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Original Article

The Effect of Pain Neuroscience Education with Motor Control and Core Stability Exercises on Non-Specific Chronic Low Back Pain in Women

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Abstract

Background: Non-specific chronic low back pain (CLBP) is a prevalent health issue, particularly among women. This study examined the effects of pain neuroscience education (PNE) combined with motor control exercise (MCE) and core stability exercises (CSE) on pain, function, and quality of life of women with non-specific CLBP.
Methods: The present study used a pre-post intervention design with three parallel comparison groups. From the target population, 45 women with non-specific CLBP were selected using convenience sampling technique. Then, they were randomly assigned to three groups of 15 including PNE with MCE, CSE, and control group. In the pre-test phase, pain intensity was measured with the Visual Analog Scale (VAS), muscle function was measured using the McGill tests, and women's quality of life was measured using the SF-36 Quality of Life questionnaire. The study was conducted in Urmia, Iran, in 2024. Subsequently, the experimental groups performed the exercises for eight weeks. Then, in the post-test phase, the factors measured in the pre-test phase were re-measured. Also, to analyze the data, paired sample t-tests and analysis of covariance (ANCOVA) were used to examine within and between group effects, respectively.
Results: Both the PNE+MCE and CSE groups showed significant reductions in pain (Mean Difference (MD=) -2.93, P=0.001; MD=-1.08, P=0.005) and disability (MD=-7.25, P=0.001; MD=-3.93, P=0.001), along with improvements in trunk flexor endurance (MD=+11.31, P=0.001; MD=+5.44, P=0.001), trunk extensor endurance (MD=+14.68, P=0.001 MD=+4.41, P=0.001), quality of life (MD=+20.43, P=0.001; MD=+9.99, P=0.001), side plank (MD=10.41, P=0.001; MD=4.86, P=0.001), and elbow plank (MD=8.75, P=0.001 MD=5.13, P=0.001). Significant between-group differences were observed for all outcomes, with the PNE+MCE group demonstrating superior improvements over both CSE and control groups in pain (2.93 vs 1.08 vs -0.31), disability (7.25 vs 3.93 vs -0.40), trunk endurance (flexors: 11.31 vs 5.44 vs -1.27; extensors: 14.68 vs 4.41 vs -0.12), quality of life (20.43 vs 9.99 vs -3.23), side plank (10.41 vs 4.86 vs -0.85) and elbow plank (8.75 vs 5.13 vs -0.11), respectively.
Conclusions: This study showed that PNE along with MCE plays an important role in managing pain and functional disability in women with non-specific CLBP. In addition, these findings suggested that this combined approach can help improve muscle function and quality of life for patients.

Keywords: Pain Management, Core Stability, Low Back Pain, Quality of Life

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1. Introduction

Low back pain (LBP) is a prevalent musculoskeletal disorder across various populations, with an estimated lifetime incidence of approximately 80%, imposing substantial personal burden and socioeconomic costs (1). Chronic low back pain (CLBP) represents a complex condition with significant public health implications. The term "non-specific" LBP is employed when pain generators remain elusive. Primary chronic musculoskeletal LBP is increasingly understood through the lens of central sensitization mechanisms (2). The precise mechanisms underlying the persistent prevalence of CLBP in women remain incompletely understood. However, several factors have been identified as potential contributors. These include obesity, low physical fitness, pregnancy, improper execution of household chores, poor workplace ergonomics, repetitive bending and heavy lifting, as well as psychological factors such as stress, anxiety, and emotional distress, which can vary across individuals. Notably, homemakers exhibit the highest incidence of LBP (3).

Patients presenting with LBP commonly exhibit a spectrum of signs and symptoms beyond pain itself. These include diminished strength and endurance of trunk musculature, leading to specific impairments in the control of deep muscles such as the multifidus and transversus abdominis, which are crucial for spinal stability. Furthermore, individuals may experience motor control dysfunction, biomechanical alterations, and spinal deformities (4). In chronic LBP patients, trunk muscle activity is notably elevated, and they often struggle with postural control, particularly during static and dynamic activities and under challenging conditions (5). In such contexts, a lack of belief in one's ability to manage and cope with pain, especially in prolonged and persistent cases, can serve as a significant predictor for the development of depression, chronic pain-related disability, and a diminished overall quality of life (6).

Quality of life is defined as an individual's perception of their position in life, influenced by the cultural and value systems within which they live. This concept is directly related to an individual's goals, expectations, standards, and concerns, reflecting a complex interplay between personal and social factors (7). CLBP significantly impacts individuals' quality of life, affecting their daily activities and work performance, with patients typically reporting low scores in physical function and limitations due to their physical health status. This not only leads to a diminished quality of life but can also contribute to psychological and social problems (8). Psychosocial factors, such as kinesiophobia and anxiety, play a crucial role, and their interaction with an individual's physical condition can have substantial effects on quality of life (9).

Pain neuroscience education (PNE) combined with motor control exercises has emerged as an effective approach for managing chronic spinal pain, addressing both central and peripheral pain mechanisms (10). By targeting these mechanisms, it can facilitate the redistribution of muscle activity and protect tissues from further pain or injury. These adaptations may have long-term benefits. Studies demonstrated that PNE and motor control interventions can significantly reduce pain intensity and improve disability and balance in patients with CLBP, showing superior outcomes compared with traditional core stability training in this population (11, 12). Furthermore, in chronic pain management, rehabilitation should consider psychosocial aspects, focusing on reducing mechanical contributions to pain persistence (13).

Core stability exercises target the strengthening of the body's central musculature, including the abdominal, lumbar, pelvic, and paraspinal muscles. Enhancing these muscles contributes to improved stability, balance, and motor function, with a focus on stabilizing the trunk and pelvic musculature (14). Core stability exercises were shown in numerous studies to significantly reduce pain intensity and enhance the quality of life in individuals with CLBP (14, 15). Given the aforementioned, the objective of this study was to examine the effects of pain neuroscience education combined with motor control exercises and core stability exercises on pain, function, and quality of life in women with non-specific chronic low back pain.

2. Methods

2.1. Design

This study used a pre-post intervention design with three parallel comparison groups and was conducted in Urmia, Iran, in 2024.

2.2. Participants

The study population comprised all women in Urmia, Iran who were referred to healthcare facilities, such as physiotherapy clinics, orthopedic departments, and corrective exercise centers. The inclusion criteria were: a pain intensity score ranging from 3 to 8 on a numerical pain rating scale, a body mass index between 20 and 25, a minimum educational attainment of a high school diploma, no spinal surgery within the previous six months, and no use of medications affecting the nervous system. Additionally, participants needed to have experienced chronic low back pain for a minimum duration of 12 weeks. The exclusion criteria were: irregular attendance at training sessions (missing two consecutive or three non-consecutive sessions), failure to attend the post-test evaluation, or participation in concurrent therapies, specific occupational activities, or regular physical exercise. Before randomization, a blinded assessor collected and documented participants' sociodemographic data and baseline clinical outcome measures.

2.3. Sample Size Determination

The sample size was calculated using G*Power software (version 3.1) for ANCOVA analysis. This calculation was based on pain intensity Visual

Analog Scale (VAS) as the primary outcome, using mean ± SD values reported by Malfliet and colleagues (12) for each group (PNE + MCE: 5.2±1.1, CSE: 5.8±1.3, Control: 6.1±1.4). With α=0.05 and power=0.80, the initial sample size was calculated as 42 participants, which was increased to 45 (15 per group) to account for potential attrition. The study participants were then randomly assigned to one of three groups (PNE+MCE, CSE, or control) using a computer-generated randomization sequence. The sequence was created via simple randomization (1:1:1 ratio) by assigning each participant a unique ID (1–45), generating random numbers for each ID using Microsoft Excel's RAND () function, and sorting IDs based on these numbers. The first 15 sorted IDs were assigned to PNE+MCE, the next 15 to CSE, and the remaining 15 to the control group. This method ensured unbiased allocation. Following ethical approval, the researcher contacted pain management, physiotherapy, and wellness centers in Urmia, Iran to coordinate with relevant authorities.

2.4. Data Collection and Measurements

2.4.1. Visual Analog Scale (VAS)

Visual Analog Scale (VAS) of pain assessment consists of a 10-centimeter horizontal line, with the left end labeled *'no pain'* and the right end labeled *'worst imaginable pain'*. Zero indicates the absence of pain, and a score of 10 signifies the most severe pain. The participants mark a point on the line that corresponds to their current pain level. The distance from the zero end to the marked point is measured with a ruler, and this measurement represents the patient's pain score. VAS has demonstrated high validity and reliability in pain measurement (16). The content validity index (CVI) was reported as high within the Iranian population (17).

2.4.2. Roland-Morris Disability Questionnaire (RMDQ)

The Persian adaptation of Roland-Morris Disability Questionnaire (RMDQ) is a validated tool for evaluating functional disability associated with low back pain. Comprising 24 self-reported items, this instrument measures pain-related limitations and disability levels, with total scores ranging from 0 to 24 where higher values reflect more severe disability. Rezaei and colleagues demonstrated strong psychometric properties for the Persian RMDQ, including a test-retest reliability of 0.91 and high responsiveness to clinical improvements in chronic low back pain management (18). They found an internal consistency (Cronbach's alpha) of 0.91 and a test-retest reliability of 0.73 (18). The content validity index (CVI) for this version was also established at 0.83 (19).

2.4.3. SF-36 Quality of Life Questionnaire (QLQ)

Quality of Life Questionnaire (QLQ) consists of 36 items divided into 8 subscales, each evaluating different dimensions of quality of life, such as physical and mental health. Scoring follows a scale from 0 to 100, where higher values reflect a more favorable quality of life. Previous study established the validity and reliability of this Quality of Life Questionnaire (QLQ) specifically within Iranian population groups (20). In our study, instead of separating physical and mental health, we considered the total quality of life score to provide an overall assessment of the participants' life satisfaction, as physical function is evaluated through muscle tests. This scale helps us predict quality of life with a subjective measure and examine whether the participant is satisfied with their life (21). The validity and reliability of this questionnaire were confirmed and reported as high (CVI=0.92) within the Iranian population (22).

2.4.4. Muscle Function Assessment

To assess trunk muscle function, McGill endurance-performance field tests were used. These tests evaluate the endurance of trunk flexor, extensor, and lateral flexor muscles. Skibski and colleagues defined the average duration that participants could maintain the three stages of these tests as the endurance score of core stabilizing muscles. These tests demonstrated high validity and reliability (23). The CVI for the Persian version of this questionnaire was reported to be 0.89 (24).

2.5. Procedure

Prior to initiating treatment, the rationale and methodology of the study were clearly explained to women with CLBP, and written informed consent was obtained. All participants completed the questionnaires of Visual Analog Scale (VAS) of pain intensity, Roland-Morris Disability Questionnaire, and Quality of Life measures during the pre-test phase, and their muscular function was assessed using McGill tests. The participants were informed about the exercise protocols, collaboration guidelines, attendance hours, and permissible absences. Each participant in the pain neuroscience education with motor control exercise group received a 20-30 minutes individual consultation with a pain neuroscience education specialist. This education aimed to identify and address misconceptions about pain, fostering a revised understanding and altering beliefs that could negatively impact recovery. Once the participants adopted adaptive beliefs, exercise therapy, with a specific focus on spinal motor control exercises, was initiated. It is crucial that motor control exercises are not started before the patient adopts adaptive pain beliefs (10). Both intervention groups participated in their respective exercise protocols for eight weeks, while the control group received no intervention during this period. In the pain neuroscience education group, each training session commenced with 10 to 15 minutes of education on pain-related neuroscience. Subsequently, patients were instructed on cognitive strategies to manage pain, emphasizing the critical importance of adhering to the prescribed "time-contingent" exercise regimen (i.e., performing activities based on a pre-set schedule regardless of transient pain) rather than adopting a "symptom-contingent" approach (i.e., avoiding movement due to fear of pain) (12).

2.6. Exercise Interventions

2.6.1. Pain Neuroscience Education+Movement Control Training Program

The pain neuroscience education (PNE) program was delivered to patients in three distinct phases. Initially, the program focused on reconceptualizing pain beliefs through individualized sessions, continuing until participants recognized and corrected their misconceptions about pain. This educational process, integral to PNE, begins prior to and during active treatment and extends throughout long-term rehabilitation via tailored exercise therapy (25). Following the adoption of adaptive pain beliefs, patients progressed to a cognitive-targeted motor control exercise program, implemented in two subsequent stages (phases 2 and 3). This program incorporated motor imagery, progressively increasing in complexity through a time-contingent approach, and was practiced across diverse environments and contexts to enhance applicability to everyday activities (10).

The second phase focuses on targeted neuromuscular re-education, encompassing: (1) time-contingent exercise for coordinated spinal muscle activation, and (2) progression from phase two to the next level using motor imagery.

The third phase targets the integration of functional and dynamic exercise, focusing on: (1) increasing exercise complexity relative to functional tasks, (2) progression towards movements that the patient fears, and (3) exercise under cognitively and psychologically stressful conditions.

Motor control exercises were conducted following the training protocol outlined by Malfliet and colleagues, ensuring that the total duration of these exercises, combined with the core stability exercise group, was equivalent. The program incorporated proprioceptive, coordination, and sensorimotor control training. Throughout all sessions, evaluations of posture, movement techniques, and breathing patterns were consistently performed. To adapt exercises to individuals' daily situations, exercise progression was performed during physical activities and daily tasks, including exercise under psychologically stressful conditions (12).

The motor control exercises were structured as follows: weeks 1 and 2 included pelvic tilt exercises, double-leg landing drills, gluteal bridges, and cat-cow movements; weeks 3 and 4 progressed to single-leg stance, single-leg bridges, cobra extensions without contact, and quadruped trunk rotations bilaterally; weeks 5 and 6 comprised single-leg stance with eyes closed, unweighted trunk flexion and extension, straight leg raises, and walking on a stable surface; weeks 7 and 8 incorporated forward trunk flexion, weighted trunk flexion and extension on an unstable surface, stance on an unstable surface, alternating straight leg raises, and eccentric squats.

2.6.2. Core Stability Exercises

These exercises, focusing on core strengthening, postural alignment, and targeted activation, were conducted for 8 weeks, with 3 sessions per week, each lasting 60 to 70 minutes. Before commencing the exercises, each participant engaged in 10 minutes of general warm-up activities such as brisk walking, light jogging, and specific stretching, followed by their individualized core stability exercises (26).

The core stability exercises consisted of: (1) Kegel exercises: contraction of the pelvic floor muscles; (2) Plank: maintaining a prone position with elbows under the shoulders and toes on the ground, ensuring hip and trunk alignment; (3) Abdominal bracing: isometric contraction of the abdominal muscles in a supine position; (4) Side bridge: a side-lying position with the elbow under the shoulder, legs extended, and lifting the hips off the ground; (5) Kegel with ball: prone position with a ball between the thighs and contraction of the pelvic floor muscles; (6) Bridge with single-leg raise: alternating hip and leg raises during a bridge; (7) Side-lying leg raise: side-lying position with a resistance band around the ankles and abduction of the legs; (8) Oblique crunch: supine position with knees flexed at 90 degrees and rotation to the right and left; (9) Supine straight leg raise: supine position with alternating vertical leg raises.

The control group received no intervention during the eight-week study period and continued their routine daily activities.

2.7. Data Analysis

The data were analyzed using both descriptive and inferential statistical methods. The Shapiro-Wilk test was used to evaluate the normality of the data distribution, while Levene's test was applied to check the homogeneity of variances. Descriptive statistics were presented for the study participants, followed by the use of paired sample t-tests to assess within-group effects and analysis of covariance (ANCOVA) to evaluate between-group effects. A significance level of $\alpha<0.05$ was established for all statistical tests. All analyses were conducted using SPSS version 26.

3. Results

Sixty-two women with CLBP were assessed for eligibility. Forty-five participants meeting all inclusion criteria were enrolled and completed all study requirements with 100% adherence. None of the participants were lost to follow-up or excluded post-allocation due to perfect attendance and compliance across all three intervention groups (n=15 per group). The demographic characteristics of the patients, including age, height, and weight, are presented in Table 1, and the descriptive statistics of the variables are provided in Table 1.

The PNE+MCE group showed significant reductions in pain (Mean Difference (MD)=-2.93, P=0.001) and disability (MD=-7.25, P=0.001), along with improvements in trunk flexor endurance (MD=+11.31, P=0.001), trunk extensor endurance (MD=+14.68, P=0.001), quality of life (MD=+20.43, P=0.001), side plank (MD=10.41, P=0.001), and elbow plank (MD=8.75, P=0.001). The CSE group also demonstrated improvements but to a lesser extent in pain (MD=-1.08, P=0.005), disability (MD=-3.93, P=0.001), trunk flexor endurance (MD=+5.44, P=0.001), trunk extensor endurance (MD=+4.41, P=0.001), quality of life (MD=+9.99, P=0.001), side plank (MD=4.86, P=0.001), and elbow plank (MD=5.13, P=0.001). However, no significant changes were observed in pain, disability, function, or quality of life in the control group ($P < 0.05$) (Table 2). Significant between-group differences were observed for all outcomes, with the PNE+MCE group demonstrating superior improvements over both CSE and control groups in pain (2.93 vs 1.08 vs -0.31), disability (7.25 vs 3.93 vs -0.40), trunk endurance (flexors: 11.31 vs 5.44 vs -1.27; extensors: 14.68 vs 4.41 vs -0.12), quality of life (20.43 vs 9.99 vs -3.23), side plank (10.41 vs 4.86 vs -0.85) and elbow plank (8.75 vs 5.13 vs -0.11), respectively.

Bonferroni-adjusted comparisons revealed a consistent efficacy gradient (PNE+MCE > CSE > control) across all outcomes: For pain, PNE+MCE showed superior reduction versus both CSE (P=0.001) and control (P=0.001), while CSE surpassed control (P=0.036). Disability followed identical patterns (P=0.003, P=0.001, P=0.020, respectively). Quality of life improvements were significantly greater in PNE+MCE versus CSE versus control (all P=0.001).

Table 1: Demographic characteristics of participants.

Variables	CSE (n=15)	PNE+MCE (n=15)	Control (n=15)	P value
Age (year)	37.13±2.80	36.73±1.79	36.53±8.42	0.758
Height (cm)	168.53±2.95	169.47±3.11	167.40±2.64	0.162
Weight (kg)	74.07±3.69	73.86±4.29	74.80±4.73	0.761
CLBP duration (months)	4.20±1.37	3.93±0.96	4.26±1.09	0.708

PNE: Pain Neuroscience Education; MCE: Movement Control Exercise; CSE: Core Stability Exercise; CLBP: Chronic Low Back Pain

Table 2: Comparison of within and between group differences in study variables.

Variables	Groups	Pre-test (M±SD)	Post-test (M±SD)	P value	
				Within-group differences	Between-group differences
Pain (0-10)	CSE	6.46±1.26	5.38±1.04	0.005	0.001
	PNE+MCE	6.50±1.02	3.57±1.16	0.001	
	Control	6.23±0.93	6.54±1.45	0.527	
Disability	CSE	18.00±2.45	14.07±1.75	0.001	0.001
	PNE+MCE	17.53±2.85	10.28±3.60	0.001	
	Control	16.60±2.90	17.00±2.61	0.930	
Quality of Life	CSE	55.15±10.66	65.92±11.11	0.001	0.001
	PNE+MCE	56.93±8.26	77.36±10.22	0.001	
	Control	57.69±8.57	54.46±6.80	0.121	
Trunk Flexors Endurance (s)	CSE	43.85±5.95	51.21±6.76	0.001	0.001
	PNE+MCE	45.34±6.84	56.65±5.78	0.001	
	Control	43.91±4.72	42.64±3.52	0.370	
Trunk Extensors Endurance (s)	CSE	43.67±6.44	55.34±7.02	0.001	0.001
	PNE+MCE	46.24±6.75	60.92±3.38	0.001	
	Control	47.40±5.35	47.28±3.54	0.830	
Side Plank (s)	CSE	40.62±6.73	45.48±4.82	0.016	0.001
	PNE+MCE	42.09±5.64	52.50±3.49	0.001	
	Control	41.67±3.27	40.87±4.54	0.480	
Elbow Plank (s)	CSE	51.52±5.40	56.63±5.36	0.001	0.001
	PNE+MCE	48.51±6.58	57.26±7.04	0.001	
	Control	44.17±4.05	44.06±3.35	0.982	

Statistically significant difference ($P < 0.05$); PNE: Pain Neuroscience Education; MCE: Movement Control Exercise; CSE: Core Stability Exercise; SD: Standard Deviation

Trunk endurance tests demonstrated PNE+MCE > CSE (flexors: P=0.013; extensors: P=0.013), PNE+MCE > control (both P=0.001), and CSE > control (both P=0.001). Plank tests confirmed this hierarchy (side plank: PNE+MCE vs CSE P=0.001, vs control P=0.001; CSE vs control P=0.011; elbow plank: PNE+MCE vs CSE P=0.010, vs control P=0.001; CSE vs control P=0.010), establishing comprehensive intervention superiority (Table 3).

4. Discussion

This study compared two interventions, pain neuroscience education combined with motor control exercises and core stability exercises, in women with non-specific CLBP. The results indicated that both interventions significantly improved pain, disability, muscle function, and quality of life after eight weeks compared with the control group. Furthermore, cognitive-targeted motor control exercises demonstrated greater efficacy in improving these variables compared with core stability exercises and the control group. A potential explanation for these findings is their association with motor pattern exercises and cognition-based training. Additionally, the results of this study were consistent with previous findings in the field of core stability and motor control exercises (11).

Abnormal brain changes and hypersensitivity in patients with CLBP significantly influence pain and fatigue experiences. Central sensitization refers to the brain's sensory processing, which can induce pain sensations even in the absence of actual tissue damage (27). Pain neuroscience education combined with motor control exercises, by activating proprioception and sensorimotor control of the spine, helps patients improve their sensory perception. In contrast, core stability exercises also have a positive impact on reducing pain and disability, but to a lesser extent than pain neuroscience education. This is likely due to the strong correlation between pain perception and disability. Research indicated that chronic pain and fatigue in conditions such as ankylosing spondylitis and CLBP are associated with functional and structural changes in the brain (27). Reports indicated that pain in patients with non-specific chronic low back pain leads to motor control deficits, and fear of pain recurrence at various times increases disability and limits individual activities (28).

Table 3: Results of Bonferroni post-hoc test to compare the two-by-two difference between the groups.

Variables	Group 1	Group 2	Mean difference	SE	P value
Pain	Control	CSE	-1.235	0.466	0.036
		PNE+MCE	-3.061	0.459	0.001
	CSE	PNE+MCE	-1.827	0.456	0.001
Disability	Control	CSE	-3.174	1.100	0.020
		PNE+MCE	-6.948	1.079	0.001
	CSE	PNE+MCE	-3.775	1.064	0.003
Quality of Life	Control	CSE	23.520	2.374	0.001
		PNE+MCE	13.536	2.317	0.001
	CSE	PNE+MCE	9.984	2.324	0.007
Trunk Flexor Endurance	Control	CSE	8.199	1.616	0.001
		PNE+MCE	13.390	1.590	0.001
	CSE	PNE+MCE	5.191	1.587	0.013
Trunk Extensor Endurance	Control	CSE	10.010	1.509	0.001
		PNE+MCE	14.423	1.445	0.001
	CSE	PNE+MCE	4.413	1.454	0.013
Side Plank	Control	CSE	4.931	1.582	0.011
		PNE+MCE	11.518	1.549	0.001
	CSE	PNE+MCE	6.587	1.558	0.001
Elbow Plank	Control	CSE	6.450	1.134	0.001
		PNE+MCE	9.622	1.033	0.001
	CSE	PNE+MCE	3.172	1.011	0.010

Statistically significant difference ($P< 0.05$); PNE: Pain Neuroscience Education; MCE: Movement Control Exercise; CSE: Core Stability Exercise; SE: Standard Error

While core stability exercises contribute to muscle strengthening and improved body stability, their effects on reducing sensitization and fear of pain are less pronounced than those of PNE (11).

To achieve optimal outcomes in the treatment and improvement of pain and disability in individuals with CLBP, it is imperative that therapeutic approaches simultaneously address both physical and psychological aspects. Failure to do so may result in limited and inadequate improvements (29). By fostering an understanding of the nature of pain and its psychological dimensions, patients gain a greater sense of empowerment to effectively manage their symptoms and comprehend their condition, which can lead to long-term reductions in pain and disability (29). In this context, the integration of PNE with MCE not only alleviates pain and disability associated with chronic low back pain but also significantly aids patients by activating proprioception, coordination, and sensorimotor control of the spine (30). MCE focus on retraining the brain and body to enhance movement patterns, thereby their selection as complementary exercises in this study following neuroscience education for participants (31). These exercises aim to optimize dynamic control by increasing muscle recruitment and correcting faulty movement patterns, particularly in patients with conditions such as non-specific low back pain and motor control dysfunction (31).

Educating patients on pain management and emotional awareness can contribute to reducing central nervous system hypersensitivity and alleviating pain. Physical feedback and cognitive biofeedback, combined with core muscle and MCE, may contribute to the greater effectiveness of this exercise program compared with core stability exercises alone in reducing pain and disability (32). Therefore, incorporating PNE into MCE as a multimodal approach, in addition to reducing pain and disability by activating proprioception, coordination, and sensorimotor control of the spine, helps patients who have a greater understanding of pain exhibit lower levels of fear and disability from pain, and improve their function. Furthermore, a study indicated that PNE can reduce catastrophizing and pain anxiety, and enhance feelings of empowerment and self-efficacy in pain management (33).

Quality of life is a crucial dimension of health, influenced by various factors including pain, disability, and muscle function. Recent study has demonstrated that core stability exercises and

PNE combined with MCE can help reduce pain and disability while enhancing muscle function in women with CLBP (11). The results indicated that combining PNE with MCE has more favorable effects on these factors and quality of life. PNE significantly enhances patients' understanding of pain, leading to reduced anxiety, increased feelings of control, and improved daily function. When PNE is combined with MCE, such as neuromuscular exercises, it can further reduce pain and disability, ultimately enhancing the quality of life for individuals with chronic pain (33). This study aligned with the findings of research conducted previously (29, 30). Disability in the context of quality of life refers to impairments in physical functioning, activity limitations, and participation restrictions. Enhancing muscle function and reducing movement limitations empowers women to perform their daily activities with improved quality and contributes to their enhanced psychological and social well-being. Therefore, incorporating PNE into an appropriate exercise protocol for individuals with non-specific CLBP, in addition to increasing their understanding of pain and its mechanisms, improves their muscle function and quality of life. The results obtained from this study, when compared with core stability exercises, were consistent with the findings reported previously (33, 34).

The findings of the present study demonstrated that combining pain neuroscience education with motor control exercises yields superior outcomes compared with core stability exercises alone in managing non-specific chronic low back pain in women, suggesting that integrated biopsychosocial approaches should be prioritized in clinical practice.

4.1. Limitations

Despite its robust findings, this study had several limitations that warrant consideration. Firstly, the generalizability of the results was constrained by the relatively small, homogeneous sample of Iranian women, which may not be representative of the broader population with non-specific CLBP across different ethnicities and genders. Secondly, the absence of a long-term follow-up assessment prevents any conclusion regarding the durability of the observed improvements in pain, function, and quality of life beyond the immediate post-intervention period. Furthermore, the reliance on self-reported outcome measures and field-based muscle endurance tests, while valid, could be supplemented with objective biomechanical analyses (e.g., electromyography or motion capture) to provide a more comprehensive understanding of the underlying neuromuscular adaptations. Finally, the control group received no intervention; while this demonstrates efficacy compared to natural history, future research should compare this combined approach to other active, established treatments to better ascertain its relative clinical superiority.

5. Conclusions

The present study demonstrated that pain neuroscience education combined with motor control exercises plays a crucial role in the management of pain and functional disability in women with non-specific chronic low back pain. Furthermore, the findings emphasized that this combined approach can contribute to improvements in muscle function and quality of life in patients. Overall, the results of this study highlighted the necessity of employing comprehensive educational and rehabilitation methods in the effective management of chronic low back pain and can serve as a guide for therapists and researchers in this field. Future research should investigate long-term effects in diverse populations, incorporate objective biomechanical measures alongside self-reported outcomes, and compare these interventions against other active treatments to establish robust clinical guidelines. These findings highlighted the need for multidisciplinary rehabilitation programs that address both physiological and cognitive aspects of chronic pain.

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Authors' Contribution

Nazila Pouraghali: Substantial contributions to the conception and design of the work, the acquisition of data for the work; drafting the work. Ebrahim Mohamad Ali Nasab Firouzjah:

Interpretation of data for the work; drafting the work and reviewing it critically for important intellectual content. Hadi Abbaszadeh Ghanati: Substantial contributions to the conception and design of the work, the acquisition, analysis, and interpretation of data for the work; drafting the work and reviewing it critically for important intellectual content. All authors have read and approved the final manuscript and agree to be accountable for all aspects of the work, such that the questions related to the accuracy or integrity of any part of the work.

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Ethical Approval

The Ethics Committees of the Institute of Sports Science in Tehran, Iran approved the present research with the code of IR.URMIA.REC.1403.033. Also, written informed consent was obtained from the participants.

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