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Original Article

Effect of Kinetic Control Retraining on Electromyographic Activity of Trunk Muscles in Patients with Lumbosacral Radiculopathy: A Randomized Controlled Trial

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Abstract

Objective: To investigate whether adding kinetic control retraining to conventional physical therapy improves trunk muscle electromyographic (EMG) activity, pain, and disability in patients with lumbosacral radiculopathy in a randomized controlled trial. **Methods**: Fifty patients (35–50 years) were randomly assigned to a study group (kinetic control plus conventional therapy) and an active control group (conventional therapy) for six weeks. EMG activity of transversus abdominis (TA), erector spinae (ES) and superficial multifidus (MF) was assessed during trunk flexion/extension as root mean square (RMS) normalized to maximum voluntary isometric contraction (%MVIC). Pain and disability were assessed using Visual Analog Scale (VAS) and Oswestry Disability Index (ODI). Outcomes were assessed by a blinded assessor who was unaware of group allocation at baseline and post-intervention. **Results**: Both groups showed improvements ($p < 0.05$). However, the study group showed greater reductions in ES and MF activity, VAS, and ODI, and increased TA activation compared with controls, suggesting clinical improvement. No adverse events. **Conclusion**: In patients with lumbosacral radiculopathy, adding kinetic control retraining to conventional physical therapy was associated with greater short-term improvements in trunk muscle activation patterns, pain, and disability than conventional physical therapy alone. However, these findings do not isolate the independent effect of kinetic control retraining. ClinicalTrials.gov ID: NCT07079202.

Keywords: Back pain, Electromyographic activity of trunk muscles, Kinetic control, Lumbosacral radiculopathy

Introduction

Lumbosacral radiculopathy is a neurological condition that occurs when one or more lumbar or sacral nerve roots are irritated or compressed, leading to pain that radiates from the lower back to the buttocks, legs, or feet[1-2]. It most frequently occurs between the levels of L4-L5 and L5-S1. The prevalence of lumbosacral radiculopathy in the general population is estimated at 3% to 5%, with a specific distribution of 2% to 5% in men and 1% to 3% in women[3-4]. This condition is frequently associated with chronic low back pain (CLBP), a condition characterized

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by recurrent or persistent pain in the back region that significantly affects disability levels and quality of life[5-6]. Evidence suggests that individuals with CLBP demonstrate altered motor control, including delayed activation and reduced recruitment of deep trunk muscles, particularly the TA. These impairments are associated with decreased spinal stability and altered neuromuscular coordination, often reflected in changes in electromyographic (EMG) activity expressed as a percentage of maximum voluntary isometric contraction (%MVIC)[7-9]. These findings emphasize the critical role of deep trunk muscles in maintaining spinal stability and motor control. EMG is widely used to quantify trunk muscle activation and guide rehabilitation strategies[10-11].

Physiotherapy plays a pivotal role among non-invasive treatment modalities in the management of lumbosacral radiculopathy[12]. Evidence supports non-surgical management as the primary approach for lumbar disc pathology with lumbosacral radiculopathy, highlighting the role of multimodal interventions such as exercise therapy, Transcutaneous Electrical Nerve Stimulation (TENS), ultrasound (US), and neural mobilization in restoring functional stability[13]. One specialized approach is kinetic control, developed by Comerford and Mottram, which focuses on identifying and retraining uncontrolled movement (UCM) patterns that may contribute to pain and functional limitations. It emphasizes movement analysis and individualized exercise prescription to improve motor control and restore efficient movement strategies[14].

Motor control exercises (MCE) have been receiving increasing attention as a rehabilitation strategy for patients with CLBP. Recent evidence (Karkamandi et al., 2021) supports their effectiveness in improving trunk muscle function by activating deep stabilizing muscles such as the transversus abdominis (TA), while reducing overactivity of superficial muscles like erector spinae (ES). Through coordinated training of trunk, pelvic floor, and respiratory muscles, MCE enhance spinal stability, improve movement patterns, and contribute to functional recovery in these patients[15].

Kinetic control retraining has been reported in recent studies from 2021 to 2022 to have potential benefits on reducing pain intensity and disability in patients with radiculopathy[16-17]. However, most existing studies investigating motor control interventions and EMG outcomes have primarily focused on chronic low back pain populations. Evidence specifically addressing neuromuscular adaptations and EMG activity in patients with lumbosacral radiculopathy remains limited. In particular, the application of kinetic control–based rehabilitation in this population has not been sufficiently explored, and its effect on trunk muscle activation patterns is still unclear. Therefore, this study aimed to investigate the effect of kinetic control retraining on trunk muscle EMG activity. The study population included patients with lumbosacral radiculopathy accompanied by CLBP.

Methods

Study Design

This randomized, controlled clinical trial was carried out at the Outpatient Clinic of the Faculty of Physical Therapy, El Nahda University during the period between July 17, 2025, and December 31, 2025.

Sample Size

Before the study, the sample size for this research was calculated using G*Power 3.1 software (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany), based on ODI data from Zaworski et al. (2021)[17]. The calculation determined that 25 patients per group were required, with independent-samples t-test, $\alpha = 0.05$, a power of 80%, and an effect size of 0.82. The effect size (0.82) was calculated by the authors based on the mean and standard deviation of the ODI data reported by Zaworski et al. (2021)[17]. Sample size was calculated based on the Oswestry Disability Index (ODI) due to limited prior effect size data for sEMG in kinetic control retraining.

Participants

Initially, sixty-one individuals of both sexes with unilateral lumbosacral radiculopathy at the levels of L4-L5 and L5-S1 were evaluated for eligibility. A neurologist diagnosed and referred patients with lumbosacral radiculopathy based on standardized clinical examination (sensory, motor, and reflex testing) and MRI confirmation of posterolateral disc herniation with nerve root compression consistent with clinical symptoms. Following the eligibility assessment, 50 participants met the criteria for participation in the present study, as illustrated in Figure 1. Those enrolled were aged 35 to 50 years, had suffered from CLBP for more than three months, and presented with a body mass index (BMI) below 30 kg/m^2, severe disability on Oswestry Disability Index ranging from (40% to 60%) according to Algarni et al. (2014)[18] and having adequate cognitive skills (Mini-Mental State Examination (MMSE) score >24) to ensure their ability to comprehend and adhere to the intervention protocol, including movement dissociation tasks. While Patients with a history of previous spinal surgeries, lumbar instability caused by structural defects (such as ligament tears or spondylolisthesis), spinal tumors, or other causes of lumbosacral radiculopathy and smokers were excluded. After screening process, six individuals were excluded because they did not fulfill the inclusion criteria and five patients declined participation. Randomization was performed by an independent researcher who generated the random allocation sequence using permuted blocks of varying sizes. Participant enrollment was carried out by a separate investigator who was not involved in sequence generation. Allocation was concealed using sequentially numbered, opaque, sealed envelopes prepared according to the generated sequence and stored in a locked drawer until use. The next envelope in the sequence was opened

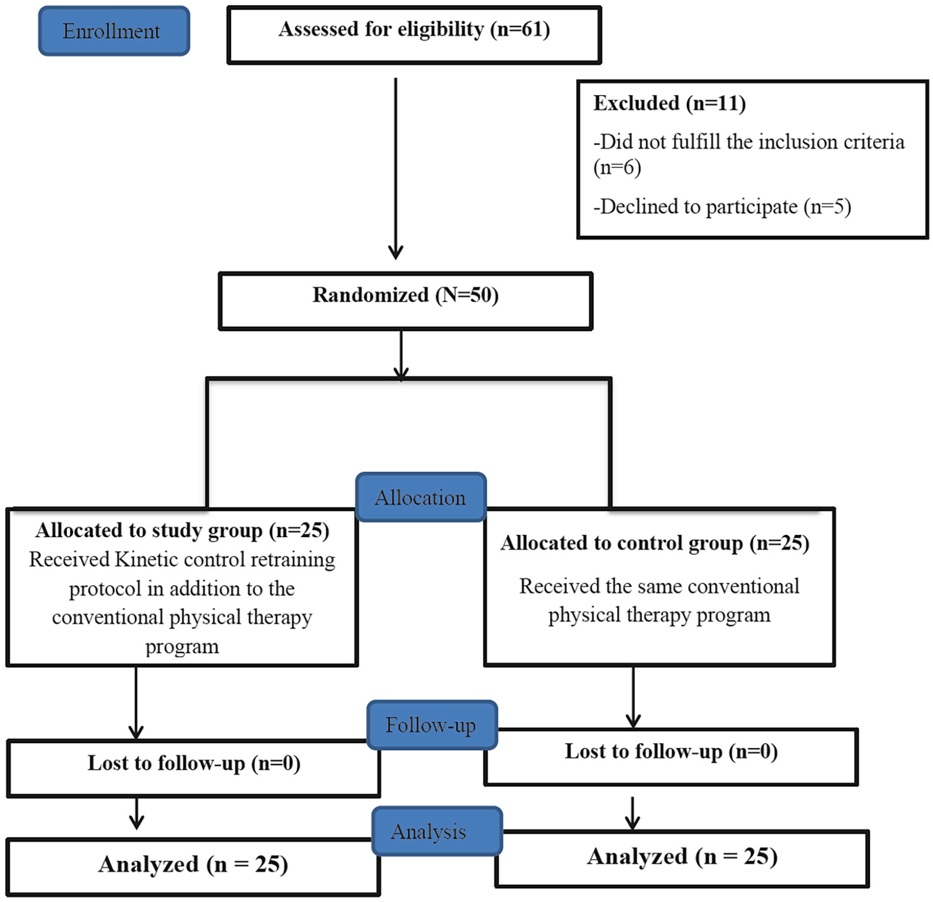

Figure 1. CONSORT flow diagram.

in the presence of the participant after formal study inclusion.

Outcome Measures

All assessments were performed by a blinded assessor, unaware of group allocation, at both baseline and immediately post-intervention.

EMG activity of trunk muscles was the primary outcome: A Digital electromyogram device (A Neuro-MEP-4-NET device (Neurosoft, Russia) was used to measure EMG activity of the TA, ES, and superficial fibers of the MF. sEMG represents a practical and cost-efficient technique for assessing muscle activity. It is widely used to evaluate muscle activity[19]. It serves as a non-invasive method. The EMG signal, representing the electrical activity released by contracting muscles, was monitored using electrodes placed on the skin above the targeted muscles. When present, skin hair was shaved from the electrode sites, and the areas were cleaned with alcohol prior to electrodes placement to minimize impedance.

Surface EMG activity for all target muscles was recorded bilaterally using a bipolar configuration, utilizing a total of four electrodes per muscle group (two per side). For the TA, the active electrodes were placed 2 cm anteromedial to the anterior superior iliac spine (ASIS), with reference electrodes positioned medially to ensure consistency at the site of pathology, Electrode placement for both the ES and superficial MF was standardized at the L4–L5 level. For the ES, the active electrodes were placed 3–4 cm lateral to the spinous processes, and for the superficial MF, electrodes were positioned approximately 2 cm lateral to the spinous processes. For both ES and MF muscles, the reference electrodes were positioned distally to the active electrodes. Patients were secured to the testing table using two rigid straps placed around the hips and legs to minimize compensatory movements[20-23].

All skin preparation followed SENIAM guidelines. To ensure signal validity and reliability, all sEMG and MVIC recordings were performed at baseline and post-intervention by a single blinded assessor, trained in standardized protocols and supervised by a senior neurophysiologist (co-author).

EMG activity was assessed during both task and MVIC trials as follows. For assessment of EMG activity of TA; Participant was in a supine position and the task consisted of active trunk flexion with arms crossed over the chest without resistance, and MVIC testing involved resisted trunk flexion via manual resistance applied to the shoulders. For assessment of EMG activity of ES and MF muscles: The Patient was lying in the prone position and the task consisted of active trunk extension without resistance, while MVIC testing involved resisted trunk extension by applying manual resistance to the back of the scapula. During MVIC trials, patients were instructed to gradually increase force over five seconds to reach maximal contraction. Each task and MVIC trials were repeated three times, 30-second rest was taken between trials and the analysis was done using the mean average of the root mean square value[24-26].

EMG signals are typically normalized through dividing the recorded signals collected during a task by a reference EMG obtained from the same muscle[27]. EMG normalization to MVIC is a standard method for controlling inter-participant and day-to-day variations in EMG studies. The normalization equation (RMS) EMG task/ (root mean square) EMG MVIC × 100 converts raw EMG signals to percentages of maximum muscle activity[28-29].

Pain intensity was assessed via the visual analog scale (VAS) which is the most extensively used tool for measuring patients' levels of pain. On LBP it has demonstrated strong validity and reliability[30]. The patients were asked to identify the degree of their current pain by marking a mark along a 10-cm line, with zero indicating no pain and ten indicating the maximum pain sensation imaginable[31].

Functional disability was evaluated using the Arabic version of the Oswestry Disability Index (ODI). This self-administered questionnaire is widely recognized as a standard tool for assessing low back functional disability[32]. It comprised of ten items, each with six levels of responses ranging from 0 to 5. To calculate the disability percentage, the total score is divided by the maximum possible score of 50 and multiplied by 100, producing a score ranging from 0% (no disability) to 100% (complete disability). Interpretation of the scale follows ODI scores: Minimum disability is represented by scores between 0 and 20%; moderate disability by scores between 20 and 40%; severe disability by scores between 40 and 60%; crippling LBP by scores between 60 and 80%; and bed confinement or significant incapacity by scores above 80%[18].

Treatment

Treatment was administered over six weeks, with three sessions per week, each lasting approximately 90 minutes for both groups[33]. This duration included rest intervals, transitions, and fatigue prevention. The same conventional physiotherapy program was administered to all participants and included:

Infrared therapy: The infrared therapy unit was applied over the back of patients for 15 minutes at a distance of 65 cm[34-35].

TENS: To concentrate the current on the lumbar spine, four electrodes were positioned in a cross-over configuration; Treatment was applied for 20 minutes at a frequency of 20 Hz using Therapic 9200 electrostimulator (EME Physio)[36].

US: It is applied to the lumbar paravertebral region using the Pulson 100 (Gymna) with a frequency set at 1 MHz and intensity of 1 W/cm^2 for 10 minutes[37]. Nerve mobilization: It was used to decompress the nerves and improve their mobility. It involved gentle, rhythmic neural tissue movements aimed at reducing mechanical nerve sensitivity. The clinician performed hip flexion while performing a straight leg raise (SLR) with concurrent ankle dorsiflexion until the point just before the pain limit, followed by plantarflexion. There were two sets of 20–30 repetitions of the sciatic neural glide. Lastly, deep breathing exercises were used to help the patient relax[38-40]. The abdominal drawing-in maneuver was performed with participants positioned on their backs with knees bent. This exercise consisted of three sets of ten repetitions, where each isometric contraction was sustained for 10 seconds. To ensure that the transversus abdominis was properly activated, subjects were coached to breathe steadily and prevent any compensatory motion in the pelvic or thoracic regions[41-43].

Kinetic control retraining for the study group only: In addition to conventional therapy, the study group received KC retraining, aims to assess and correct UCM patterns that contribute to pain, dysfunction, or injury, focusing on restoring optimal muscle coordination and joint stability by retraining force management during functional movement[14,44].

Prior to initiating the retraining program, the direction of movement associated with symptoms (lumbar flexion, extension, and rotation) was identified using motor control tests. Muscle assessment also included evaluation of gluteus maximus range of motion, as well as flexibility of the rectus femoris and hamstrings. Each patient underwent at least three tests based on their clinical presentation, and the aim and procedure of each test were explained in detail[17].

Based on these findings, individualized retraining strategies were implemented. These included patient education to increase awareness of UCM patterns, restoration of proper muscle synergy, and retraining of movement control in the symptomatic direction through repeated practice of correct movement patterns. Patients actively practiced these movements using visual and palpatory cues, along with manual guidance, unloading techniques, and verbal instructions provided by the therapist. Exercises were initially performed in supported positions and progressively advanced toward more functional tasks as control improved, with emphasis

Table 1. Representative exercises and progression.

Exercise	Progression
Trunk Lean (Standing)	Started with arm support and manual palpation to maintain neutral lumbar alignment; range was gradually increased and progressed to unsupported hip hinging while fading tactile feedback.
Double Knee Extension (Sitting)	Started with unilateral knee extension and manual palpation to maintain neutral lumbar control; range was gradually increased and progressed to bilateral extension while fading tactile feedback, ensuring no loss of neutral alignment or symptom provocation.
Forward Lean (Sitting)	Started with an elevated seat height and manual/visual feedback to maintain neutral lumbar control; range and load were gradually increased as control improved, progressing from partial to full weight-bearing during sit-to-stand, ensuring no loss of neutral alignment or symptom provocation.

on maintaining neutral lumbar alignment and avoiding symptom provocation. Each session included 30 minutes of KC retraining, structured to emphasize movement quality rather than resistance or intensity. Exercises were performed as slow, low-effort repetitions (10 repetitions per set with approximately 10-second isometric holds), with each exercise lasting approximately 2–3 minutes. Rest intervals were incorporated to maintain neuromuscular focus and prevent muscle fatigue. Progression was based on performance, requiring successful completion of three consecutive sets while maintaining neutral alignment. All sessions were supervised by a trained physical therapist. Additionally, a home program consisting of 1–2 exercises performed three times daily was prescribed as an integral part of the protocol. Adherence was recorded at the beginning of each session based on patient self-report[16,40,45].

Representative exercises included: [14]

1. **Trunk Lean (Standing)**: The participant performed forward trunk leaning while maintaining a neutral lumbar spine. The normal pattern allowed approximately 70° of trunk flexion without lumbar flexion.
2. **Double Knee Extension (Sitting)**: The participant performed bilateral knee extension from a seated position while maintaining a neutral lumbar spine. The normal pattern allowed 10–15° from full knee extension without pelvic or spinal compensation.
3. **Forward Lean (Sitting)**: The participant leaned forward from the hips while maintaining a neutral lumbar spine. The normal pattern allowed approximately 30° of forward trunk lean without compensatory spinal flexion.

Representative exercises and their progression are summarized in Table 1.

Statistical Analysis

Statistical analyses were performed using SPSS for Windows version 23 (SPSS, Inc., Chicago, IL), with an Alpha level of 0.05. All participants completed the study; a per-protocol analysis was used, with no missing data or protocol deviations. The data were checked for extreme scores, homogeneity of variance, and normality, with the Shapiro-Wilk test confirming normal distribution of all measured variables ($p > 0.05$). Data for all outcomes except for sex and the affected side (counts) were expressed as mean ± standard deviation. A two-way mixed-design MANOVA was used to assess the combined effect of all outcomes across the groups. To protect against type I error, follow-up univariate ANOVAs with Bonferroni adjustments were performed whenever MANOVA indicated significant differences. Effect size was calculated using G*Power 3.1 software (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany) to quantify the magnitude of differences between both groups post-treatment and provide a measure of practical significance beyond p-values. For comparisons between two groups, Cohen's d was used and interpreted according to standard benchmarks (0.2 = small, 0.5 = medium, 0.8 = large).

Safety Monitoring

Safety and adverse events were monitored at the beginning and end of each session. Participants were instructed to report any symptom exacerbation, such as increased radicular pain or muscle soreness. A protocol was in place to modify or discontinue treatment if any significant clinical worsening occurred; however, no adverse events or harms were reported in either group throughout the 18-session intervention

Results

No adverse events, harms, or significant clinical worsening were reported in either group, and no participants required modification or discontinuation of the intervention.

Table 2. Baseline demographic and clinical characteristics of patient.

Characteristics	Study Group (n=25)	Control Group (n=25)	t- value	P Value
Age (years)	42.64±5.27	43.52±5.52	-0.58	0.57
Weight (kg)	73.52±8.94	74.18±7.18	-0.24	0.81
Height (cm)	167.16±6.34	166.84±8.16	0.16	0.88
BMI (kg/m^2)	26.28±2.57	26.57±2.23	-0.42	0.68
Chronicity of low back pain (Months)	8.02±1.68	8.4±1.38	-0.39	0.7
Sex, n (%)				
Female	13(52%)	15 (60%)	χ^2=0.72	0.39
Male	12 (48%)	10 (40%)		
Affected side, n (%)				
Right	14 (56%)	16 (64%)	χ^2=0.33	0.56
Left	11 (44%)	9 (36%)		

BMI, body mass index; χ^2, Chi Square; Data are mean± SD for all demographics except sex and affected side (%), P-Value < 0.05 indicate statistical significance.

Baseline patient characteristics

The data in Table 2 indicated that there were no statistically significant differences between both groups in demographic variables and baseline clinical characteristics ($p > 0.05$).

Effect of treatment on EMG activity of TA, MF, ES, VAS and ODI

A mixed-design multivariate analysis was conducted to examine the differences between the two groups in the magnitude of changes observed in their outcome scores. Statistically significant multivariate effects were detected for the main effect of group (Wilks' Λ = 0.48, F(8, 41) = 5.5, *P*-value < 0.001, partial Eta Squared η^2 = 0.52), for the effect of time from pre- to post-treatment (Wilks' Λ = 0.02, F(8, 41) = 315.89, P-value < 0.001, partial η^2 = 0.98), as well as for the interaction between group and time (Wilks' Λ = 0.15, F(8, 41) = 29.09, *P*-value < 0.001, partial η^2 = 0.85).

Within-group comparison

The results showed a statistically significant reduction in the normalized RMS values of bilateral MF and ES muscle activity and in the mean scores of VAS, ODI after treatment in comparison with that before treatment in both groups ($p < 0.05$) while, a statistically significant increase was observed in the normalized RMS values of bilateral TA muscles activity, after treatment in comparison with that before treatment as shown in Table 3.

Between-groups comparison

At baseline, no statistically significant differences were observed between the two groups ($p > 0.05$) across all measured outcomes. Following treatment, statistically significant differences were found between both groups in the normalized root mean square values of bilateral MF, ES, and TA muscle activity, as well as in the mean scores of VAS and ODI, favoring the study group, as presented in Table 4.

Discussion

The current study was conducted to investigate the effect of the Kinetic Control retraining on EMG activity of trunk muscles, pain and functional disability in patients with lumbosacral radiculopathy. In line with our primary hypothesis, the results of the present study suggest that combining Kinetic Control retraining with conventional therapy may enhance short-term outcomes in trunk muscle activation, pain, and functional disability. However, these findings should be interpreted with caution given the limited radiculopathy-specific evidence and the methodological constraints of surface electromyography.

Kinetic control retraining targets movement and motor control deficits and has shown benefits in nonspecific low back pain, with limited direct evidence in lumbosacral radiculopathy despite shared neuromuscular impairments[46].

The significant improvement in pain and functional ability observed within the study group relative to the control group might be attributed to the patients' active participation in the treatment in the study group. This explanation is supported by Stochkendahl et al., (2018), who mentioned that patient education and active participation in treatment significantly improve outcomes for individuals with LBP. They mentioned that integrating cognitive training and exercise therapy demonstrated strong-level evidence for enhancing functional capacity

Table 3. Within-groups comparisons from baseline to 6 weeks of intervention for VAS, ODI, EMG activity of TA, MF and ES muscles.

Outcomes	Study Group (n=25)		Control Group (n=25)	
	Change from baseline to 6 weeks		Change from baseline to 6 weeks	
	MD (95% CI)	P Value	MD (95% CI)	P Value
VAS (cm)	5.24 (4.69,5.79)	0.001	3.72 (3.17,4.27)	0.001
ODI (%)	37.28 (34.56,40)	0.001	26.48 (23.76,29.2)	0.001
EMG activity of TA muscle right (%)	-14.92 (-17.87,-11.97)	0.001	-5.27 (-8.22,-2.32)	0.001
EMG activity of TA muscle left (%)	-13.96 (-17.29,-10.63)	0.001	-5.62 (-8.96,-2.29)	0.001
EMG activity of superficial multifidus (MF) muscle right (%)	18.85 (16.16,21.53)	0.001	8 (5.32,10.69)	0.001
EMG activity of superficial multifidus (MF) muscle left (%)	18.75 (14.73,22.41)	0.001	7.55 (3.71,11.39)	0.001
EMG activity of ES muscle right (%)	27.52 (23.91,31.14)	0.001	9.99 (6.37,13.61)	0.001
EMG activity of ES muscle left (%)	15.89 (13.15,18.63)	0.001	3.11 (0.37,5.85)	0.001

Data are presented as mean difference (MD) with 95% confidence interval (CI). A p-value < 0.05 indicates statistical significance. MD: mean difference; CI: confidence interval; VAS: Visual Analogue Scale; ODI: Oswestry Disability Index; TA: transversus abdominis; MF: Superficial multifidus; ES: erector spinae.

Table 4. Between-groups comparisons for all outcome measures pre and post treatment.

Outcomes	Time	Study Group (n=25)	Control Group (n=25)	MD(95% CI)	P Value	Cohen d
VAS (cm)	*Baseline*	7.48±1.53	7.26±1.42	0.22 (-0.62,1.06)	0.42	1.61
	After 6 weeks	2.24±0.63	3.54±0.95	-1.3 (-1.89,-0.71)	0.001	
ODI (%)	*Baseline*	47.52±5.92	48.08±8.2	-0.56 (-4.53,3.51)	0.78	3.38
	After 6 weeks	10.24±2.82	21.6±3.83	-11.36 (-13.27,-9.45)	0.001	
EMG activity of TA muscle right (%)	*Baseline*	43.23±5.39	42.79±4.63	0.44 (-2.41,3.3)	0.76	1.97
	After 6 weeks	58.15±5.88	48.06±4.21	10.09 (5.02,15.16)	0.001	
EMG activity of TA muscle left (%)	*Baseline*	41.02±3.09	42.03±2.39	-1.02 (-4.86,2.82)	0.6	2.03
	After 6 weeks	54.97±2.06	47.66±2.74	7.31(1.32,13.31)	0.001	
EMG activity of superficial multifidus (MF) muscle right (%)	*Baseline*	83.25±8.32	82.33±6.27	0.92 (-3.27,5.11)	0.66	1.43
	After 6 weeks	64.4±7.78	74.33±5.95	-9.92 (-13.87,-5.98)	0.001	
EMG activity of superficial multifidus (MF) left (%)	*Baseline*	84.82±8.98	84.51±7.7	0.31 (-4.45,5.07)	0.9	2.15
	After 6 weeks	66.25±3.42	76.96±6.15	-10.71 (-16.65,-4.77)	0.001	
EMG activity of ES muscle right (%)	*Baseline*	79.19±8.43	78.99±6.74	0.19 (-5.3,5.68)	0.9	2.95
	After 6 weeks	51.66±4.35	69±7.07	-17.34 (-22.72,-11.96)	0.001	
EMG activity of ES muscle left (%)	*Baseline*	81.17±6.08	80.8±7.24	0.37 (-6,6.75)	0.91	2.43
	After 6 weeks	65.27±5.79	77.69±4.35	-12.41 (-18.42,-6.4)	0.001	

Data are mean±SD, P-Value < 0.05 indicates statistical significance, MD: mean difference, CI: confidence interval, VAS: Visual analogue scale, ODI: Oswestry disability index, TA: Transversus abdominis, MF: Superficial Multifidus, ES: erector spinae, Cohen's d for effect size (0.2 = small, 0.5 = medium, 0.8 = large).

and reducing pain intensity in patients with CLBP[47]. Also, Comerford and Mottram (2012) highlighted that kinetic control retraining has been reported to improve outcomes regarding range of motion, disability, pain and the ability to return to daily functional activities by combining mental and physical retraining[14]. Although these mechanisms are primarily supported in CLBP, they may have potential clinical relevance to lumbosacral radiculopathy due to overlapping neuromuscular control impairments; however, direct evidence in this population remains limited.

On the other hand, the significant decrease in pain and functional disability observed in the control group might be attributed to the neural gliding of the sciatic nerve. Butler (2000) noted that neural gliding techniques have been associated with improvements in range of motion and reductions in pain, although these have been primarily studied in general LBP populations[48].

These findings are consistent with previous EMG studies demonstrating that trunk muscle activation varies with exercise conditions and positioning, which supports the use of targeted exercise selection in rehabilitation[10-11].

Furthermore, these results align with those reported by Kanchan and Anap Deepak (2024) and Alfa et al. (2021), who indicated that MCE —especially those following the kinetic control concept — led to reductions in pain and enhanced functional performance compared to other interventions in patients with lumbar radiculopathy[40,45].

The current results regarding prominent improvement of pain intensity and functional ability in the study group were in line with those of Mohammadi et al., (2017) who stated that MCE targeting retraining of neuromuscular control and trunk coordination led to significant improvements in pain, disability, and motor control impairment. These motor control improvements may also be relevant to lumbar radiculopathy due to shared neuromuscular impairments[49].

Patients with LBP exhibit altered movement patterns characterized by UCM, which contribute to their symptoms[45]. Cho et al., (2013) found that CLBP patients had significantly lower TA contraction rates compared to normal subjects[50], while Ehsani et al., (2016) reported increased activity of superficial back muscles relative to deep abdominal muscles, reflecting motor control dysfunction[51]. Similarly, Park et al., (2016) reported that MCE were more efficient than stretches in reducing compensatory pelvic movements and decreasing activity of ES muscle in individuals with LBP. These findings support the role of motor control–based interventions in improving trunk muscle coordination and movement control, although their direct applicability to lumbar radiculopathy remains limited[52].

Further supporting these outcomes, a meta-analysis by Shanbehzadeh et al., (2022) revealed that MCE significantly increased the TA contraction ratio and improved both pain as well as functional disability scores among people with CLBP compared to other interventions. While emphasizing the need for further research in lumbar radiculopathy[53]. Moreover, Capel-Alcaraz et al. (2023) reported that MCE produced greater reductions in pain and disability than other interventions. Although these findings derived from chronic nonspecific low back pain populations and should be interpreted cautiously when applied to lumbar radiculopathy[54].

Contrary to these results, Hall et al., (2009) reported there were no significant changes in trunk muscle EMG activity. This contradiction between two studies might be attributed to different methodology. In study of Hall et al., (2009), MCE was conducted for single session, and this was insufficient to restore deep abdominal muscle motor control but, in this study, kinetic motor retraining was conducted for eighteen training sessions that allowed measurable improvements in neuromuscular control[55]. This may have potential relevance to lumbar radiculopathy where similar motor control deficits are present; however, direct evidence in this population remains limited.

Limitations

The main one was lack of follow up to determine the long-term effect of kinetic control retraining. Furthermore, because the used interventions require direct connection between the therapist and the patients, it was impossible to blind the physiotherapist. Moreover, the findings of this study cannot be generalized as the sample was convenient rather than random to represent the entire population.

While surface EMG allows reliable assessment of superficial muscles (such as MF and ES), it cannot reliably isolate deep muscles such as the transversus abdominis; this limitation was considered during data interpretation, and future studies may use fine-wire EMG or ultrasound for more precise assessment.

Conclusions

In patients with lumbosacral radiculopathy, adding kinetic control retraining to conventional physical therapy was associated with greater short-term improvements in trunk muscle activation patterns, pain, and disability than conventional physical therapy alone. However, these findings do not isolate the independent effect of kinetic control retraining, and further studies with longer follow-up periods are recommended.

Ethics Approval

The study was approved by the Ethics Committee of the Faculty of Physical Therapy, Cairo University (No. P.T.REC/012/004918) and was conducted in accordance with the Declaration of Helsinki (1964) and its later amendments.

Consent to Participate

Written consent form was obtained from every participant.

Authors' Contributions

Conceptualization, M.M.E conceived the study, performed the experimental work, collected the data, and wrote the primary draft of *the manuscript. N.A.S conducted the random allocation of patients and contributed to writing, together with S.M.A and N.I.R. M.M.E and S.A.A assisted in data review and parts of the experimental work. A.A.E contributed to manuscript writing. All authors read and approved the final version of the manuscript.*

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