International Journal of Sport Studies for Health

Journal Homepage

# Effects of a 14-Week Rehabilitation Program Based on a Customized Multimodal Protocol in Individuals with Chronic Non-Specific LBP

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A r t i c l e   I n f o

**Article type:**
*Original Research*

**How to cite this article:**
Ahanjan, S. (2026). Effects of a 14-Week Rehabilitation Program Based on a Customized Multimodal Protocol in Individuals with Chronic Non-Specific LBP. *International Journal of Sport Studies for Health*, *9*(2), 1-8.
http://dx.doi.org/10.61838/kman.intjssh.5071



A B S T R A C T

**Objective:** To evaluate the effectiveness of a 14-week multimodal rehabilitation program compared with flexion-based and extension-oriented exercise protocols on pain-related disability and lumbar range of motion in adults with chronic non-specific low back pain.

**Methods and Materials:** In a single-center, assessor-blinded, parallel-group randomized controlled trial, 180 adults with CLBP (≥4 months; 45–72 years) were allocated (n=60/group) to: (1) multimodal comprehensive program (specialized therapeutic exercise + aquatic movements + physiotherapy modalities + massage; 90–100 min/session, 3×/week), (2) flexion-based protocol (45–60 min/session, 3×/week), or (3) extension-oriented protocol (45–60 min/session, 3×/week). Outcomes were assessed at baseline, post-intervention, and 1-month follow-up. Primary outcome was disability/pain impact using the Quebec Back Pain Disability Scale (QBPDS). Lumbar range of motion (LROM) was measured via field tests (trunk flexion, lateral flexion right/left, and supine hip/knee flexion). Analyses used repeated-measures MANOVA/ANOVA (time×group), Tukey post-hoc tests, and paired t-tests (α≤0.05).

**Findings:** QBPDS improved within all groups (Group 1: t=15.705, p=0.001; Group 2: t=9.410, p=0.001; Group 3: t=6.930, p=0.001). Group 1 showed the greatest reduction (54.70→16.10; follow-up 21.20) versus Group 2 (53.12→29.12; follow-up 40.80) and Group 3 (55.70→31.70; follow-up 42.10), with between-group differences favoring Group 1 (Tukey p≤0.01). LROM improved significantly in Group 1 across all tests (e.g., trunk flexion t=7.771, p=0.001) and in Group 2 (all p=0.001), while Group 3 showed no trunk-flexion change (t=1.302, p=0.216). Gender effects were non-significant (p>0.05).

**Conclusion:** A 14-week customized multimodal rehabilitation program produced greater and more sustained improvements in disability/pain and lumbar mobility than either flexion-based or extension-oriented exercise alone in adults with chronic non-specific LBP.

**Keywords:** *Chronic non-specific low back pain; Multimodal rehabilitation; Aquatic therapy; Lumbar range of motion.*

Article history:
Received 13 February 2026
Revised 22 February 2026
Accepted 26 February 2026
Published online 27 February 2026

## 1. Introduction

Exercise therapy is strongly recommended for the management of chronic non-specific low back pain (CNSLBP). Despite advances in therapeutic options—including pharmacological treatments, physiotherapy, surgery, acupuncture, and transcutaneous electrical nerve stimulation (TENS)—no single intervention has proven universally effective for low back pain (LBP) (1). Approximately 75% of individuals with acute LBP recover spontaneously within six weeks; however, 10–25% progress to chronic low back pain (CLBP), defined as symptoms persisting for more than three months (2). CLBP is frequently associated with somatic and psychological comorbidities, such as headaches, gastrointestinal disturbances, and mood disorders, which further complicate clinical management (2, 3). Exercise therapy remains a cornerstone of CLBP treatment, with substantial evidence supporting flexibility and strengthening exercises targeting the abdominal, trunk extensor, and lower-limb musculature (4). Research indicates that exercise therapy yields variable outcomes depending on the condition's phase. For instance, Hayden et al.(4) demonstrated that exercise interventions are more effective in chronic than acute LBP, while Tulder et al. found limited benefits in the acute phase but significant improvements in chronic cases(4, 5). These findings have led to the development of structured exercise protocols tailored to diverse patient needs. Two widely used approaches are flexion-based and extension-oriented exercise protocols (6). The flexion-based protocol emphasizes exercises designed to strengthen and stretch key muscle groups—such as the gluteus Maximus and hamstrings—to enhance pelvic stability, improve posture, and reduce mechanical stress on the lumbar spinen (7). In contrast, the extension-oriented method is based on the premise that abnormal spinal postures, particularly excessive lumbar lordosis, contribute to pain by increasing strain on posterior spinal structures. Through directional preference and extension-focused exercises, this approach aims to centralize symptoms and restore normal spinal mechanics (8). Electromyographic studies indicate that these protocols activate distinct muscle groups and recruitment patterns, reflecting different biomechanical targets (PIELE et al., 2024). Nevertheless, their comparative effectiveness in CLBP management remains unclear (9).

In contrast, the extension-oriented exercise method is founded on the principle that abnormal spinal postures—particularly excessive lumbar lordosis—are primary contributors to low back pain. Such postural deviations increase mechanical stress on posterior spinal structures and surrounding soft tissues, potentially resulting in pain and functional impairment. The extension-oriented approach seeks to correct these imbalances through targeted extension exercises and directional preference strategies, with the aim of centralizing symptoms and restoring normal spinal mechanics (10). The overarching objective of any exercise-based rehabilitation program is to restore pain-free movement, enhance functional capacity, and facilitate a return to normal daily activities. However, given the differing theoretical foundations and biomechanical emphases of flexion-based and extension-oriented protocols, it remains unclear which approach is more effective for individuals with chronic low back pain (11). Considering the multifactorial nature of CLBP and the wide range of available therapeutic options, comparative research is necessary to identify the most effective rehabilitation strategies. Therefore, the present study aims to evaluate and compare the efficacy of flexion-based and extension-oriented exercise protocols with a comprehensive, guideline-based multimodal intervention in patients with CLBP. By assessing pain reduction, functional improvement, and biomechanical outcomes, this study seeks to contribute to evidence-based clinical practice and optimize rehabilitation approaches for chronic low back pain. Despite evidence supporting both flexion-based and extension-oriented exercise protocols, systematic reviews and international clinical guidelines consistently recommend multimodal, non-pharmacological interventions as the first-line treatment for chronic non-specific low back pain, particularly when single-modality exercise programs fail to produce sustained long-term benefits (12-14). A multimodal approach—integrating land-based therapeutic exercise with aquatic therapy, manual therapy or massage, and physical modalities—can simultaneously target multiple pain-related mechanisms, including central sensitization, muscle inhibition, fear-avoidance behaviors, and impaired proprioception. These complex mechanisms are unlikely to be fully addressed by isolated directional exercise protocols alone (15, 16). Aquatic therapy, in particular, is supported by high-level evidence demonstrating superior pain reduction and functional improvement compared with land-based exercise alone in individuals with CLBP (17, 18). Accordingly, the present trial was designed to compare a guideline-based, individualized multimodal rehabilitation program—comprising therapeutic exercise, aquatic therapy, physiotherapy modalities, and massage—with the two most commonly applied standardized directional exercise protocols (flexion-based and extension-oriented) in an Iranian population with chronic non-specific low back pain.

## 2. Methods and Materials

### *2.1 Study Design*

This single-center, parallel-group randomized controlled trial was conducted in Tehran, Iran, at Amirkabir University of Technology in collaboration with the Sports Medicine and Health Center of the Keshtirani Moj Complex. The study followed a pretest–posttest design with a one-month follow-up period and aimed to compare the effectiveness of three 14-week rehabilitation programs in individuals with chronic non-specific low back pain (CLBP), defined as symptoms persisting for at least four months. The study was conducted in accordance with the ethical standards of the institutional and national research committee and complied with the principles of the Declaration of Helsinki. The research protocol was reviewed and approved by the Ethics Committee of the Department of Sport Sciences and Health at Amirkabir University of Technology (Approval No: D/10119/99; June 18, 2025). Written informed consent was obtained from all participants prior to enrollment in the study. Due to the nature of the rehabilitation interventions, blinding of participants and therapists was not feasible. However, to minimize assessment bias, all outcome measurements were performed by a blinded assessor who was unaware of group allocation.

### *2.2 Participants*

A total of 180 participants (120 males and 60 females) diagnosed with chronic non-specific low back pain were recruited through convenience sampling from physiotherapy clinics and public advertisements. The mean age was 52 years (range: 45–72 years), mean height was 171.2 cm, and mean body weight was 74 kg. Participants were randomly assigned to three intervention groups (n = 60 per group). Baseline analysis confirmed homogeneity across groups in age, pain intensity, and disability scores measured by the Quebec Back Pain Disability Scale (QBPDS).

#### *2.2.1 Inclusion Criteria*

Participants were eligible if they:

1. Had non-specific chronic low back pain lasting ≥3 months.
2. Were between 45 and 72 years of age.

#### *2.2.2 Exclusion Criteria*

Participants were excluded if they had systemic diseases (cardiovascular, metabolic, autoimmune), prior spinal surgery or trauma, structural spinal abnormalities (e.g., spondylolisthesis, scoliosis >10°), neuromuscular or joint disorders, radiculopathy, osteoporosis, inflammatory rheumatic disease, cancer, pregnancy, or prior experience with flexion- or extension-based rehabilitation programs. All participants underwent medical screening, including history taking, physical examination, X-ray, and lumbar MRI, to exclude specific spinal pathologies.

### *2.3 Outcome Measures*

Primary outcomes included functional disability and lumbar range of motion (LROM). Disability was assessed using the validated Quebec Back Pain Disability Scale (QBPDS). Lumbar mobility was measured using standardized anthropometric field tests: standing forward flexion, right and left lateral flexion, and the supine knee-to-chest test. Measurements were taken at baseline, post-intervention (14 weeks), and one-month follow-up. All assessments were conducted twice by the same trained examiner, and mean values were recorded.

### *2.4 Interventions*

All groups participated in supervised sessions three times per week for 14 weeks. Group 1 (Comprehensive Multimodal Program): Sessions lasted 90–100 minutes and included therapeutic exercise, aquatic therapy in a heated pool (30–32°C), physiotherapy modalities (TENS, ultrasound, superficial heat), and massage therapy. The intervention was delivered in three progressive phases: pain reduction (Weeks 1–3), functional strengthening (Weeks 4–8), and neuromuscular rehabilitation (Weeks 9–14). Group 2 (Flexion-Based Exercise Program): Participants completed standardized flexion-oriented exercises during 45–60 minute sessions.

Group 3 (Extension-Oriented Exercise Program): Participants followed a directional preference protocol emphasizing lumbar extension exercises with gradual introduction of flexion movements. All programs emphasized controlled execution, proper technique, and progressive overload to ensure safety and optimize rehabilitation outcomes.

### 2.5 *Statistical Methods*

Post-intervention outcomes, including pain-related disability measured by the Quebec Back Pain Disability Scale (QBPDS) and lumbar range of motion (LROM), were analyzed across three time points: baseline (pre-test), post-intervention (14 weeks), and one-month follow-up. A repeated-measures multivariate analysis of variance (MANOVA) was conducted to evaluate within-group (time), between-group (intervention), and interaction (group × time) effects. When significant multivariate effects were observed, follow-up univariate ANOVAs were performed. Pairwise comparisons were conducted using Tukey's honestly significant difference (HSD) post-hoc test to control for Type I error in multiple comparisons. Within-group changes over time were examined using paired-samples t-tests for variables meeting normality assumptions. For variables that did not satisfy normal distribution criteria, non-parametric tests were applied: the Mann–Whitney U test for two-group comparisons and the Kruskal–Wallis H test for comparisons among three groups. Where appropriate, post-hoc analyses with Bonferroni adjustment were conducted following significant Kruskal–Wallis results. All statistical analyses were performed using IBM SPSS Statistics (version 26.0 or later; IBM Corp., Armonk, NY, USA). A two-tailed p-value $\leq 0.05$ was considered statistically significant.

## 3. Results

A total of 180 patients with chronic low back pain (CLBP) participated in the trial (120 males and 60 females). The overall mean age was 52 years (range: 45–72 years), with a mean height of 171.2 cm and mean body weight of 74 kg. Baseline demographic and clinical characteristics by group are summarized in Table 1.

**Table 1.** Baseline demographic and clinical characteristics by intervention group

| Group | Gender | n | Weight (kg) | Age (years) | Height (cm) |
|---|---|---|---|---|---|
| Group 1 (Comprehensive) | Male | 47 | 74.1 | 53.9 | 171.2 |
| | Female | 13 | | | |
| Group 2 (Flexion based exercises) | Male | 39 | 75.4 | 51.2 | 169.4 |
| | Female | 21 | | | |
| Group 3 (Extension oriented exercises) | Male | 34 | 72.3 | 50.8 | 173.1 |
| | Female | 26 | | | |
| Overall Mean | | | 74.0 | 52.0 | 171.2 |

Quebec Back Pain Disability Scale (QBPDS) scores at baseline, immediately after the 14-week intervention, and at the one-month follow-up are presented in Table 2. Across all participants, the baseline QBPDS mean was 54.50, consistent with substantial pain-related disability. Following the interventions, the overall mean QBPDS decreased to 25.64 at post-test and remained lower than baseline at follow-up (34.70), indicating an overall reduction in pain-related disability over time. Group-level trends showed the greatest improvement in Group 1 (Comprehensive), with QBPDS decreasing from 54.70 at baseline to 16.10 post-intervention and 21.20 at follow-up (p=0.001). Groups 2 and 3 also improved significantly (both p=0.001), but with smaller reductions and higher follow-up scores than Group 1. Between-group comparisons (Tukey's test, $p \leq 0.01$) indicated that Group 1 outperformed Groups 2 and 3, with benefits that persisted at one-month follow-up.

**Table 2.** QBPDS scores at baseline, post-intervention, and 1-month follow-up

| Group | Pre-test | Post-test | Difference (post) | Follow-up (1 month) | t | Sig (p) |
|---|---|---|---|---|---|---|
| Group 1 (Comprehensive) | 54.70 | 16.10 | 35.40 | 21.20 | 15.705 | 0.001** |
| Group 2 (Flexion based exercises) | 53.12 | 29.12 | 26.50 | 40.80 | 9.410 | 0.001** |
| Group 3 (Extension oriented exercises) | 55.70 | 31.70 | 28.00 | 42.10 | 6.930 | 0.001** |
| Overall Mean | 54.50 | 25.64 | 29.96 | 34.70 | 7.330 | 0.001 |

Statistical tests (as reported): Repeated measures MANOVA and paired t-tests for within-group changes; Tukey's post-hoc test for between-group comparisons.

Note: $p < 0.01$ (**, as reported). Sample size: n=60 per group (total n=180).

Lumbar range of motion outcomes are summarized in Table 3. Both Group 1 and Group 2 demonstrated statistically significant within-group improvements across trunk flexion, right/left lateral flexion, and supine hip/knee flexion (all p=0.001). Group 1 generally showed the largest absolute improvements (e.g., trunk flexion decreased from 29.30 cm to 16.10 cm, p=0.001), consistent with better functional mobility. Group 2 also improved substantially (e.g., trunk flexion from 25.58 cm to 16.30 cm, p=0.001). In Group 3, trunk flexion did not improve significantly (p=0.216), while significant improvements were observed for right and left lateral flexion (p=0.003 and p=0.004, respectively) and supine hip/knee flexion (p=0.013). Between-group post-hoc testing (Tukey's, p≤0.01) confirmed significant differences favoring Group 1 over Groups 2 and 3.

**Table 3.** Lumbar Range of Motion (LROM) changes (cm)

| Group | Position | Pre-test (cm) | Post-test (cm) | t | Sig (p) |
|---|---|---|---|---|---|
| Group 1 (Comprehensive) | Trunk flexion | 29.30 | 16.10 | 7.771 | 0.001* |
| | Lateral flexion (Right) | 39.20 | 23.40 | 5.610 | 0.001* |
| | Lateral flexion (Left) | 40.60 | 27.10 | 6.820 | 0.001* |
| | Supine hip/knee flexion | 31.20 | 27.10 | 5.420 | 0.001* |
| Group 2 (Flexion based exercises) | Trunk flexion | 25.58 | 16.30 | 6.785 | 0.001* |
| | Lateral flexion (Right) | 46.10 | 38.20 | 7.902 | 0.001* |
| | Lateral flexion (Left) | 48.82 | 40.10 | 9.370 | 0.001* |
| | Supine hip/knee flexion | 27.10 | 20.30 | 8.731 | 0.001* |
| Group 3 (Extension oriented exercises) | Trunk flexion | 26.56 | 17.10 | 1.302 | 0.216 |
| | Lateral flexion (Right) | 45.20 | 39.10 | 3.464 | 0.003* |
| | Lateral flexion (Left) | 47.91 | 39.30 | 3.415 | 0.004* |
| | Supine hip/knee flexion | 24.40 | 20.20 | 2.850 | 0.013** |

Statistical tests (as reported): Paired t-tests for within-group changes; Tukey's post-hoc test for between-group comparisons (*p≤0.01; **p≤0.05). Sample size: n=60 per group.

MRI evaluation indicated an increase in multifidus muscle diameter in Group 1, suggesting training-related hypertrophy. No significant gender effects were observed (p>0.05). Overall, the comprehensive multimodal program (Group 1) produced the most pronounced and sustained improvements in pain-related disability and lumbar mobility, followed by the flexion-based program (Group 2), while the extension-oriented program (Group 3) showed the least improvement, particularly for trunk flexion.

## 4. Discussion

The findings of this study demonstrate a substantial reduction in pain among patients who received the selected comprehensive treatment, with an average decrease of 69.7% in pain-related disability scores. These results are consistent with previous research by Van Tulder et al. (2000) and Danneels et al. (2001), which supports the effectiveness of comprehensive and exercise-based rehabilitation strategies for managing chronic low back pain (5) and L.A. Danneels et al. (19), which supports the effectiveness of comprehensive and exercise-based rehabilitation strategies for managing chronic low back pain. In comparison, the mean pain scores in both the Extension oriented exercises and Flexion based exercises groups decreased following the intervention; however, the magnitude of improvement was smaller than that observed in the selected comprehensive treatment group. The greater reduction in pain in the comprehensive group can likely be attributed to the multimodal structure of the intervention, which combined therapeutic exercises, aquatic therapy, physiotherapy modalities, and massage therapy into an integrated rehabilitation protocol. This coordinated approach may have addressed multiple physiological and biomechanical contributors to chronic low back pain simultaneously. From another perspective, although both the Extension oriented exercises and Flexion based exercises groups experienced meaningful pain reduction during the active treatment phase, these improvements declined considerably within one month after the cessation of the program. This pattern suggests that the benefits of isolated exercise-based interventions may not be sustained in the long term without continued practice or complementary supportive therapies.

Regarding lumbar range of motion (ROM), improvements were observed in all treatment groups after the intervention. However, the most substantial increase in spinal ROM was associated with the comprehensive treatment method. Among the comparison groups, the Flexion based exercises group demonstrated greater gains in

ROM than the Extension oriented exercises group. This difference may be explained by the specific biomechanical emphasis of each protocol. The Flexion based exercises approach prioritizes repeated flexion movements and stretching components, which may directly enhance spinal flexibility. In contrast, the Extension oriented exercises method primarily focuses on extension-based movements, which may be more effective for symptom centralization and pain control than for global mobility enhancement. Notably, no significant improvement in trunk flexion was observed in the Extension oriented exercises group, highlighting its limited influence on certain movement patterns. The superior ROM outcomes in the comprehensive treatment group can be attributed to two main factors: (1) its strong emphasis on functional rehabilitation aimed at restoring mobility, coordination, and neuromuscular control, and (2) the longer duration and higher intensity of treatment sessions compared with the other groups. Interestingly, although the Extension oriented exercises group achieved slightly greater pain reduction than the Flexion based exercises group, the latter was more effective in improving spinal flexibility and overall ROM. This distinction likely reflects the different biomechanical focuses of the two approaches—extension-oriented strategies in the Extension oriented exercises protocol versus flexion-focused movements in the Flexion based exercises program—each influencing distinct aspects of lumbar function.

Regarding demographic variables, no significant effect of sex was observed on treatment outcomes. Both male and female participants demonstrated comparable improvements in pain reduction and functional recovery, indicating that the rehabilitation protocols were equally effective across genders. In addition, patient satisfaction and perceived quality of life improved substantially in the comprehensive treatment group. These improvements may be attributed not only to physical recovery but also to the psychological benefits associated with regular therapeutic exercise. Increased self-confidence, reduced perceptions of physical vulnerability, enhanced mood, and greater independence in daily activities likely contributed to these positive outcomes. The holistic structure of the comprehensive intervention—integrating physical rehabilitation, functional training, and supportive therapeutic modalities—appears to have played a pivotal role in promoting overall well-being. By simultaneously addressing physical symptoms, neuromuscular function, and psychosocial factors, the program facilitated broader improvements beyond pain reduction alone. Exercise therapy within the selected treatment method—particularly its structured and progressively advanced regimen—resulted in significant strengthening of core stabilizing muscles, including the internal and external obliques, multifidus, trunk extensors, and rectus abdominis. Notably, an increase in muscle diameter was observed, especially in the multifidus, a critical stabilizer of the lumbar spine. These muscular adaptations likely contributed to enhanced intervertebral stability, improved spinal flexibility, and more effective motor control, particularly in the lumbopelvic region. In addition, the program promoted improvements in muscular endurance, reduced fatigue, enhanced coordination, and reinforced both static and dynamic stability. Neuromuscular control and movement efficiency were also significantly improved—findings consistent with previous research (4, 20, 21). Importantly, these physiological improvements translated into clinically meaningful functional gains. Participants in the selected treatment group reported greater ease in performing essential daily activities such as sitting, standing, walking, and turning in bed without pain key indicators of improved functional capacity, independence, and overall quality of life.

An important distinction concerns the nature of the movement adaptations achieved. Although the Extension oriented exercises and Flexion based exercises groups demonstrated improvements primarily in static or position-specific measures, these gains tended to diminish after completion of the rehabilitation program. In contrast, the selected comprehensive treatment emphasized dynamic movement training and neuromuscular coordination, leading to improvements that were not only greater in magnitude but also more durable and functionally transferable to everyday activities. Despite its rigorous methodology and encouraging findings, this study has several limitations. First, the use of convenience sampling within a single clinical setting may have introduced selection bias. Participants recruited through physician referrals or public advertisements may differ from the broader chronic low back pain (CLBP) population in terms of motivation, socioeconomic background, health literacy, or access to care, thereby limiting external validity. Second, the absence of a no-treatment control group restricts causal inference. Although significant improvements were observed, it cannot be definitively concluded that all changes were attributable solely to the interventions, as factors such as placebo effects, spontaneous symptom fluctuation, or regression to the mean may have contributed. Third, reliance on self-reported outcomes, including the Quebec Back Pain Disability Scale, introduces the possibility of response bias, recall bias, and social desirability effects. Participants in the multimodal intervention group may have had heightened expectations of benefit, potentially influencing their responses. Fourth, the one-month follow-up period is relatively short for a chronic and often recurrent condition such as CLBP. Longer follow-up durations are needed to determine the sustainability of treatment effects and recurrence prevention. Additionally, although lumbar range of motion was assessed by a trained examiner under standardized conditions, the anthropometric field techniques employed may lack the precision and sensitivity of advanced measurement tools such as digital inclinometry or motion analysis systems. Another limitation relates to differences in intervention dosage. Group 1 received longer and more intensive multimodal sessions compared with the shorter, exercise-only protocols administered in Groups 2 and 3. This discrepancy complicates the isolation of specific therapeutic components and raises questions regarding dose–response relationships and real-world feasibility. Finally, although focusing on non-specific CLBP and excluding serious spinal pathology enhanced internal validity, it may have overlooked subtle biomechanical or neuromuscular dysfunctions that could moderate individual treatment responses. Future studies incorporating stratified treatment approaches, objective biomechanical assessments, and extended follow-up periods are warranted to strengthen the robustness and generalizability of these findings.

## 5. Conclusion

Based on the findings of this study, the selected treatment method—a systematic, multidisciplinary, and integrative rehabilitation program combining individualized therapeutic exercises, aquatic therapy, physiotherapy modalities, and massage therapy—demonstrated superior effectiveness in reducing pain, improving spinal mobility, enhancing muscular strength and endurance, and increasing patient satisfaction. These results highlight the value of comprehensive, functionally oriented rehabilitation strategies in the management of chronic low back pain. By addressing physical impairments, neuromuscular control, and functional capacity within a coordinated framework, the program achieved more substantial and sustained clinical improvements compared with isolated exercise approaches. Accordingly, it is recommended that clinical practice incorporate complex, individualized, and multimodal rehabilitation models similar to the selected treatment method to optimize therapeutic outcomes and promote long-term sustainability in the management of chronic low back pain.

## Authors' Contributions

S. A. was solely responsible for the conceptualization, study design, methodology development, data collection, statistical analysis, interpretation of findings, manuscript preparation, and final approval of the submitted version. The author accepts full responsibility for the integrity and accuracy of the work.

## Declaration

Artificial intelligence (AI)-assisted language tools were used solely for language editing and clarity improvement during manuscript preparation. The author reviewed and validated all content to ensure accuracy, integrity, and compliance with journal standards. No AI tools were used for data analysis, data interpretation, or the generation of scientific results.

## Transparency Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

## Acknowledgments

The author would like to thank all participants who generously contributed their time and effort to this study. Also, express my appreciation to the staff of the Sports Medicine and Health Center of Keshtirani Moj Complex for their logistical and clinical support during the intervention period. Special thanks are extended to the physiotherapists and research assistants who assisted with data collection and supervision of rehabilitation sessions.

## Declaration of Interest

The authors report no conflict of interest.

## Funding

According to the authors, this article has no financial support.

## Ethical Considerations

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. The research protocol was reviewed and approved by the Research Ethics Committee of the Department of Sport Sciences and Health at Amirkabir University of Technology (Approval No: D/10119/99; June 18, 2025). Written informed consent was obtained from all participants prior to enrollment. Participants were informed of their right to withdraw from the study at any time without consequence.

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