back pain: ligament subfailure injuries lead to muscle control dysfunction. Eur Spine J. 2006;15(5):668-676. doi:10.1007/s00586-005-0925-3.
5. Hodges PW, Gandevia SC. Activation of the human diaphragm during a repetitive postural task. J Physiol. 2000;522(Pt 1):165-175. doi:10.1111/j.1469-7793.2000.t01-1-00165.xm.
6. Kolar P, Sulc J, Kyncl M, Sanda J, Neuwirth J, Bokarius AV, et al. Stabilizing function of the diaphragm: dynamic MRI and synchronized spirometric assessment. J Appl Physiol (1985). 2010;109(4):1064-1071. doi:10.1152/japplphysiol.01216.2009.
7. Kolar P, Sulc J, Kyncl M, Sanda J, Cakrt O, Andel R, et al. Postural function of the diaphragm in persons with and without chronic low back pain. J Orthop Sports Phys Ther. 2012;42(4):352-362. doi:10.2519/jospt.2012.3830.
8. Janssens L, Brumagne S, McConnell AK, Hermans G, Troosters T, Gayan-Ramirez G. Greater diaphragm fatigability in individuals with recurrent low back pain. Respir Physiol Neurobiol. 2013;188(2):119-123. doi:10.1016/j.resp.2013.05.028.
9. Sannasi R, Dakshinamurthy A, Dommerholt J, Desai V, Kumar A, Sugavanam T. Diaphragm and core stabilization exercises in low back pain: a narrative review. J Bodyw Mov Ther. 2023;36:221-227. doi:10.1016/j.jbmt.2023.07.008.
10. Jiang X, Sun W, Chen Q, Xu Q, Chen G, Bi H. Effects of breathing exercises on chronic

low back pain: a systematic review and meta-analysis of randomized controlled trials. J Back Musculoskelet Rehabil. 2024;37(1):13-23. doi:10.3233/BMR-230054.

11. Li H, Jia C, Yang Y, Wang J, Jin S. Diaphragmatic training for nonspecific low back pain: a systematic review and meta-analysis. Arch Phys Med Rehabil. 2026. Epub ahead of print. doi:10.1016/j.apmr.2026.03.001.

12. Finta R, Nagy E, Bender T. The effect of diaphragm training on lumbar stabilizer muscles: a new concept for improving segmental stability in the case of low back pain. J Pain Res. 2018;11:3031-3045. doi:10.2147/JPR.S181610.

13. Masroor S, Tanwar T, Aldabbas M, Iram I, Veqar Z. Effect of adding diaphragmatic breathing exercises to core stabilization exercises on pain, muscle activity, disability, and sleep quality in patients with chronic low back pain: a randomized controlled trial. J Chiropr Med. 2023;22(4):275-283. doi:10.1016/j.jcm.2023.07.001.

14. Yu D, Yu Y, Peng Q, Luo J, He X. Clinical efficacy of breathing training combined with core stability training in chronic nonspecific low back pain. Pak J Med Sci. 2023;39(4):1008-1012. doi:10.12669/pjms.39.4.6918.

15. Vicente-Campos D, Sanchez-Jorge S, Terron-Manrique P, Guisard M, Collin M, Castano B, et al. The main role of diaphragm muscle as a mechanism of hypopressive abdominal gymnastics to improve non-specific chronic low back pain: a randomized controlled trial. J Clin Med. 2021;10(21):4983. doi:10.3390/jcm10214983.

16. Dulger E, Bilgin S, Bulut E, Tufekci O, Toraman F. The effect of stabilization exercises on diaphragm muscle thickness and movement in women with low back pain. J Back Musculoskelet Rehabil. 2018;31(2):323-329.

17. Park SH, Lee MM. Effects of a progressive stabilization exercise program using respiratory resistance for patients with lumbar instability: a randomized controlled trial. Med Sci Monit. 2019;25:1740-1748. doi:10.12659/MSM.913036.

18. Oh YJ, Park SH, Lee MM. Comparison of effects of abdominal draw-in lumbar stabilization exercises with and without respiratory resistance on women with low back pain: a randomized controlled trial. Med Sci Monit. 2020;26:e921295. doi:10.12659/MSM.921295.

19. Fairbank JC, Pynsent PB. The Oswestry Disability Index. Spine (Phila Pa 1976). 2000;25(22):2940-2952. doi:10.1097/00007632-200011150-00017.

20. Fritz JM, Irrgang JJ. A comparison of a modified Oswestry Low Back Pain Disability Questionnaire and the Quebec Back Pain Disability Scale. Phys Ther. 2001;81(2):776-788.

21. Childs JD, Piva SR, Fritz JM. Responsiveness of the Numeric Pain Rating Scale in patients with low back pain. Spine (Phila Pa 1976). 2005;30(11):1331-1334.

22. Grooms DR, Grindstaff TL, Croy T, Hart JM, Saliba SA. Clinimetric analysis of pressure biofeedback and transversus abdominis function in individuals with stabilization classification low back pain. J Orthop Sports Phys Ther. 2013;43(3):184-193. doi:10.2519/jospt.2013.4397.

23. Kanli K, Yigitoglu PH, Ozgul A. Investigation of the effects of different

treatment approaches on lumbar stabilizer muscles and diaphragm motility in individuals with chronic low back pain. Turk J Phys Med Rehabil. 2024;70(3):358-369. doi:10.5606/tftrd.2024.13257.