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Motor Control Exercises: Effects on Sciatic Nerve Mechanical Sensitivity, Erector Spinae and Quadratus Lumborum Muscle Thickness, and Abdominal Endurance in Patients with Lumbar Radiculopathy

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Abstract

Lumbar radiculopathy refers to irritation or compression of spinal nerve roots in the lower back. This condition produces discomfort, weakness, numbness, or tingling that spreads from the lower back to the buttocks, thighs, and sometimes the legs and foot. The study aims to evaluate the effectiveness of motor control exercises on sciatic nerve mechanical sensitivity, erector spine and quadratus lumborum thickness, and abdominal endurance in individuals with lumbar radiculopathy. Thirty-two patients were randomly recruited from SGT Hospital, Gurugram's Physiotherapy OPD based on the inclusion criteria. The experimental group was given motor control exercises, while the control group received normal exercises. Mechanical sensitivity of sciatic nerve, abdominal endurance and Muscle thickness of erector spinae and Quadratus lumborum was measured. The result showed significant improvement in thickness of quadratus lumborum, abdominal endurance and mechanical sensitivity of sciatic nerve.

Keywords: Abdominal Endurance, Diagnostic Ultrasonography, Lumbar Radiculopathy, Mechanical Sensitivity, Motor Control Exercise, Straight Leg Raise.

Introduction

It is one of the most common symptoms seen by spine surgeons. It affects both men and women equally and is estimated to impact 3-5% of the population. Ageing increases the chance of spinal degeneration. Men often suffer symptoms in their 40s, whereas women usually encounter them in their 50s and 60s. Lumbar radiculopathy is primarily brought on by degenerative spondyloarthropathies. Patients frequently experience back pain when they first notice their radiculopathy, which by definition, is pain that frequently feels like electric, burning, or sharp and travels down the involved legs (1). Patients with low back discomfort may have compromised spinal stability and control (2). The pain that is referred to in the lower extremity is frequently referred to as sciatica. Sciatica's radiating pain is often attributed to mechanical compression of the nerve roots caused by lumbar intervertebral disc herniation, among other possible causes. Sciatica is caused by more than only mechanical compression from lumbar disc herniation (3). The exact aetiology is uncertain. Examples of inflammatory processes include neural adhesions, arachnoiditis, and virus-induced mononeuritis. The SLR test is the most commonly used physical examination to diagnose sciatica and lumbar disc hernia. The straight leg lift might resemble discomfort due to sensitivity issues, as seen in neuritis. One important aspect of the straight leg raise is its ability to mimic the patient's pain via sensitivity issues, as demonstrated by neuritis' ability to increase mechanosensitive, inflammation's ability to maintain normal nerve conductivity in the absence of axonal damage, and radiculitis' ability to produce these correlates without applying pressure to the nerve root. This could explain the limitations in the identification of nerve root compression (3, 4). When the SLR causes pain below the knee and along the sciatic nerve's route between 30 and 70 degrees of hip flexion, it is considered positive. A positive test could indicate problems anywhere along the sciatic nerve's path, including the spine, buttocks, and thighs (SLR moves the sciatic nerve to the nerve roots). Existing research on neural movement during the

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Straight Leg Raise (SLR) in healthy people and those with pathology, as well as an understanding of potential causes of sciatic symptoms, suggests that the SLR may not be the most effective test for detecting lumbar intervertebral disc herniation or other forms of mechanical nerve compression. Instead, it is more suited for evaluating brain mechanosensitivity without determining the underlying reason (4). CT and MRI are the "gold standard" for evaluating muscle size, as they can precisely detect changes in the cross-sectional area of specific muscles or muscle groups. However, these methods are exceedingly expensive, time-consuming, and typically located in certain regions of the hospital. Initially, ultrasonic (US) techniques were employed to determine the thickness of skeletal muscle or fat deposits, possibly as a substitute for a skinfold caliper. However, developments in ultrasound technology and the creation of mobile B-mode (image-producing) equipment that can make cross-sectional images of muscle from reflected US waves may be able to provide an alternate technique for identifying alterations to specific muscles or muscle groups. (5).

Physiotherapists developed the pressure biofeedback unit (PBU), which detects movement of the lumbar spine in relation to an air-filled reservoir and helps retrain stabilizing muscles using specific exercises (6). Such pressure sensors can be used to measure the deep abdominal muscles' fatigue time objectively and offer helpful visual biofeedback during treatment. Recent publications have examined the ability to contract the transversus abdominis muscle, as well as feedback on local low back muscle activation. The "PRONE test," also known as the "transversus abdominis muscle contraction test," has been used in this study to demonstrate proper transversus abdominis muscle contraction during abdominal hollowing while lying on one's back. Muscle contraction or relaxation is indicated by a change in inflation bulb pressure (7).

The solution focusses on engaging the deep trunk muscles to restore control and coordination (8, 9). Investigating the effects of core stabilization training on erector spinae muscle contraction characteristics. A stabilization exercise program could significantly improve trunk muscle function and minimize erector spinae muscle stiffness (10). No research has been discovered that examine the effects of motor control exercises on the mechanical sensitivity of the sciatic nerve, the thickness of the erector spinae and quadratus lumborum muscles, or abdominal endurance in persons with lumbar radiculopathy. The purpose of this study was to investigate the efficiency of motor control exercises on mechanical sensitivity of the sciatic nerve, thickness of the erector spinae and quadratus lumborum, and abdominal endurance in participants with lumbar radiculopathy. The null Hypothesis will have no significant effects of motor control exercises on mechanical sensitivity of sciatic nerve, thickness of erector spinae and quadratus lumborum and abdominal endurance in subjects with lumbar radiculopathy whereas alternate hypothesis will be significant effects of the variables.

Methodology

The study used a Pretest Posttest Control group design and was carried out at the SGT Medical College, Hospital, and Research Institute's Physiotherapy Out-Patient Department (OPD) in Gurugram, Haryana. Thirty-two patients met the inclusion and exclusion criteria. The sample size was estimated using G power program with an effect size of d=0.9, α err.prob=0.05, and power (1-β err. prob) =0.80. Individuals aged 30-50 years of both genders who had been pre-diagnosed with lumbar radiculopathy and complained of Lower Back Pain (LBP) with pain and/or numbness radiating below the knee were eligible. Teoporosis and fibromyalgia), as well as those who are currently pregnant or in the early stages of postpartum. The Institutional Ethical Committee of SGT University's Faculty of Physiotherapy provided ethical approval.

All the subjects participated in the study were randomly assigned to two groups (Figure 1): Group A (Experimental group) and Group B (Control group). Participants were assessed, and readings were taken accordingly in assessment form. Baseline measurements were consisting of 4 outcomes i.e., 1. Mechanical sensitivity of sciatic nerve 2. Abdominal endurance 3. Muscle thickness of erector spinae and Quadratus lumborum. Group A (Experimental Group) receives motor control exercises done for 6 weeks [3 sessions per week], while Group B (Control Group) receives conventional exercises [for 6 weeks -3 sessions per week]. After 6 weeks all the outcome measures were re-evaluated.

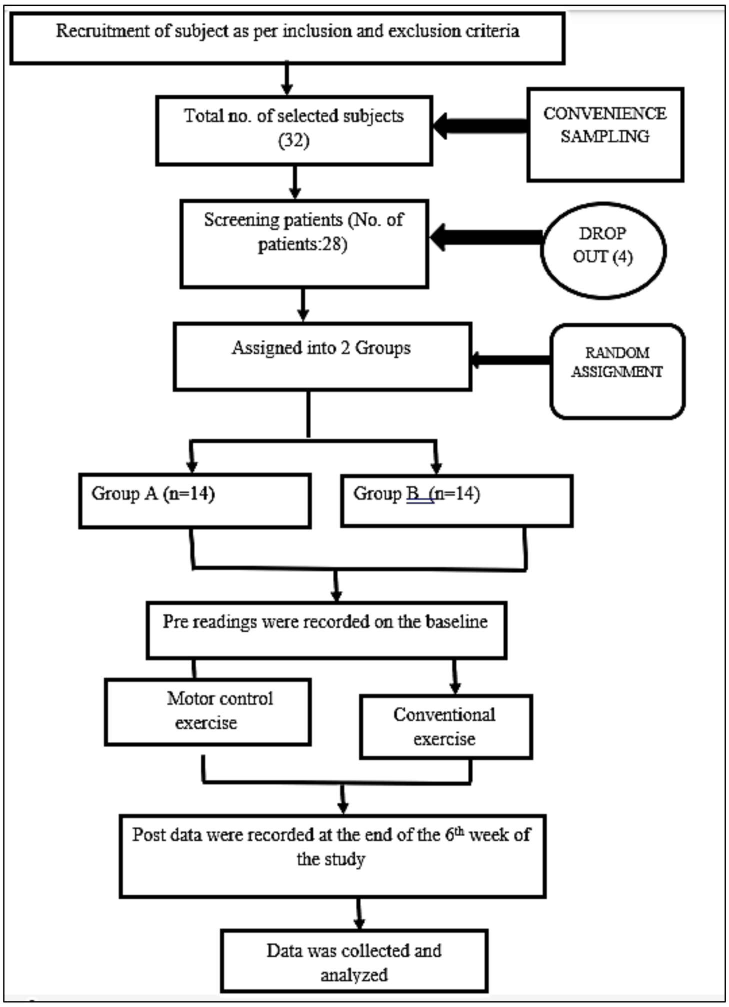

Figure 1: Study Flow chart

Measurement of Mechanical Sensitivity of Sciatic Nerve

The individuals lay supine, with a typical cushion supporting their head in a neutral position. The examiner was on the same side as the patient, as the lifted limb was on the bed's side. The examiner placed his hands distally behind the calf/Achilles tendon and proximally behind the patella. With this grip, the subject's leg was passively elevated to 90 degrees, hip in neutral rotation, knee extended, and ankle free. This was done several times until the initial symptoms arose or the symptoms at rest grew by 30%. If no reaction was received, the SLR was stopped at 90 degrees. At the hip flexion angle, a structural differentiation movement (hip internal rotation or ankle dorsiflexion) is performed in response to the location of the evoked responses. Responses (proximal = buttock/hamstring, distal = below the knee) were used to determine whether the symptoms were neurological or musculoskeletal in origin. These site-specific approaches highlight nerve movement while not disrupting the surrounding musculoskeletal structures in the relevant region. The distinguishing movement for patients with symptoms in the gluteal and/or hamstring regions is passive dorsiflexion of the ankle (also known as distal differentiation). This was accomplished by slowly dorsiflexing the ankle from neutral (loose) to 90° dorsiflexion while maintaining the SLR angle and moving the examiner's proximal hand from above the knee to the ball and toes of the foot (as in the Bragard test). Ankle dorsiflexion, without tightening the biceps femoris muscle, applies pressure to and pushes the sciatic nerve distally. For patients with distal reproduction of symptoms (below the knee), hip internal rotation was employed to differentiate neurally elicited reactions. . The examiner twisted their wrists to cause internal rotation of the hip joint while keeping the same hand positioning as indicated earlier with the SLR. Maintaining the SLR angle and avoiding hip adduction during triggered reactions. If the SLR produced no responses prior to or at 90 degrees of hip flexion, the test was considered inconclusive, and no structural distinction was performed. If structural distinction did not increase the SLR-induced symptoms, the test was ruled negative (3).

Measurement of Thickness of Erector Spinae

The thickness of the muscle was assessed by diagnostic ultrasonography. A linear ultrasound probe was used (frequency range: 7–12 MHz) and gel for the ultrasound probe were required. Patient was positioned on a treatment table in a prone (face-down) that is comfortable for them. The patient's back muscles should feel at peace. To preparation for the probe, apply a generous amount of gel to the patient's skin over the erector spinae muscle. Align the long axis of the erector spinae muscle with the ultrasound probe, which is perpendicular to the skin's surface. Image Take a transverse (cross-sectional) picture of the erector spinae muscle. Starting at the L3-L4 or L4-L5 vertebrae in the lower lumbar region is a nice location to begin. The erector spinae muscle's thickness was measured from the anterior to posterior border, including the fascia (11).

Measurement of Thickness of Quadratus Lumborum

The patient was placed in a lateral decubitus position, with the assessed side up. The quadratus lumborum muscle is more easily approached from this position. A generous amount of gel was applied to the patient's skin across the quadratus lumborum muscle and align the long axis of the muscle by placing the ultrasonic probe perpendicular to the skin's surface. A transverse (cross-sectional) picture of the quadratus lumborum muscle was taken halfway between the lowest rib and the iliac crest, where measurements are most commonly made. Measure the quadratus lumborum muscle's thickness from the anterior to the posterior border, taking the fascia into account (12).

Abdominal Endurance

Endurance was measured with a stopwatch (Heuer Micro Split 1000) and the Chattanooga Stabilizer pressure biofeedback sensor. The inflatable cell's lower border was positioned in the middle of the abdomen, near the anterior superior iliac spines (ASIS). The participants were taught how to perform an abdominal drawing-in manoeuvre (ADIM), as described by Richardson *et al*. in 1996, to selectively contract their transverse abdominis muscle (13). To avoid early weariness, a maximum of six practice attempts were permitted. Readings were obtained at the start and end of each 10-second contraction in three consecutive contractions (measured with a stopwatch). The variations in pressure readings were calculated using a baseline pressure of 70 mm Hg. Further analysis was carried out utilizing the computed mean change in pressure at the end of the three contractions. Prior to each contraction, the pressure biofeedback unit was "zeroed" to 70 mm Hg and readings were recorded at full expiration (14).

Rehabilitation Protocol

Motor skill drill the biological foundation for motor control exercise (MCE) is based on the hypothesis that persons with LBP have impaired spine stability and control. As a result, the program was designed to improve movement and posture control, as well as the function of certain lumbopelvic muscles (15). Throughout the MCE program, the treating therapist assessed and altered trunk muscle recruitment, posture, movement pattern, and respiration. Exercises were advanced based on the patient's tiredness level, pain tolerance, and observed movement control. Each session of the MCE program lasted approximately 20 to 30 minutes (Table 1).

Table 1: Motor Control Exercises (MCE)

Stage/Progression	Exercise	Intensity
Stage 1 (1st–3rd sessions)	1. ADIM in supine	7 sec hold, 10 reps
	2. ADIM in quadruped	7 sec hold ,10 reps
	3. ADIM in sitting	7 sec hold, 10 reps
	4. ADIM in standing	7 sec hold,10 reps
Stage 2 (4th–9th sessions)	5. ADIM in supine with heel slide (each leg)	4 sec hold, 10 reps
	6. ADIM in supine with leg lift (each leg)	4 sec hold ,10 reps
	7. ADIM in supine with bridging (two legs)	7 sec hold, 10 reps

	8. ADIM in supine with single-leg bridge	7 sec hold, 10 reps
	9. Supine ADIM with curl-up (elbows on the table)	7 sec hold, 10 reps
	10. Supine ADIM with curl-up (hands over the forehead)	7 sec hold, 10 reps
	11. ADIM in horizontal side support with knees bent	7 sec hold, 10 reps
	12. ADIM in horizontal side support with knees straight	7 sec hold, 10 reps
	13. Side-lying horizontal side support with ADIM	7 sec hold, 10 reps
	14. ADIM in quadruped with arm raise	7 sec hold, 10 reps
	15. ADIM in quadruped with leg raise	7 sec hold, 10 reps
	16. ADIM in quadruped with alternate arm and leg raise	7 sec hold, 10 reps
Stage 3 (10th–12th sessions)	17. Rolling from side to side with ADIM	10 reps
	18. Sit-stand transfer with ADIM	10 reps
	19. Wall squatting with ADIM	5 sec hold, 10 reps
	20. Walking with ADIM (10 min)	7 sec hold, 10s relax, 10 reps

Use of conventional exercises Include exercises for flexibility, stretching, and stabilizing. All subjects have to perform. One knee to the chest, two knees to the chest, stretches for lower trunk rotation include hamstring, piriformis, calf, half-knee hip, and pelvic tilt.

Statistical Analysis

Statistical analysis was carried out using IBM SPSS 25 for Windows. Data was entered into an Excel spreadsheet, tabulated, and statistically analyzed for this purpose. All of the variables' means and standard deviations were calculated. Tables and graphs were utilized to present the data's qualities. Statistical significance was determined at $p < 0.05$.

Results

In this study, total individuals aged 30 to 50 years were chosen who matched the inclusion criteria and followed the therapy procedure for 6 weeks. Out of 28 individuals, 19 are female and 9 are male. They are divided into two groups: Group A and Group B. The age demographics of groups A and B were analyzed (Table 2). The mean age of individuals in the experimental and control groups was 39.64 and 40.64, respectively.

Table 2: Independent Sample t Test between the Groups

Variables	Mean ± SD		t Value	p Value
Age	**Group A**	**Group B**	0.424	0.675
	39.64±6.47	40.64±5.99		

Table 3: Paired Sample t Test within the Group a (Pre-Post)

Variable			Mean ±SD	t Value	p Value
Mechanical sensitivity of sciatic nerve		Pre	38.64 ± 6.59	10.83	0.000
		Post	42.14 ± 6.89		
Abdominal endurance		Pre	7.76 ± 1.82	5.57	0.000
		Post	8.40 ± 1.83		
Muscle thickness of erector spinae	Right	Pre	2.63 ± 1.08	1.006	.333
		Post	2.69 ± 1.14		
	Left	Pre	2.57 ± 1.09	0.519	.612
		Post	2.52 ± 0.98		
Muscle thickness of	Right	Pre	2.51 ± 0.55	2.31	.038
		Post	2.57 ± 0.52		

quadratus lumborum	Left	Pre	2.39 ± 0.53	2.83	.014
		Post	2.48 ± 0.50		

The paired sample t test was performed to analyse the differences within experimental group A, and there was a significant difference in sensitivity (0.000), abdominal endurance test (0.000), and quadratus lumborum thickness (0.38 and 0.14) for the right and left sides, respectively (Table 3). Paired t-test was used to analyze difference within Conventional Group B and showed significant differences in variables Mechanical sensitivity of sciatic nerve (0.009), Abdominal endurance (0.0001) (Table 4).

Table 4: Paired Sample t Test within the Group B (Pre-Post)

Variable			Mean ± Standard Deviation	t Value	p Value
Mechanical sensitivity of sciatic nerve		Pre	39.85 ± 8.24	3.040	0.009
		Post	41.00 ± 7.91		
Abdominal endurance		Pre	7.65 ± 1.42	4.794	0.0001
		Post	7.90 ± 1.42		
Muscle thickness of erector spinae	Right	Pre	2.38 ± 0.77	0.734	.419
		Post	2.43 ± 0.69		
	Left	Pre	2.53 ± 0.83	0.834	.476
		Post	2.52 ± 0.81		
Muscle thickness of quadratus lumborum	Right	Pre	2.57 ± 0.65	1.816	.092
		Post	2.54 ± 0.65		
	Left	Pre	2.58 ± 0.69	0.817	.428
		Post	2.60 ± 0.67		

Table 5: Independent Sample t test between the Groups (Mechanical Sensitivity of Sciatic Nerve and Abdominal Endurance)

Variable			Mean ± Standard Deviation		t Value	p Value
Mechanical sensitivity of sciatic nerve			Group A	Group B		
		Pre	38.64 ± 6.59	39.85 ± 8.24	.430	.670
		Post	42.14 ± 6.89	41.00 ± 7.91	.407	.687
Abdominal endurance		Pre	7.76 ± 1.82	7.65 ± 1.42	.173	.864
		Post	8.40 ± 1.83	7.90 ± 1.42	.807	.427
Muscle thickness of ES	**Right**	Pre	2.63 ± 1.08	2.38 ± 0.77	.697	.492
		Post	2.69 ± 1.14	2.43 ± 0.69	.718	.479
	Left	Pre	2.57 ± 1.09	2.53 ± 0.83	.122	.903
		Post	2.52 ± 0.98	2.522 ± 0.81	.012	.990
Muscle thickness of QL	**Right**	Pre	2.51 ± 0.55	2.57 ± 0.65	.225	.824
		Post	2.57 ± 0.52	2.54 ± 0.65	.143	.887
	Left	Pre	2.39 ± 0.53	2.58 ± 0.69	.825	.417
		Post	2.48 ±.50	2.60 ± 0.67	.529	.601

At baseline and the conclusion of the sixth week, an Independent Sample T-Test was performed to analyse and compare intra-group differences in the variables Mechanical sensitivity of the sciatic nerve and abdominal endurance. Both variables produced non-significant findings (Table 5). The Independent Sample T-Test was employed at baseline and at the conclusion of the sixth week to analyse and compare intra-group differences for the variables quadratus lumborum muscle thickness and erector spinae (Table 5).

Discussion

This study was done to find out the effects of motor control exercises on mechanical sensitivity of sciatic nerve, abdominal endurance and on muscle thickness of erector spinae and quadratus lumborum. The primary findings of this current study are as: (a) there is a significant difference found for mechanical sensitivity of sciatic nerve, abdominal endurance and thickness of quadratus lumborum. (b) The result for thickness of erector spinae found to be non-significant. The sensitivity of sciatic nerve has significantly improved in both the groups. This study's findings support the conclusion that motor control exercises are statistically helpful in enhancing sciatic nerve sensitivity. This is supported by a study (16) that found that regular exercise can help lessen neuropathic symptoms. Glial cell activation is critical to the genesis and maintenance of neuropathic pain. Activated glial cells in the spinal dorsal horn release a variety of mediators, including proinflammatory cytokines that enhance synaptic plasticity and neuronal activity. This reduced microglial activation and BDNF expression in the spinal dorsal horn. Furthermore, activation of the endogenous opioid system during exercise training was one of the most often mentioned explanations for how exercise alleviated neuropathic pain. Another physiological process involved the activation of group III and IV muscle afferents in skeletal muscle after exercise intervention (17). Our study also found substantial differences in abdominal endurance within the group analysis. The positive changes could be attributed to the use of core training, which improves core stability and depicts the complex interaction of passive (joint articulations and spinal ligaments) and active (neural and muscular) subsystems that keep intervertebral neutral zones within physiological limits. Furthermore, research suggests that exercise-induced adaptation will likely increase the coordination of synergistic and stabilizer core muscle groups. Because the exercises are performed on an unstable platform, curl-ups and back extensions may be a more effective technique to strengthen core muscles. Additionally, because the core muscles stabilize the axial skeleton, this kind of functional exercise may improve the body's capacity for improved stability and balance. It is well known that performing back and abdominal workouts on a surface put tension on the muscles and triggered neuroadaptive processes that improved stability and proprioceptor activity in the early stages. According to reports, co-activating the local and global muscles increases vertebral stiffness, which is crucial for enhancing lumbar spine stability which results in enhances endurance (18).

The findings of the present investigation also revealed that there were notable variations in the thickness of the quadratus lumborum within the group. The quadratus lumborum (QL) muscle's thickness and functionality can benefit from motor control training. With the help of these exercises, the lumbar spine will be supported and stabilized more effectively by improving the control and coordination of the deep stabilizing muscles, particularly the QL (19). Overall, the evidence suggests that motor control exercises can enhance the function and activation of the QL muscle. These sorts of exercises can have an impact on muscle form and function, even though particular changes in the thickness of the QL (20). Here are some possible physiological changes that might take place: An outline of the physiology behind these changes are as follows.

First muscle hypertrophy which happens as a result of the muscle's response to stress and load during exercise, which is adaptation. The body responds to microscopic injury to the muscle fibers by repairing and strengthening them, which causes the muscles to grow larger. Second, increased protein synthesis, the quadratus lumborum muscle fibers experience mechanical stress and microtears during exercise, particularly strength training or resistance workouts. A series of physiological reactions are brought on by this, including an increase in protein synthesis. Third, neural adaptations to the neuromuscular system's efficiency and coordination have been improved as a result of these modifications which improves the body's capacity to recruit and activate the QL's muscular fibers, improving muscle function and possibly increasing muscle thickness.

The results of this present study also indicated that there was no significant change in the thickness of the erector spinae following motor control workouts because physiological cellular changes take a very long time to manifest. This claim is supported by research Kelsey and White, 1980 that stated the erector spinae muscles' thickness can be benefitted from motor control training (21). These workouts frequently feature controlled, gradual motions, which can aid in recruiting more erector spinae muscle fibers. Increased recruitment of the erector spinae muscles can lead to hypertrophy, or an increase in muscle fiber size, making them thicker and stronger. Noticeable changes in muscle thickness usually take a few weeks to several months to develop. Other authors' studies discovered that the ES muscle's thickness and tissue blood volume changed in a similar manner in response to alterations in lumbar curvature angles (22, 23). More intriguingly, the oxyhemoglobin to deoxyhemoglobin ratio tended to decrease as ES muscle thickness decreased. Interestingly, the ratios of Oxy-Hb and Deoxy-Hb for Total-Hb varied significantly when the lumbar spine was flexed more than 40 degrees. The ES muscle has a well-developed capillary network and a much longer isometric trunk extensor endurance duration than other human skeletal muscles (24). We hypothesize that the ES muscle's specific features can explain the small decrease in hemodynamics. It was critical to take a long-term approach to training and muscle building. The study's limitations include the small number of participants, which may limit the scope of the conclusions. A larger sample size would produce more accurate results while increasing the study's statistical power. It may have included individuals with particular characteristics (such as age or degree of fitness), which may have limited the generalizability of the findings. Diversity in participant demographics would increase the study's external validity. Future scope of the study can be follow-up over an extended period of time, conducting longitudinal research that keeps track of participants would be a great way to learn more about the durability and long-term benefits of motor control exercises.

Conclusion

The study concludes that motor control workouts have potential benefits for enhancing abdominal endurance, quadratus lumborum thickness, and sciatic nerve sensitivity. These activities may improve muscular function and potentially increase muscle thickness through neural adaptations, enhanced protein synthesis, and muscle hypertrophy.

Abbreviations

SLR: Straight Leg Raise, MRI: Magnetic Resonance Imaging, PBU: Pressure Biofeedback unit, ADIM: Abdominal Drawing-In Maneuver, MCE: Motor Control Exercise, LBP: Low Back Pain.

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Author Contributions

Pious Divya: Conceptualization, Investigation, Methodology, and Writing Original Draft, Siddhartha Sen: Conceptualization, Supervision, Formal Analysis, Writing Review and Editing, Snigdha Tiwari: Supervision, Review and Editing.

Conflict of Interest

There is no conflict of interest.

Ethics Approval

Ethical approval was taken from the Institutional Ethical Committee of the Faculty of Physiotherapy at SGT University with the Approval letter number: SGTU/FPHY/2022/430.

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