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# Effect of motor control exercise among subjects with unilateral lumbar radiculopathy

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**Abstract**
Chronic back pain is a raising problem nowadays in the population. Age group from 18 to 55 has been shown the progression of symptoms in the era. 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. Patients were initially classified into flexion and active extension subgroups based on history, clinical examination. Specific impairments were prescribed. Limited evidence has been found till now on treatment emphasizing motor control exercises using classification system. Even though many studies had this system was used to develop management program in which the patients were instructed in symptom reducing strategies for positioning and functional movement.
Pain in these disorders is associated with functional control loss around the vertebral movement area due to the uncontrolled movements there will be movement impairment. This is manifested during dynamic and / or static features. Patients with a lack of flexion are more likely to their habitual landing position. On the other hand, patients with active extensions of active extensions are decreased in more extension. Ringiasti Tryes Checks (RCT) failed to find consistent evidence for improvised results. A proposed explanation to the inability to identify effective treatments is the lack of success in the supplies of patients that are more likely to respond to a specific processing approach.
Patients with the lack of movement control deficits are a considerable subgroup that can benefit specific pattern of exercise.
Exercises to address the direction been done on low back pain patients by using motor control exercises. The aim of this is conducted to investigate the effect of Motor control exercise among the subjects with Lumbar radiculopathy. Total of 68 subject was divided into experimental group of 34 and control group of 34 and the experimental group received motor control exercise, were control group received only hot pack and conventional back pain exercises six times per week for 2 weeks. readings and measurement taken before and after the intervention for lumbar joint range of motion using goniometer, numeric pain rating scale and Oswestry disability index questionnaire respectively.

**Keywords:** Lumbar radiculopathy, movement impairment, motor control exercise, straight leg raise, disability, classification

## Introduction
Low back pain (LBP) is an extremely common problem that most people experience at some point in their life [1]. Lumbar pain are defined as pain under the border of lumbar region and above the gluteal folds of the lower back region, with or without foot foot [2]. Low back pain is classified as specific (pain caused by imparment of lumbar region muscles) [3 4]. Specific low back pain of spinal origin includes spinal fractures, herniated discs, spinal stenosis, spondyloarthritis, tumours, infection. Nonspinal origin includes hip conditions, diseases of pelvic organs (endometriosis, prostatitis) and vascular (aortic aneurysm) and systemic disorders [5], Specific low back pain of spinal origin includes spinal fractures, herniated discs, spinal stenosis, spondyloarthritis, tumours, infection. N [6, 7]. While low back pain is caused by specific causes, back pain cannot develop from interaction of biological factors, and social [8]. According to his duration, low pain can be acute (the start and lasts less than six weeks), subsequently (six-twelve), cliffs) or repeat [9]. It is estimated that 85% of the patients with low back pain in the primary care are without specific diagnosis, they are classified as non-specific pain. Men often suffer symptoms in their 40s, whereas women usually encounter them in their 50s and 60s [10]. Lumbar radiculopathy is primarily brought spondyloarthropathies on by degenerative Patients frequently experience back pain when they first notice their radiculopathy, which by definition [11, 12], is pain that frequently feels like electric, burning, or

sharp and travels down the involved legs, Patients with low back discomfort may have compromised spinal stability and control [13].

In degenerative patients often affect movement pattern, pain is felt over particular movement pattern like flexion or extension based on this movement examination this a clinician can come to conclusion flexion pattern or extension pattern [14]. Referred pain is often ascribed to the mechanical compression of the intervertebral Roots, among the other people's lumbar, the important mechanical contrary disability composition [15]. Accurate etiology is uncertain. Straight leg raise (SLR) test is the most commonly used physical examination to diagnose lumbar disk testic [16]. The lift of the straight leg can resemble discomfort because of sensitivity problems, as shown in Neuritis. An important aspect of the right foot is their ability to imitate the patient's problems [17], as shown the neurical ability to maintain axonal damage, and the ravens to produce these correlations. When SLR causes pain beneath the leather up to the sciatica between 30 and 70 degrees of the hip, is regarded as a positive [18]. A positive test can show significance of disc bulge involving Patho-anatomical diagnosis which does not guide physical therapy treatment approach [19]. Search existing on nervous movements when you increase right legs and people in healthy, as the meaning of the proof possible to detect the intervertebral herniation [20]. The solution focuses to engage the deep trunk muscles to restore the check and coordination. Study the effects of central stabilization training on the features of spin 'sharp contraction [21, 22]. An exercise program significantly improves muscles action in controlled manner and minimizes the stiffness of the global mobiliser muscles of lumbar. No research revealed the effect of motor check exercise on the Lumbar motor control [23, 24]. Movement disorders are associated with a painful loss of normal physiological movement around a vertebral region [25]. This may occur secondary due to changes in connective tissue or more likely to maintain muscles around the sensitive region [26]. These patients usually will move to the pain of pain and this may be associated with flexion, stretching, side flexion or can be multidirection. The disorders of the movement disorders are associated with a painful loss of normal physiological movement around a vertebral region [27]. This may occur secondary due to changes in connective tissue or more likely to keep muscles around the sensible region of the raised[28]. These patients usually develop uncontrolled movement pattern shooting which may be associated with flexion, stretching, and side flexion or may be multidirectional [29]. Most of chronic low back pain associated in uncontrolled movements which is a major missing component in musculoskeletal practice. These disorders are associated with changes functional activities of subjects in the spine segment in the primary direction of pain [30]. In these disorders, there is no movement movement in the sense of pain. Pain in these disorders is associated with functional control loss around the vertebral movement area due to reduced global firing muscle leads to impairment [31, 32]. This is manifested during dynamic and / or static features. Patients with a lack of flexion are more likely to their habitual position. On the other hand, patients with active extensions of active extensions are decreased in more extension [33].

Treatment option for the patients with Non-specific chronic low back pain (NS-CLBP) is aim at masking the pain or treating the symptoms in clinical medicine has not clearly effective [34]. Ringiasti Tryes Checks (RCT) failed to find consistent evidence for improvised results. A proposed explanation to the inability to identify effective treatments is the lack of success in the supplies of patients that are more likely to respond to a specific processing approach. Indeed, I movement specific treatment approach using motor control exercise is aiming at treating the root cause in large heterogeneous group of patients [35].

Patients with motor control deficits are a substantial subgroup that they may benefit from specific motor control exercise. After the patient have been explained the mechanisms of the ongoing pain sensitization, they will be educated on the mechanics of the spine, the nature of ongoing tissue sensitization with their habitual adoption of end range postures and the importance of the muscle system of the lumbo-sacral region to control spinal motion segments and minimize strain. They will often have to be made aware of the lack of control, or sense of their neutral spine positions [36].

## Materials and Methods

### Materials

- Consent form
- Hot pack
- Goniometer
- Oswestry disability index
- Numeric pain rating scale
- Pen
- Data recording sheet: to record the data
- Plinth
- Swiss ball

### Methodology source of data

Patients with an age ranging from 22 to 50 years who have pain in the back from the out-patient department of kanachur hospital.

### Method of data collection (Including sampling procedure)

The data for this study will be collected from people who have non-specific chronic back pain in kanachur hospital. The method of data collection will include the following steps:

### Definition of study subjects

Subjects with non-specific back pain and forward head posture in an age group from 22 to 50.

### Inclusion and exclusion criteria

- Age22-50 yrs (both females and males).
- Pain localized to the lower lumbar spine (L4/L5 or L5/S1) region.
- Absence of “red flags” (specific causes of LBP such as cauda equina syndrome or inflammatory disease)
- Absence of dominant “yellow flags” (identification of beliefs, emotions, and behaviors that interact with the pain problem)
- Clear mechanical basis of the disorder (pain related to postures and movements)
- Associated impairments in the control of the motion segment(s) in the provocative movement direction(s)
- Absence of impaired movement of the symptomatic segment in the painful direction of movement or loading (based on clinical joint motion palpation examination)

**Exclusion criteria**

- Evidence of specific diagnosis, e.g., spondylolisthesis, Inflammatory disease
- Presence of red flags
- Presence of dominant yellow flags
- Previous spine surgery, pregnant at the time of the study or 6 months, postpartum
- Recently undergone a period of motor control rehabilitation

**Parameters used for comparison and statistical analysis used:** The standard statistical analysis will be applied to the collected data and the study outcome measures will be compared between two groups for statistical significance by independent sample t-test between the groups.

- **Duration of study:** Approximately 6 months.
- **Follow UP:** Subjects will be assessed for study outcome measures i.e. reduction of pain, increased range of motion of lumbar joint using universal goniometer and Oswestry disability index scale.

**Methodology**

It is a quasi-experimental study with study population of 68 samples selected with a set of inclusion and exclusion criteria from various chronic back pain patients from kanachur hospital. Subjects will be taken from the study setting and participants will be allocated into two arms (Group A and B) by purposive sampling method. A pre-test will be conducted before the intervention. The pain & range of motion, lumbar joint were checked and assessed in the subjects. Range of motion will be assessed by using universal goniometer and pain assessed using numeric pain rating scale, disability measure by Oswestry disability index. When the patient will be in rested sitting position to measure the range of motion of the all 6 range of movement will be measured with the universal goniometer on the lumbar joint. Pain will be assessed by Numeric pain rating scale, disability will be questioned using the questionnaire. After assessing the pre-test, group-A (Experimental group) will be given hot pack, motor control excercises will be given and group-B (Control group) will be given only hot pack and conventional excercise isometric exercise. The total duration of exercises is for the period of 4weeks, after which the patients will be assessed for post-test values with set outcome measures of range of motion of lumbar region and pain scale, disability index.

**Outcome Measure**

**Pain rated by numerical pain rating scale:** The pain was the main component to solve with the study.it will be solved using the scale called Numerical Pain Rating Scale which will be having some grades and patient will evaluate it when the pre and post measurement is taken.

**Range of motion using universal goniometer**

Worldwide used universal goniometer will help in measuring range of motion and it helps to evaluate the approach applied is worked for the back pain.

**Disability by oswestry disability index questionnaire**

A questionnaire form which help the patient and as well as therapist to measure the disability the subject have and will help into a view towards the improvement.

**Procedure**

- **Phase 1:** Ethical clearance the synopsis were submitted to Institutional Research Committee (IRC) and permissions were obtained.
- **Phase 2:** Enrolment of participants the permissions were obtained from IRC to carry out the study, the participants were enrolled based on the inclusion and exclusion criteria. An informed consent have taken from the participants before beginning the study.
- **Phase 3:** Data collection 68 subjects were allotted in to both the experimental groups respectively to obatain the relief from back pain and movement impairment by using motor control exercise by measuring the pain using NPRS scale, disability Oswestry disability questionnaire.

**Group A (Experimental group)**

Subjects will be explained about treatment protocol
Waiter bow flexion exercise

- **Patient position:** The patient stands with their feet shoulder-width apart.
- **Controlled movement:** The patient is asked to bow forward, keeping their knees straight, and hold a weight or object in front of them, simulating a waiter holding a tray. Hold for 10 seconds. Relax & do the exercise again & repeat for 5 times.

**The sitting forward lean exercise**

- **Patient position:** The patient sits on a chair or examination table with their feet flat on the floor.
- **Controlled movement:** The patient is asked to lean forward, keeping their knees straight, and stretch their arms out in front of them. Hold for 10 seconds. Relax & do the exercise again & repeat for 5 times.

**Hot pack application**

Keeping the nicely wrapped hot bag in a cotton towel and keep on the posterior back portion of the subject in prone lying.

**Group B (control group)**

34 subjects of this group will be given only hot pack and isometric exercise and along with that superman exercise.

Isometric exercise & conventional exercise subject placed in supine lying position was instructed the subject press lumbar region against therapist hand Hold for 10 seconds. Relax repeat for 5 times repeat the exercise again. Along with that superman exercise were given.

**Results**

In the present study 68 subjects were recruited, with 34 in each group. Participants of Group A were examined for effectiveness of motor control exercises and conventional treatment and Group B were given conventional therapy to the patient with chronic lumbar radiculopathy and disability to the patient in kanachur hospital. Before the intervention patients were subjected to lumbar radiculopathy pain and disability with the motor control exercise and different outcome measures such as NPRS scale, Oswestry disability index (ODI) and range of motion. The collected data of this study was subjected to various statistical tests with respect of analysis of age, gender, and study parameters. Data were also subjected to test of hypothesis.

**Interpretation**

- Comparison of the Age between the two groups shows that Age is higher in Group B group with a t value of-0.176 and is statistically non-significant with a p value of 0.861
- Comparison of the ODI pre Test between the two groups shows that ODI pre Test is higher in Group B group with a t value of-0.763 and is statistically non-significant with a p value of 0.448
- Comparison of the ODI post-test between the two groups shows that ODI post-test is higher in Group B group with a t value of-10.066 and is statistically significant with a p value of < 0.001
- Comparison of the ODI Difference between the two groups shows that ODI Difference is higher in Group A group with a t value of 8.991 and is statistically significant with a p value of < 0.001
- Comparison of the NPRS pre Test between the two groups shows that NPRS pre Test is higher in Group B group with a t value of-2.662 and is statistically significant with a p value of 0.01
- Comparison of the NPRS post Test between the two groups shows that NPRS post Test is higher in Group B group with a t value of-17.408 and is statistically significant with a p value of < 0.001
- Comparison of the NPRS Difference between the two groups shows that NPRS Difference is higher in Group A group with a t value of 13.839 and is statistically significant with a p value of < 0.001.

**Fig 1:** Motor control waiter bow exercise (starting position)

**Fig 2:** Waiter bow flexion exercise (end position)

**Fig 3:** Motor control forward lean exercise (starting position)

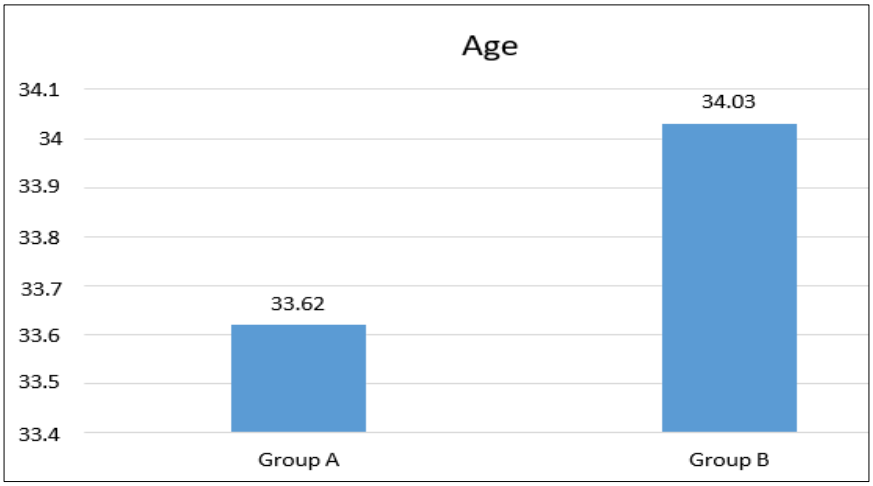
**Fig 4:** Motor control forward lean exercise (end position)

**Analysis of age (Group A & Group B)**

This study involved a convenience sample of people with chronic back pain and disability from Kanachur hospital, Mangalore. 34 patients were allocated in Group A and 34 has been in Group B each with an age range between 18-50 years. The mean age of the study participant of Group A was 34 years and Group B was 34 years.

| | Group A (N=34) | Group B (N=34) | T | P-Value |
|---|---|---|---|---|
| | Mean ± SD | Mean ± SD | | |
| Age | 33.62±9.85 | 34.03±9.49 | -0.176 | 0.861 |

**Analysis of age of subject in group A and group B:** The mean age of the study participants of Group A was 34 years and Group was 34 years with standard deviation of 9.85 years in Group A and 9.49 years.




**Graph 1:** Representation of the number of subject in each age group

Comparison of the Age between the two groups shows that Age is higher in Group B group with a t value of-0.176 and is statistically non-significant with a p value of 0.861.

**Analysis of study outcome measures oswestry disability index, numerical pain scale, range of motion of lumbar joint**

**Table 1:** Analysis of outcome measure of both groups-oswestry disability index

| | Group A(N=34) | Group B (N=34) | T | P-Value |
|---|---|---|---|---|
| | Mean ± SD | Mean ± SD | | |
| ODI Pre-Test | 39.65±6.68 | 40.74±4.95 | -0.763 | 0.448 |
| ODI Post-Test | 8.18±4.76 | 25.59±8.89 | -10.066 | < 0.001 |
| ODI Difference | 31.47±5.97 | 15.15±8.74 | 8.991 | < 0.001 |

**Table 2:** Analysis of outcome measure of both groups-numeric pain rating scale

| | Group A (N=34) | Group B (N=34) | T | P-Value |
|---|---|---|---|---|
| | Mean ± SD | Mean ± SD | | |
| NPRS pre Test | 8.26±1.54 | 9.09±0.93 | -2.662 | 0.01 |
| NPRS post Test | 1±1.23 | 6.26±1.26 | -17.408 | < 0.001 |
| NPRS Difference | 7.26±1.31 | 2.82±1.34 | 13.839 | < 0.001 |

**Table 3:** Analysis of outcome measure of both groups-numeric pain rating scale

| | Group A (N=34) | Group B (N=34) | T | P-Value |
|---|---|---|---|---|
| | Mean ± SD | Mean ±SD | | |
| ROM-Flexion pre test | 49.65±12.6 | 44.06±12.57 | 1.831 | 0.072 |
| ROM-Flexion post test | 72.82±5.18 | 48.15±10.62 | 12.172 | < 0.001 |
| ROM-Flexion Difference | -23.18±13.73 | -4.09±2.93 | -7.93 | < 0.001 |
| ROM Extension pre test | 42.76±10.06 | 36.91±10.21 | 2.38 | 0.02 |
| ROM Extension post test | 62.94±4.33 | 41.79±9.73 | 11.577 | < 0.001 |
| ROM extension difference | -20.18±10.05 | -4.88±1.59 | -8.762 | < 0.001 |
| ROM side flexion L pre test | 26.74±6.69 | 24.62±4.59 | 1.522 | 0.133 |
| ROM side flexion L post test | 37.85±5.03 | 31.26±6.32 | 4.756 | < 0.001 |
| ROM side flexion L Difference | -11.12±4.95 | -6.65±4.83 | -3.771 | < 0.001 |
| Rom side flexion R Pre test | 26.44±6.57 | 24.38±4.66 | 1.491 | 0.141 |
| Rom side flexion R post test | 39.56±7.22 | 31.35±6.6 | 4.894 | <0.001 |
| Rom side flexion R Difference | -13.12±6.36 | -6.97±5.18 | -4.37 | <0.001 |
| Rom rotation L Pre post | 43.18±9.64 | 30.71±9.09 | 5.49 | <0.001 |
| Rom rotation L Pre post | 72.76±6.49 | 37.09±10.27 | 17.123 | <0.001 |
| Rom rotation L Difference | -29.59±9.03 | -6.38±3.33 | -14.056 | <0.001 |
| Rom rotation R Pre Test | 43.21±9.82 | 31.53±10.26 | 4.795 | <0.001 |
| Rom rotation R Post test | 73.65±6.95 | 37.59±10.59 | 16.597 | <0.001 |
| Rom rotation R Difference | -30.44±8.76 | -6.06±3.85 | -14.856 | <0.001 |

**Discussion**

This study was kept into the view through this was an important component around all people going through from mostly the age from 20-50. In consideration with the inclusion criteria and they were grouped into two, Group A and Group B. Group A considered as the experimental group and group B considered as control group. Here the experimental group that is the Group A we are going to constitute the Motor control with combination of hot pack. In the control group, that is the group B was treated with hot pack and isometrics and conventional exercise of back.

Shilpi Chhabra was also conducted similar study were this research to see the effectiveness of motor control exercise in lumbar radiculopathy in movement impairment involving lumbar region. They compared the motor control with conventional physical therapy and conventional physical therapy alone in 38 computers professional from a same fame. The study has shown the addition of motor control exercise in the treatment of chronic back pain.

Numerous interventions are available for patients with low back-related disorders. The challenge for physical therapists is to identify the most appropriate intervention for each patient, based on the findings from a standardized examination. This task is difficult because the etiology of LBP is unknown in the majority of cases. The intention of this study is to know the clinical reasoning process of clinicians when deciding how to classify patients into subgroups for treating specific impairments.

The patients in this study had a predisposition to flex, hyperextend or rotate, and laterally bend their lumbar spine when assuming different positions during various movements of the trunk and limbs. Since the prevalence of flexion and extension related symptoms are common in LBP, we did not focus on other direction related symptoms like lateral shift pattern and multi directional instability pattern.

Improvement of movement control through exercises leads to a decrease of Lumbar radiculopathy pain & symptoms and improves functional disability due to back pain. However, as no control groups were included, no direct conclusions on the efficacy can be drawn. This case series further illustrates the effectiveness of sub grouping LBP patients, as all patients in this study achieved better results regarding the pain and disability.

Symptoms associated with disorders of the low back(lumbar radiculopathy) typically resolve within 4 weeks of onset, and only 5% of individuals have symptoms that persist longer than 4 weeks.

Improvement in both functional ability and symptoms reduction after the treatment were observed. The patients did not experience a recurrence of low back-related symptoms, during the treatment and advised the patient to continued their home exercise program and activity modifications. Together, these observations suggest that our approach may have positively influenced the patient's recovery.

The study was under taken in a hospital setup and participant included were from age 22 50. The experimental study which have under gone the motor control exercise were improved in pain, increase in range of motion, sense also got improved and the disability also got improved in the group.

The result implies in the study is: Comparison of the Oswestry disability index post-test between the two groups shows that Oswestry disability index is higher in Group B group with a t value of-10.066 and is statistically significant with a p value of pain and disability.

**Discussion**

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Numerous interventions are available for patients with low back-related disorders. The challenge for physical therapists is to identify the most appropriate intervention for each patient, based on the findings from a standardized examination. This task is difficult because the etiology of LBP is unknown in most cases. The intention of this study is to know the clinical reasoning process of clinicians when deciding how to classify patients into subgroups for treating specific impairments.

The patients in this study had a predisposition to flex, hyperextend or rotate, and laterally bend their lumbar spine when assuming different positions during various movements of the trunk and limbs. Since the prevalence of flexion and extension related symptoms are common in LBP, we did not focus on other direction related symptoms like lateral shift pattern and multi directional instability pattern.

Compared to conventional exercise, motor control exercises waiter bow flexion exercise & sitting forward lean exercise had shown some patients had a significant improvement in disability & pain.

Improvement of movement control through exercises leads to a decrease of Lumbar radiculopathy pain & symptoms and improves functional disability due to back pain. However, as all patients in this study achieved better results regarding the pain and disability. Symptoms associated with disorders of the low back (lumbar radiculopathy) typically resolve within few sessions of treatment (motor control exercise).

**Conclusion**

The study was conducted to evaluate the effect of Motor control exercise lumbar radiculopathy and disability in lumbar region. By dividing into two groups the the motor control exercise was co-operated into the group A and that group A has shown the significant improvement with the outcome measures. So this study have proven the alternate hypothesis and reject the null hypothesis.

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**Reference**


1. Martin BI, Deyo RA, Mirza S, *et al.* Expenditures and health status among adults with back and neck problems. JAMA. 2008;299(6):656-664.
2. van der Windt DAWM, Simons E, Riphagen II, *et al.* Physical examination for lumbar radiculopathy due to disc herniation in patients with low-back pain. Cochrane Database Syst Rev. 2010;2:CD007431.
3. Konstantinou K, Hider SL, Jordan JL, *et al.* The impact of low back-related leg pain on outcomes as compared with low back pain alone: A systematic review of the literature. Clin J Pain. 2013;29(7):644-654.
4. Lewis RA, Williams NH, Sutton AJ, *et al.* Comparative clinical effectiveness of management strategies for sciatica: systematic review and network meta-analyses. Spine J. 2015;15(6):1461-1477.
5. Kreiner DS, Shaffer WO, Baisden JL, *et al.* An evidence-based clinical guideline for the diagnosis and treatment of degenerative lumbar spinal stenosis (update). Spine J. 2013;13(7):734-743.
6. Gadjradj PS, Arts MP, Tulder VMW, *et al.* Management of symptomatic lumbar disk herniation: An international perspective. Spine (Phila Pa 1976). 2017;42(22):1826-1834.
7. Peul WC, Houwelingen VHC, Hout VDWB, *et al.* Surgery versus prolonged conservative treatment for sciatica. N Engl J Med. 2007;356(22):2245-2256.
8. Jacobs WC, van Tulder M, Arts M, *et al.* Surgery versus conservative management of sciatica due to a lumbar herniated disc: A systematic review. Eur Spine J. 2011;20(4):513-522.
9. Wong JJ, Côté P, Sutton D, *et al.* Clinical practice guidelines for the noninvasive management of low back pain: A systematic review by the Ontario Protocol for Traffic Injury Management (OPTIMa) Collaboration. Eur J Pain. 2017;21(2):201-216.
10. Saragiotto BT, Maher CG, Yamato TP, *et al.* Motor control exercise for chronic non-specific low-back pain. Cochrane Database Syst Rev. 2016;1:CD012004.
11. Coulter ID, Crawford C, Hurwitz EL, *et al.* Manipulation and mobilization for treating chronic low back pain: A systematic review and meta-analysis. Spine J. 2018;18(5):866-879.
12. Butler DS. The sensitive nervous system. Adelaide: Noigroup Publications; 2000.
13. Shacklock MO. Neurodynamics. Physiotherapy. 1995;81(1):9-16.
14. Gilbert KK, James CR, Apte G, *et al.* Effects of simulated neural mobilization on fluid movement in cadaveric peripheral nerve sections: Implications for the treatment of neuropathic pain and dysfunction. J Man Manip Ther. 2015;23(4):219-225.
15. Brown CL, Gilbert KK, Brismee JM, *et al.* The effects of neurodynamic mobilization on fluid dispersion within the tibial nerve at the ankle: An unembalmed cadaveric study. J Man Manip Ther. 2011;19(1):26-34.
16. Boudier-Revéret M, Gilbert KK, Allégue DR, *et al.* Effect of neurodynamic mobilization on fluid dispersion in median nerve at the level of the carpal tunnel: A cadaveric study. Musculoskelet Sci Pract. 2017;31:45-51.
17. Cleland JA, Hunt G, Palmer J. Effectiveness of neural mobilization in the treatment of a patient with lower extremity neurogenic pain: A single-case design. J Man Manip Ther. 2004;12(3):143-152.
18. Stochkendahl MJ, Kjaer P, Hartvigsen J, *et al.* National clinical guidelines for non-surgical treatment of patients with recent onset low back pain or lumbar radiculopathy. Eur Spine J. 2018;27(1):60-75.
19. Berry JA, Elia C, Saini HS, Miulli DE. A review of lumbar radiculopathy, diagnosis, and treatment. Cureus. 2019;11(10):e5934.
20. Hodges P, Richardson C, Jull G. Evaluation of the relationship between laboratory and clinical tests of transversus abdominis function. Physiother Res Int. 1996;1(1):30-40.
21. Pesonen J, Shacklock M, Rantanen P, *et al.* extending the straight leg raise test for improved clinical evaluation of sciatica: Reliability of hip internal rotation or ankle dorsiflexion. BMC Musculoskelet Disord. 2021;22:1-8.
22. O'Sullivan PB, Phyty GD, Twomey LT, Allison GT. Evaluation of specific stabilizing exercise in the treatment of chronic low back pain with radiologic diagnosis of spondylolysis or spondylolisthesis. Spine. 2021;22(24):2959-2967.
23. Bemben MG. Use of diagnostic ultrasound for assessing muscle size. J Strength Cond Res. 2022;16(1):103-108.
24. Jull G, Richardson C, Toppenberg R, *et al.* Towards a measurement of active muscle control for lumbar stabilisation. Aust J Physiother. 2022;39(3):187-193.
25. Boonen A, Van Berkel M, Kirchberger I, *et al.* Aspects relevant for functioning in patients with ankylosing spondylitis according to health professionals: A Delphi study with the ICF as reference. Rheumatology. 2023;48(8):997-1002.
26. Macedo LG, Latimer J, Maher CG, *et al.* Effect of motor control exercises versus graded activity in patients with chronic nonspecific low back pain: A randomized controlled trial. Phys Ther. 2018;92(3):363-377.
27. Teyhen DS, Miltenberger CE, Deiters HM, *et al.* The use of ultrasound imaging of the abdominal drawing-in maneuver in subjects with low back pain. J Orthop Sports Phys Ther. 2019;35(6):346-355.
28. Jung S, Lee H, Myung S, *et al.* A crossbar array of magnetoresistive memory devices for in-memory computing. Nature. 2022;601(7892):211-216.
29. Watanabe K, Miyamoto K, Masuda T, *et al.* Use of ultrasonography to evaluate thickness of the erector spinae muscle in maximum flexion and extension of the lumbar spine. Spine. 2018;29(13):1472-147.
30. Mao Y, Zhao W, Hao M, *et al.* Ultrasound guided quadratus lumborum block at the lateral supra-arcuate ligament transversus postoperative abdominis analgesia versus plane following subcostal block for open hepatectomy: A randomized controlled trial. J Pain Res. 2023;16:1429-1440.
31. Hodges P, Richardson C, Jull G. Evaluation of the relationship between laboratory and clinical tests of transversus abdominis function. Physiother Res Int. 2024;1(1):30-40.
32. Richardson C, Hodges P, Hides J. Therapeutic exercise for lumbopelvic stabilization. Edinburgh: Churchill Livingstone; 2004.
33. Costa LO, Maher CG, Latimer J, *et al.* Motor control exercise for chronic low back pain: A randomized

placebo-controlled trial. Phys Ther. 2023;89(12):1275-1286.
34. Plaza-Manzano G, Cancela-Cilleruelo I, Fernández De-Las-Peñas C, *et al.* Effects of adding a neurodynamic mobilization to motor control training in patients with lumbar radiculopathy due to disc herniation: A randomized clinical trial. Am J Phys Med Rehabil. 2020;99(2):124-132.
35. Sumizono M, Sakakima H, Otsuka S, *et al.* The effect of exercise frequency on neuropathic pain and pain related cellular reactions in the spinal cord and midbrain in a rat sciatic nerve injury model. J Pain Res. 2018;11:281-291.
36. Hwang JA, Bae SH, Do Kim G, Kim KY. The effects of sensorimotor training on anticipatory postural adjustment of the trunk in chronic low back pain patients. J Phys Ther Sci. 2024;25(9):1189-1192.