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Original Article

# Comparison of different exercises on muscle thickness, pain, and disability in patients with low back pain: A randomized controlled study

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***ABSTRACT***

**Objectives:** The aim of this study was to compare the effects of stabilization exercises, McKenzie exercises, and home exercises on pain, disability, and muscle thickness of the transversus abdominis (TrA), multifidus (MF) and gluteus maximus (Gmax) in patients with low back pain.

**Patients and methods:** The prospective, randomized controlled study was conducted between November 7, 2022, and February 7, 2023. A total of 45 patients (30 males, 15 females; mean age: 40.93±5.31 years; range, 30 to 50 years) with low back pain were randomly divided into three groups: stabilization exercise group (SG), McKenzie exercise group (MG), and home exercise group (HG). Pain intensity and disability were evaluated using the Visual Analog Scale and the modified Oswestry Disability Index. Ultrasonographic imaging was used to assess TrA, MF, and Gmax muscle thickness before and after an eight-week intervention program.

**Results:** There were no significant differences in baseline demographic characteristics among the groups (p>0.05). After treatment, statistically significant improvements were observed in pain, modified Oswestry Disability Index scores, and muscle thickness (TrA, MF, and Gmax) in the SG and MG (p<0.05). In the HG, significant improvements were found in pain and some muscle thickness measurements, but no significant change was observed in disability (p>0.05). Comparisons among the groups showed that SG demonstrated significantly greater improvements in disability scores (p=0.008) and muscle thickness (p<0.001) compared to HG. The SG also had superior results in TrA, MF, and Gmax muscle thickness when compared to MG and HG (p<0.05).

**Conclusion:** Stabilization exercises were found to be more effective in improving deep trunk muscle (TrA and MF) and Gmax thickness, as well as reducing disability compared to McKenzie and home exercise programs. McKenzie exercises also provided significant improvements in muscle thickness and pain, whereas the home exercise program showed limited effects. The results emphasize the importance of supervised exercise interventions, particularly stabilization exercises, in managing low back pain.

***Keywords:*** Low back pain, McKenzie exercises, muscle thickness, stabilization exercises.

Low back pain (LBP) is an economic burden for society. It leads to functional disability resulting in the loss of working days. A review of the literature indicates that 75% or more of patients with LBP are temporarily disabled and approximately 5% suffer from permanent disability.[1] The prevalence of LBP is reported to be 84%, and the prevalence of chronic LBP is approximately 23%.[2] Low back pain can have many causes such as vertebral fracture, malignancy, intervertebral disc degeneration, physical and mental comorbidities, smokers, and consequences due to disc displacement. In a systematic review comprising 3,097 participants, significant associations were concluded between various magnetic resonance imaging (MRI) findings and LBP. The results revealed a substantial correlation with disc bulge (odds ratio [OR]=7.5, 95% confidence interval [CI]: 1.3-44.6), disc extrusion (OR=4.4, 95% CI: 2.0-9.7), and spondylolysis (OR=5.1, 95% CI: 1.7-15.5).[3]

Back muscle dysfunction is frequently observed in individuals experiencing LBP.[4] The paraspinal muscles play a crucial role in supporting proper

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function and stability of the lumbar spine.[5] The passive system formed by osteoligamentous structures, the active system formed by local and global muscles, and the control mechanism formed by the neural system are effective in providing and maintaining lumbopelvic control.[6] The multifidus (MF) and transversus abdominis (TrA) muscles contract faster than other muscles involved in lumbopelvic segmental stabilization; thus, they help maintain body balance in all movements of the human body.[7] Transversus abdominis contraction causes tension in the thoracolumbar fascia by increasing intra-abdominal pressures. The tight connection of the thoracolumbar fascia with MF contributes to lumbopelvic motor control.[8] Disruption of lumbopelvic stability may cause negative effects on postural balance and physical performance. As a result of weakness in these muscles, an individual becomes vulnerable to injuries.[6]

Gluteus maximus (Gmax) stabilizes the pelvis during trunk rotation and movement of the center of gravity. Hip extensor muscle impairment was predicted in people with LBP.[9] Gluteus maximus is involved in transferring upward forces from the lower limbs to the spine during longitudinal movements and in the stability of the sacroiliac joint. Functional failure of this muscle can impair lumbopelvic stability and exacerbate the pressure exerted on the waist.[10]

The basis of treatment is conservative approach that includes modification of activities of daily living that place a load on the spine and an appropriate exercise program in cases where there is no surgical indication for LBP. The aim of exercise therapy is to reduce pain and improve functionality in daily life. Studies have demonstrated that this can be achieved by relieving the load on the related tissues and increasing the strength and stabilization of the trunk muscles.[11] Multiple exercise methods are used for LBP, such as stabilization exercises, McKenzie exercises, pilates, and yoga.[12,13] Our study focused on stabilization and McKenzie exercises.

Stabilization exercises are based on motor control of the deep trunk muscles and increasing the thickness of these stabilizing muscles, thus improving spinal stability.[12,14] McKenzie exercises are a form of physical therapy aimed at alleviating back pain and are based on movement of the nucleus pulposus within the intervertebral disc, depending on the adopted position and direction of the movements of the spine.[13]

Although most of the studies in the literature on LBP have focused on the effectiveness of exercises, these studies generally focus on pain and functional improvement. However, the effect of exercises on the thickness and stabilization properties of specific muscle groups remains limited, particularly for critical muscles such as MF, TrA, and Gmax. Although the relationship between LBP and the size of these muscle groups has been extensively investigated, studies examining the effects of specific exercises on MF, TrA, and Gmax muscle thickness are limited.[15] The unique aspect of the present study is the comparative evaluation of the effects of stabilization exercises, McKenzie exercises, and home program exercises on MF, TrA, and Gmax muscle thickness. Demonstrating how changes in muscle thickness are related to pain and functional recovery will allow for a more targeted and individualized determination of treatment modalities. In this context, our study aimed to investigate the holistic effect of exercises on muscle thickness, as well as on pain and functional recovery.

## PATIENTS AND METHODS

This prospective, randomized controlled study was conducted between November 7, 2022, and February 7, 2023. Patients between the ages of 18 and 50 years with a diagnosis of LBP (according to MRI and clinical symptoms of the patients) who presented to the Physical Medicine and Rehabilitation outpatient clinic of the Şırnak State Hospital with complaints of LBP persisting for more than six weeks were included in the study. Patients who had severe spinal stenosis, had radiculopathy, spondylosis or spondylosisthesis, had a history of spinal surgery, had neurological deficits, had neurologic, orthopedic or congenital problems that would prevent physical activity, had diseases that would interfere with exercise such as cardiovascular and chronic obstructive pulmonary disease, had systemic inflammatory rheumatic disease, had a diagnosis of infection or malignancy, and pregnant patients were excluded from the study. A total of 45 patients (15 patients in each group) were included in the study. A total of 72 patients were screened to reach this number of cases. Since 21 patients did not meet the study criteria, and six patients refused to participate in the study for social reasons, 27 patients were excluded. The patients included in the study were randomly divided into three groups according to the order of presentation. Patients were first assigned to the stabilization exercise group (SG), followed by the McKenzie exercise group (MG) and the home exercise group (HG). Randomization continued by cycling back to SG and repeating the same order. Stratified randomization was applied based on sex, ensuring an equal number of male and female patients in each group. Patient recruitment was terminated when 15 patients were reached in each group. The study was terminated with a total of 45 patients (30 males, 15 females; mean age: 40.93±5.31 years; range, 30 to 50 years). The flowchart is demonstrated in Figure 1. The study protocol was approved by the Fırat University Non-Interventional Research Ethics Committee (Date: 03.11.2022, No: 2022/13-20). Written informed consent was obtained from all participants. The study was conducted in accordance with the principles of the Declaration of Helsinki. This study was registered in the ClinicalTrials.gov database with the number NCT05927051.

Treatment duration was determined as 24 sessions. Patients were ultrasonographically reevaluated at the end of eight weeks of treatment to evaluate the effectiveness of the clinical treatments. Stabilization exercise group practiced core stabilization exercises, MG practiced McKenzie exercises, and HG was recommended home exercises by a specialized physiotherapist. Therapists practicing the assessment and treatment in the study were different. The researcher administering the assessment and the exercises were blinded. Assessments were practiced by a physician.

All patients were evaluated by the same investigator before and after treatment, and demographic information was recorded. A 10-cm Visual Analog Scale (VAS) was used to assess the pain intensity of the patients.[16] Zero was defined as no pain and 10 as the most severe pain encountered in life; the patients were asked to describe the intensity of their pain on the scale. The VAS was filled out at the initial presentation and repeated after eight weeks of exercise.

The modified Oswestry Disability Index (MODI) was used to determine the level of functionality of the patients. This test consists of pain intensity, self-care, lifting, walking, sitting, standing, sleeping, sexual life, social life, and traveling. Questions are scored between 0 and 5, and questions that patients

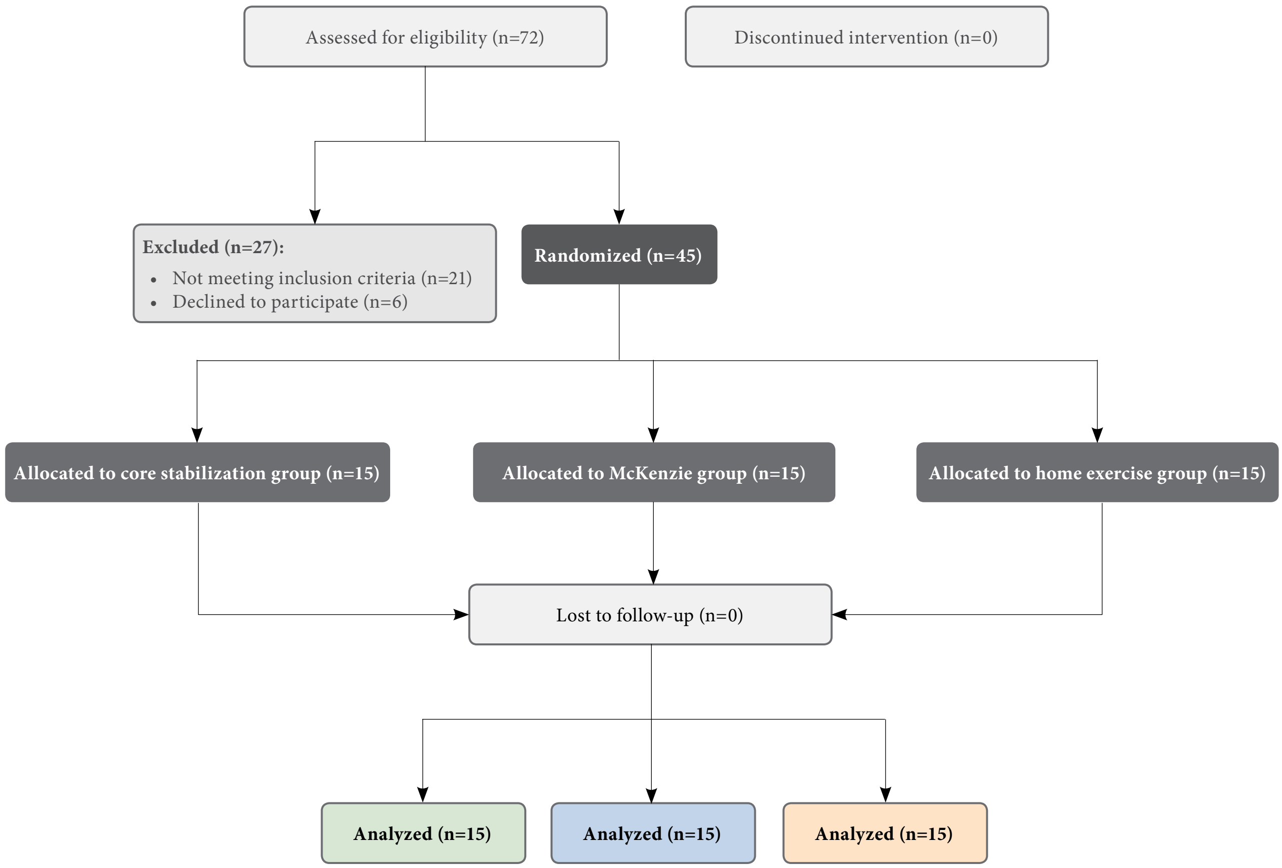


**Figure 1.** Flowchart of the participants.

did not answers are not evaluated. The MODI score was calculated with the following formula: (patient's score/maximum possible score)*100.[17] The validity and reliability of the Turkish version of MODI was previously conducted by Yakut et al.[17] The MODI was filled out at the initial presentation and repeated after eight weeks of exercise.

Ultrasonography is a valid, reliable, and noninvasive method commonly used to measure muscle thickness.[18] All ultrasonographic measurements were performed by a physical medicine and rehabilitation specialist with five years of experience in musculoskeletal ultrasonography. To ensure the reliability of the measurements, the measurements were performed by the same person following standardized procedures. Before the measurement, all participants were instructed not to move during the measurement. Evaluations were performed using B mode (Aplio 300; Toshiba Medical Systems Corp., Otawara, Tochigi, Japan). A linear probe (PLT-704SBT, 7.5 MHz) was used to measure TrA thickness, and a convex probe (PVT-375DT, 3.5 MHz) was used to measure MF and Gmax thickness. All measurements were collected at the end of normal exhalation to avoid being affected by respiration.[19]

To assess TrA, a linear probe was placed transversely at the intersection of the iliac crest with the midpoint of the anterior axillary line, with the patient in supine position.[20]

The measurement of MF was performed with the patient in the prone position, supported with the same pillow under the abdomen. The convex probe was positioned in a longitudinal orientation, centered over the L4 spinous process, then translated laterally, and tilted medially to visualize the facet joint. The distance between the L4-5 facet joint and the muscle and subcutaneous tissue was measured.[21]

The measurement of Gmax was performed with the patient in the prone position, hands in front of the head, with the center of the convex probe placed on the ischial tubercle.[22]

Stabilization exercises were applied to the patients in SG, McKenzie exercises were performed to the patients in MG, and home exercises were suggested to HG. A total of 24 sessions, three times per week over a period of eight weeks, was performed by the same person. Each movement was performed for 10 repetitions, maintaining the same position for 8 sec. Before starting the program, warm-up exercises were given, and cat stretching, camel stretching, and pelvic translation exercises were preferred for the beginning. All treatment groups lasted for eight weeks, three days in a week. All 45 patients completed the treatment.

Stabilization exercises were performed in six steps: *(i)* segmental control exercises (SCEs) focused on the isolated activation of the TrA, MF, and pelvic floor muscles; *(ii)* SCEs emphasizing co-contraction of the TrA, MF, and pelvic floor muscles in various positions, including prone, supine, and quadruped (crawling); *(iii)* SCEs performed within a closed kinetic chain framework; *(iv)* progression of SCEs to low-load conditions by incorporating limb leverage during open-chain movements; *(v)* advancement of SCEs to more functional tasks; and *(vi)* incorporation of TrA and MF co-contraction during external load application, movement complexity, and increased resistance, ensuring the lumbar spine remains in a neutral position, along with integrating co-contraction techniques into light aerobic exercises, such as walking and other physical activities (Table 1).[23]

McKenzie exercises were prescribed according to each participant's directional preference identified at baseline. Accordingly, the program consisted of prone on elbows, prone on hands (press-up), standing backward bending (lumbar extension), knee-to-chest in supine, and spinal flexion in sitting.

Participants in the third group were provided with a home-based exercise regimen consisting of stretching routines targeting the erector spinae, hip flexors, hamstrings, and gastrocnemius-soleus muscle groups. During the initial session, they were also instructed in strengthening exercises for the abdominal muscles and hip extensors. They were asked to perform these exercises independently at home three times per week over an eight-week period. Weekly follow-up charts were used to evaluate the compliance of patients participating in the home exercise program and reminder messages were sent. Patients with 80% or more compliance with the exercise program were included in the analyses. Patients who performed exercises below the specified level were excluded from the study.

Patients participating in the study were only included in the exercise programs specified in the study and did not receive any other concurrent treatment such as pharmacological, interventional, or physical therapy. This was explained to the

**TABLE 1**
**Exercise program details for SG, MG, and HG**

| Phase | SG | MG | HG |
|---|---|---|---|
| Warm-up (5 min) | Segmental extremity movements, centering, roll down | Prone lying, prone on elbows | Pelvic tilts, standing forward bend |
| Exercise program (35 min) | | | |
| | 1. One leg stretch | 1. Prone on elbows | 1. Hamstring stretching |
| | 2. Double leg stretch | 2. Prone press-up (prone on hands) | 2. Erector spinae stretching |
| | 3. Shoulder bridge | 3. Standing lumbar extension (bending backward) | 3. Hip flexor stretching |
| | 4. Chest lift | 4. Flexion in lying (knee-to-chest position) | 4. Gastro-soleus stretching |
| | 5. Hundreds | 5. Flexion in sitting | 5. Abdominal muscle strengthening |
| | 6. Side band | | 6. Hip extensors strengthening (glute bridges) |
| | 7. Arm opening | | |
| | 8. Cobra | | |
| | 9. Swimming | | |
| | 10. Push up | | |
| Cool-down (5 min) | Cat stretching, camel stretching, relaxation exercises | Standing forward flexion, deep breathing | Cat stretching, forward flexion, relaxation exercises |

SG: Stabilization exercise group; MG: McKenzie exercise group; HG: Home exercise group.

patients at the beginning of the study and stated in the written consent form. The exclusion of other treatments provided a standardization in terms of evaluating the effectiveness of the study.

### Statistical analysis

The G*Power software version 3.1 (Heinrich-Heine Universität Düsseldorf, Düsseldorf, Germany) was used to determine the number of participants to be included in the study. Bhadauria and Gurudut[24] calculated the effect size for the disability difference as 1.310 in a similar study. To achieve a power exceeding 95%, 42 participants (14 per group) were required, with a significance level of 5% and an effect size of 1.310 (df=26; t=1.683).

The data obtained in the study were analyzed using IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Frequency, percentage, mean, and standard deviation (SD) were used as descriptive statistical methods in the evaluation of the data. Kurtosis and skewness values were analyzed to determine whether the research variables were normally distributed. In the relevant literature, the results of the kurtosis and skewness values of the variables between +1.5 and –1.5, +2.0 and –2.0 are accepted as normal distribution. It was determined that the variables showed normal distribution. One-way analysis of variance (ANOVA) was used to compare quantitative continuous data between groups. The Scheffe test was used as a complementary post-hoc analysis to determine the differences after the one-way ANOVA. In the analysis of the data, mixed design ANOVA was used to examine group, time, and group*time interactions. In the analysis of covariance, pretest values were assigned as covariates. When the pretest values were controlled, the differences in posttest values were examined. Percentage changes (delta [Δ] values) were calculated separately for each patient using the following formula: (posttreatment-baseline)/baseline * 100.

## RESULTS

Demographic characteristics of the patients are listed in Table 2. There was no statistically significant difference between the baseline demographic variables of the three groups (p>0.05). The comparison of before and after treatment for

**TABLE 2**
Comparison of baseline demographics of SG, MG, and HG groups

| | SG (n=15) | | MG (n=15) | | HG (n=15) | | |
|---|---|---|---|---|---|---|---|
| Characteristics | Mean±SD | Min-Max | Mean±SD | Min-Max | Mean±SD | Min-Max | *p* |
| Age (year) | 40.33±5.32 | 31-50 | 41.60±5.32 | 30-50 | 40.87±5.56 | 32-50 | 0.780 |
| Length (cm) | 171.47±9.98 | 154-188 | 170.47±10.61 | 155-187 | 169.73±8.49 | 155-182 | 0.908 |
| Weight (kg) | 76.73±7.85 | 65-95 | 76.20±7.72 | 65-92 | 75.93±12.87 | 60-96 | 0.882 |
| BMI (kg/cm$^2$) | 26.23±3.20 | 22.49-33.73 | 26.16±2.41 | 21.16-30.04 | 26.21±2.77 | 21.88-30.67 | 0.971 |
| Pain duration (week) | 17.13±2.88 | 12.00-24.00 | 17.80±4.07 | 12.00-30.00 | 16.47±3.46 | 12.00-27.00 | 0.218 |

SG: Stabilization exercise group; MG: McKenzie exercise group; HG: Home exercise group; BMI: Body mass index; SD: Standard deviation.

the three groups is given in Table 3. No significant difference was observed between the groups in baseline and posttreatment values in VAS. The effect of time was highly significant, indicating that the treatment process led to a significant improvement in VAS values in general. However, no significant difference was found in combined effect of group and time in VAS. No significant difference was found between the groups at baseline in MODI. Significant difference was concluded in time effect and in the interaction between group and time, indicating that the treatment process improved MODI scores overall. No significant difference was found between the groups at baseline and after treatment in the left TrA evaluation. Time effect and group-time effect were significant. There was no significant difference between the baseline and posttreatment groups in the right TrA measurements. However, time effect and group-time effect were significant in both cases. There was no significant difference between the groups in the baseline values of MF measurements for the left side. Time effect and group-time effect were significant. For the right side, there was no difference between the groups at baseline, but the time effect and the group-time effect were significant. No significant difference was observed between the groups in the left side baseline values of Gmax measurements. However, the time effect and group-time effect were significant. There was no significant difference between the groups in the baseline values on the right side. Time effect and group time effect were significant. When the comparison of the change between before and after treatment was analyzed among the groups, no significant difference was obtained in pain (p=0.227). Significant differences were found in changes of MODI (p=0.008 <0.05), TrA left (p<0.001), TrA right (p<0.001), MF left (p<0.001), MF right (p=0.001 <0.05), Gmax left (p<0.001), and Gmax right (p<0.001) parameters. Percentage changes (Δ values) in the clinical parameters are summarized in Table 4.

## DISCUSSION

This study demonstrated that stabilization and McKenzie exercise programs were effective on pain, disability, and muscle thickness in patients with LBP. In addition, stabilization and McKenzie exercises were more effective on TrA, MF, and Gmax muscle thickness than the home exercise program. This study demonstrated the superiority of stabilization exercises in increasing deep trunk muscles and Gmax thickness and improving endurance. In addition, this study is important because it is the first to examine the effects of stabilization exercises, McKenzie exercises, and home exercise program on muscle thickness of TrA, MF, and Gmax, pain, and disability.

Studies have demonstrated the effectiveness of the TrA and MF muscles in maintaining balance with minimum effort by resisting gravity and meeting the loads during limb movements.[25] The simultaneous contraction of MF and TrA concurrently provides stability of spinal segments and trunk stabilization. Therefore, weakness of the core muscles can lead to movement disorders, injuries, and pain.[26] An imbalance between the abdominal and hip extensor muscle strength can contribute to lumbar instability and reduced functional ability.[27] Reduced strength in the Gmax is associated with a higher risk of LBP, and weakness in the Gmax, MF, and TrA muscles may diminish thoracolumbar fascia tension and lumbar stability by affecting force closure.[28,29] While research confirms that chronic LBP is associated with decreased thickness and isometric contraction capacity in the TrA and MF muscles, the optimal

**TABLE 3**
Within-group and between-group comparisons before and after treatment

| | SG (n=15) | MG (n=15) | HG (n=15) | | |
|---|---|---|---|---|---|
| | Mean±SD | Mean±SD | Mean±SD | F[a] | *p* |
| VAS (baseline) | 7.000±1.464 | 6.733±1.387 | 6.733±1.907 | 0.138 | 0.871 |
| VAS (after treatment) | 3.867±1.187 | 4.133±1.767 | 4.600±2.131 | 0.683 | 0.511 |
| Group | | Fb=0.133; p=0.876; $\eta^2$=0.006 | | | |
| Time | | Fb =103.910; p=**0.000**; $\eta^2$=0.712 | | | |
| Group* time | | Fb =1.261; p=0.294; $\eta^2$=0.057 | | | |
| MODI (baseline) | 51.807±18.893 | 51.433±13.586 | 52.393±15.948 | 0.013 | 0.987 |
| MODI (after treatment) | 25.440±14.523[x] | 37.113±13.723[xy] | 45.807±10.737[y] | 9.134 | **0.001** |
| Group | | Fb=3.129; p=0.054; $\eta^2$=0.130 | | | |
| Time | | Fb=32.260; p=**0.000**; $\eta^2$=0.434 | | | |
| Group* time | | Fb=4.303; p=**0.020**; $\eta^2$=0.170 | | | |
| ANCOVA | | F=9.254; p<0.001; $\eta^2$=0.311 | | | |
| TrA-left (baseline) | 3.053±0.658 | 3.068±0.568 | 3.053±0.361 | 0.004 | 0.996 |
| TrA-left (after treatment) | 3.273±0.665[x] | 3.201±0.573[y] | 3.103±0.365[z] | 0.360 | 0.700 |
| Group | | Fb=0.094; p=0.910; $\eta^2$=0.004 | | | |
| Time | | Fb=855.770; p=**0.000**; $\eta^2$=0.953 | | | |
| Group* time | | Fb=112.255; p=**0.000**; $\eta^2$=0.842 | | | |
| ANCOVA | | F=112.259. p<0.001; $\eta^2$=0.846 | | | |
| TrA-right (baseline) | 3.035±0.543 | 3.041±0.557 | 3.059±0.384 | 0.009 | 0.991 |
| TrA-right (after treatment) | 3.237±0.541[x] | 3.160±0.559[x] | 3.089±0.377[y] | 0.333 | 0.719 |
| Group | | Fb =0.060; p=0.942; $\eta^2$=0.003 | | | |
| Time | | Fb =74.544; p=**0.000**; $\eta^2$=0.640 | | | |
| Group* time | | Fb =13.406; p=**0.000**; $\eta^2$=0.390 | | | |
| ANCOVA | | F=13.169. p<0.001; $\eta^2$=0.391 | | | |
| MF-left (baseline) | 26.353±1.707 | 26.404±2.709 | 26.055±2.502 | 0.097 | 0.908 |
| MF-left (after treatment) | 27.235±1.747[x] | 26.733±2.844[y] | 26.259±2.654[y] | 0.589 | 0.559 |
| Group | | Fb =0.273; p=0.762; $\eta^2$=0.013 | | | |
| Time | | Fb =44.086; p=**0.000**; $\eta^2$=0.512 | | | |
| Group* time | | Fb =8.592; p=**0.001**; $\eta^2$=0.290 | | | |
| ANCOVA | | F=8.423. p<0.001; $\eta^2$=0.291 | | | |
| MF-right (baseline) | 26.644±2.191 | 26.444±2.678 | 26.186±2.706 | 0.123 | 0.885 |
| MF-right (after treatment) | 27.429±2.195[x] | 26.815±2.857[y] | 26.388±2.733[y] | 0.603 | 0.552 |
| Group | | Fb =0.321; p=0.727; $\eta^2$=0.015 | | | |
| Time | | Fb =51.285; p=**0.000**; $\eta^2$=0.550 | | | |
| Group* time | | Fb =7.506; p=**0.002**; $\eta^2$=0.263 | | | |
| ANCOVA | | F=7.185. p=0.002; $\eta^2$=0.260 | | | |
| Gmax-left (baseline) | 24.927±4.690 | 24.369±5.214 | 24.864±2.245 | 0.077 | 0.926 |
| Gmax-left (after treatment) | 26.754±3.838[x] | 24.504±5.211[y] | 24.929±2.249[y] | 1.370 | 0.265 |
| Group | | Fb =0.459; p=0.635; $\eta^2$=0.021 | | | |
| Time | | Fb =36.609; p=**0.000**; $\eta^2$=0.466 | | | |
| Group* time | | Fb =26.636; p=**0.000**; $\eta^2$=0.559 | | | |
| ANCOVA | | F=34.277. p<0.001; $\eta^2$=0.626 | | | |
| Gmax-right (baseline) | 24.988±4.190 | 24.453±4.651 | 24.770±2.304 | 0.073 | 0.929 |
| Gmax-right (after treatment) | 26.616±3.832[x] | 24.646±4.668[y] | 24.906±2.314[y] | 1.232 | 0.302 |
| Group | | Fb =0.453; p=0.639; $\eta^2$=0.021 | | | |
| Time | | Fb =33.851; p=**0.000**; $\eta^2$=0.446 | | | |
| Group* time | | Fb =18.942; p=**0.000**; $\eta^2$=0.474 | | | |
| ANCOVA | | F=20.186. p<0.001; $\eta^2$=0.496 | | | |

SG: Stabilization exercise group; MG: McKenzie exercise group; HG: Home exercise group; SD: Standard deviation; VAS: Visual Analog Scale; MODI: Modified Oswerty Disability Index; TrA: Transversus Abdominus muscle; MF: Multifidus muscle; Gmax: Gluteus maximus muscle; [a]: One way analysis of variance; [b]: Mixed Design Analysis of Variance, In ANCOVA analyses, pre-test values were assigned as covariates. When the pre-test was taken under control, the difference between the post-test values was analyzed. The letters x, y and z represent the results of Posthoc analysis. There is a statistically significant difference between different letters.

**TABLE 4**
Between-group comparisons of delta (Δ %) measurements

| | SG (n=15) | MG (n=15) | HG (n=15) | | | | | |
|---|---|---|---|---|---|---|---|---|
| Δ Measurements | Mean±SD | Mean±SD | Mean±SD | F | $p$* | $p^{1-2}$ | $p^{1-3}$ | $p^{2-3}$ |
| ΔVAS (%) | 43.82±15.21 | 37.73±23.51 | 31.50±26.71 | 1.141 | 0.22 | | | |
| ΔMODI (%) | 44.67±35.12 | 25.20±27.38 | 5.61±33.92 | 5.475 | 0.02 | 0.133 | <0.001 | 0.156 |
| ΔTrA-left (%) | −7.48±2.16 | −4.46±1.32 | −1.66±0.56 | 56.520 | <0.001 | <0.001 | <0.001 | <0.001 |
| ΔTrA-right (%) | −6.87±1.71 | −4.05±1.27 | −1.11±4.62 | 14.341 | <0.001 | <0.001 | <0.001 | 0.001 |
| ΔMF-left (%) | −3.37±1.90 | −1.21±1.49 | −0.75±1.83 | 9.504 | <0.001 | <0.001 | <0.001 | <0.001 |
| ΔMF-right (%) | −2.97±1.92 | −1.36±1.46 | −0.77±1.32 | 7.696 | <0.001 | 0.001 | <0.001 | 0.001 |
| ΔGmax-left (%) | −8.26±6.71 | −0.58±0.16 | −0.26±0.04 | 20.524 | <0.001 | <0.001 | <0.001 | <0.001 |
| ΔGmax-right (%) | −7.04±5.89 | −0.80±1.02 | −0.55±1.04 | 16.549 | <0.001 | <0.001 | <0.001 | <0.001 |

SG: Stabilization exercise group; MG: McKenzie exercise group; HG: Home exercise group; SD: Standard deviation; VAS: Visual Analog Scale; MODI: Modified Oswerty Disability Index; TrA: Transversus Abdominus muscle; MF: Multifidus muscle; Gmax: Gluteus Maximus muscle; $p^{1-2}$: Comparison of SG and MG; $p^{1-3}$: Comparison of SG and HG; $p^{2-3}$: Comparison of MG and HG.

exercises to enhance their thickness and strength remain debated. Therefore, this study investigated the effects of Stabilization, McKenzie, and home exercise program and concluded that stabilization exercises were more effective on muscle thickness.

In a study by Batıbay et al.[29] comparing Pilates mat exercises and home exercise programs in females with chronic LBP, both exercises were shown to be effective. Previous research investigated the use of Pilates and stabilization exercises as a therapeutic method for patients with chronic LBP. These studies indicated core stabilization based exercises effectively improve pain and disability rates among patients with chronic LBP.[30,31] According to the results of our study, stabilization exercises increased TrA, MF, and Gmax muscle thickness in individuals with LBP. A well-established relationship exists between thinning of the MF and TrA muscles at the L5 spinal segment and three clinical consequences: strength deficits, neuromuscular dysfunction, and persistent LBP.[32,33] Therefore, this study is important in demonstrating the improvements in muscle thickness achieved through stabilization exercises. In addition, the results are not surprising, as stabilization exercises provide motor learning specifically in these muscles. In a narrative review, it was demonstrated that motor control exercises, defined as an exercise to increase strength of deep trunk muscles and decrease the overactive external trunk muscles, increased muscle mass of TrA and MF, improved deep muscle activation and proprioception, and decreased fat muscle and delay muscle activation.[34] A functional MRI study revealed that stabilization exercises elicited neural activity in the primary motor and somatosensory cortex regions that somatotopically map to core musculature, suggesting neuroplastic reorganization capabilities.[35] Therefore, targeted stabilization training appears capable of restoring deep trunk muscle activation, refining lumbar spine proprioception and reinforcing sensory inputs that sustain typical organization in corresponding cerebral regions.[34] Our results were in parallel with the literature. Core stabilization exercises have been demonstrated to increase thickness of TrA and decrease LBP in individuals with chronic LBP.[36] Narouei et al.[37] also concluded that a four-week core stabilization training increased TrA and MF muscle thickness. However, there was no statistical increase in MF contracted thickness and Gmax muscle thickness. It was suggested that this result was due to the onset of thickening in these muscles during the four-week period. We may have obtained these results due to the possible reason of eight weeks of training in our study. Stabilization exercises were found to improve MF muscle size in patients with acute LBP, which was found to be associated with the size of LDH lesions.[38,39] The efficacy of stabilization exercises was demonstrated by an increase in the baseline thickness of TrA on the left side and during the active abdominal drawing-in maneuver for the right TrA. Furthermore, these exercises were observed to enhance the thickness of the left TrA muscle during straight leg raise and the contracted left MF muscle.[15]

The exercises are assigned according to the patient's directional preference, aligning with the specific movement direction that alleviates their symptoms.[15] In clinical practice, patients often show reduced pain with spinal extension movements; in such cases, rehabilitation exercises should focus on extending the spine. Centralization is the process in which pain that radiates from the spine to distant areas gradually moves back toward the spine as a result of specific, repeated movements.[15] It is surprising that McKenzie exercises were found to increase TrA, MF, and Gmax muscle thickness in this study. McKenzie exercises focus on sustained posture and repeated movements.[13] The fact that these exercises caused hypertrophy in these muscles in this study despite not focusing on the deep abdominal muscles may be due to the neuromuscular adaptation of the exercise. Further studies should investigate the mechanism. Improvements in symptoms such as disability and pain might stem from increase in deep abdominal muscles' thickness in LBP patients. Unlike the present study, Hosseinifar et al.[15] concluded that stabilization exercises increased TrA muscle thickness but not McKenzie exercises.

According to the results of our study, pain decreased clinically in all exercise groups but did not reach a statistically significant level in group comparisons. It was also determined that disability decreased in the SG and MG, but the decrease in disability did not reach a statistically significant level in the HG. Clinically, the greatest change in pain and disability was observed in stabilization exercises. This may have occurred as a result of changes in the strength of the muscles that were weak in these patients and caused disruption of lumbopelvic stability. There may also be different underlying mechanisms. These mechanisms may be an improvement in the quality of movements following a reduction in loading and an improvement in the coordination of the trunk muscles.[37] Since the greatest change occurred in the deep abdominal muscles with stabilization and McKenzie exercises, the greatest improvement in pain and disability may have occurred in this group. Stabilization exercises have the potential to exhibit superior effectiveness in alleviating pain, particularly among individuals with compromised TrA activation. Consequently, an ultrasonography-based prediagnosis assessing the recruitment of TrA could offer valuable insights to clinicians for prescribing stabilization exercises.[40] Additionally, a duration of stabilization exercises lasting more than eight weeks might hold greater significance for reducing pain.[37] The reason why we did not reach a statistically significant level in pain may be that we terminated the treatment at eight weeks. Further studies should include a longer exercise program. Narouei et al.[37] also concluded that four-week stabilization exercises provided a reduction in pain and disability in patients with chronic LBP. However, since they used electrotherapy application as a control group, they obtained more reduction in the exercise group. We found that disability decreased significantly as a result of the supervised exercise training we applied. In parallel with the results of our study, Bhadauria et al.[24] also found that lumbar stabilization exercises had positive effects on pain and disability in patients with chronic LBP. It was concluded that these effects were more pronounced than dynamic strengthening training. In another study comparing stabilization and McKenzie exercises, pain improved in both groups; however, disability decreased only in the SG.[15] Our results are consistent with the literature.

This study had some limitations. One of the important results of this study was that the home exercise program was effective on the parameters evaluated; however, this effect was insufficient compared to other supervised exercise methods. This result showed the importance of providing supervised education to our patients clinically. This study is important in terms of emphasizing the importance of different exercise applications on clinical symptoms and thickness changes in deep muscle groups in patients with LBP. However, not including a control group in the study, in which no exercise method was applied, can be viewed as a limitation. As a result of the inclusion of the control group, the importance of exercise can be expressed more clearly. Future studies can be planned in this way. Furthermore, not conducting the arm assignment according to standard randomization processes may be a limitation. The etiologies of the participants were not homogeneously evaluated in this study. However, patients with specific etiologies such as severe spinal stenosis, radiculopathy, spondylolysis, spondylolisthesis, infection, malignancy, or systemic inflammatory disease were excluded. Nevertheless, individual differences in the underlying causes of LBP may exist, and this may have resulted in different responses to the effectiveness of exercises. This limitation is an important point to consider when interpreting the results of this study. In future studies, it would be useful to determine the etiology of LBP in participants in detail and analyze subgroups. In addition, patients were only allowed to perform the specified exercise programs, and no concurrent pharmacological or other physical therapy methods were applied in this study. However, individual lifestyle or pain management of the participants could affect the results. Lastly, we did not evaluate the possible effects of other treatment modalities on the study results. In future studies, we recommend assessing the treatment history of the participants in detail.

In conclusion, all types of exercises applied to individuals with LBP were effective on deep abdominal and lumbar muscle thickness, pain, and disability. However, stabilization exercises were found to be more effective on deep trunk muscle thickness, Gmax thickness, and disability compared to McKenzie exercises and the home exercise program. This is the first study to examine the effects of these three exercise groups on muscle thickness, pain, and disability. Further studies should include longer follow-up periods to further validate these results.

**Data Sharing Statement:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

**Author Contributions:** Conceptualization and study design; data analysis and/or interpretation; drafting the initial manuscript; critical revision of the manuscript; preparation of references and funding statements; management of study materials: M.Ş.E., S.B.Y.; Provided control/supervision, critical review was performed: S.B.Y.; Data collection and/or processing was conducted: M.Ş.E., (lead) with contribution from S.B.Y.; The literature review was conducted by M.Ş.E.

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