Research Article

Comparing the Effects of the Postural Restoration Exercises with and without Core Stability Exercises in Patients with Non-Specific Chronic Low Back Pain

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ABSTRACT

Introduction: This study compares the effect of postural restoration (PR) exercises with and without core stability exercises on the pain, intensity, function, quality of life (QoL), and passive range of motion (PROM) at lumbo pelvic-femoral complex in patients with non-specific chronic low back pain.

Materials and Methods: This was an interventional type of randomized clinical trial study. The participants were 45 female patients (48.1±6.11 years, 161.4±5.06 cm height, 65.08±6.9 kg weight, and 24.9±2.8 body mass index). They were randomly divided into three equal groups: Group 1=PR exercises and core exercises, group 2=PR exercises, and group 3=control group. Pain intensity, function, QoL, and PROM were measured with the visual analog scale, Oswestry disability index, short form-36 questionnaire, and goniometer. The analysis of covariance was used to compare the means in the study groups before and after the intervention. The intervention groups performed the exercises for six weeks.

Results: The results showed a significant difference between the QoL, pain intensity, function, and PROM of left hip adduction in the group with PR exercises with and without core exercises and control (P=0.000). In the PR group with core exercises (P=0.001) and without core exercises (P=0.001), a significant increase was observed in the adduction of the left hip. There was no significant difference between the function (P=0.850), pain (P=0.120), QoL (P=0.328), and PROM (P=0.094) in the intervention groups.

Conclusion: PR exercises with and without core stability are equally effective in reducing pain and improving function, QoL, and hip adduction range of motion in women with left anterior interior chain patterns.

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Introduction

Non-specific chronic low back pain (NCLBP) is a common musculoskeletal disorder disease that occurs without a specific reason and affects many patients (90%) with lower back pain (LBP) [1]. The prevalence of this disease increases in people between the ages of 35 to 55 years [2]. Lumbo-pelvic-femoral area involvement, such as chronic LBP [3], sacroiliac joint dysfunction [4], pelvic impingement [5], and lateral pelvic pains occur in people [6]. These patients are vulnerable to injuries, such as hip joint compression, due to excessive stress and tension. Disorders, such as unilateral muscle weakness, excessive muscle activity, shortness of the ligament or capsule (range of motion [ROM]), the unfavorable position of the diaphragm muscle, and asymmetric posture may be associated with lumbar-pelvic-femoral disorders that can lead to NCLBP [5].

The therapeutic exercises that were used in this investigation are unique. These exercises are not common to restore the postural position of the lumbo pelvic-femoral complex (LPFC) [7], and the identification of a restricted left hip posterior capsule/ischio femoral ligament as it relates to LBP and or postural asymmetry is rarely discussed [7, 8]. Until now, postural restoration (PR) exercises have not been discussed to activate the adductor magnus to achieve a desired position in the pelvis (internal rotation of the left hemipelvis), as well as increasing flexibility and eliminating the shortness of the posterior capsule in patients and strengthening the gluteus maximus muscle in recent articles, and they were mostly as case reports [7].

If the patient's LBP is associated with an asymmetric posture pattern and a right-handed pattern [7] (attributed to right-hand dominance) or a left anterior-internal chain (left AIC) [8] (anatomical asymmetry), there are specific interventions to address the disorders. Our body has some anatomical asymmetry, such as asymmetry in the number of lung lobes, a larger right diaphragm, and dominancy of the right side [9]. These asymmetries can cause excessive use of one side of the body; for example, too much use of the right side can result in standing more on the right leg and pelvic position changes [9]. The chain pattern is common in right-handed people. In these people, asymmetry related to the alignment of the bones and the placement of the muscles and ligaments can be seen. Accordingly, in the pattern of postural asymmetry, some muscles are weak, and some are strong and short [8, 9]. As a result, this causes a change in the position of the pelvis in such a way that the right hemi-pelvic is in the posterior pelvic tilt, and the left hemi-pelvic is in the anterior pelvic tilt (in the sagittal plane) and rotates forward (on the frontal plane).

In a person with such asymmetric posture, the force of gravity causes the body's center of gravity to shift to the right half; hence, there is a tendency to put more weight on the right leg. In compensation, the right hemi-pelvic is in internal rotation and adduction, and the left hemi-pelvic is in abduction and external rotation [8]. When the left hip is placed in compensatory external rotation, it causes shortening and limitation of the posterior capsule of the hip on this side. As a result, the possibility of moving to the left (internal rotation and adduction of the left hip) is limited. This position causes the acetabulum cavity on the left side to move slowly at the femur's head. This pelvis position causes the hamstrings and left Ischiocondylar adductor magnus (ICAM) muscles to lengthen and weakness [8, 10]. If the right hip is placed in internal rotation, it causes the right gluteus maximus to be weaker and longer than the left gluteus maximus [10]. If the left pelvis of the patient was in an anterior tilt in the sagittal plane, forward rotation in the transverse plane causes the femoral neck to be compressed on the cotyloid horn of the acetabulum during the Ober test. As a result, a bony barrier was created, and the Ober test became positive [11].

If one aims to correct this three-plane asymmetry, we can get help from the left hamstring muscles. The left hamstring muscles extend the left hip and create a posterior tilt, causing the restoration of the anterior tilt in the sagittal plane. If right hip abduction and left hip adduction are activated, it could help return the pelvic girdle to a more neutral state in the frontal plane. Finally, the right gluteus maximus (hip external rotation), left gluteus medius, and ICAM (hip internal rotation) could help restore position in the transverse plane [8, 10]. The pelvis was placed in a neutral position by activating the left hamstrings and abdominals, and the Ober test became negative [12].

One of the most effective and innovative treatment methods for patients with back pain is using central stability exercises to improve performance and reduce pain. Back pain can cause weakness of the muscles in the central region, inhibit muscle firing, and increase mechanical disorders in the spine, which can create a cycle of pain-spasm pain and decrease endurance, muscle strength, and functional disorders in patients [13]. Neuromuscular re-education and strengthening of the core musculature play an essential role in increased spinal column stability and, in turn, minimized pain associated with stability [14]. The main emphasis of core strengthening is focused on muscular stabilization of deep abdominal muscles, diaphragm, pelvic floor muscles, and para-spinal and gluteal musculature, and optimal firing of all core muscles is proposed to be necessary for the greatest amount of spinal stability [15]. Transversus abdominus (TrA), multifidus, diaphragm, and pelvic floor muscles have been considered the primary stabilizers of the LBP. They play a role in postural control and are associated with eccentric deceleration or resisting momentum [16]. The TrA and multifidus muscles of the pelvic floor and diaphragm work synergistically via their contraction to provide postural and trunk stability. This is done by increasing intra-abdominal pressure [17]. The diaphragm flattens during inspiration to increase IAP, thoracic volume, and lower intra-thoracic pressure [8]. In this study, core exercises were used to help stabilize LPFC. This study investigates and compares the effect of PR exercises with and without core exercises on pain intensity, function, quality of life (QoL), and PROM at LPFC in patients with NCLBP and using unique unilateral exercises. In addition, this study investigates the effect of these exercises on the pattern of asymmetry in the pelvis and the limitation of the posterior capsule of the left hip in right-handed people with a pattern of left AIC [8, 10, 11].

Materials and Methods

Study design and participants

The present study was an interventional type of randomized clinical trial. After selecting the subjects based on research criteria and completing the consent form, we recorded their personal information, including their height, weight, gender, body mass index (BMI), and then their body condition, including treatment records and the onset of pain. Then, the subjects were randomly divided into three groups: Group 1=experimental group of PR exercises with core exercises (n=15); group 2=experimental group of PR exercises (n=15); group 3=control (n=15) who did not do any exercises. The subjects participated voluntarily, and all completed the consent form. Exercises were performed once daily, six days a week for 6 weeks. The evaluation and treatment were done by the researcher (physiotherapist) during six weeks. A total of five people in three groups were excluded from the study.

Inclusion criteria

The inclusion criteria were as follows: Female patients with NCLBP, according to the diagnosis of a specialist, without referral pain to the lower limbs, the lasting pain for at least three months since the onset, improving with rest and aggravating with activity, and no prohibition of therapeutic exercises. Also, all patients with left AIC and a positive Ober test on the left side were included.

Exclusion criteria

The exclusion criteria were as follows: Suffering from infection, tumor, rheumatoid diseases, vertebral fractures, referral pain to the lower limbs, osteoporosis, severe postural deformity, congenital spine abnormalities, spondylolisthesis, night pain, female urinary tract diseases, using anti-inflammatory drugs, painkillers, and having medical practice history.

Individuals were not subjected to special treatment methods and other sports exercises during the study period. A total of 45 female patients aged 35 to 55 years working in a welfare organization participated in this study. They suffered from NCLBP with a history of more than three months of pain in the lumbar pelvic-thigh girdle area on the left side.

The Mean±SD age was 48.1±6.11 years, height 161.4±5.06 cm, weight 65.08±6.9 kg, and BMI 24.9±2.8 kg/m^2. The participants were first subjected to a basic visual assessment. The assessment included the way of standing, leaning more on the right leg, the rotation of the left hemi pelvis forward and its anterior tilt, the rotation of the right hemi pelvis backward, and the right hip in internal rotation and adduction, and the left hip in external rotation and abduction [18].

Study assessments

The necessary tests were performed to determine the left AIC pattern:

The adduction drop test (positive Ober test in people in the left AIC pattern) [19];

Evaluation of the hip extension [Thomas test], which may have a positive Thomas test and a positive Ober test if the anterior hip ligaments are healthy [19];

The hip abduction passive raising test, which is positive in the left AIC pattern;

Evaluation of trunk rotation range, which in people with the left AIC pattern, the passive rotation of the trunk becomes positive to the left [18, 19];

Internal rotation test of the glenoid cavity of the humerus, in which the inside of the left shoulder is more than the right shoulder [18].

The tests and visual observations showed all patients had a left AIC pattern in the lumbar pelvic-femoral joint area. Before and after the exercise interventions, the pain intensity, functional disability, range of motion of the hip joint, and QoL were measured in all three groups with the visual analog scale, Oswestry disability index, goniometer, and short form-36 QoL questionnaire, respectively.

Data collection tools

The visual analog scale was used to collect data related to the pain intensity of the subjects. This scale is one of the most reliable pain rating scales, and its reliability coefficient (ICC) has been obtained at 0.91.

The Oswestry disability index was used to evaluate the degree of disability. This questionnaire contains 10 items, each scored from 0 to 5, and the maximum score of the questionnaire is 50.

The short form-36 QoL questionnaire was used to evaluate the QoL. It has 36 questions and measures the general QoL with its eight domains. In this questionnaire, a lower score indicates a lower QoL and vice versa [20].

A goniometer, which has acceptable inter-examiner repeatability, was used to measure the range of motion of the joints. The data were collected before and after the interventions [21].

Study variables

Independent variables included PR and core exercises, and dependent variables were pain, functional disability, range of motion, and QoL.

The first group: Postural restoration and core exercises

A total of 15 patients were randomly included in this group. The exercises were performed for six weeks. PR exercises were performed once or twice a day, and core stability exercises were performed once daily under the researcher's supervision. Before starting the intervention, the researcher taught the above exercises entirely. The presented exercises were performed based on therapeutic exercises, such as warm-up, progressive overload, specificity, continuity, and cool-down. The evaluation and treatment were done by the researcher (physiotherapist) during six weeks.

Postural restoration with core exercises

Diaphragmatic breathing

Diaphragmatic breathing exercise improves ventilation efficiency, decreases respiratory rate, increases the diaphragm's downward and upward movements, and improves gas exchange and oxygenation. The exercises included deep respiration, holding the breath for 3 to 10 s, and 10 repetitions before starting and focusing on respiration to increase awareness of respiratory patterns, rate, and volume. From the second week, the balloon was used during exhalation. The balloon acts as a Thera-Band for the diaphragm and intercostal muscles [22, 23].

Right side-lying left anterior gluteus medius with weighted femoral acetabular internal rotation and abduction

The purpose of this exercise is to activate the internal rotation of the front of the gluteus medius to help keep the femoral head in the optimal position in the acetabular cavity and prevent further external rotation, which reduces the articular surface of the femoral head in the acetabular cavity (Figure 1). In cases where the Thomas test is negative, and there is laxity of the anterior capsule and ligament, it is necessary to strengthen and activate the anterior part of the left gluteus medius [7].

Right side-lying respiratory left adduction pull back

This exercise was used to move the acetabulum into a normal posture until the movement of the femur can occur within a corrected (anatomically normal) acetabulum position. In this exercise, the knees and hips are in 90 degrees of flexion, and the lumbar spine is in flexion

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Figure 1. Right side-lying left anterior gluteus medius with weighted femoral acetabular internal rotation and abduction [7]

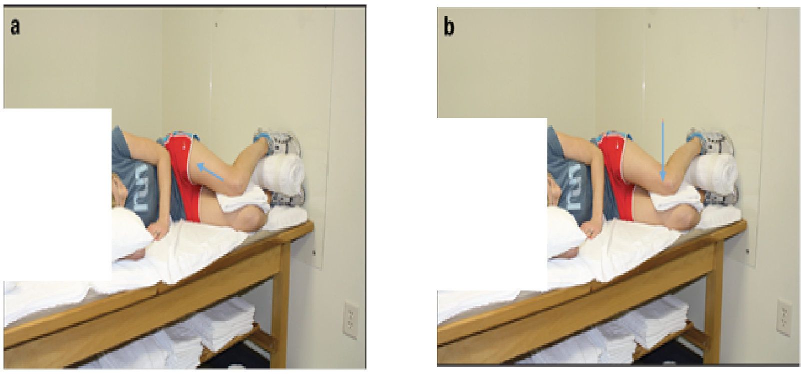

Figure 2. Right side-lying respiratory left adductor pull back

(posterior pelvic tilt) (Figure 2). Unlike an anterior tilt position, this position inhibits the para-spinal and relaxes and lengthens them. Placing the feet on the wall provides distal stability for proximal movement [7, 8].

90-90 left hemibridge with a left hip shift

This exercise is performed to counteract the anterior tilt of the pelvis. Muscle activation causes the movement of the left hip (acetabulum on the femur) to adduction internal rotation. It increases the length of the ligament and posterior capsule of the left hip (Figure 3). Taking the right leg off the wall and raising it causes the rectus femoris to pull the ilium forward and the left side to be pulled back using the hamstrings. The 90-90 hemibridge activates the hamstrings unilaterally. This exercise activates the hamstrings and abdominals [7].

Left side-lying scissor slides with ball

This exercise facilitates the left hip shift (acetabular movement over the femoral head and into internal rotation) and activates the left adduction magnus (Figure 4). This exercise is used to improve the flexibility of the ligament and posterior capsule of the left hip and create a passive internal rotation of the left hip [22, 23].

Left side-lying knee-to-knee

The left femoral acetabular is placed in approach and internal rotation (Figure 5). This exercise is used to strengthen the movement of the left acetabulum over the femoral and facilitate the lengthening of the posterior capsule/ligament of the patient's left hip, and for the left femoral head to be correctly placed inside the left acetabulum cavity and obtain left hip passive internal rotation [24].

Core exercises

Abdominal bracing

The goal of abdominal bracing was to re-use the abdominal muscles and use a stimulating contraction of the core global muscles [24].

Long sitting reverse curl up

The goal of the long sitting reverse curl-up excursive was to activate the oblique and abdominal muscles used in the sagittal planes and frontal planes (right and left trunk rot) during exhalation and inhibition of the para-

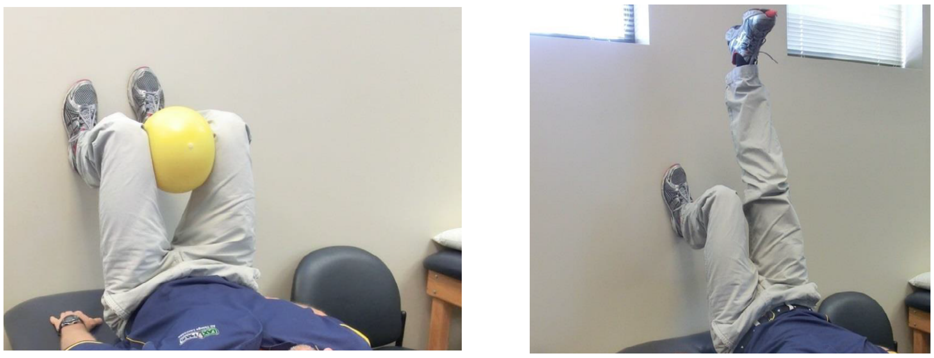

Figure 3. 90–90 left hemi bridge with left hip shift [18]

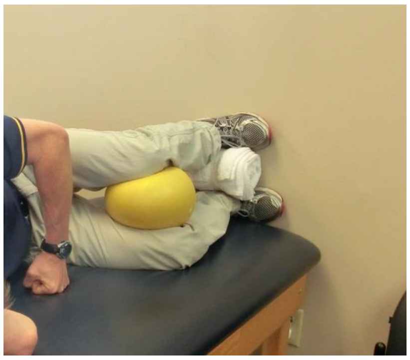

Figure 4. Left side-lying scissor slides with a ball to facilitate left hip, shifting (acetabular movement over the femoral head into internal rotation) left Acetabulofemoral (AF) internal rotation, and left ICAM activation [18]

spinal (to prevent anterior shift) and trunk or pelvis stability [25].

Supine bridging

Supine bridging aimed to increase dynamic stability and strengthen extensor muscles [22].

Abdominal marching

The goal of abdominal marching was to activate the transverse abdominal muscle on both sides, the oblique muscles, and the rectus abdominis [26].

Adduction ball squeeze

The adduction ball squeeze exercise activates the adduction and pelvic floor muscles bilaterally for stabilization.

The second group: Postural restoration exercises

A total of 15 patients were randomly included in this group. Exercises were performed for 6 weeks. PR exercises were performed once or twice a day. Before starting the intervention, the researcher taught the above exercises entirely. The presented exercises were performed based on therapeutic exercises, such as warm-up, progressive overload, specificity, continuity, and cool-down. The evaluation and treatment were done by the researcher (physiotherapist) during 6 weeks.

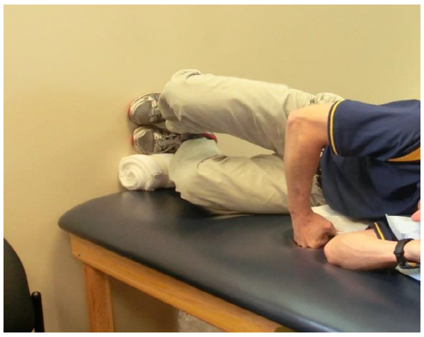

Figure 5. Left side-lying knee-to-knee in a position of left acetabular femoral internal rotation with left femoral acetabular internal rotation and adduction [18]

The third group: Control group

Volume and frequency of exercises

PR exercises consisted of 5 to 10 repetitions, 1 to 2 sets once or twice a day, and the duration of muscle contraction was 3 to 5 s. It included inhaling through the nose and exhaling through the mouth, taking 4-5 deep breaths, and holding the breath for 3-5 s. During the exercise, feedback on respiratory and muscle cramps was given [7]. Core stability exercises consisted of 8 to 10 repetitions, 1 set once every day from static to dynamic.

Statistical methods

Since covariance assumptions were established in most variables, the analysis of covariance with bootstrap intervals was used to test hypotheses and control the primary differences. All analyses were performed with the SPSS software, version 26, at a significance level of $P \leq 0.05$.

Results

Based on the descriptive data, the Mean±SD age of the samples was 48.1±6.11 years, their height equaled 161.4±5.06 cm, weight was 65.08±6.9 kg, and the BMI was 24.9±2.8 kg/m^2. Also, the results of the one-way analysis of variance showed no significant difference between the mean of age ($F_{(2, 36)}=2.32$, $P=0.112$), height ($F_{(2, 36)}=0.972$, $P=0.388$), weight ($F_{(2, 36)}=1.29$, $P=0.228$), and BMI ($F_{(2, 36)}=1.05$, $P=0.357$) between the study groups.

The results of the Shapiro-Wilk test showed that the variables of pain intensity, function, QoL, flexion range of motion, extension, abduction, adduction, and internal and external rotation of the hip joint in three groups of PR with core exercises, PR alone, and control in pre-test and post-test were distributed normally ($P<0.05$).

The results of the Levene test showed that the hypothesis of homogeneity of variance in the study variables was established (P<0.05). The results of the regression lines showed that the regression lines' slopes of the study variables were also established (P<0.05). Finally, the assumption of a linear relationship between the covariate and dependent variables in the study variables was established based on the distribution diagrams.

The results of the analysis of covariance of the pre-test stage in Table 1 showed a significant difference between the adjusted mean of the pain intensity of the LPFC in people with NCLBP in the group of PR exercises with (mean=2.34) and without core exercises (mean=3.07) and control (mean=5.5) ($F_{(2, 35)}$=37.6, η^2=0.68, P=0.000). Therefore, the Bonferroni post hoc test with bootstrap confidence intervals was used to determine the differences and test the hypothesis. The results of the post hoc Bonferroni test showed that PR with core exercises (BCa 95% CI, 2.5%, 3.7%; P=0.001) and PR without core exercises (BCa 95% CI, 1.7%, 4.1%; P=0.001) led to a significant decrease in the intensity of LPFC pain in people with NCLBP (BCa 95% CI, 2.5%, 3.7%; P=0.001). Finally, no significant difference was observed between the adjusted mean of LPFC pain intensity in people with NCLBP in PR exercises with and without core exercises (BCa 95% CI , 0.12%, -1.6%; P=0.120) (Figure 6).

The results showed a significant difference between the adjusted function means of the LPFC in people with NCLBP in the group of PR exercises with (mean=9.98) and without core exercises (mean=10.29) and control (mean=21.72) ($F_{(2, 35)}$=22.6, η^2=0.56, P=0.000). Figure 7 shows the results of the post hoc test with bootstrap intervals, showed that PR with core exercises (BCa 95% CI, -7.3%, -1.16%; P=0.001) and PR exercises without core exercises (BCa 95% CI, -7.5%, -15.2%; P=0.001) led to a significant decrease in the function of the LPFC in people with NCLBP. However, there is no significant difference between the adjusted function mean of the LPFC in people with NCLBP in the group of PR exercises with and without core exercises (BCa 95% CI, 2.7%, -3.8%; P=0.850) (Figure 7).

The analysis of covariance results showed a significant difference between the adjusted mean of the QoL in people with NCLBP in the group of PR exercises with (mean=117.5), without core exercises (mean=114.5), and

Table 1. Results of analysis of covariance

Variables	Source	SS	df	MS	F	Sig.	H²
Pain	Pre-test	2.34	1	2.34	3.36	0000	51.0
	Group	8.70	2	4.35	6.37	000.0	68.0
	Error	22.32	35	942.0			
Functional disability	Pre-test	9.1083	1	9.1083	6.47	000.0	57.0
	Group	3.1023	2	4.35	6.22	000.0	56.0
	Error	9.796	35	7.22			
Quality of life	Pre-test	9.4618	1	9.4618	55.60	000.0	63.0
	Group	5.3570	2	2.1785	4.23	000.0	57.0
	Error	5.2669	35	2.76			
Adduction of the left leg	Pre-test	8.152	1	8.152	2.77	000.0	68.0
	Group	09.196	2	04.98	5.49	000.0	73.0
	Error	2.69	35	98.1			
Adduction of the right leg	Pre-test	3.37	1	3.37	44.6	016.0	15.0
	Group	7.8	2	38.4	756.0	477.0	04.0
	Error	8.202	35	79.5			

Abbreviations: SS: Sum of squared; df: Degree of freedom; MS: Mean square.

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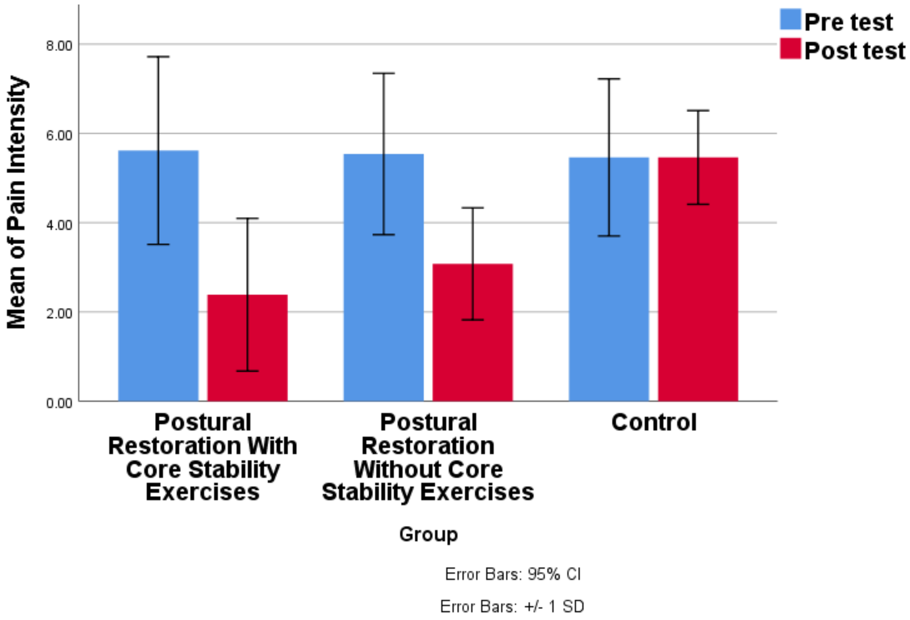

Figure 6. Mean±SD of pain intensity

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control (mean=95.8) ($F_{(2, 35)}$=23.4, η^2=0.57, P=0.000). Figure 8 shows the results of the post hoc test with bootstrap intervals, showing that PR with core exercises (BCa 95% CI, 30.5%, 13.05%; P=0.001) and PR without core exercises (BCa 95% CI, 25.4%, 11.7%; P=0.001) led to a significant increase in the QoL in people with NCLBP. Finally, there is no significant difference between the adjusted mean of the QoL in people with NCLBP in the group of PR exercises with and without core exercises (BCa 95% CI, 8.8, -3.5; P=0.328) (Figure 8).

The results showed a significant difference between the adjusted mean PROM of left thigh adduction in people with NCLBP group with PR exercises (mean=21.96), without core exercises (mean=20.2) and control (mean=16.6) ($F_{(2, 35)}$=49.5, η^2=0.73, P=0.000). According to Figure 9, the results of the post hoc test with bootstrap intervals showed a significant difference between the adjusted mean of the left thigh adduction range of motion in people with NCLBP in the group of PR exercises with core exercises (mean=21.96) and control (mean=16.6) (BCa 95% CI, 4.1%, 6.2%; P=0.001). In other words, PR with core exercises (BCa 95% CI, 4.1%, 6.2%; P=0.001) and without core exercises (BCa 95% CI, 3.1%, 5.22%; P=0.001) led to a significant increase in the adduction range of motion of the thigh of

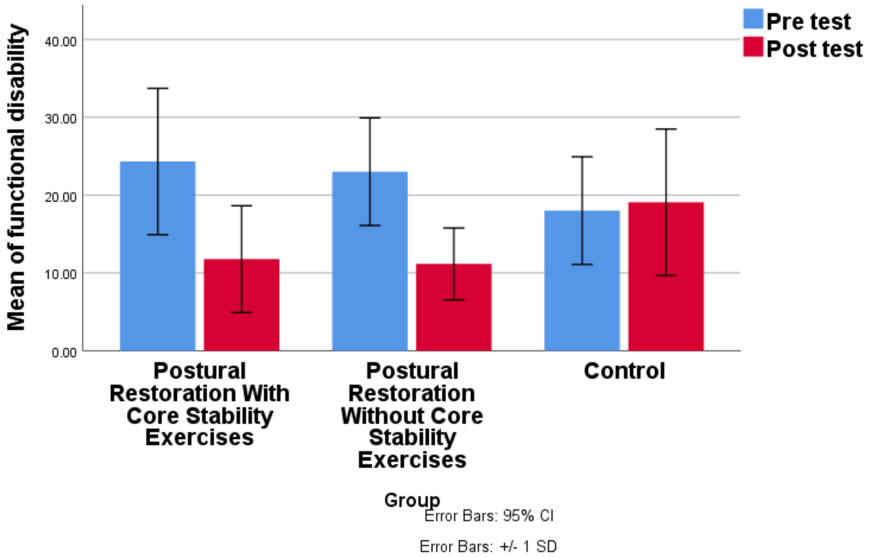

Figure 7. Mean±SD of functional disability

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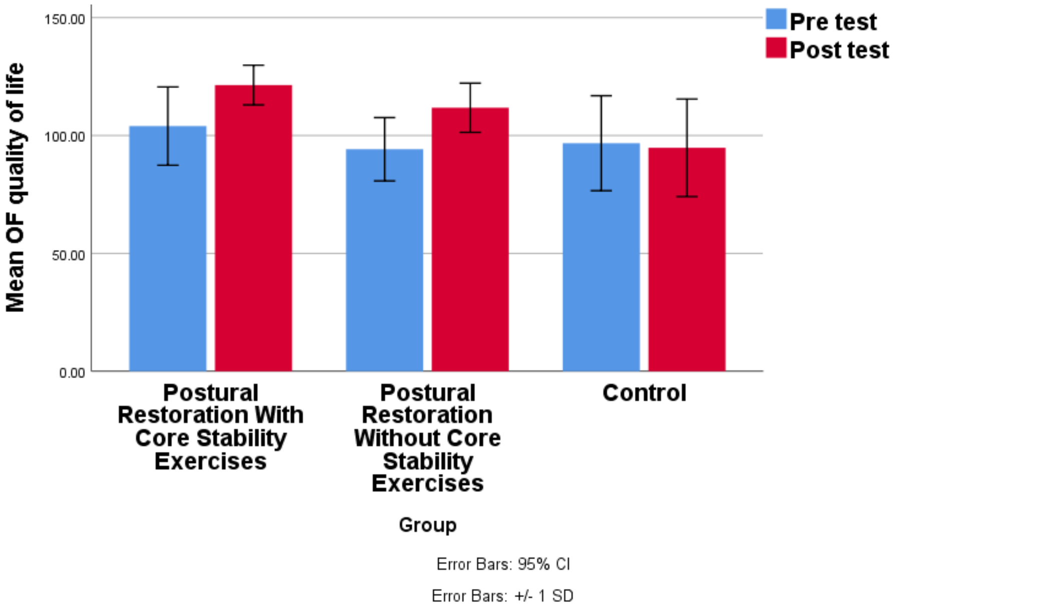

Figure 8. Mean±SD of the quality of life

the left leg in people with NCLBP. Finally, there is no significant difference between the adjusted mean of the left leg thigh adduction PROM in people with NCLBP in the group of PR exercises with (mean=21.96) and without core exercises (mean=20.4) (BCa 95% CI, -0.11%, 2.3%; P=0.094). Also, no significant difference was observed between the adjusted mean PROM of right leg thigh adduction in people with NCLBP in the group of PR exercises with (mean=20.2) and without core exercises (mean=21.01) and control (mean=19.8) ($F_{(2, 35)}$=0.756, η^2=0.04, P=0.477) (Figure 9).

Discussion

This study compared the effects of PR exercises with and without core exercises on the pain intensity, function, QoL, and PROM at LPFC and described unique therapeutic exercises without manual techniques. The intervention study used to correct the pelvis or femur and increase elongation of their left posterior hip capsule appeared to eliminate their NCLBP. If the patient was compensating to move the left hemi-pelvic to anterior tilt and the left hip to external rotation, the posterior capsule/ligament of the left hip is tightened and causes laxity of the anterior ligaments of the left hip [8]. The result is a compensatory pattern for the left AIC to help realign the left femur, which is inward with the pelvis tilted forward and rotated forward toward the sagittal position [8]. We must provide exercises to the flexibility of the left posterior hip capsule or ligaments to allow the femoral head to be seated back in the acetabulum and to provide neuromuscular re-education of internal rotation musculature (anterior gluteus medius, ICAM) to achieve femoral internal rotation instead of femoral external rotation [8].

We assumed that the activation of the left hamstrings (left hip extension acetabulum moving on the femur) would help to realign the pelvis and also moving the left hip into adduction and internal rotation would increase the extensibility of the posterior hip capsule and ischiofemoral ligament to increase the realign of the femoral head within the acetabulum [8]. The scissor-slide exercises were used to help regain left posterior hip capsule elongation and move the left hip into internal rotation and adduction [7, 22]. The knee-to-knee exercises can help activate or recruit the right gluteus maximus, left adductor magnus (AM), and abdominals to help hold the left acetabulum over the left femoral head. Adduction with internal obliques can help increase pelvic stability [22, 27]. The right-side-lying left anterior gluteus medius exercises can help activate the left gluteus medius for internal hip rotation (to maintain femoral head position within the acetabulum) and to avoid possible compensatory external left hip rotation [7]. The 90-90 hemibridge with balloon exercise activates the hamstrings unilaterally. This exercise stabilizes the pelvis in a neutral position, isometric hamstring activation, to make it easier for many patients to achieve control [7]. Using a balloon in any activity will activate resistance to exhalation and concentric contraction of internal obliques and transverse abdominals. Right reaching in this technique helps the patient to sense the desired left posterior pelvic rotation. If the pelvis tilts anteriorly, the ischial tuberosity moves proximally and away from the tibia, resulting in

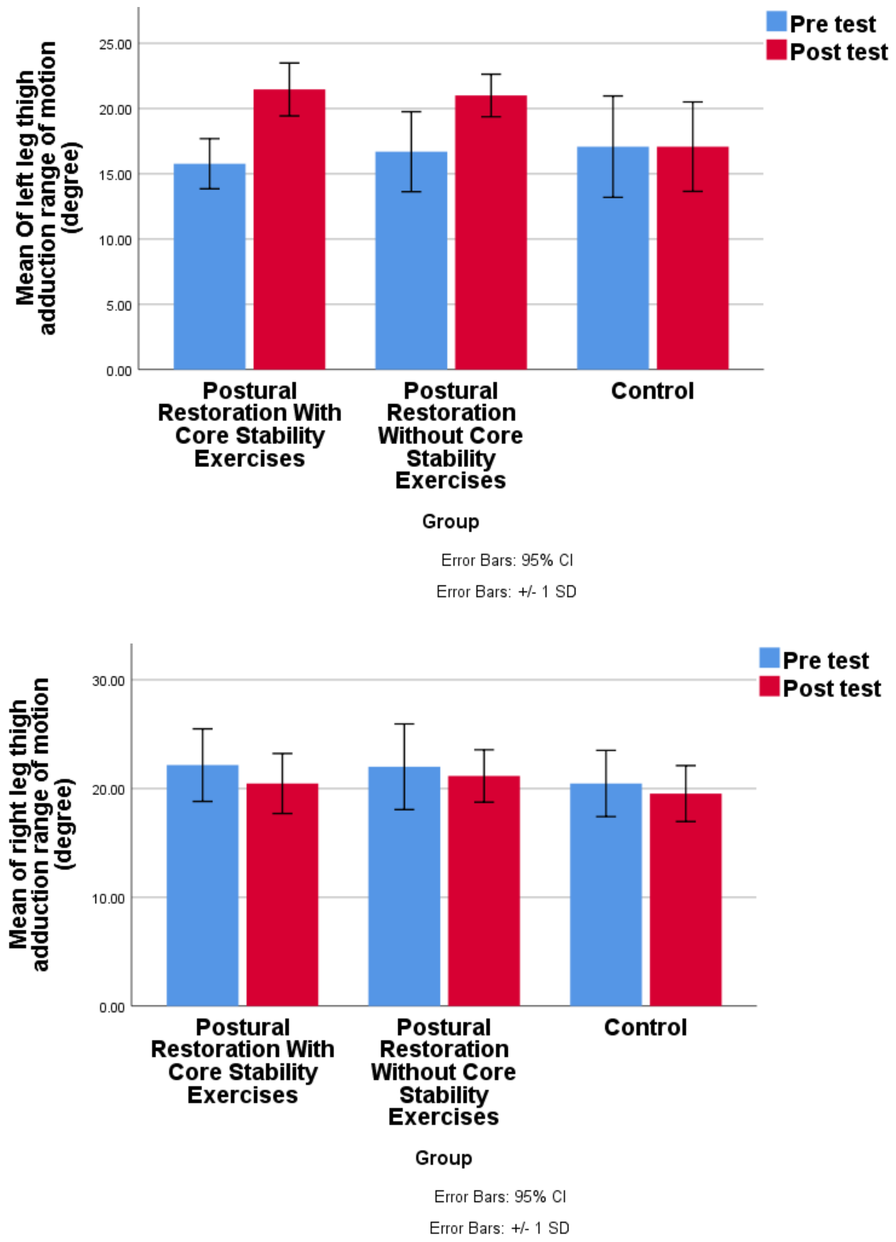

Figure 9. Mean±SD of right and left leg thigh adduction range of motion (degree)

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overlengthening and weakening of the hamstring complex. Consequently, this powerful muscle group cannot perform its postural function of stabilizing the pelvis [18]. In a patient with a forwardly rotated pelvis and an anterior tilt, unilateral hamstring activation should rotate the pelvis in a posterior pelvic tilt via hamstring activation also helps decrease lumbar lordosis and may increase intra-abdominal pressure [18, 26]. Abdominal activation via balloon blow assists in achieving a posterior pelvic tilt (decreased anterior pelvic tilt), lumbar flexion (decreased lumbar lordosis), and rib depression or internal rotation (decreased rib elevation or external rotation) and may increase intra-abdominal pressure. If the pelvis is in a neutral position, the femoral head should be free to adduct without abutting the acetabulum's cotyloid rim [18]. The increased hip adduction and reduced lumbopelvic pain may have resulted from a pelvic–femoral position change. If the hip joint is not neutral, the position of the acetabulum over the femoral head is not neutral, which may influence the results of the Ober test [18].

After performing the appropriate 90-90 exercise (balloon hemibridge 90-90), all patients, except for two participants, showed a significant increase in left leg hip adduction, as assessed by the Ober test. The results showed a significant difference between the adjusted mean PROM of left thigh adduction with PR exercises (mean=21.96), without core exercises (mean=20.2), and control (mean=16.6) (P=0.000). In other words, PR with core exercises (P=0.001) and without core exercises (P=0.001) led to a significant increase in the adduction range of motion of the thigh of the left leg in people with NCLBP. There is no significant difference between the adjusted mean of the left leg thigh adduction PROM in the group of PR exercises with (mean=21.96) and without core exercises (mean=20.4) (P=0.094). In the present study, the Ober test was negative in most patients in both groups in the third week of interventions, while there was no change in the positive Ober test in the control group. These results are consistent with the results of a case report and the results of a study conducted by Tenney et al. [11]. In this case study, the effect of activating the abdominal and hamstring muscles on the positive Ober test was consistent with the results obtained in this research. The asymmetry pattern associated with a poly articular chain of muscles is located on the left and right sides of the interior thoracoabdominal pelvic cavity, known as the AIC [18]. The AIC consists of the diaphragm and psoas muscles. The iliacus tensor facialata supports each chain, biceps femoris, and vastus lateralis muscles on the left or right side.

If a person has increased muscle tone through the left AIC, the pull of these muscles will rotate and tilt the left hemi pelvis forward and anteriorly, which will increase lumbar lordosis and rotate the lumbar and lower thoracic vertebrae to the right [18]. The upper thoracic vertebrae then rotate back to the left to compensate for the lower vertebral rotation. Upper thoracic rotation to the left limits the ability of the left abdominal muscles to maintain a zone of apposition (ZOA) of the left hemi diaphragm. The ZOA is the diaphragm portion directly opposed to the inner aspect of the lower ribcage [17, 18]. With a suboptimal left ZOA, the left hemi diaphragm is placed in a more linear or flattened position, which decreases its ability to function as a respiratory muscle [28, 29]. In this more linear position, the left hemi diaphragm may function more as a spinal stabilizer than the left psoas in the left AIC [29].

Abdominals oppose the diaphragm and help pull the ribs down into internal rotation, which helps to maintain an optimal ZOA. The 90-90 exercises are used to reciprocally inhibit left AIC tone via left abdominal and hamstring activation, to increase the left ZOA, and to rotate the pelvis posteriorly in the sagittal and transverse plane into a more neutral position [7]. Hamstrings extend the hip; therefore, they reciprocally inhibit hip flexors. Hamstrings and abdominals also aid in inhibiting paraspinal muscles via a posterior pelvic tilt or hip extension, a decrease in lumbar extension, and an increase in lumbar flexion. A more neutral pelvic position would decrease pain associated with torque in LPFC and allow the femur to adduct on the acetabulum without restriction, producing a negative Ober test [7, 30]. Waldron et al. conducted a case study to investigate the use of PR exercises for pelvic alignment, core stability during the treatment of dysfunction, and the difference in the range of motion of the hip joint. The treatment results showed pain relief and increased range of motion of left hip adduction and left internal rotation. The right hip gained 14 degrees of external rotation, and the internal rotation of the right shoulder increased by 15 degrees. The Ober test became negative after 17 days [31].

When the patients in the present study reported that they were pain-free and the Ober test was observed to be negative, bilateral stabilization exercises were used. Gaining stabilization strength would help patients maintain their hip position. It is an intervention strategy for LBP and lumbo-femoral hip pain [32, 33]. Abdominal marching exercise activates bilateral transverse abdominus, obliques, and rectus abdominis [26]. This exercise has been recommended for patients to stabilize the trunk [34]. The long sitting reverse curl-ups exercise was prescribed for muscle activation of abdominal obliques (both eccentric and concentric) in the sagittal and transverse planes (right and left trunk rotation) during exhalation and muscle inhibition of para spinal (to avoid an anterior pelvic tilt), again to stabilize the pelvis or trunk. Previous studies have reported a decrease in pain in people with NCLBP after performing core exercises [23, 32, 35], and their results are consistent with the findings of this research. Only two participants reported decreased pain after performing the hamstring/abdominal exercise. The results showed a significant difference between the adjusted mean of the pain intensity in the group of PR exercises with (mean=2.34) and without core exercises (mean=3.07) and control (mean=5.5) ($F_{(2, 35)}$=37.6, η^2=0.68, P=0.000). Also, the results showed that PR with core exercises (P=0.001) and PR without core exercises (P=0.001) led to a significant decrease in the intensity in people with NCLBP (P=0.001). No significant difference was observed between pain intensity in PR exercises with and without core exercises (P=0.120).

The above results can change the position of the pelvis to a more neutral position, which reduces the pressure on the muscles, joints, and ligaments associated with musculoskeletal pain patterns [36]. Another possible reason for this reduction in pain can be the increase in the activity of the transverse abdominis muscle, which leads to stability, protection of the spine, and stress reduction on the lumbar vertebrae and intervertebral disk. Core stability and diaphragmatic respiration can strengthen the diaphragm muscle as an essential respiratory and postural muscle. The results of our studies on the effect of core exercises and respiratory exercises on reducing pain and disability are consistent with other studies [23]. This result is consistent with the results of Robey et al. [37]. Robey et al. (2013) reported a patient suffering from sacroiliac joint pain who received PR exercises. The results showed a noticeable reduction in pain from 7.10 on the numerical pain scale to 0.10, and the Oswestry disability index decreased from 48% to 40% during five weeks of the intervention [37].

The results showed a significant difference between the adjusted function means in the group of PR exercises with (mean=9.98) and without core exercises (mean=10.29) and control (mean=21.72) (P=0.000). The results showed that PR with core exercises (P=0.001) and PR exercises without core exercises (P=0.001) led to a significant decrease in the function. However, there is no significant difference between the adjusted function mean in the group of PR exercises with and without core exercises (P=0.850). This result is consistent with the results of Boyle [38]. This research investigated the effect of the right side-lying respiratory left adductor pull-back exercise, one of the PR exercises, on lumbar-pelvic pain, which reduced pain and improved function [39]. This exercise affects the lumbar-pelvic-femoral area by affecting the ischio-femoral ligament, ZOA, right anterior outlet, and left anterior inlet, activating the left adduction and transverse abdominals and the inferior obturator, inhibiting and increasing the length of the para-spinal on both sides. PR exercises positively impact lumbar-pelvic-femoral alignment or posture, reduce pain, and improve function [39].

Regina and Tamás. concluded that diaphragmatic exercise affected the thickness of other active stabilizers of the lumbar spine, such as transverse abdominis and lumbar multifidus, reduced pain, and improved function [38]. In a study by Shah et al. [23], core stability exercises and diaphragmatic respiratory exercises are more effective for pain and improving function than core stability exercises alone [23]. Activation of the left hamstring, adductor magnus, and left gluteus medius simultaneously with activating the right gluteus maximus causes the left hip posterior capsule to stretch. The analysis of covariance results showed a significant difference between the adjusted mean of the QoL in the group of PR exercises with (mean=117.5), without core stability exercises (mean=114.5), and control (mean=95.8) (P=0.000). The results showed that PR with core exercises (P=0.001) and PR without core exercises (P=0.001) significantly increased QoL. Finally, there is no significant difference between the adjusted mean of the QoL in the group of PR exercises with and without core exercises (P=0.328).

These results are consistent with the results of Gopal Nambi's study [40]. In this study, which was conducted on changes in pain intensity and QoL with yoga and exercise in NCLBP patients, it was concluded that there was a reduction in pain intensity and improvement in the QoL in both yoga and exercise groups. Core exercises and respiratory exercises focus on the abdominal respiratory system. The abdominal respiratory method supplies oxygen evenly throughout the body and causes the lumbar muscles to expand, thus reducing tension and stress and ultimately reducing fatigue. Anxiety and other emotions affect muscle function. The rib fibers of the diaphragm are aerobic and produce Adenosine triphosphate (ATP), thus causing muscle contraction. Therefore, regular exercise by patients with NCLBP improves their QoL and increases their physical and mental health index [41]. A possible mechanism for improving QoL may be improving autonomic functions by creating neuro-hormonal mechanisms [41]. Self-awareness exercises may increase cognitive flexibility, which may cause a further reduction of stress, anxiety, and pain and, as a result, improve the QoL [42].

Conclusion

PR exercises with and without core stability exercises reduce pain and improve the QoL and functional disability, as well as increase the range of motion of adduction of the left hip and make the Ober test of the left hip in NCLBP patients with the left AIC pattern. All the results indicate no difference in the effect of the combined protocol of PR exercises with and without core exercises. Our findings can be used in patients with NCLBP and LPFC.

Ethical Considerations

Compliance with ethical guidelines

All study procedures followed the guidelines from the Ethics Committee of the Sports Science Research Institute (SSRI) (Code: IR.SSRI.REC.1401.1629).

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Authors' contributions

Data curation, writing original draft preparation, investigation, software: Nasrin Fouladi; Conceptualization, methodology, review, editing and supervision: Homan Minoonejad and Reza Rajabi.

Conflict of interest

The authors declared no conflict of interest.

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