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Two manual therapy techniques for management of lumbar radiculopathy: a randomized clinical trial

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Abstract

Context: Evidence has shown that spinal mobilization with leg movement (SMWLM) and progressive inhibition of neuromuscular structures (PINS) are individually effective in the management of lumbar radiculopathy. However, previous evidence reported data for only a short-term study period and did not investigate the effect of the combined manual therapy techniques.

Objectives: To compare the combined effects of two manual therapy techniques (SMWLM and PINS) with the individual techniques alone (SMWLM or PINS) in the management of individuals with lumbar radiculopathy.

Methods: A total of 60 patients diagnosed with unilateral lumbar radiculopathy secondary to disc herniation were randomly allocated into three groups: 20 participants each in the SMWLM, PINS, and combined SMWLM + PINS groups. Each group attended two treatments per week for 30 min each, for three months. Participants were assessed at baseline, immediately posttreatment, and then at three, six, and nine months follow-up using the Visual Analog Scale (VAS), Rolland-Morris Disability Questionnaire (RMDQ), and Sciatica Bothersomeness Index (SBI).

Results: Between-groups analyses using a two-way repeated-measures analysis of variance indicated significant interactions between groups and follow-up times for

all outcomes ($p=0.001$). Participants receiving combined SMWLM + PINS treatment experienced greater improvement in leg pain, back pain, disability, and sciatica at all timelines (immediately posttreatment, and three, six, and nine months follow-up) than the participants receiving SMWLM or PINS alone ($p<0.05$). However, participants receiving SMWLM alone showed better improvement than the participants receiving PINS alone at all timelines ($p<0.05$).

Conclusions: A combined SMWLM + PINS treatment protocol showed greater improvement than the individual techniques alone in the management of individuals with LR in this study.

Keywords: lumbar disc herniation; lumbar radiculopathy; neuromuscular inhibition; spinal mobilization.

Lumbar radiculopathy is characterized by radiating pain in an area of the leg typically served by one lumbar or sacral spinal nerve root in combination with dermatomal and/or tendon reflex abnormalities [1]. The problem is commonly caused by degenerative conditions, such as a herniated nucleus pulposus or lumbar spinal stenosis, and occurs in approximately 3–5% of the population, with about 10–25% of those affected having a recurrence of symptoms that usually persist for more than three months [2].

Studies have indicated that conservative management of lumbar radiculopathy should be attempted in the absence of worsening neurological signs or cauda equina syndrome before surgical interventions [3, 4]. Based on this, many forms of conservative care, including manual therapy, have been developed and investigated in the management of this condition [5–7]. Moreover, evidence from international guidelines [8–10] and systematic reviews [11–13] indicate that manual therapy techniques are effective for both short and long-term pain and disability management in patients with back-related lower extremity symptoms. Despite this, there are no standardized

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guidelines for appropriate manual therapy techniques comprising the most effective interventions for individuals with lumbar radiculopathy, suggesting that more treatment options are needed [8–17].

A previous study [18] investigated the effect of two manual therapy techniques, spinal mobilization with leg movement (SMWLM) and progressive inhibition of neuromuscular structures (PINS), in the management of lumbar radiculopathy; results showed that both SMWLM and PINS were individually effective on pain, disability, and sciatica, but no significant differences were observed between the two manual therapy techniques postintervention. That study [18] reported data for a short-term period (eight weeks postintervention) and did not investigate combined manual therapy techniques. Given that SMWLM has been hypothesized to relieve nerve compression [19] and PINS has been hypothesized to normalize reflex activity in the neuromuscular structures [20], we hypothesized that a combination of the two techniques could produce a better outcome than the individual techniques alone. Accordingly, this study was conducted to examine the combined effect of SMWLM and PINS in the management of individuals with lumbar radiculopathy secondary to disc herniation.

Methods

Research design and ethics

This was a single-blind, parallel, randomized, clinical trial; the research participants were blinded to randomization. Because of the nature of the study, investigators were not blinded, but outcomes assessors and data analysts were blinded. Ethical approval to conduct this study was obtained from the Health Research Ethics Committee of the Federal Medical Centre (FMC), Nguru, Yobe State, Nigeria (Registration number: FMC/N/CL.SERV/355/VOL.IV/139). Written informed consent was obtained from the participants, they were assured of their rights to withdraw from the study at any point in time, and their full anonymity was maintained. The trial was registered with the Pan African Clinical Trial Registry (PACTR201907782710996) on July 11, 2019. The study was begun on July 15, 2019 and ended on September 11, 2020.

Sample size estimation

The sample size was calculated using the G*Power version 3.1 software [21]. The effect size used for calculating the sample size was obtained from previous research by Das et al. [22] using disability as the primary outcome. The probability level (α), the power (p), the effect size (ES), the number of groups, the number of measurements, and correlation among repeated measures used for the calculation were set at 0.05, 0.8, 0.38, 3, 6, and 0.5, respectively, which yielded a total sample size of 45 participants (15 per group), using repeated measures (between

factors) analysis of variance (ANOVA). According to a previous study [23], a 20% attrition rate should be accounted for a clinical trial of equal allocation to groups, so our the sample size was adjusted to 60 participants (20 per group) to anticipate this potential loss due to attrition.

Eligibility criteria

Participants diagnosed as having a chronic (lasting three months or longer) [2–4] lumbar radiculopathy secondary to L4/L5 and L5/S1 lumbar disc herniation (confirmed on magnetic resonance imaging) were included in the study. Patients with chronic lumbar radiculopathy were selected because of the prior evidence that acute cases may resolve spontaneously within a few weeks of onset [2–4]. Adults with an age range of 18–65 years having unilateral radiculopathy and pain in the distribution of sciatic nerve (leg-dominant symptoms) were included. Pain was accepted as evidence of L5/L4 root compression when distributed to the anterolateral aspect of the leg and the dorsum of the foot, and as evidence of L5/S1 root compression when distributed to the posterior aspect of the leg extending to the heel and lateral aspect of the foot. Radiating pain was evoked by specific clinical tests, including slump, straight leg raising [24–26], and Lasègue's sign [27]. The exclusion criteria were: diagnosis of lumbar disc herniation with bilateral radiculopathy, diagnosis of other back conditions (e.g., failed back syndrome, spondylolysis/spondylolisthesis, spinal stenosis, mechanical low back pain or neoplastic and infectious processes), and participants currently receiving treatments. Participants with severe nerve root compression (non-ambulant/wheelchair-bound) or having cauda equine syndrome were also excluded because it was believed that these participants might better benefit from surgery [28].

Data collection procedure

Participant recruitment: Participants were referred from the general outpatient department (GOPD) and surgical outpatient department (SOPD) to the department of physiotherapy where the study was conducted. Participants were verbally invited to participate in the study and then screened for eligibility by a trained orthopedic physiotherapist (M.S.D.). Participants who met the eligibility criteria and were willing to participate were recruited, and written informed consents were obtained. Participants were recruited consecutively throughout the study period until the sample size needed was achieved.

Outcomes assessment: Outcomes were assessed at baseline and posttreatment (after three months of intervention). Treatment ended after three months of intervention and then patients were given lumbar stabilization and stretching exercises [18] as a home regimen. Outcomes were further assessed through physical visits and phone calls at three, six, and nine months of follow-up.

- (1) *Visual Analog Scale (VAS)*: This scale was used to measure leg and back pain intensities experienced by the participants. The assessment was based on a horizontal 10 cm scale varying from 0 (no pain in the leg) to 10 cm (the worst pains ever). VAS has been shown to have high interobserver reliability coefficient ($r=0.88$) and a 30% change is considered clinically significant [29].
- (2) *Roland Morris Disability Questionnaire (RMDQ)*: This questionnaire was used to measure functional limitation among participants. Scores range from 0 to 24, with higher scores reflecting more severe

disability. The RMDQ has been shown to have a high level of internal consistency reliability (Cronbach's alpha of 0.87), and test-retest reliability (ICC of 0.9); 2–3 (8–12%) point change is considered clinically significant [29].

- (3) *Sciatica Bothersomeness Index (SBI)*: This scale was used to assess the level of sciatica among participants. The scale's scores range from 0 to 24, with higher scores reflecting more severe sciatica bothersomeness. This scale has a high level of internal consistency reliability (Cronbach's alpha of 0.70) and test-retest reliability (ICC of 0.90); a change of 6.5 points is considered clinically significant [30].

Randomization of participants: Eligible participants who provided informed consent were randomized into one of three treatment groups: SMWLM, PINS, or combined SMWLM + PINS. A randomization timeline was prepared by a research assistant who had no communication with the participants throughout the trial and was unaware of the study protocol. The randomization series (using block randomization) was created using SAS 9.4 statistical software with the participants likely to be assigned to a group with an equal chance of allocation (Figure 1).

Intervention procedure: There were three intervention groups in this study, with the first group receiving SMWLM, the second group receiving PINS, and the third group receiving combined SMWLM + PINS treatment techniques. Treatments sessions for both the single and combined treatment groups were carried out on the same day. However, participants in the single treatment groups spent additional time receiving lectures on lumbar spine anatomy, to compensate for not receiving dual therapies. Each group (both single and combined) attended two treatments per week of for 30 min each, for three months. Additionally, each group also received neural tissue mobilization [31] as a baseline treatment.

SMWLM technique: Participants in the SMWLM group received SMWLM as per Mulligan's guidelines [32]. The participant was laid on the side, facing the treating physiotherapist (PT; M.S.D.), with the leg to be treated on top. An assistant PT supported the uppermost leg. The treating PT then bent over the participant and put one thumb, supported by the other, on the spinous process of the affected vertebra as determined with reference to the posterior superior iliac crest. The treating PT then pressed down on the palpated spinous process. This pressure was maintained while the participant actively performed the straight leg raise (SLR) for the leg supported by the assistant PT, in as much as this did not cause pain. This position was retained for 30 s, after which the treating PT released the pressure on the spinous process and the participant lowered the supported leg to the treatment table. Three repetitions were applied during the first visit. However, as the participant improved in subsequent visits, the assistant PT applied overpressure on the supported leg as the participant performed the SLR. This was also maintained for 30 s, after which the leg was lowered to the treatment table (Figure 2). This procedure was repeated six times on subsequent visits.

PINS technique: Participants in the PINS group received the PINS program as per Dowling's guidelines [20]. Two connected points, named primary and endpoints, were palpated using the index fingers of both hands. The points were areas of most and least sensitivity, respectively, found along a neuromuscular structure. When an area of

least sensitivity (endpoint) was found, a moderate ischemic compression was applied with the index finger of one hand without relieving the pressure until the treatment is complete. When an area of most sensitivity was found (primary point), a moderate ischemic compression was also applied with the index finger of the other hand for 30 s, after which another sensitive point was identified with the middle finger of the same hand proximal to the endpoint without relieving the pressure of the index finger. When the pressure on the middle finger was noted as more sensitive than on the index finger, then the index finger pressure was relieved and that of the middle finger was maintained without relieving the endpoint pressure. This was maintained for 30 s before the third point was identified. Similar patterns for all identified sensitive points were followed continuously along the neuromuscular continuum until the last point, approximately 2 cm proximal to the endpoint, was found. The pressure was maintained for 30 s concurrently on the two points (the last and the endpoint) and then relieved (Figure 3).

Compliance with home program: Therapeutic exercises (lumbar stabilization and stretching exercises) were initiated at low speed (beginner stage) during the treatment sessions to ensure that each participant received appropriate exercise instructions and progression modes before discharge. After treatment ended, participants were given a handout detailing appropriate exercise dosages and progressions. We provided the same exercise guidelines reported in our previous study [18]. Additionally, exercise compliance was assessed and reinforced every four weeks via phone calls and every 3 months at in-person visits. Further, participants were also asked to refrain from all other rehabilitation techniques or exercise not prescribed by the trial physiotherapists; this was also monitored periodically via phone calls and physical visits.

Statistical analysis: All data were analyzed using SPSS 23.0 (SPSS, Inc.). Descriptive statistics were used to summarize the demographics and clinical parameters of the participants. Shapiro-Wilk test was used to assess the normality of the data, while Levene's test was used to assess the homogeneity of variances among groups. One-way ANOVA was used to compare outcomes at baseline. The primary aim of the study (effects of interventions on pain, disability, and sciatica) was examined by the use of two-way repeated-measures ANOVA with the intervention group (SMWLM, PINS, and combined SMWLM + PINS) as the between-subject variable and time (baseline, posttreatment, and three, six, and nine months follow-up) as the within-subject variable. Separate ANOVAs were performed with the outcomes (back pain, leg pain, disability, and sciatica) as the dependent variables and for each ANOVA, the analysis of interest was the two-way interaction (Group $\times$ Time). The data of the participants lost to follow-up were treated by intention-to-treat analysis (ITT) by removing the lost data in the analysis (on protocol/per protocol/completer analysis procedure) [33]. Differences between the means were considered at 5% probability level ($p < 0.05$) and the value of confidence interval (CI) was set at 95%.

Results

A total of 60 participants (age range, 36–59 years; mean age, 47.8 ± 4.32 years) were enrolled in the study, with 20

Figure 1: Chart demonstrating the flow of patients through this randomized clinical study.

Figure 2: Spinal mobilization with leg movement. The patient is lying on the side with the affected lower limb uppermost, and the treating physiotherapist (PT) is facing and stooping over the patient. The treating PT pushes down the chosen spinous process using reinforced thumbs and the assistant PT supports the uppermost leg of the patient when straight leg raising is performed.

participants each in the SMWLM, PINS, and combined SMWLM + PINS treatment groups. Thirty-seven (61.7%) participants were men and 23 (38.3%) participants were women. One participant in the SMWLM + PINS treatment group was lost at the nine-month follow-up period and his data was adjusted through intention-to-treat (ITT) analysis by removing the nine-month follow-up data from the analysis. No significant differences were observed in the baseline characteristics of the study participants among groups (Table 1).

Between-groups analyses using a two-way repeated-measures ANOVA indicated significant interactions between group and time (Group $\times$ Time) for all outcomes: RMDQ [$F(4, 116)=15.994$; $p=0.001$], VAS in the leg [$F(4, 116)=14.107$; $p=0.001$], VAS in the back [$F(4, 116)=7.469$, $p=0.001$], SBI [$F(4, 116)=8.073$; $p=0.001$] (Table 2).

Figure 3: Progressive inhibition of neuromuscular structures. The patient is lying prone and the treating physiotherapist (PT) is standing at the same side with the patient's ipsilateral lower limb. The treating PT's proximal index finger is placed at the primary end point and the distal index finger is placed at the secondary end point. The proximal finger of the PT applies ischemic compression at primary end points, moving progressively towards the distal index finger to approximately the 2 cm mark, and then both pressures are relieved at once.

Post-hoc analyses (of Group $\times$ Time effects) indicated that participants who received combined SMWLM + PINS=treatment experienced greater improvement in leg pain ($p<0.05$), back pain ($p<0.05$), disability ($p<0.05$) and sciatica bothersomeness ($p<0.05$), immediately posttreatment (Table 3), and at three-month (Table 4), six-month (Table 5), and nine-month (Table 6) follow-up periods than the participants receiving SMWLM or PINS alone. However, participants receiving SMWLM showed better improvement than the participants receiving PINS at all timelines (Tables 3–6).

Discussion

This study investigated the combined effects of SMWLM and PINS compared with the individual techniques alone in the management of individuals with lumbar

radiculopathy secondary to disc herniation. The findings of this study showed that there were significant within-group differences for all outcomes at all timelines (immediately posttreatment and three, six, and nine months follow-up periods), indicating that all measures significantly improved over time from baseline to 12 months. This finding is congruent with those of a previous study [18], in which a significant improvement in all outcomes at all timelines was reported. Similar findings were also reported in other previous studies [22, 31, 34, 35] that examined the effect of SMWLM compared with other interventions. However, in contrast with a previous study [18] and other studies [22, 34, 35], ours examined the combined effects of

Table 1: Baseline demographics and clinical characteristics.

Variable	SMWLM Mean (SD) (n=20)	PINS Mean (SD) (n=20)	Combined Mean (SD) (n=20)	p-value
Age, years	45.44 (8.84)	49.51 (10.06)	47.33 (12.09)	0.176
BMI, kg/m ²	24.59 (1.83)	25.35 (2.52)	26.73 (2.86)	0.682
DOS, months	8.95 (1.07)	9.10 (0.97)	9.05 (1.02)	0.981
RMDQ	13.40 (3.83)	13.25 (3.14)	14.13 (3.40)	0.114
VASL	8.75 (2.05)	7.50 (2.04)	7.26 (2.02)	0.825
VASB	4.67 (3.21)	4.81 (2.73)	4.94 (2.56)	0.089
SBI	16.35 (4.30)	15.35 (4.30)	17.51 (4.76)	0.813

BMI, body mass index; DOS, duration of symptoms; PINS, progressive inhibition of neuromuscular structures; RMDQ, Rolland–Morris disability questionnaire; SBI, sciatica bothersome index; SD, standard deviation; SMWLM, spinal mobilization with leg movement; VASL, Visual Analog Scale for leg pain; VASB, Visual Analog Scale for back pain.

Table 2: Two-way repeated measures ANOVA for between group and time interactions.

Variable	<i>F(df)</i>	p-value
RMDQ		
Group	202.071 (2, 58)	<0.001
Time	25.322 (2, 116)	<0.001
Group $\times$ Time	15.994 (4, 116)	<0.001
VASL		
Group	139.673 (2, 58)	<0.001
Time	9.901 (2, 116)	<0.001
Group $\times$ Time	14.107 (4, 116)	<0.001
VASB		
Group	121.303 (2, 58)	<0.001
Time	15.645 (2, 116)	<0.001
Group $\times$ Time	7.469 (4, 116)	<0.001
SBI		
Group	89.966 (2, 58)	<0.001
Time	13.178 (2, 116)	<0.001
Group $\times$ Time	8.073 (4, 116)	<0.001

RMDQ, Rolland–Morris Disability Questionnaire; SBI, sciatica bothersome index; VASL, Visual Analog Scale for leg pain; VASB, Visual Analog Scale for back pain.

Table 3: Baseline to posttreatment change scores for clinical outcomes.

Variable	Group (n)	Baseline Mean (SD)	Posttreatment Mean (SD)	Within-group change score Mean (SD)	Between-group change score Mean (95% CI)	p-value
RMDQ	SMWLM (20)	13.40 (3.83)	11.04 (3.14)	2.36 (4.61)	5.03 (2.41–5.81)	0.001
	PINS (20)	13.25 (3.14)	11.23 (4.81)	2.02 (5.30)		
	COMBINED (20)	14.13 (3.40)	9.11 (3.12)	5.11 (3.64)		
VASL	SMWLM (20)	8.75 (2.05)	5.62 (1.23)	3.14 (2.12)	3.48 (1.82–3.47)	0.001
	PINS (20)	7.50 (2.04)	5.21 (1.03)	2.28 (3.36)		
	COMBINED (20)	7.26 (2.02)	4.01 (1.61)	3.25 (2.97)		
VASB	SMWLM (20)	4.67 (3.21)	3.21 (1.98)	1.46 (1.32)	2.88 (0.96–3.02)	0.034
	PINS (20)	4.81 (2.73)	4.02 (2.54)	0.81 (2.71)		
	COMBINED (20)	4.94 (2.56)	3.05 (1.36)	1.89 (0.65)		
SBI	SMWLM (20)	16.35 (4.30)	12.32 (5.11)	4.02 (4.31)	4.62 (3.96–7.21)	0.020
	PINS (20)	15.35 (4.30)	13.01 (4.69)	2.34 (6.03)		
	COMBINED (20)	17.51 (4.76)	11.97 (5.48)	5.56 (4.61)		

CI, confidence interval; RMDQ, Rolland–Morris Disability Questionnaire; SBI, Sciatica Bothersome Index; SD, standard deviation; VASL, Visual Analog Scale for leg pain; VASB, Visual Analog Scale for back pain.

Table 4: Posttreatment to three-month follow-up change scores for clinical outcomes.

Variable	Group (n)	Immediate posttreatment Mean (SD)	Three-month follow-up Mean (SD)	Within-group change score Mean (SD)	Between-group change score mean (95% CI)	p-value
RMDQ	SMWLM (20)	11.04 (3.14)	8.13 (4.38)	2.92 (6.27)	4.97 (1.24–5.03)	0.001
	PINS (20)	11.23 (4.81)	8.04 (3.98)	3.18 (5.01)		
	COMBINED (20)	9.11 (3.12)	5.87 (5.16)	3.26 (4.88)		
VAS	SMWLM (20)	5.62 (1.23)	4.02 (2.43)	1.62 (3.33)	2.43 (1.10–3.31)	0.042
	PINS (20)	5.21 (1.03)	4.01 (1.89)	1.18 (2.45)		
	COMBINED (20)	4.01 (1.61)	2.68 (3.01)	1.35 (1.68)		
VASB	SMWLM (20)	3.21 (1.98)	2.98 (3.71)	0.25 (1.00)	1.67 (1.13–1.88)	0.022
	PINS (20)	4.02 (2.54)	3.97 (2.62)	0.05 (2.33)		
	COMBINED (20)	3.05 (1.36)	2.21 (2.53)	0.84 (1.96)		
SBI	SMWLM (20)	12.32 (5.11)	8.82 (6.21)	3.50 (2.19)	2.60 (1.88–6.27)	0.012
	PINS (20)	13.01 (4.69)	11.01 (8.87)	2.01 (4.52)		
	COMBINED (20)	11.97 (5.48)	7.12 (4.69)	4.85 (3.83)		

RMDQ, Rolland–Morris Disability Questionnaire; SBI, Sciatica Bothersome Index; VASL, Visual Analog Scale for leg pain; VASB, Visual Analog Scale for back pain.

Table 5: Three-month to six-month follow-up change scores for clinical outcomes.

Variable	Group (n)	Three-month follow-up Mean (SD)	Six-month follow-up Mean (SD)	Within-group change score Mean (SD)	Between-group change score mean (95% CI)	p-value
RMDQ	SMWLM (20)	8.13 (4.38)	5.33 (2.71)	2.78 (1.21)	3.03 (2.14–4.01)	0.001
	PINS (20)	8.04 (3.98)	6.00 (4.01)	2.04 (2.67)		
	COMBINED (20)	5.87 (5.16)	2.71 (2.86)	3.18 (1.02)		
VASL	SMWLM (20)	4.02 (2.43)	2.14 (1.20)	1.587 (2.41)	1.64 (1.08–2.11)	0.048
	PINS (20)	4.01 (1.89)	2.88 (2.13)	1.33 (3.64)		
	COMBINED (20)	2.68 (3.01)	1.03 (0.68)	1.65 (2.03)		
VASB	SMWLM (20)	2.98 (3.71)	2.34 (2.67)	0.64 (1.39)	1.01 (0.92–1.97)	0.021
	PINS (20)	3.97 (2.62)	3.68 (1.59)	0.31 (1.80)		
	COMBINED (20)	2.21 (2.53)	1.07 (0.34)	1.14 (0.76)		
SBI	SMWLM (20)	12.32 (5.11)	5.02 (4.53)	3.80 (1.04)	4.02 (1.27–4.80)	0.001
	PNS (20)	13.01 (4.69)	9.63 (6.49)	1.38 (3.17)		
	COMBINED (20)	11.97 (5.48)	3.56 (3.84)	3.54 (0.88)		

RMDQ, Rolland–Morris Disability Questionnaire; SBI, Sciatica Bothersome Index; VASL, Visual Analog Scale for leg pain; VASB, Visual Analog Scale for back pain.

Table 6: Six-month to nine-month follow-up change scores for clinical outcomes.

Variable	Group (n)	Six-month follow-up Mean (SD)	Nine-month follow-up Mean (SD)	Within-group change score Mean (SD)	Between-group change score mean (95% CI)	p-value
RMDQ	SMWLM (20)	5.33 (2.71)	4.72 (1.33)	0.62 (1.68)	1.26 (0.88–3.46)	0.028
	PINS (20)	6.00 (4.01)	5.68 (4.22)	0.32 (2.03)		
	COMBINED (20)	2.71 (2.86)	1.26 (1.04)	1.45 (0.87)		
VASL	SMWLM (20)	2.14 (1.20)	1.88 (0.22)	0.26 (0.98)	1.52 (1.32–2.07)	0.044
	PINS (20)	2.88 (2.13)	2.67 (1.69)	0.21 (0.41)		
	COMBINED (20)	1.03 (0.68)	0.42 (0.03)	0.61 (0.02)		
VASB	SMWLM (20)	2.34 (2.67)	1.97 (3.67)	0.37 (1.24)	1.02 (0.87–1.69)	0.001
	PINS (20)	3.68 (1.59)	2.31 (2.54)	1.37 (0.98)		
	COMBINED (20)	1.07 (0.34)	0.22 (0.10)	0.85 (1.27)		
SBI	SMWLM (20)	5.02 (4.53)	3.31 (1.87)	1.72 (2.22)	1.05 (0.98–2.57)	0.020
	PNS (20)	9.63 (6.49)	7.98 (2.77)	1.64 (3.34)		
	COMBINED (19)	3.56 (3.84)	1.67 (0.13)	1.89 (1.84)		

RMDQ, Rolland–Morris Disability Questionnaire; SBI, Sciatica Bothersome Index; VASL, Visual Analog Scale for leg pain; VASB, Visual Analog Scale for back pain.

the two treatment techniques (SMWLM and PINS) and data were reported for long-term follow-ups.

Our findings also showed that there were significant between-group differences in all outcomes with the combined treatment group (SMWLM + PINS) having greater improvement in all outcomes (pain, disability, and sciatica bothersomeness) at all timelines than the individual treatment groups (SMWLM or PINS). Additionally, the SMWLM group showed better improvement than the PINS group. These findings are similar to those of Das et al. [22], Thakur et al. [31], and Yadav et al. [35], which reported better improvement in the SMWLM group than the comparison groups. In contrast to our current findings, a previous study by Ahmed et al. [34] reported better improvement in the comparison group than the SMWLM group. Another previous study [18] reported no between-group differences in all outcomes which further contrasted this current finding.

The significant improvement achieved in our study after administering a combined treatment approach may not be unrelated to the ability of the two treatment techniques in ameliorating nerve root compression and sciatica. First, SMWLM has been indicated to relieve nerve compression through increased intervertebral disc space gapping, nucleus deformation, and simultaneous approximation in the alternate layers of the annulus, thereby producing favorable therapeutic effects on the intervertebral disc [19]. While decreased diffusion of water and loss of proteoglycans are hallmarks of disc degeneration, it has been suggested that fluid exchange is integral to maintaining disc nutrition [36]. Mobilizations such as posterior–anterior (P–A) glides have been reported to result in pain

relief and improved motion in individuals with low back pain [37–39] while also improving disc hydration [40–42]. Given that SMWLM is a form of P–A gliding mobilization, it is conceivable that this technique could correct the positional fault by relieving pressure from the structures that compress the nerves, improving disc hydration, and also reducing the extent of pain via centralization [19].

On the other hand, PINS has been indicated to reduce lower limb radiating pain through increased hyperemia and washing away of the metabolites in the neuromuscular structures following myofascial trigger point deactivation [20]. Additionally, the ischemic compression applied on the sensitive neuromuscular structures using PINS may also elicit counterirritant effect in which large, fast-conducting afferent fibers in the dorsal horn of the spinal cord and collateral fibers in the substantia gelatinosa or adjacent interneurons inhibit the transmission of pain via the spinothalamic tract [20]. In this manner, pressure acts as a stimulant to neighboring tissues, reducing the sensitivity of the original tender point and thus resolving pain [43]. Similar findings were also reported by a previous study [44] which indicated that sciatic nerve manipulation may promote healing of the soft tissues by stimulating the functions of the nervous system to improve nervous system adaptability and decrease sensitivity, helping to alleviate the symptoms. All these effects of SMWLM and PINS may be responsible for the better improvement achieved in the combined treatment group.

Moreover, in analyzing our data, it was observed that the participants' body mass indices (BMIs) ranged from the normal weight to overweight, with the combined

treatment group having the highest mean BMI. Despite having a higher mean BMI, the combined treatment group showed better improvement (in all outcomes) than the individual manual therapy groups, indicating that this improvement may be attributed to the combined therapies (SMWLM + PINS) administered in this group. This finding corroborates with those of Vismara et al. [45], who reported greater improvement in biomechanical parameters of the thoracic spine in obese patients with chronic low back pain managed with osteopathic manipulative treatment (OMT) than those treated with specific exercises. Similar findings were also reported by Licciardone et al. [46], who indicated that the OMT effects for LBP intensity and back-specific functioning were independent of baseline patient demographic characteristics, comorbid medical conditions, and medication use.

Although therapeutic exercises were incorporated along with the manual therapy techniques in our study, we found that these exercises cannot be used as sole treatments for individuals suffering from lumbar radiculopathy secondary to disc herniation [47–49]. However, given the significance of a well-trained core in the for back stability, it is conceivable that these exercises may be used as adjunct therapies [50, 51]. Additionally, it is also worthy of note that the long-term improvement achieved in our study may be attributed to the combined effects of both manual and exercise therapies.

Limitations

This study was limited to individuals with unilateral lumbar radiculopathy and data was collected in only one clinical setting. Additionally, this study did not also assess psychosocial variables that may be associated with chronic and persistent conditions like lumbar radiculopathy secondary to disc herniation. Further, it might have also been useful to use a 4th group as a control, which could have allowed us to monitor the natural evolution of the disease and pain. Future studies should be conducted to address these issues.

Clinical relevance to osteopathic medicine

Osteopathic manipulative treatment (OMT) is a set of hands-on techniques used by osteopathic physicians (DOs) to diagnose, treat, and prevent illness or injury. OMT is performed by a DO; while manipulative therapy in our study was not performed by a DO, similarities may be appreciated. Our study demonstrated the therapeutic efficacy of using PINS as an indirect OMT in the management of LDHR. The application of PINS involves the palpation of myofascial trigger

points (TrPs) along a neuromuscular structure and then applying ischemic compression to progressively deactivate those TrPs. PINS technique is very similar to other indirect OMTs such as strain-counter strain (SCS) or positional release therapy (PRT), only TrPs are progressively deactivated along a neuromuscular continuum in the PINS technique. It is therefore recommended that osteopaths and other highly informed healthcare professionals may consider the use of PINS either as a sole or an complementary treatment in the management of patients with lumbar radiculopathy secondary to disc herniation.

Conclusions

Our results showed that combined SMWLM and PINS therapy along with a structured home exercise program was better than the individual techniques alone in the management of individuals with lumbar radiculopathy secondary to disc herniation.

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Competing interests: Authors state no conflict of interest.

Informed consent: Written informed consent was obtained from the participants and they were assured of their rights to withdraw from the study at any point in time and their full anonymity was maintained.

Ethical approval: Ethical approval to conduct this study was obtained from the Health Research Ethics Committee of the Federal Medical Centre (FMC), Nguru, Yobe State, Nigeria (Registration number: FMC/N/CL.SERV/355/VOL.IV/139). The trial was registered with the Pan African Clinical Trial Registry (PACTR201907782710996) on July 11, 2019.

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