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Effect of manual therapy on pain, disability and neural mobility in patients of lumbar prolapsed intervertebral disc: A randomized controlled trial

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Abstract

Introduction: Lumbar prolapsed intervertebral disc (PIVD) is a common health issue affecting young and middle-aged populations. The aim of the present study was to determine the effect of manual therapy interventions on pain, disability, and neural mobility in lumbar PIVD patients.

Material and methods: Eighty-eight participants were assigned to four groups (22 people in each group): Spinal Mobilization with Leg Movement (SMWLM) group, High-Velocity Low Amplitude (HVLA) thrust group, Neural Mobilization (NM) group and Control Treatment (CT) group. The outcomes measures, viz. changes in pain, disability, and straight leg raise range of motion (SLR ROM), were assessed at baseline, after four weeks of treatment, and after a six-week follow-up.

Results: The greatest mean improvement was seen in the SMWLM group, with a VAS score of 6.05 ± 1.32, compared to the HVLA group (3.68 ± 0.75), NM group (3.2 ± 0.62) and CT group (1.91 ± 1.22), ODI score of 15.65 ± 2.43 compared to the HVLA group (11.89 ± 1.29), NM group (10.85 ± 1.53) and CT group (3.77 ± 2.43) and a SLR ROM score of 15.06 ± 3.1 compared to the HVLA group (7.89 ± 2.21), NM group (7.07 ± 2.58) and CT group (1.59 ± 2.58).

Conclusions: SMWLM group showed the most significant mean change for visual analog scale, Oswestry Disability Index, and SLR ROM compared to other groups. SMWLM may be a better viable choice in conservative management of lumbar PIVD.

Keywords: intervertebral disc herniation, manipulation therapy, physical therapy

Introduction

Lumbar prolapsed intervertebral disc (PIVD) is a common spinal ailment that affects young and middle-aged populations [1]. It may be defined as the displacement of disc material beyond the standard intervertebral disc space [2]. It is the commonest cause of low back pain with a 60–80% lifetime prevalence, and is among the most common causes of radiating lower limb pain [3]. Lumbar radiculopathy, referred to as radiating pain to the lower limb, accompanies 10% of cases of low back pain. Prevalence is common in the 30 – to 50-year age group [4]. Herniation of disc content causes pain, weakness, or numbness in the corresponding myotome or dermatome [5]. Common risk factors associated with lumbar radiculopathy are obesity, smoking, sedentary lifestyle, and socioeconomic conditions [6]. The most common level of disc herniation at the lumbar level is L4-L5 and L5-S1 [6,7]. The Intervertebral disc herniates mostly in the posterolateral direction, leading to compression of the nerve root [8]. Asymptomatic individuals might have radiological findings of disc herniation, protrusions, and annular tear [9]. Disc herniation causes compression of spinal nerve roots that, causes pain [10]. The degree of disc herniation is not correlated with the severity of pain [11].

Although surgical management gives faster short-term relief in symptoms compared to conservative management [12], it is associated with complications such as dural tear, and superficial wound infection [13] and re-operation may be required [14]. Before undergoing surgery, in the absence of worsening neurological symptoms, studies recommend conservative therapy of lumbar radiculopathy [15,16]. Therefore, different types of non-surgical treatment approaches, such as manual therapy interventions, have been developed and put to the test to treat this ailment [17,18].

Moreover, international guidelines [19,20] and systematic reviews [21−23] support the clinical importance of manual therapy interventions in short-term and long-term pain and disability management related to lower limb symptoms associated with back pain. Despite this, there are no standard guidelines for specific manual therapy intervention in lumbar radiculopathy, this creating a research gap to find more treatment options to ameliorate lumbar radiculopathy [19−23].

One such manual therapy intervention is Spinal Mobilization with Leg Movement (SMWLM). It has been found to significantly improve outcomes when combined with exercise and electrotherapy in lumbar radiculopathy as compared to exercise and electrotherapy alone [24]. Manipulations using rapid thrust technique result in relief from local and radiating acute low back pain [25]. Research evidence also suggests that neural mobilization (NM) is effective at managing spinal radiculopathy by decreasing intra-neural edema and restoring neural mobility [26].Therefore, it is possible that these manual therapy interventions may also be effective in the treatment of Lumbar PIVD.

However, no study has yet compared the efficacy of these three manual therapy techniques in the treatment of lumbar PIVD. As these three techniques use different biomechanical and physiological mechanisms, the aim of the present study is to determine the effect of these manual therapy interventions on pain, disability and neural mobility in patients of lumbar PIVD with radiculopathy; it is hypothesized that they will be effective in improving the symptoms of lumbar PIVD.

Material and methods

A double-blinded, randomized controlled trial was conducted with intention to treat analysis. It was performed according to the Consolidated Standards of Reporting Trials (CONSORT) 2010. The Institutional Ethics Committee (IEC) approved the research protocol (vide letter no. PTY/2019/1014, dated 11.09.2019). The trial was registered in the Clinical Trial Registry of India (trial number CTRI/2020/01/023037).

Participants

The sample size was determined before the group allocation. Sample size (total 88 individuals, 22 in each group) was calculated based on a 99% confidence interval and 80% power with a pooled standard deviation of 2.2 [27] and minimal clinically important difference (MCID) of 2.09 [28] for primary outcome measure, i.e. pain, considering a dropout rate of 20%.

To decrease the drop out rate, participants were offered convenient schedule, comfortable environment and treatment sessions being free of cost. Participant screening and selection is shown in the flow diagram as per CONSORT guidelines (Fig. 1). In accordance with the Helsinki declaration (2013), the participants clearly informed of the study's procedures in their local vernacular language and their informed consent was taken before admission.

Inclusion criteria: patients with lumbar PIVD causing pain, disability, and limitation in straight leg raise range of motion (SLR ROM), unilateral radiating pain to the leg below the knee, having radiological evidence of PIVD and nerve root compression by magnetic resonance imaging (MRI) with age group between 18–50 years.

Exclusion criteria: sequestrated disc, osteoporosis, trauma, recent sprain, hypermobility, pregnancy, tuberculosis or previous history of lumbosacral surgery.

PIVD was determined as the source of leg pain by physiotherapists (authors of this study) in consultation with the referring physician and the radiologist who confirmed the MRI findings. Patients were referred from general outpatient department to the Department of Physiotherapy, Guru Jambheshwar University of science & Technology, Hisar. Written informed consent was taken from all the subjects. They were free to withdraw from the study at any point and full anonymity was maintained. Participants were randomized into four groups; experimental groups: SMWLM group, High-Velocity Low Amplitude (HVLA) group, NM group and a Control Treatment (CT) group. A random computer-generated sequence of numbers was used for allocation among groups.

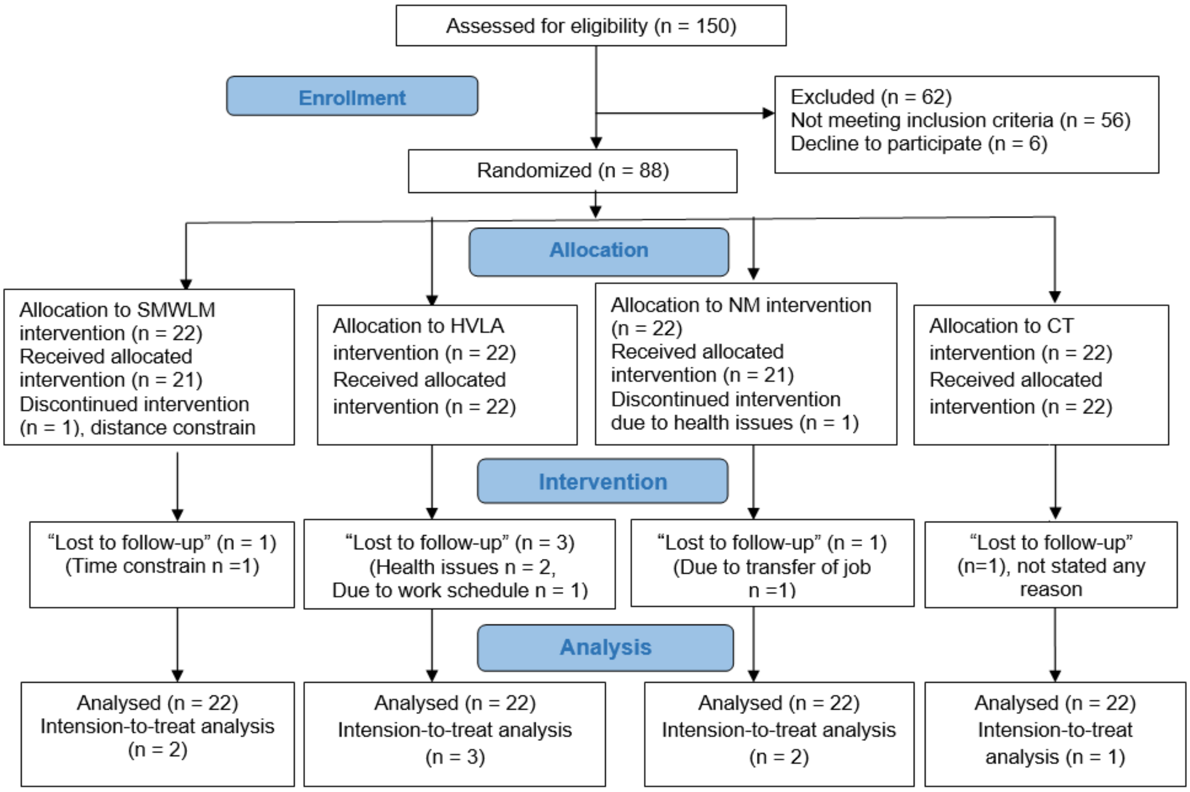

Fig. 1. Flow diagram as per CONSORT guidelines

CT – control treatment, HVLA – high velocity low amplitude, NM – neural mobilization, SMWLM – spinal mobilization with leg movement

Procedure

SMWLM Group

The participant lay on their side with the involved leg upwards. An assistant supported the involved leg. The therapist bent forward over the patient and placed one thumb on the side of the spinous process reinforced by another thumb. The therapist pressed down the chosen spinous process. The participant was asked to perform a straight leg raise actively with the affected side leg in pain-free zone, and the therapist maintained pressure on the spinous process. After maintaining this position for 30 seconds, the therapist removed the pressure from the spinous process and the patient lowered the supported leg on the treatment table. Three repetitions were performed on the first visit, and three sets of six repetitions in consequent treatment sessions, applying a slight passive overpressure at the end of the range of motion [24,29]. Passive overpressure was maintained for 30 seconds.

HVLA Group

The participant lay down in lateral recumbent position(affected side leg up), with his/her upper foot in the popliteal fossa of the lower leg [30]. The therapist rotated the upper trunk to produce rotation and lateral flexion at the lumbar, followed by counter-rotation to manipulate a specific segment by HVLA thrust within anatomical limits.

NM Group

The participant was in a supine position. The therapist raised the participant's affected leg through a pain-free range from the couch, maintaining extension at the knee joint. The nerve was mobilized using gentle oscillations. The amplitude of these oscillations was increased as per patient response. Three sets of ten oscillations with a maximum range of pain-free SLR were given in every session. Intermittent lumbar traction (ILT) (traction force 30% of body weight) and interferential therapy (IFT) (four electrodes crossed pattern) were also applied to all groups for 15 minutes [31,32]. Any increase in leg pain during treatment session was reported as an adverse event. If an adverse event was reported, no further treatment was delivered on that day. All the participants were advised to do lumbar stabilization and stretching exercises as a home program after completion of the four-week intervention.

Outcomes measures

The primary outcome measures of this study were pain and disability. SLR ROM was secondary outcome measure. Pain and disability were assessed by using visual analog scale (VAS) and Oswestry Disability Index (ODI) respectively. SLR ROM was assessed where leg symptoms were noted, using a digital goniometer. Outcome measures were assessed at baseline, after four weeks of interventions, and after six weeks follow-up. All the outcome measures were recorded by a blinded assessor.

Statistical analysis

Statistical analysis was performed using SPSS 21.0 software. The Kolmogorov-Smirnov test was used to check the normality of data. *Post hoc* analysis was performed to determine treatment effects. One-way ANOVA was used for comparison between groups. Treatment effects within each group were calculated using repeated measures ANOVA. Level of significance was set at 0.05 (p-value).

Results

Baseline Comparison

Eighty-eight subjects participated in the study. Eight participants dropped out from the study (Fig. 1). Intention-to-treat analysis was performed and the missing data was imputed by carrying forward the last recording of the participant who dropped out from the study. Table 1 depicts the baseline data characteristics. No significant differences were in the pre-intervention scores of all four groups, indicating that all the groups were similar at baseline.

Comparison among groups

The mean change in VAS scores differed significantly between the groups. *Post hoc* analysis showed significant improvement in VAS score in the SMWLM group (6.05 ± 1.32) as compared to the HVLA group (3.6 ± 0.75), NM group (3.2 ± 0.62) and CT group (1.91 ± 1.22) (Tab. 2).

Tab. 1. One-way ANOVA for baseline characteristics

	SMWLM Mean ± SD	HVLA Mean ± SD	NM Mean ± SD	CT Mean ± SD	F	p
VAS	8.1 ± 0.97	8 ± 0.88	7.8 ± 1.15	8.1 ± 0.77	0.438	0.726
ODI	26.75 ± 2.4	27.84 ± 1.68	27.6 ± 1.6	27.76 ± 1.18	1.615	0.193
SLR ROM	48.44 ± 1.17	47.87 ± 1.16	48.72 ± 1.53	48.56 ± 1	1.719	0.17

CT – control treatment, F – post hoc, HVLA – high velocity low amplitude, NM – neural mobilization, ODI – oswestry disability index, SD – standard deviation, SLR ROM – straight leg raise range of motion, SMWLM – spinal mobilization with leg movement, VAS – visual analog scale.

Tab. 2. *Post hoc* analysis (one-way ANOVA) for mean change in outcome variables between different groups

Variables	SMWLM MD ± SD (95%CI)	HVLA MD ± SD (95%CI)	NM MD ± SD (95%CI)	CT MD ± SD (95%CI)	F	p
Mean VAS change	6.05 ± 1.32 (5.43 to 6.67)	3.68 ± 0.75 (3.32 to 4.04)	3.2 ± 0.62 (2.91 to 3.49)	1.91 ± 1.22 (1.35 to 2.46)	57.94	0.0001*
Mean ODI change	15.65 ± 2.43 (14.51 to 16.79)	11.89 ± 1.29 (11.27 to 12.51)	10.85 ± 1.53 (10.13 to 11.57)	3.77 ± 2.43 (2.66 to 4.87)	126.62	0.0001*
Mean SLR ROM change	15.06 ± 3.1 (16.51 to 13.61)	7.89 ± 2.21 (8.95 to 6.82)	7.07 ± 2.58 (8.28 to 5.86)	1.59 ± 2.58 (2.76 to 0.41)	89.66	0.0001*

95%CI – confidence interval, CT – control treatment, F – post hoc, HVLA – high velocity low amplitude, MD – mean difference, NM – neural mobilization, ODI – oswestry disability index, P – significance at ≤ 0.05*, SD – standard deviation, SLR ROM – straight leg raise range of motion, SMWLM – spinal mobilization with leg movement, VAS – visual analog scale.

The results indicate a statistically significant difference between groups for mean change in ODI scores. *Post hoc* analysis showed a significantly greater improvement in ODI in the SMWLM group (15.65 ± 2.43) compared to the HVLA group (11.89 ± 1.29), NM group (10.85 ± 1.53) and CT group (3.77 ± 2.43) (Tab. 2). The results indicate a statistically significant difference between groups for mean change in SLR ROM scores. *Post hoc* analysis showed a significant improvement in SLR ROM in the SMWLM group (15.06 ± 3.1) compared to the HVLA group (7.89 ± 2.21), NM group (7.07 ± 2.58) and CT group (1.59 ± 2.58) as shown in Table 2.

No significant differences were found between the HVLA group and NM group for all three variables. Therefore, it can be inferred that SMWLM was most effective in improving VAS, ODI and SLR ROM in lumbar PIVD. The results also suggest that HVLA and NM were effective at improving VAS, ODI and SLR ROM and in decreasing pain and disability compared to the control group.

Pre-intervention, post-intervention and follow-up comparison

Within group comparisons showed statistically significant improvements in post-intervention scores and follow-up scores in all groups compared to pre-intervention scores (Tab. 3). No significant difference was found between post-intervention scores and follow-up scores. These results suggest that patients improved after the application of treatment, and that this improvement was maintained during the follow-up period (Tab. 3).

Discussion

The objective of the present study was to determine the effects of different manual therapy techniques on pain, disability, and neural mobility in the lumbar PIVD. The study confirms that SMWLM, HVLA and NM interventions applied in combination with ILT and IFT effectively reduce pain and disability and improve SLR ROM. All outcomes improved after four weeks of intervention, and treatment effects were maintained after a six-week follow-up period. Our study findings showed that SMWLM is most effective in treating lumbar PIVD among all the interventions.

Our findings are corroborated by Satpute et al. [24]. SMWLM repositions the affected segment. SMWLM may correct small positional fault [26,29,33]. SMWLM has the ability to relieve nerve compression through increased intervertebral disc space gapping and nucleus deformation [29,34]. The use of SMWLM may be associated with activation of pain inhibition via the descending suppression pathway in the periaqueductal grey matter of the midbrain [35]. SMWLM also induces a sympatho-excitatory response that produces pain

Tab. 3. Repeated measures for VAS, ODI and SLR ROM scores of all groups at different levels of protocol

Groups		Pre-intervention	Post-intervention	Follow-up	F	p
			Mean ± SD			
SMWLM	VAS	8.1 ± 0.97	2.05 ± 1.05	1.8 ± 1.32	305.742	0.0001*
	ODI	26.75 ± 2.4	11.1 ± 0.85	11.15 ± 1.14	778.633	0.0001*
	SLR ROM	48.44 ± 1.17	63.5 ± 3.67	63.72 ± 4.68	333.034	0.0001*
HVLA	VAS	8 ± 0.88	4.32 ± 1.34	4.32 ± 1.7	242.975	0.0001*
	ODI	27.84 ± 1.68	15.95 ± 0.91	16.05 ± 1.35	1283.527	0.0001*
	SLR ROM	47.87 ± 1.16	55.76 ± 2.47	55.72 ± 2.5	230.264	0.0001*
NM	VAS	7.8 ± 1.15	4.6 ± 0.94	4.65 ± 0.88	208.793	0.0001*
	ODI	27.6 ± 1.6	16.75 ± 2.05	16.6 ± 2.06	816.590	0.0001*
	SLR ROM	48.71 ± 1.53	55.79 ± 2.18	55.68 ± 2.12	153.051	0.0001*
CT	VAS	8.1 ± 0.77	6.19 ± 1.08	6.29 ± 1.15	38.779	0.0001*
	ODI	27.76 ± 1.18	24 ± 1.95	24.19 ± 1.69	53.330	0.0001*
	SLR ROM	48.56 ± 1	50.14 ± 2.57	50.17 ± 2.8	7.013	0.0002*

CT – control treatment, F – post hoc, HVLA – high velocity low amplitude, NM – neural mobilization, ODI – oswestry disability index, P – significance at ≤ 0.05*, SD – standard deviation, SLR ROM – straight leg raise range of motion, SMWLM – spinal mobilization with leg movement, VAS – visual analog scale.

relief, possibly due to the SLR and slight passive overpressure components of the technique [36]. The greater improvement observed in the SMWLM group may be due to the combination of spinal mobilization and active SLR followed by slight passive overpressure; this has been confirmed in several published randomized controlled trials [24,34,37]. However, these published randomized controlled trials have limited outcome measures and follow-ups, which are addressed by the present study.

The HVLA thrust applied in lumbar PIVD improves intervertebral disc space height and reduces intra-discal pressure. In addition, the enhanced intervertebral disc space height improves the lumbar range of motion [38]. Pain inhibition occurs at the dorsal horn level by altering neuroplasticity and central sensitization. Spinal manipulation produces a novel stimulus that acts as a counter-irritant to C fibre-mediated pain [39,40]. However, unilateral mobilization at the lumbar spine may result in changes in "sympathetic nervous system" activity to an extent [41]. Changes in the sympathetic nervous system may activate a descending pain inhibitory system by activating the periaqueductal grey matter mechanism. Our findings regarding the effects of manipulation in lumbar PIVDare corroborated by those of previous studies [25,30].

NM improve the gliding of the nerve, thus relieving symptoms [26]. Bertolini et al. [42] report that nerve root compression causes compromised microcirculation leading to demyelination and neural edema. Inflammatory response and neural tissue hypoxia is resolved by the oscillations applied during NM. The oscillations applied within a pain-free zone during NM also reduce mechano-sensitivity [42]. Our findings are confirmed by those of Gupta et al. which indicate that NM is effective in pain management in lumbar radiculopathy [43]. NM breaks adhesions [33] and facilitates neurodynamics, thereby decreasing pain and increasing SLR in lumbar PIVD patients[26,33].

Minimum clinically important difference (MCID) can be used as a threshold value to assess a clinically meaningful and significant changes in outcome measures. For VAS, the MCID has been reported to be 2 [44]. Mean improvements in VAS were 6.05 in the SMWLM group, 3.68 in the HVLA group, and 3.2 in the NM group, which exceed the MCID. An MCID value of 10 has been reported for ODI [44]. Mean improvements of ODI were 15.65 in the SMWLM group, 11.89 in the HVLA group and 10.85 in the NM group which exceed MCID. Minimal detectible change (MDC) for SLR has been reported to be 5.7 [45]. Mean improvements in SLR were 15.06 in the SMWLM group, 7.89 in the HVLA group and 7.07 in the NM group, which exceed MDC. Therefore, it can be postulated that improvements in experimental groups were not only statistically significant but also clinically significant.

The present study has significant practical implications. Lumbar PIVD is one of the common reasons for workplace absenteeism and disability [46]. It places a heavy economic burden on society and reduces work output. Patients getting pharmacological and surgical management experience a number of associated possible complications, together with high cost. Manual therapy interventions can minimize the need of medicines and surgical procedure.

The study has several notable strengths. This is the first randomized controlled trial that compares different manual therapy interventions with control group. Blinding and sample size calculation were performed to decrease the bias. Results are not only statistically significant but also clinically important.

The study has some limitations. The study data was collected in only one clinical research laboratory; however, the population was stratified on the basis of gender and age group before random allocation to different groups to decrease research bias. In future studies should aim to optimize dose, and improve efficacy in bilateral radiculopathy and combination therapy with long-term follow-up.

Conclusions

The manual therapy interventions SMWLM, HVLA and NM, combined with ILT and IFT, are effective in treating lumbar PIVD with radiculopathy. Our findings indicate that of these techniques, SMWLM is most effective at reducing pain and disability and improving SLR ROM in patients of lumbar PIVD with radiculopathy.

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Conflicts of Interest
The authors have no conflict of interest to declare.

References

1. Deyo RA, Mirza SK. Clinical practice. Herniated lumbar intervertebral disk. N Engl J Med. 2016; 374(18): 1763-72.
2. Schoenfeld AJ, Weiner BK. Treatment of lumbar disc herniation: Evidence-based practice. Int J Gen Med. 2010; 3: 209-14.
3. Lawrence DJ, Meeker W, Branson R, Bronfort G, Cates JR, Haas M, et al. Chiropractic management of low back pain and low back-related leg complaints:

a literature synthesis. J Man Phys Ther. 2008; 31(9): 659-74.
4. Atlas SJ, Chang Y, Kammann E, Keller RB, Deyo RA, Singer DE. Long-term disability and return to work among patients who have a herniated lumbar disc: the effect of disability compensation. J Bone Joint Surg Am. 2000; 82(1): 4-15.
5. Kreiner DS, Hwang SW, Easa JE, Resnick DK, Baisden JL, Bess S, et al. An evidence-based clinical guideline for the diagnosis and treatment of lumbar disc herniation with radiculopathy. Spine J. 2014; 14(1): 180-91.
6. Demirel A, Yorubulut M, Ergun N. Regression of lumbar disc herniation by physiotherapy. Does non-surgical spinal decompression therapy make a difference? Double-blind randomized controlled trial. J Back Musculoskelet Rehabil. 2017; 30(5): 1015-22.
7. Moustafa IM, Diab AA. Extension traction treatment for patients with discogenic lumbosacral radiculopathy: a randomized controlled trial. Clin Rehabil. 2013; 27(1): 51-62.
8. Koes BW, Van Tulder MW, Peul WC. Diagnosis and treatment of sciatica. BMJ. 2007; 334(7607): 1313-7.
9. Singla S, Sharma R, Sharma R, Singh A, Dhillon AS, Satti SK. Comparison between clinical finding and magnetic resonance imaging finding of lumbar prolapsed intervertebral disc. Int J Orthop Sci. 2020; 6(4): 670-4.
10. Airaksinen O, Brox JI, Cedraschi C, Hildebrandt J, Klaber-Moffett J, Kovacs F, et al. Chapter 4. European guidelines for the management of chronic nonspecific low back pain. Eur Spine J. 2006; 15(Suppl 2): S192-S300.
11. Sertpoyraz F, Eyigor S, Karapolat H, Capaci K, Kirazli Y. Comparison of isokinetic exercise versus standard exercise training in patients with chronic low back pain: a randomized controlled study. Clin Rehabil. 2009; 23(3): 238-47.
12. Gugliotta M, da Costa BR, Dabis E, Theiler R, Jüni P, Reichenbach S, et al. Surgical versus conservative treatment for lumbar disc herniation: a prospective cohort study. BMJ Open. 2016; 6(12): e012938.
13. Weinstein JN, Tosteson TD, Lurie JD, Tosteson AN, Hanscom B, Skinner JS, et al. Surgical vs nonoperative treatment for lumbar disk herniation: the Spine Patient Outcomes Research Trial (SPORT): a randomized trial. JAMA. 2006; 296(20): 2441-50.
14. Kim CH, Chung CK, Park CS, Choi B, Kim MJ, Park BJ. Reoperation rate after surgery for lumbar herniated intervertebral disc disease: nationwide cohort study. Spine. 2013; 38(7): 581-90.
15. Valat JP, Genevay S, Marty M, Rozenberg S, Koes B. Sciatica. Best Pract Res Clin Rheumatol. 2010; 24: 241-52.
16. Schoenfeld AJ, Weiner BK. Treatment of lumbar disk herniation: evidence based practice. Int J Gen Med. 2010; 3: 209-14.
17. Ostelo RW. Physiotherapy management of sciatica. J Physiother. 2020; 66(2): 83-8.
18. Maxwell CM, Lauchlan DT, Dall PM. The effects of spinal manipulative therapy on lower limb neurodynamic test outcomes in adults: a systematic review. J Man Manip Ther. 2020; 28(1): 4-14.
19. Stochkendahl MJ, Kjaer P, Hartvigsen J, Kongsted A, Aaboe J, Andersen M, 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.
20. National Guideline Centre (UK). Low Back Pain and Sciatica in Over 16s: Assessment and Management. London: National Institute for Health and Care Excellence (NICE); 2016.
21. Hidalgo B, Detrembleur C, Hall T, Mahaudens P, Nielens H. The efficacy of manual therapy and exercise for different stages of non-specific low back pain: an update of systematic reviews. J Man Manip Ther. 2014; 22(2): 59-74.
22. Slater SL, Ford JJ, Richards MC, Taylor NF, Surkitt LD, Hahne AJ. The effectiveness of sub-group specific manual therapy for low back pain: a systematic review. Man Ther. 2012; 17(3): 201-12.
23. Clar C, Tsertsvadze A, Court R, Hundt GL, Clarke A, Sutcliffe P. Clinical effectiveness of manual therapy for the management of musculoskeletal and non-musculoskeletal conditions: systematic review and update of UK evidence report. Chiropr Man Therap. 2014; 22(1):1-34.
24. Satpute K, Hall T, Bisen R, Lokhande P. The effect of spinal mobilization with leg movement in patients with lumbar radiculopathy – a double-blind randomized controlled trial. Arch Phys Med Rehabil. 2019; 100(5): 828-36.
25. Santilli V, Beghi E, Finucci S. Chiropractic manipulation in the treatment of acute back pain and sciatica with disc protrusion: a randomized double-blind clinical trial of active and simulated spinal manipulations. Spine J. 2006; 6(2): 131-7.
26. Thakur A, Mahapatra RK. Effect of Mulligan spinal mobilization with leg movement and shacklock neural tissue mobilization in lumbar radiculopathy: a randomised controlled trial. J Med Internet Thesis. 2015; 2(3): 27-30.
27. Bilgilisoy Filiz M, Kiliç Z, Uçkun A, Çakir T, Koldaş Doğan Ş, Toraman NF. Mechanical traction for lumbar radicular pain: supine or prone? A randomized controlled trial. Am J Phys Med Rehabil. 2018; 97(6): 433-9.
28. Emshoff R, Bertram S, Emshoff I. Clinically important difference thresholds of the visual analog scale:

a conceptual model for identifying meaningful intraindividual changes for pain intensity. Pain. 2011; 152(10): 2277-82.
29. Mulligan BR. Update on spinal mobilisations with leg movement. J Man Manip Ther. 1997; 5(4): 184-7.
30. Shokri E, Kamali F, Sinaei E, Ghafarinejad F. Spinal manipulation in the treatment of patients with MRI-confirmed lumbar disc herniation and sacroiliac joint hypomobility: a quasi-experimental study. Chiropr Man Therap. 2018; 26: 1-16.
31. Ariel E, Levkovitz Y, Goor-Aryeh I, Ratmansky M. The effects of TENS, interferential stimulation, and combined interferential stimulation and pulsed ultrasound on patients with disc herniation-induced radicular pain. J Back Musculoskelet Rehabil. 2022; 35(2): 363-71.
32. Liu ZZ, Wen HQ, Zhu YQ, Zhao BL, Kong QC, Chen JY, et al. Short-term effect of lumbar traction on intervertebral discs in patients with low back pain: correlation between the T2 value and ODI/VAS score. Cartilage. 2021; 13(1_suppl): 414S-423S.
33. Das SM, Dowle P, Iyengar R. Effect of spinal mobilization with leg movement as an adjunct to neural mobilization and conventional therapy in patients with lumbar radiculopathy: Randomized controlled trial. J Med Sci Res. 2018; 6(1): 11-9.
34. Danazumi MS, Bello B, Yakasai AM, Kaka B. Two manual therapy techniques for management of lumbar radiculopathy: a randomized clinical trial. J Osteopath Med. 2021; 121(4): 391-400.
35. Vicenzino B, Paungmali A, Teys P. Mulligan's mobilization-with-movement, positional faults and pain relief: current concepts from a critical review of literature. Man Ther. 2007; 12(2): 98-108.
36. Tsirakis V, Perry J. The effects of a modified spinal mobilisation with leg movement (SMWLM) technique on sympathetic outflow to the lower limbs. Man Ther. 2015; 20(1): 103-8.
37. Ashraf B, Ahmad S, Ashraf K, Kanwal S, Ashraf S, Khan N, et al. Effectiveness of Spinal Mobilization with Leg Movement Versus McKenzie Back Extension Exercises in Lumbar Radiculopathy. Pakistan J Medical Health Sci. 2021:15(5):1436-40.
38. Cramer GD, Cambron J, Cantu JA, Dexheimer JM, Pocius JD, Gregerson D, et al. Magnetic resonance imaging zygapophyseal joint space changes (gapping) in low back pain patients following spinal manipulation and side-posture positioning: a randomized controlled mechanisms trial with blinding. J Manipulative Physiol Ther. 2013; 36(4): 203-17.
39. Perry J, Green A, Singh S, Watson P. A preliminary investigation into the magnitude of effect of lumbar extension exercises and a segmental rotatory manipulation on sympathetic nervous system activity. Man Ther. 2011; 16(2):190-5.
40. Bialosky JE, Bishop MD, Robinson ME, Zeppieri Jr G, George SZ. Spinal manipulative therapy has an immediate effect on thermal pain sensitivity in people with low back pain: a randomized controlled trial. Phys Ther. 2009; 89(12): 1292-303.
41. Perry J, Green A. An investigation into the effects of a unilaterally applied lumbar mobilisation technique on peripheral sympathetic nervous system activity in the lower limbs. Man Ther. 2008; 13(6): 492-9.
42. Bertolini GR, Silva TS, Trindade DL, Ciena AP, Carvalho AR. Neural mobilization and static stretching in an experimental sciatica model: an experimental study. Rev Braz Fisioter. 2009; 13(6): 493-8.
43. Gupta R, Sharma S, Sharma RK, Sharma S. Effect of Neurodynamic Mobilisation Plus Core Stability on Pain and Motor Nerve Conduction Velocity in Athletes with Lumbar Radiculopathy. Pol J Sport Tour. 2021; 28(3): 3-7.
44. Ostelo RW, Deyo RA, Stratford P, Waddell G, Croft P, Von Korff M, et al. Interpreting change scores for pain and functional status in low back pain: towards international consensus regarding minimal important change. Spine. 2008; 33(1): 90-4.
45. Ekedahl H, Jönsson BO, Frobell RB. Fingertip-to-floor test and straight leg raising test: validity, responsiveness, and predictive value in patients with acute/subacute low back pain. Arch Phys Med Rehabil. 2012; 93(12): 2210-15.
46. Lo J, Chan L, Flynn S. A systematic review of the incidence, prevalence, costs, and activity and work limitations of amputation, osteoarthritis, rheumatoid arthritis, back pain, multiple sclerosis, spinal cord injury, stroke, and traumatic brain injury in the United States: a 2019 update. Arch Phys Med Rehabil. 2021; 102(1): 1151-31.