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Comparing the effects of motor control exercises and PNF exercises on postural control, strength, endurance, and proprioception in women with chronic nonspecific low back pain

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Abstract

Background: Low back pain is a common debilitating condition and a major clinical and socio-economic problem in the most industrialized and non-industrialized countries.

Aim: The aim of this study was to compare the effect of motor control exercises and PNF exercises on postural control, strength, endurance and proprioception in women with chronic non-specific low back pain.

Materials and Methods: Forty-five women with non-specific chronic low back pain selected by convenience sampling and randomly divided into three groups of 15 (motor control exercises, PNF exercises, and control group). The pre-test included posture control, flexor and extensor muscle strength of the trunk, trunk muscle endurance, and proprioception using Y balance, dynamometer, McGill, and Goniometer tests, respectively. The subjects of the experimental groups performed the training program for 8 weeks under the supervision of the instructor and according to the training protocol. Then, the post-test was performed. Paired t-test and analysis of covariance at the significance level of 0.05 were used to collect data.

Results: The results showed that motor control and PNF exercises improved proprioception, postural control, endurance, and strength of trunk flexor and extensor muscles in women with non-specific chronic low back pain ($\alpha \leq 0.05$). The results also showed that there was no significant difference between the effects of motor control and PNF exercises on proprioception, postural control, flexor muscle endurance, and extensor muscle strength ($\alpha \geq 0.05$).

Discussion: Motor control and PNF exercises are effective in improving the proprioception, postural control, endurance, and strength of flexor and extensor muscles of the trunk with non-specific chronic low back pain, and both training methods are effective in treating chronic non-specific low back pain.

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1. Introduction

Back pain is a major global challenge, a debilitating condition and common worldwide [1]. Epidemiological studies have shown that more than 80% of the world's population experience it at least once in their lifetime [2]. Non-specific low back pain (NSLBP) without detectable pathoanatomical symptoms has been reported as the major type of low back pain with a ratio of above 90-95% [3]. The total cost of low back pain for communities is estimated at $ 50 million to $ 100 million a year [4]. Low back pain should be considered as a syndrome and an important factor in causing functional disability in the patient and a factor in causing severe economic losses in society [5]. Sawant and Shinde (2019) stated that the deep muscles of the trunk are responsible for maintaining the stability of the spine, and poor endurance of the trunk muscles may put pressure on inactive structures and therefore cause back pain. Patients suffering from low back pain often have many signs and symptoms of pain, decreased muscle strength and endurance of the trunk, impaired movement control, biomechanical changes, and a deformed spine [6].

The goal of motor control exercises is to restore optimal spinal control for proper trunk function. One of the strategies used to achieve spinal control is coordination exercises of trunk muscles such as transverse abdominal muscles, internal oblique muscles and external oblique muscle. The therapist’s goal during movement control exercises is to create a pattern of proper contraction for trunk muscles with normal function of other systems such as the respiratory system and pelvic floor muscles [7]. Assessing the stability of this area is very important. For the stability of the trunk, five components are considered: strength, endurance, flexibility, motor control, and performance [8].

Motor control exercises are done to separate the functions of the muscles and improve the proprioception, reach the normal range of motion and increase the person's awareness of the performance and movements of the lumbar and pelvic areas. The human body continuously combines information from three sensory systems to maintain balance. In these exercises, all three somatosensory, vestibular, and visual systems are challenged; However, there is generally no change in the visual and vestibular systems, and the most adaptations occur in the somatosensory system [9].

Because people with low back pain are associated with the problem of delaying the onset of deep trunk muscle activity, motor control exercises alter the stability and dynamic control of the spine in people with low back pain, so that patients who have recovered from a period of low back pain are prone to recurrence and chronicity if not treated with motor control exercises [10].

Today, various stretching exercises are used to develop flexibility, including proprioceptive neuromuscular facilitation exercises. The mechanism of effect of PNF methods on increasing muscle flexibility is a neurophysiological mechanism including the muscle stretching reflex. This mechanism increases traction tolerance, which is achieved by increasing muscle strength or increasing the sensation of pain relief [11]. PNF stretching helps to stimulate more anterior motor cells of the spinal cord through the use of the most motor pathways, resulting in more motor units being activated and better movement with more muscle tension. The amount and extent of the muscular response also increase with increasing resistance [12].

Motor control is described as the control and coordination of lumbar and pelvic movements, while PNF is defined as a type of muscle learning that enhances motor neuron function and facilitates muscle contraction. According to the studies, it seems that exercise therapy can be considered an effective method for the treatment of chronic nonspecific low back pain.

Motor control exercises and other types of exercises, including manual therapy, sensory accuracy exercises, and Mackenzie exercises, has been compared in researches but so far, due to the beneficial effects of PNF exercises, no research has compared the effects of movement control exercises and PNF. Therefore, the aim of the present study was to compare the effects of motor control exercises and PNF exercises on postural control, strength, endurance, and proprioception in women with chronic nonspecific low back pain.

2. Materials and Methods

The current study is an applied and quasi-experimental investigation. The research design is pretest-posttest with a control group. The statistical population of this study consisted of women with chronic non-specific low back pain in the age range of 30-35 who referred to a specialist in the winter of 2020 and diagnosed as patients by a physician based on symptoms. The statistical sample size were 45 patients (G-power by the 80% confidence) being selected by the available method based on entry and exit criteria. They randomly divided into three groups: motor control exercises (15 people), PNF exercises (15 people), and control group (15 people). All three groups had a pre-test.

Inclusion criteria include age range 30-35 years, people with chronic nonspecific low back pain, female gender, no specific pathology in the spine, no spinal surgery, no sciatica, no acute low back pain in 4 weeks left to test, inactivity physical or intense exercise in the 24 hours before the test, as well as exclusion criteria, including exclusion from the study in the absence of 3 sessions in training, exclusion from the study if unwilling to continue working and giving up, acute low back pain, abnormal congenital structural disorders of the spine and pelvis, spinal surgery, sciatica and the presence of specific pathologies in the spine.

Pre-test included posture control, flexor and extensor muscle strength of the trunk, trunk muscle endurance, and proprioception using Y balance, dynamometer, McGill, and Goniometer tests, respectively. Subjects in the two experimental groups exercised for 8 weeks at 3 sessions per week (Tables 1 and 2), while the control group did not exercise at all. A post-test was performed after 8 weeks.

In the present study, descriptive statistical methods including mean and standard deviation were used to describe the collected data. Also, the Shapiro-Wilk test was used to evaluate the normality of the data distribution. A paired t-test was used to analyze the difference between the means within the group, and for analysis of the difference between the group means. The analysis of covariance with the Tukey post hoc test was used. All analyses were performed using SPSS software version 22 at a significance level of 0.05. The code of ethics obtained for the present study is No. 87096 from the Institute of Physical Education and Sports Sciences.

Table 1. Motor control exercises

Week	Exercise	Set × Repetition	Rest between movements	Rest between sets
1	A, B, C, D, E	10×3	10 s	20 s
2	B, C, D, E, F, G	10×3	10 s	20 s
3	C, D, E, F, G, H, I	10×3	12 s	24 s
4	E, F, G, H, I, J, K, L	10×3	12 s	24 s
5	G, H, I, J, K, L, M, N	10×3	12 s	24 s
6	J, K, L, M, N, O, P, Q	10×3	13 s	26 s
7	M, N, O, P, Q, R, S, T	15×3	13 s	26 s
8	P, Q, R, S, T, U, V, W	15×3	13 s	26 s

Phase I exercises. A: co-contraction of the abdominal muscles; B: a co-contraction of the multifidus muscle; C: Isometric contraction of the abdomen; D: Move the knee to the side; E: extended Sit-ups; F: knees together; G: Lift the leg from behind.

Phase II exercises. H: raising and lowering the pelvis in the supine position; I: raise the leg and pelvis in a supine position; J: raising the arms in a Four-legged position; K: Lifting limbs in Four-legged; L: Scott; M: Launch; N: single foot launch.

Phase III exercises on the ball. O: isometric contraction of the transverse abdominal muscles and multifidus while sitting on the ball; P: decrease and increase the lumbar arch while sitting on the ball; Q: move to the sides while sitting on the ball; R: raising the head in a supine position on the ball; S: raising the head and shoulders in the prone position on the ball; T: raising the foot in the prone position on the ball; U: fold the legs into the abdomen while the ball is between the knees; V: moving the foot to the sides with the ball between the knees; W: stretching and tests on the ball and stretching the back muscles.

Table 2. PNF exercises protocol

Week	Exercise	Set × Repetition	Rest between movements	Rest between sets	Time to create resistance
1 & 2	Isometric contractions of trunk flexors and extensor	3×15	30 s	60 s	**10 s**
3 ,4 & 5	Isometric contractions of trunk muscle Concentric contractions of trunk flexors Eccentric contractions of trunk flexors	3×15 3×15 3×15	30 s 30 s 30 s	60 s 60 s 60 s	**5 s** **5 s** **5 s**
6 ,7 & 8	Lift pattern Chop pattern	3×15 3×15	30 s 30 s	60 s 60 s	**10 s** **10 s**

2.1. Measurements

2.1.1. Postural control (Y test)

The subject stood at a three-way intersection with both dominant leg and the non-dominant leg (single-legged) and performed the achievement action by moving the markers and returning to normal on both feet. The distance that the subject moved the marker was recorded as her achievement distance (Figure 1). All subjects performed actions in each direction 3 times. The mean was divided by the length of the leg (cm) and then multiplied by 100. Thus, the achievement distance was obtained as a percentage of the foot length [13, 14]. The researchers reported the reliability of the excellent test ($P \geq 0.05$ and ICC=0.88-0.99) [15].

Score = The achievement distance (cm) / foot length (cm) × 100

2.1.2. Strength measurement using a manual dynamometer

Measurement of trunk flexors muscle strength. The subject was positioned supine on the bed, arms behind her head, legs fixed, and knees flexed at 90 degrees. The dynamometer pad was placed one inch below the sternal slit. Another strip was fastened to the dynamometer around the bed. The subject was asked to pull her trunk up with maximum effort (Figure 2). An average of 3 attempts was recorded. The researchers reported test-retest validity for this test of 0.87 [16].

Measurement of trunk extensor muscle strength. The subject was lying on her back on the bed with her hands behind her head. The distal part of the thighs was fixed. The dynamometer pad was placed in the middle of the line connecting the two upper inner angles of the individual's shoulder. A stabilising strap was fastened on top of the dynamometer and around the bed, and the athlete's legs were supported on a pillow at 30 degrees of knee flexion. Then, the subject was asked to pull her trunk up with maximum effort to record an average of 3 attempts per kilogram (Figure 2). The researchers reported test-retest validity of 0.85 for this test [16].

2.1.3. Endurance measurement

Measurement of trunk muscle endurance. McGill functional tests used, which have acceptable validity and reliability [17] and include four tests of crunch, modified Sorensen, and side plank (right and left) and performed as follows:

a) Crunch test. To evaluate the endurance of trunk flexors, the person was lying on a bed with a 90-degree flexion knee, a book was placed vertically 12 cm from the examiner's fingertips. The subject was asked to place her fingers on the book (Figure 3). The length of time a person can stay in this position was measured by a stopwatch and recorded as the person's score.

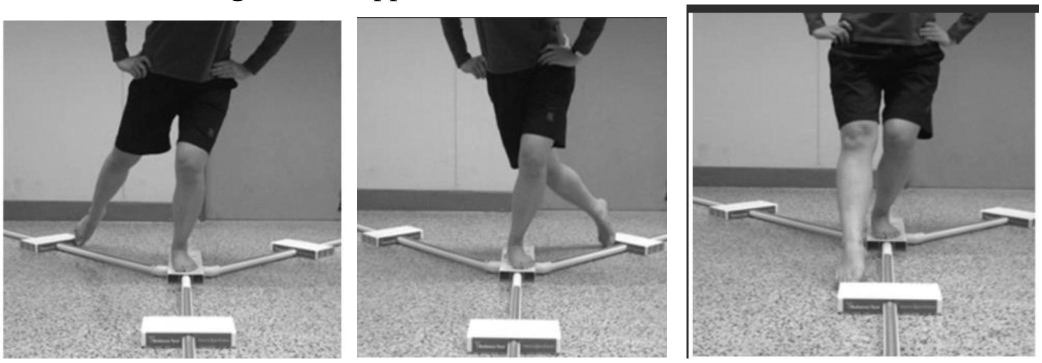

Figure 1. Postural control (Y test)

Figure 2. Strength measurement using a manual dynamometer

Figure 3. Endurance measurement

b) Modified Sorensen Test. The person lies on her back on the bed with trunk out of the bed until the large trochanter touches the edge of the bed. The person's legs were fixed, then the person was asked to keep her trunk parallel to the ground with her arms crossed over her chest (Figure 3). The length of time a person was able to maintain their status was recorded as their score.

c) Side-plank test (right and left). The person was asked to perform the side-plank movement to assess the endurance of the lateral flexors of the trunk (Figure 3). The length of time a person was able to maintain her position was recorded as a person's score [17].

2.1.4. Measurement of proprioception

A goniometer used to measure proprioception. In order to prevent the pelvis from receding during bending and to separate the trunk and pelvic movements, the lower limbs immobilized in the leg, knee, and thigh areas with a special frame. Markers were then attached to the middle of the upper outer surface of the arm, the ridge of the iliac crest, and the outer upper surface of the hip joint. The subject was then placed in a comfortable, stable standing position without shoes or socks. The legs were shoulder-width apart. The arms were crossed. The elbows were bent in front of the shoulders. The neck was kept normal. The eyes were closed to remove visual afferents. Then, the center of the goniometer placed on the iliac crest and goniometer arms adjusted (one arm on the marker mounted on the outer part of the thigh and the other arm on the 30-degree bend). The subject asked to bend up to 30° with her eyes closed and at a uniform speed and relatively slowly (Figure 4). This test was repeated three times. The number of errors in each movement was the difference between the mentioned angles and the target angle. The mean amount of error in postural reconstruction in three repetitions was recorded as the amount of postural reconstruction error and if the mean amount of error was less than three degrees, the proprioception of the subject's back was considered healthy. The researchers reported the validity of this test to be 0.85 [18].

2.1.5. Motor control exercise protocol

The motor control group received training 8 week, three times a week. These exercises included about 10 min of warm-up, about 40 min of motor control exercises, and 10 min of recovery exercises in the form of stretching exercises (Table 1).

2.1.6. PNF exercises protocol

PNF exercises were performed for 8 weeks for about 30-40 min 3 times a week. Warm-up done for 10 min and recovery exercises done for 5 min (Table 2).

Figure 4. Measurement of proprioception

3. Results

The demographic characteristics of the research subjects are presented in Table 3.

The three groups were not different in terms of demographic characteristics.

Table 4 shows the descriptive findings of the subjects and the significance level of the paired t-test of the present study.

Table 3. Demographic characteristics (age, height, weight) of the samples

Group	Age (Year)	Body weight (kg)	Height (m)
Motor control	33.9 ± 2.21	64.32 ± 4.81	173.76±6.76
PNF	32.08 ± 2.16	63.14 ± 7.74	170.18±7.56
Control	32.17 ± 2.19	66.02 ± 5.65	172.22±7.17

Table 4. Descriptive information of variables and results of paired t-test

Variable	Group	Pretest	Pretest	*P*	Effect size
Posture control	Motor control	1.47 ± 47.73	2.61 ± 52.50	**0.001**	**3.244**
	PNF	1.25 ± 48.23	2.04 ± 52.28	**0.001**	**3.24**
	Control	1.42 ± 47.21	1.35 ± 48.67	**0.267**	**1.028**
Flexor muscle strength	Motor control	1.88 ±12.53	1.40 ±16.46	**0.0001**	**2.090**
	PNF	1.57 ± 13.26	1.65 ± 17.80	**0.0001**	**2.89**
	Control	0.98 ± 14.60	0.96 ± 14.73	**0.653**	**0.132653**
Extensor muscle strength	Motor control	1.35 ± 11.13	2.45 ± 15.46	**0.0001**	**3.207**
	PNF	1.68 ± 12.46	1.40 ± 16.40	**0.0001**	**2.345**
	Control	1.72 ± 13.86	1.34 ± 14.33	**0.204**	**0.273**
Endurance (crunch)	Motor control	1.68 ± 11.80	2.25 ± 17.33	**0.0001**	**3.29**
	PNF	2.29 ± 12.60	1.16 ± 15.93	**0.0001**	**1.45**
	Control	1.99 ±12.46	1.34 ±12.66	**0.892**	**0.100503**
Endurance (modified Sorensen)	Motor control	2.41 ± 30.13	2.24 ± 41.82	**0.0001**	**4.85**
	PNF	2.25 ± 29.73	3.039 ± 39.33	**0.0001**	**4.266667**
	Control	2.72 ± 29.53	2.82 ± 29.20	**0.560**	**0.121324**
Endurance (right plank)	Motor control	3.35 ± 13.53	3.26 ± 17.60	**0.0001**	**1.21495**
	PNF	3.30 ± 13.66	2.78 ± 17.26	**0.0001**	**1.090909**
	Control	3.41 ± 13.21	3.09 ± 13.46	**0.189**	**0.0733314**
Endurance (left plank)	Motor control	3.19 ± 12.93	3.04 ± 16.40	**0.0001**	**1.087774**
	PNF	2.84 ± 12.51	2.61 ± 16.13	**0.0001**	**1.274648**
	Control	2.68 ± 12.66	2.86 ± 12.86	**0.363**	**0.074627**
Proprioception	Motor control	2.05 ± 36.66	2.47 ± 32.47	**0.001**	**2.043902**
	PNF	1.92 ± 34.86	1.98 ± 32.66	**0.001**	**1.145833**
	Control	1.12 ± 35.66	0.941 ± 36.20	**0.751**	**0.482143**

Using paired t-test, the pretest-posttest scores of the variables were compared in groups. As can be seen in Table 4, there was a significant difference between the scores of the variables in the motor control group and PNF in the pretest and posttest ($P \leq 0.05$); But there was no significant difference between pretest and posttest scores of variables in the control group; Therefore, it can be concluded that 8 weeks of motor control and PNF exercises had a significant effect on improving postural control, strength, endurance and proprioception.

To compare the effect of motor control exercises and PNF on the mentioned variables in women with chronic nonspecific low back pain in three groups, analysis of covariance was used to determine the differences between groups in the post-test. The results of the analysis of covariance are reported in Table 5.

Table 5. Results of analysis of covariance to compare variables between the three groups

Group	df	F	P	Eta^2
Posture control	2	20.27	0.03*	**0.64**
Flexor muscle strength	2	21.06	0.005*	**0.73**
Extensor muscle strength	2	14.98	0.02*	**0.51**
Endurance (crunch)	2	14.74	0.01*	**0.78**
Endurance (modified Sorensen)	2	25.04	0.01*	**0.62**
Endurance (right plank)	2	24.35	0.001*	**0.76**
Endurance (left plank)	2	29.65	0.001*	**0.71**
Proprioception	2	15.29	0.006*	**0.88**

$P \leq 0.05^*$

The results of the analysis of covariance showed that after controlling the effect of pre-test (covariance), there is a significant difference between three groups in the variables in the post-test ($P<0.05$); Tukey post hoc test was used to compare the two groups. The results of the Tukey post hoc test are shown in Table 6.

4. Discussion

The aim of this study was to compare the effects of motor control exercises and PNF exercises on postural control, strength, endurance, and proprioception in women with chronic nonspecific low back pain.

The results displayed that motor control and PNF exercises improve postural control in women with non-specific chronic low back pain. The results of this study were consistent with the results of the study of Niederer and Mueller (2020) [19], Eridom Wong et al. (2019) [20], Javadipour, Norasteh and Babagol Tabar Samakoush (2020) [21], Kiani and Fattahi (2020) [22], and Sobhy (2017) [23].

In rehabilitation of patients with chronic low back pain, the goal is to restore normal muscle function and increase spinal stability by reducing pain and disorders in these patients [19]. Changes in movement pattern and the deep lumbar muscles use as the main muscles involved in stabilizing this area in patients with chronic non-specific low back pain, which can cause pain and loss of muscle balance and ultimately negatively affect patients' performance [20]. Therefore, the positive effects of motor control and PNF exercises on improving postural control in these patients can be justified because it involves the deep muscles of the lumbar, pelvis and abdomen by improving the movement pattern. Movement control exercises increase the sensitivity of muscle spindles and the interaction of gamma and alpha neurons, and ultimately facilitate muscle contraction. Increased spindle sensitivity and improved neuromuscular control have been reported after these exercises.

Table 6. Summary of Tukey post hoc test results to compare the two groups in the measured variables

Variable	Group	Motor control	PNF	Control
Posture control	Motor control		0.712	0.046*
	PNF	-		0.043*
	Control	-	-	
Flexor muscle strength	Motor control		0.029*	0.004*
	PNF	-		0.000*
	Control	-	-	
Extensor muscle strength	Motor control		0.175	0.081*
	PNF	-		0.001*
	Control	-	-	
Endurance (crunch)	Motor control		0.065	0.000*
	PNF	-		0.000*
	Control	-	-	
Endurance (modified Sorensen)	Motor control		0.044*	0.000*
	PNF	-		0.000*
	Control	-	-	
Endurance (right plank)	Motor control		0.952	0.000*
	PNF	-		0.004*
	Control	-	-	
Endurance (left plank)	Motor control		0.965	0.005*
	PNF	-		0.009*
	Control	-	-	
Proprioception	Motor control		0.956	0.000*
	PNF	-		0.000*
	Control	-	-	

*$P \leq 0.05$

Another reason that movement control exercises have been found to be effective is the stimulation of the central nervous system. The central nervous system coordinates the contractions agonist and antagonist muscles. PNF stretches stimulate more anterior horn motor cells through the use of most motor pathways, resulting in a greater number of motor units and better movements with more muscle tension. Also, by increasing the amount of resistance, the amount and extent of the muscular response increases [24].

The results of the study showed that motor control and PNF exercises improve muscle strength in women with non-specific chronic low back pain. However, there was no significant difference in trunk muscle strength between the pretest and posttest of the control group, which indicates the effect of motor control exercises and PNF on trunk muscle strength in women with chronic nonspecific low back pain. Motor control exercise is one of the most effective strategies to prevent muscle weakness and destruction; because it improves strength and function of the muscles. Since the reduction in muscle mass contributes the development of sarcopenia [6], the effect of motor control and PNF exercises on muscle hypertrophy and its myogenic processes in people with chronic nonspecific low back pain is important [25]. Neuromuscular responses to motor control exercises involve not only the spindles but the entire sensory system, and all sensory structures are able to receive stimuli and participate in facilitating the input of gamma motor neurons [26]. The results of this study are consistent by

Halliaday and Ferreira (2019) [27], Kiani and Fattahi (2020) [22].

The results showed that there was a significant difference between the pretest and posttest of the motor control group and PNF exercises in muscle endurance in the control group; however, there was no significant difference in trunk muscle endurance between pre- and post-test, indicating motor control exercises and PNF have no effect on trunk muscle endurance in women with chronic non-specific low back pain. Researchers stated that the lumbar muscles, as the supporting and postural muscles of the body, contract faster than other muscles and atrophy and weakness, and this reduces the endurance of the muscles [28]. Therefore, exercises can increase muscle endurance and, subsequently, improve low back pain and disability in patients. Accordingly, exercises improve the endurance capacity of the flexor and extensor muscles in creating stability of the trunk, and by raising the threshold of fatigue of the trunk muscles, they greatly improve pain and inability to function. Eighty percent of back pain is muscular in nature and is corrected with strengthening exercises in the abdomen and lumbar. The exercises of this research include the lumbar and abdomen [29]. The results of this study are consistent by Halliaday and Ferreira (2019) [27], Kiani and Fattahi (2020) [22].

The results of the study showed that motor control and PNF exercises improve proprioception in women with non-specific chronic low back pain; while in the control group, no significant difference was observed in the proprioception of the trunk. Patients with chronic mechanical low back pain have profound proprioception disturbances, and these disorders are associated with pain in these patients. Proprioception receptors transmit joint and muscle information through the sensory nerves to the central nerve centers, and what improves stability and prevents injury is neuromuscular coordination [30]. The results of this finding are consistent with the results of Letafatkar et al. (2017) [18], Sobhy (2017) [23], Hosseinabadi et al. (2020) [31], Kiani and Fattahi (2020) [22], and Asadi (2020) [32]. Studies have shown that proprioception is teachable, and rehabilitation programs based on proprioception training improve functional movements. To train the proprioception, this system must be involved, and for this purpose, it is provided with special exercises. To improve proprioception, exercise on unstable surfaces, such as gym ball training, is recommended because it stimulates the proprioception receptors. Also, exercise on unstable surfaces may use inactive lumbar muscles and actively engage them, so the central nervous system receives more appropriate and effective stimuli from the afferent nerves of the proprioception receptors of these muscles [33]. The results of this study and other consistent studies showed that central stability training improves the proprioception of patients in the lower back; Motor control exercises in this study have the nature of central stability [34].

As limitations of the study, we were not able to control the subject's life style, nutrition and movement habits.

5. Conclusion

Overall, the results of the present study showed that performing 8 weeks of motor control and PNF exercises can improve postural control, strength, endurance, and proprioception in women with chronic nonspecific low back pain. Therefore, it is recommended that practitioners use motor control and PNF exercises to improve muscular endurance and strength of the trunk and improve postural control and proprioception to reduce back pain in patients with non-specific chronic low back pain.

Conflict of interest

The authors declared no conflicts of interest.

Authors' contributions

All authors contributed to the original idea, study design.

Ethical considerations

The author has completely considered ethical issues, including informed consent, plagiarism, data fabrication, misconduct, and/or falsification, double publication and/or redundancy, submission, etc.

Data availability

The dataset generated and analyzed during the current study is available from the corresponding author on reasonable request.

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