Bulletin of Faculty of Physical Therapy

ORIGINAL RESEARCH ARTICLE Open Access

Effectiveness of telerehabilitation-based mckenzie method versus manual therapy in low-back pain management: a randomised controlled trial

Chidozie Mbada[1], Oluwasegun Oladele Olanipekun[2], Adekola Ademoyegun[3,4*], Michael Ogbonnaya Egwu[4], Moses Makinde[5], Tadesse Gebrye[1], Oluwatobi Ademola Sonuga[6] and Francis Fatoye[1]

Abstract

Background Studies comparing the effectiveness of telerehabilitation and spinal manual therapy (SMT) for chronic non-specific low-back pain (NSLBP) are limited. This study aimed to compare the efficacy of the telerehabilitation-based McKenzie therapy (TBMT) and SMT among patients with NSLBP.

Methods Forty-nine consenting patients randomised into either TBMT ($n=28$) or SMT ($n=21$) group completed the study. TBMT is a mobile phone-based telerehabilitation involving the 'McKenzie extension protocol'. SMT is a grade II (10 oscillations) posterior-anterior central vertebral pressure on the offending spinous process. Both interventions were applied thrice weekly for eight weeks, and outcomes were assessed on Pain Intensity (PI), Activity Limitation (AL), Participation Restriction (PR), and Health-related Quality of Life (HRQoL) in the fourth and eighth weeks.

Results Within-group comparison across baseline, 4th and 8th week indicate that SMT had a significant effect on PI ($F=132.804$, $p=0.001$), AL ($F=75.984$, $p=0.001$), PR ($F=99.428$, $p=0.001$) and for all the scales of SF-12 except for mental health domain ($p>0.05$). Similarly, TBMT had a significant effect on PI ($F=243.631$; $p=0.001$), AL ($F=85.930$; $p=0.001$), PR ($F=48.425$; $p=0.001$), and for all the scales except also for mental health domain ($p>0.05$). However, there were no significant differences ($p>0.05$) in the treatment effects between SMT and TBMT, except for the 'health perception' ($p=0.045$) scale at week four and the 'mental health' scale ($p=0.023$) at week eight.

Conclusion Telerehabilitation-based McKenzie method and SMT are effective in chronic NSLBP, with TBMT leading to significantly higher long-term health perception improvement.

Trial Registration Pan African Clinical Trial Registry (PACTR202010667228786), Registered 27 October 2020-Retrospectively registered.

Keywords McKenzie method, Spinal manual therapy, Vertical oscillatory pressure, Low-back pain, Telerehabilitation

*Correspondence:
Adekola Ademoyegun
aademoyegun@gmail.com
Full list of author information is available at the end of the article

Introduction

Low-back pain (LBP) is a common musculoskeletal disorder that is caused by abnormalities or impairment in the anatomical structure and function of the back, and it leads to significant disability that can affect daily activities and work [1]. As a result, LBP is a common reason for medical consultations, affecting people of all ages, genders, contexts, and regions without discrimination [2, 3]. The 2021 Global Burden of Disease Study reported that LBP is the leading cause of years lived with disability worldwide [4]. According to epidemiological reports, approximately 80% of individuals will experience LBP at some point in their lives [5]. Most LBP cases are non-specific, meaning they have an unknown cause or no identifiable pathology [6]. Only a small percentage of cases (5%-10%) have a specific cause [6]. In more than 50% of affected individuals, LBP becomes chronic, lasting more than 12 weeks, and is less amenable to therapeutic intervention [6].

Physiotherapy is a common and effective conservative management for LBP [7]. Of the different approaches in physiotherapy armamentaria for chronic LBP; exercise is the primary intervention in non-specific LBP (NSLBP) [8]. In addition, manual therapy (MT) approaches such as Maitland's posterior-anterior vertebral mobilizations [9], and its oscillation-based variant, called the Nwugarian technique (vertical oscillatory pressure (VOP)—a vertical manipulative thrust on the spinous process; and transverse oscillatory pressure (TOP)—manipulative thrust on the transverse processfor unilaterally distributed symptoms [10, 11] have been reported to be beneficial in terms of reduction in pain and disability, and improvement in function and quality of life. Other specific therapies, such as McKenzie therapy, are also effective in managing chronic LBP symptoms [12]. However, there is still no consensus on which approach is better [13].

There is a disagreement over whether MT or other specific therapies like McKenzie therapy are more effective in reducing pain and promoting functional outcomes for patients with NSLBP [14]. Rubinstein et al. [14] suggest that there is little clinical difference between MT and McKenzie therapy in treating patients with chronic LBP. The results showed that MT was no better or worse than other therapies, except for differences in patient and provider preferences. A systematic review compared MT with McKenzie method of managing chronic LBP. From the results, both MT and the McKenzie method were found to be effective. However, McKenzie method was found to have a superior effect in reducing pain in the short term and decreasing disability measures in the long term [15]. On the other hand, Paatelmaet al. [16] found no differences between MT and McKenzie therapy in terms of pain and disability at any follow-up period (3, 6, and 12 months). Manual therapy practice can be a challenging technique for clinicians who have physical limitations or small stature. Additionally, it requires more training, carries a higher risk of patient injury, and necessitates more one-on-one care, which may increase the cost and safety concerns [17]. Likewise, the potential limitations of providing access to effective treatment using the McKenzie method by clinicians certified in the technique are a matter of concern. In instances where certified clinicians are limited, as well as the strong association between obtaining positive patient outcomes and certification in the McKenzie method could prove a hindrance or compromise optimal patient care [17, 18]. Thus, advancements in technology, now provide new platforms and paradigms to offer self-care using specific therapies like the McKenzie therapy for patients with LBP [19]. Specifically, telerehabilitation presents a promising solution to bridge the gap in service delivery, particularly in areas lacking physiotherapy services [20]. According to a study conducted by Mbada et al. [19], the mobile-application platform of McKenzie therapy has shown comparable clinical outcomes to in-person care using McKenzie therapy, with lower cost estimates. However, studies investigating the effectiveness of telerehabilitation-based versus clinic-based interventions for NSLBP are still limited [21]. Therefore, this study aimed to compare the efficacy of telerehabilitation-based McKenzie therapy (TBMT) and spinal manual therapy (SMT) in managing patients with chronic NSLBP.

Materials and methods

Participants

Patients with chronic NSLBP attending the Out-patient Physiotherapy Department of Obafemi Awolowo University Teaching Hospitals Complex, Ile-Ife, Nigeria were consecutively recruited into this randomised controlled trial. The trial was registered with the Pan African Clinical Trial Registry (Identification number: PACTR202010667228786). Patients who were diagnosed with NSLBP for at least three months, and who did not have any apparent deformities in their trunk or upper and lower limbs were included in this study. Patients with a directional preference for extension based on the McKenzie Institute's Lumbar Spine Assessment Algorithm (MILSAA) were also eligible for the study. MILSAA is a diagnostic checklist developed by the McKenzie Institute International to classify patients and assign them to specific movement patterns that alleviate their symptoms based on clinically induced directional preference. However, patients with a recent history of spinal surgery within the past year, red flags (e.g., spinal tumors, infections, fractures, or cauda equina syndrome), yellow flags (such as depression, neurological problems, etc.),

and those with a gravid uterus were excluded from the study.

To calculate the required sample size for this study, a formula by Chan [22]—$c \times \pi 1\ (1- \pi 1) + \pi 2(1-\pi 2)/(\pi 1 - \pi 2)$ was used. Where $C = 7.9$ for 80% power; $\pi 1$ and $\pi 2$ are proportion estimates, $\pi 1 = 0.25$ and $\pi 2 = 0.65$. Accordingly, $n = 7.9 \times (0.25\ (1 - 0.25) + 0.65\ (1 - 0.65)/(0.25 - 0.65) = 20.49 \approx 21$ per group. To account for attrition and loss to follow-up, 10% of 42 was estimated and added for this study. Therefore, an estimated sample of 46 patients was proposed for this study. Figure 1 shows the CONSORT diagram of the flow of participants through the study.

Procedure

Participants were recruited consecutively but assigned randomly to two treatment groups until they all completed the eight-week treatment programme. To introduce blinding and eliminate bias, a research assistant meticulously recorded data on the number of patients invited to participate, those who declined, and those who were deemed ineligible due to the set inclusion criteria. Only those who met the eligibility requirements and voluntarily agreed to participate were then randomly assigned to either treatment group A or B by the same assistant, who had no involvement in the treatment process. To ensure equal-sized treatment groups, the permutedblock technique [23],involving a block size of 4 was used. The random block permutations were computer-generated using a factorial equation formula: (4!) / (2!) (2!) = 24. The printouts of all 24 permutation sequences-generated were sequentially numbered, cut, and placed in sealed envelopes (e.g., the permutations include AABB, ABAB, BABA, ABBA, etc.). Accordingly, participants were randomised to either the TBMT or SMT group based on every permuted sequence that was randomly drawn from the envelope, and this process was repeated as participants were recruited (Fig. 2).

Pre-Treatment Screening

Before enrolling participants in this study, a baseline assessment was conducted. Height and weight of the participants were measured, and they were screened based on the inclusion and exclusion criteria that had previously been specified. Socio-demographic (age, sex, occupation,education level, marital status), clinical

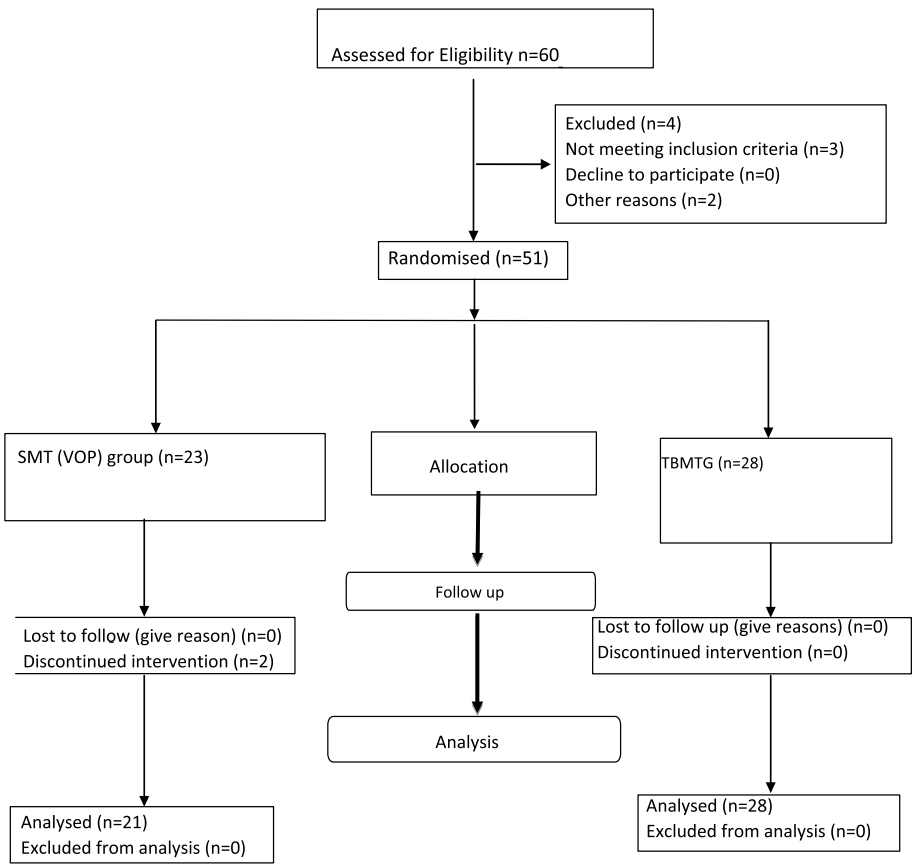

Fig. 1 Consort diagram of flow of participants through the study

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	2
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	4
	2b	Specific objectives or hypotheses	6
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	7
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	Nil
Participants	4a	Eligibility criteria for participants	6
	4b	Settings and locations where the data were collected	6
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	9
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	10
	6b	Any changes to trial outcomes after the trial commenced, with reasons	Nil
Sample size	7a	How sample size was determined	6
	7b	When applicable, explanation of any interim analyses and stopping guidelines	Nil
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	7
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	7
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	7
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	7
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	7
	11b	If relevant, description of the similarity of interventions	8
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	10
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	10
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	7, 30
	13b	For each group, losses and exclusions after randomisation,together with reasons	30
Recruitment	14a	Dates defining the periods of recruitment and follow-up	10
	14b	Why the trial ended or was stopped	10
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	23, 24
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	11
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	11
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	Nil
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	Nil
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	Nil
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	17
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	17
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	17
Other information			
Registration	23	Registration number and name of trial registry	6
Protocol	24	Where the full trial protocol can be accessed, if available	Nil
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	Nil

Fig. 2 CONSORT 2010 checklist of information to include when reporting a randomised trial

profile (onset of back pain, recurrence, duration of complaint), and any information on previous interventionsfor the current complaints were also obtained. Participants were included in this study based on their eligibility according to the MILSAA algorithm. This algorithm provides a clear and straightforward classification of spinal-related disorders, based on the cause-and-effect relationship between a patient's historical pain behaviour and pain response during the assessment process. This relationship is evaluated through repeated test movements, positions, and activities.

During the assessment, the participants were examined for their directional preference. Directional preference involves repeated movements in both standing and lying positions, in sagittal and frontal planes, while assessing the participants' symptomatic and mechanical responses. After the repeated movement testing, participants returned to the same standing position. They were asked if their pain was centralizing or peripheralizing during and after movements or if there was no effect, following standardized instructions in the MILSAA. The mechanical response of the participants to repeated movements was used to determine their directional preference. Those who showed flexion, lateral, or no response to repeated movements were excluded from the study. Only those who responded with an extension in the MILSAA assessment were eligible for this study and were randomised into both groups.

Eligible participants were requested to undertake a series of outcome measures prior to participating in the interventions. These measures consisted of the Quadruple Visual Analogue Scale (QVAS), Roland Morris Low-Back Pain Disability Questionnaire (RMLDQ), Oswestry Disability Index (ODI), and SF-12 General Health Status Questionnaire (SF-12). Participants were required to complete these measures for each intervention at the baseline, fourth week, and eighth week of the study.

Telerehabilitation-Based McKenzie Therapy

The TBMT group received a mobile phone-based application of the Mechanical diagnosis and therapy (MDT) described by Mbada et al. [24]. The MDT App was designed to combine the McKenzie extension protocols and back care education. It offers personalised and guided self-therapy using the same protocol in the McKenzie Protocol, which includes 'extension lying prone', 'extension in prone', and 'extension in standing'. A detail of this intervention has been reported in an earlier publication [25]. Performance feedback and progress tracking are tele-monitored through enhanced caregiver support via telephone calls and SMS.

Spinal Manual Therapy

A posterior-anterior unilateral pressureSMT approach, labelled as vertical oscillatory pressure (VOP) was performed, as described by Nwuga [26]and Egwuet al.[11]. In the VOP procedure, the participant was lying in a prone position. The practitioner placed their thumb on the identified spinous process of the vertebra of the spine. The practitioner uses three fingers to palpate between the spinous processes: one above, one on, and one below the spinous process. Then, a grade II joint mobilisation (digital pressure) with oscillation applied using the thumbs adjacent to one anotheras described by Snodgrass et al. [27] was implemented. Grade II joint mobilization involves performing a large amplitude movement within the free range without moving into any resistance or stiffness. The oscillation procedure was repeated 10 times with a 6-s interval between each oscillation, totalling 60 s. After 20 s of rest, this procedure was repeated, and cryotherapy was applied to the area where digital pressure was applied. The practitioner used a stopwatch to time the oscillatory and rest durations. This procedure was performed three times per week for eight weeks by the same practitioner. Also, the VOP group received the same back care education instructions as home programme [25].

Post-Treatment Assessment

Two more assessments were carried out after conducting the baseline assessment of all participants upon inclusion into the study. These re-assessments were scheduled for the 4th and 8th week after the participants entered the study. During these sessions, the participants answered all the outcome measure questionnaires. After the study ended, the patients who participated were followed up for approximately a month to determine the sustained efficacy and safety outcomes.

Health Research Ethical Committee of the Institute of Public Health, Obafemi Awolowo University, Ile-Ife, Nigeriagave ethical approval for this study (IPHOAU/12/1046). The purpose of the research was explained to the individual consenting participants. A written informed consent form, which was available in both English and Yoruba (the local language in the study setting) languages, was used in the recruitment for the study.

Statistical Analysis

Descriptive statistics of mean and standard deviation, and percentageswere used to summarize the data. Independent Chi-square and t-test were used to compare baseline general and clinical variables. Repeated Measure ANOVA was used for within-group comparison of the

effects of the different treatment regimens across baseline, 4th, and 8th weeks of intervention. Independent t-test was employed to compare between-group mean changes at 4th and 8th week of intervention. Alpha level was set at 0.05. The data analysis was carried out using SPSS 16.0 version software (SPSS Inc, Chicago, Illinois, USA).

Results

The mean age, weight, height, and body mass index (BMI) of all participants were 45.8 ± 10.4 years, 76.6 ± 12.7 kg, 1.66 ± 0.07 m, and 27.8 ± 4.06 kg/m^2, respectively. Most of the participants in both groups were females (SMT = 71.4%; TBMT = 64.3%), and those in the public service occupation category (SMT = 52.4%; TBMT = 53.6%). The mean duration of LBP was 10.0 ± 2.73 months. From the result, participants in the two groups were comparable in their general characteristics, except in weight and BMI (Table 1). Table 2 shows the comparison of baseline measures between groups. From the result, pain intensity, activity limitation, participation restriction, and HRQoL measures were comparable ($p > 0.05$). The outcome parameters of participants in both groups were compared across the baseline, fourth, and eighth weeks of the study, as presented in Tables 3 and 4. Significant differences ($p < 0.05$) were observed in the outcome parameters across the 3-time points of the study, except for the mental health domain (MHD) with a p-value of 0.158 for SMT (Table 3) and p-value of 0.167 for TBMT (Table 4) on SF-12. No significant differences ($p > 0.05$) were observed in the treatment outcome (mean change) between the two groups at the end of the 4th week of the study (i.e., the difference between week four outcomes and baseline) except for item HP on the SF-12 where the SMT had a significantly higher mean ($p = 0.045$) (Table 5). No significant differences ($p > 0.05$) were observed in the treatment outcome (mean change) across the two groups at the end of the 8th week of the study (i.e., the difference between week eight outcomes and baseline), except for item MH on the SF-12 where the SMT had a significantly higher mean ($p = 0.023$) (Table 6).

Table 1 Comparison of the participants' general characteristics by treatment groups ($N = 49$)

Variable	SMT ($n = 21$)	TBMT ($n = 28$)		
	n(%)	*n*(%)	χ^2/t	*p*-value
Gender				
Male	6(28.6%)	10(35.7%)	0.278[a]	0.598
Female	15(71.4%)	18(64.3%)		
Age Group (yrs), n(%)				
Less than 40	8(1.68)	7(1.96)	3.096[a]	0.377
40–50	6(1.26)	7(1.96)		
51–60	7(1.47)	11(3.08)		
Greater than 60	0(0)	3 (0.84)		
Occupation, n(%)				
Artisan	5(23.8%)	5(17.9%)	15.694[a]	0.266
Trading	5(23.8%)	5(17.9%)		
Civil servant	11(52.4%)	15(53.6%)		
Student	0(0.00%)	2(7.1%)		
Farmers	0(0.00%)	1(3.6%)		
	$\bar{x}$±SD	$\bar{x}$±SD		
Age (yrs)	43.4 ± 8.2	47.6 ± 11.5	-1.422[b]	0.162
Weight (Kg)	72.2 ± 7.3	79.9 ± 14.9	-2.169[b]	0.035*
Height (m)	1.66 ± 0.09	1.66 ± 0.06	-0.209[b]	0.836
BMI (Kg/m^2)	26.4 ± 3.58	28.8 ± 4.17	-2.061[b]	0.045*
Pain duration (month)	9.71 ± 2.90	10.3 ± 2.62	-0.672[b]	0.502

Key: % Percentage, *SMT* Spinal Manual Therapy, *TBMTG* Telerehabilitation-Based McKenzie Therapy Group, [a]Chi-square test statistics, [b] t-test, * significant difference

Discussion

This study aimed to compare the efficacy of TBMT and SMT in managing patients with chronic NSLBP. The patients who took part in this study were mostly working-class adults in the middle-age category (45.8 ± 10.4 years). The patients in this study was within the age bracket in which LBP was confirmed to be preponderant. LBP is reported to be common between the ages of 30 and 50 years and becomes more common with advancing age [28].Also, some studies have confirmed that LBP is common among working-class middle-aged people [28], and coincidentally, most of the patients in this study were public workers.

The patients in this study had long-standing pain of about 10 months. Chronicity of LBP leads to persistent and debilitating symptoms, affecting both the physical and psychological aspects of the patient [29, 30]. Physiological impacts of non-specific LBP include pain, reduced range of motion, muscle strength, and endurance [29, 30]. Additionally, chronic LBP can lead to psychosocial consequences such as negative attitudes, pain beliefs, and changes in mood state [29, 31].

A randomised controlled trial was carried out to establish the relative efficacy of SMT and TBMT on PI, AL, PR, and HRQoL among the patients in this study. Both groups of patients had comparable values for baseline measures of PI, AL, PR, and HRQoL. It is believed that baseline characteristics are important predictors/moderators of treatment outcomes in clinical trials for LBP [32]. Comparability in baseline measures in clinical trials helps to reduce the chances of co-founders other than the intervention in predicting outcomes, so that any outcomes can be attributed to the intervention and not

Table 2 Comparison of the participants' baseline parameters ($N=49$)

Variable	SMT ($n=21$)	TBMT ($n=28$)		
	$\bar{x} \pm SD$	$\bar{x} \pm SD$	t	*p*-value
Pain intensity (QVAS)				
Current	5.19 ± 2.36	4.71 ± 1.61	0.841	0.405
Average	5.67 ± 1.59	5.18 ± 1.22	1.217	0.230
Least	2.48 ± 1.29	3.00 ± 1.68	-1.190	0.240
Worst	7.19 ± 1.47	7.21 ± 1.23	-0.062	0.951
QVAS score	60.16 ± 15.58	57.02 ± 11.70	0.805	0.425
Activity limitation (RMDQ)	12.62 ± 5.35	11.89 ± 5.35	0.470	0.640
Participation restriction (OLBPS)	22.98 ± 9.83	21.79 ± 8.60	0.424	0.673
HRQoL (SF-12)				
Scale -				
PF	26.98 ± 23.26	30.36 ± 25.68	-0.473	0.553
RL	93.33 ± 14.08	95.00 ± 12.47	-0.438	0.388
BP	60.00 ± 23.13	65.00 ± 20.82	-0.793	0.579
HP	34.29 ± 26.47	40.89 ± 19.25	-1.012	0.201
EF	42.86 ± 21.25	52.14 ± 22.67	-1.457	0.362
SF	92.86 ± 11.57	86.61 ± 12.70	1.770	0.024
RL	93.33 ± 14.08	90.00 ± 16.10	0.756	0.124
MH	54.60 ± 14.85	59.85 ± 12.55	-1.337	0.129
Domain –				
MHD	70.91 ± 8.61	72.15 ± 4.72	-0.643	0.029
PHD	53.65 ± 13.92	57.81 ± 9.00	-1.270	0.022

Key: $\bar{x}$ = Mean, *SD* Standard Deviation, *QVAS* Quadruple Visual Analogue Scale, *RMDQ* Roland Morris Disability Questionnaire, *OLBPS* Oswestry Low-Back Pain Scale, *HRQoL* Health-Related Quality of Life, *HP* Health perception, *PF* Physical function, *RP* Role Limitation –physical, *RE* Role limitation – emotional, *SF* Social functioning, *MH* Mental health, *BP* Bodily pain, *EF* Energy fatigue, *MHD* Mental health domain, *PHD* Physical health domain

to other factors. However, Friedman et al.[33] submitted that for some measurements, the baseline data may not accurately reflect the patient's actual condition at the time of baseline, as the baseline assessment is usually performed close to the time of intervention. Therefore, it is possible that the results obtained at different stages of the study could have been mainly due to the effects of the various treatment regimens.

Findings on within-group comparison of the effect of SMT across the three-time points of the study revealed that it was an effective intervention, as it had significant effects on the PI, AL, PR, and HRQoL. These findings are comparable to previous results that showed evidence for the effectiveness of VOP as an SMT in LBP [34–36]. Since the evolution of VOP by its progenitor, Prof V.C.B. Nwuga, there have been efforts at generating evidence for its effectiveness. Nwuga, in 1982 found that spinal mobilization has an analgesic effect on LBP. In another study conducted by Nwuga [36], it was found that SMT, particularly the VOP, stimulates the afferent fibre connected to the large diameter nerves to produce neuro-physiological effects that relieve pain in patients with LBP. Other researchers, including Egwu et al. [11], have also reported that VOP is effective in reducing pain intensity and restoring spinal mobility in both youths and elders with degenerative restrictions. Also, Ojoawo et al. [37] found that VOP can significantly improve pain and disability in patients with chronic LBP. Based on these studies, it can be concluded that VOP is an effective treatment option for chronic LBP, improving pain, disability, and HRQoL in patients with chronic LBP.

Similar to the preceding, a within-group comparison of the effect of TBMT across the three-time points of the study indicates that the intervention had significant effects on the PI, AL, PR, and HRQoL. This finding is consistent with an earlier report by Mbada et al. [19] where telerehabilitation application of the McKenzie therapy was found effective in managing patients with chronic NSLBP. While there is an apparent paucity of studies on the telerehabilitation application of the McKenzie principle, however, explanations of how the traditional McKenzie method achieves its therapeutic goals may be extrapolated to the finding of this study. Studies are replete on the effectiveness of McKenzie therapy on LBP outcomes [15, 38]. The therapeutic effects of the McKenzie protocol depend largely on patients'

Table 3 Comparisons of treatment outcomes among participants in spinal manual therapy group across the three time points of the study($n=21$)

	Baseline $\bar{x} \pm SD$	4th week $\bar{x} \pm SD$	8th week $\bar{x} \pm SD$	F-ratio	p-value
Pain intensity					
Current	5.19 ± 2.36^{a}	3.33 ± 0.91^{b}	1.43 ± 1.33^{c}	55.133	0.001*
Average	5.67 ± 1.59^{a}	3.62 ± 1.28^{b}	1.76 ± 0.89^{c}	119.009	0.001*
Least	2.48 ± 1.29^{a}	0.90 ± 1.09^{b}	0.43 ± 0.68^{c}	56.892	0.001*
Worst	7.19 ± 1.47^{a}	5.05 ± 0.67^{b}	3.24 ± 1.04^{c}	139.736	0.001*
QVAS score	60.2 ± 15.6^{a}	40.0 ± 8.03^{b}	21.4 ± 9.81^{c}	132.804	0.001*
Activity limitation	12.6 ± 5.35^{a}	6.48 ± 3.23^{b}	2.19 ± 1.57^{c}	75.984	0.001*
Participation restriction	21.78 ± 8.59^{a}	10.21 ± 5.39^{b}	5.78 ± 3.11^{c}	99.428	0.001*
HRQoL (SF-12)					
Scales -					
PF	26.98 ± 23.25^{a}	53.97 ± 18.19^{b}	62.70 ± 17.40^{c}	25.621	0.001*
RP	93.33 ± 14.08^{a}	81.67 ± 17.91^{b}	88.33 ± 16.91^{a}	6.732	0.003*
BP	60.00 ± 23.13^{a}	80.95 ± 14.10^{b}	81.43 ± 15.66^{c}	13.557	0.001*
HP	34.29 ± 26.47^{a}	59.76 ± 27.54^{b}	76.90 ± 14.27^{c}	21.951	0.001*
EF	42.86 ± 21.25^{a}	69.52 ± 14.99^{b}	80.00 ± 25.30^{c}	19.503	0.001*
SF	92.86 ± 11.57^{a}	82.14 ± 11.57^{b}	77.38 ± 7.52^{c}	19.001	0.001*
RL	93.33 ± 14.08^{a}	73.33 ± 15.26^{b}	70.00 ± 12.55^{c}	24.060	0.001*
MH	54.60 ± 14.85^{a}	63.18 ± 5.42^{b}	72.06 ± 4.99^{c}	22.064	0.001*
Domain					
MHD	70.91 ± 8.61^{a}	72.04 ± 7.94^{a}	74.86 ± 7.77^{a}	1.912	0.158
PHD	53.65 ± 13.91^{a}	69.09 ± 9.63^{b}	77.34 ± 9.31^{c}	32.032	0.001*

*Superscripts (^{a,b,c}).*For a particular variable, mean values with different superscript are significantly ($p < 0.05$) different. Mean values with same superscripts are not significantly ($p > 0.05$) different. The pair of cell means that is significant has different superscripts.*Significant difference; *QVAS* Quadruple Visual Analogue Scale, *RMDQ* Roland Morris Disability Questionnaire, *OLBPS* Oswestry Low-Back Pain Scale, *HRQoL* Health-Related Quality of Life, *HP* Health perception, *PF* Physical function, *RP* Role Limitation –physical, *RE* Role limitation – emotional, *SF* Social functioning, *MH* Mental health, *BP* Bodily pain, *EF* Energy fatigue, *MHD* Mental health domain, *PHD* Physical health domain

differences and pathologic conditions, such as the type of McKenzie syndrome [39]. For instance, in derangement syndrome, spinal flexion can cause the nucleus pulposus to move towards the back due to increased compression on the front surface of the intervertebral disc [39]. As a result, extension in derangement syndrome is proposed to lessen stress on the posterior annulus, reduce nerve root compression, and relieve pain [39]. During extension exercise, nuclear pressure is reduced when the compressive force is transferred from the vertebral disc body unit to the apophyseal joints [40]. Additionally, according to Adams et al. [41], the neural arch in extended postures can stress-shield the posterior annulus, and this may explain why extension exercises can relieve lower back pain in some patients.

Furthermore, previous studies indicate that extension movements lead to the anterior migration of nuclear tissue, whereas posterior migration occurs during flexion [40, 42]. Therefore, it is suggested that the success of the McKenzie method's extension principle may be related to the exercises' capacity to reduce posterior protrusions in some intervertebral discs and have an effect on internal displacements [43]. Alternatively, extension movements can help alleviate pain by reducing the forces that act on the pain-sensitive tissues [41]. This is because, during the extension manoeuvre, the spinal vertebrae can hinge around the facet joints, thereby unloading the entire disc [41]. In addition, extension movements within the disc itself can transfer the load from the anterior annulus and nucleus to the posterior annulus [44]. This effect is magnified after creep-loading. Some studies have shown that sustained and repeated extension movements can increase the height of the spine, possibly by unloading the disc and allowing it to rehydrate [45]. In sum, irrespective of the mode of delivery of the McKenzie protocol, it seems to have a significant effect in terms of all the treatment outcomes [46].

The finding of this study shows that both the SMT and TBMT groups were comparable in their effects on LBP outcomes in the short term. There were no significant differences in the mean change values at the end of the 4th week of the study (i.e., the difference between week four outcomes and baseline), except for HP on the SF-12, where the TBMT group had a significantly

Table 4 Comparisons of treatment outcomes among participants in telerehabilitation-based McKenzie therapy group across the 3 time points of the study ($n = 28$)

	Baseline x̄ ± SD	4th week x̄ ± SD	8th wee ± SD	F-ratio	*p*-value
Pain intensity					
Current	4.71 ± 1.61[a]	2.93 ± 1.15[b]	0.75 ± 0.70[c]	136.619	0.001*
Average	5.18 ± 1.22[a]	3.25 ± 0.75[b]	1.04 ± 1.07[c]	198.314	0.001*
Least	3.00 ± 1.68[a]	0.54 ± 0.84[b]	0.04 ± 0.19[c]	84.126	0.001*
Worst	7.21 ± 1.23[a]	4.25 ± 1.69[b]	2.50 ± 1.32[c]	248.127	0.001*
QVAS score	57.0 ± 11.7[a]	34.8 ± 7.56[b]	14.3 ± 8.97[c]	243.631	0.001*
Activity limitation	11.9 ± 5.35[a]	5.14 ± 3.10[b]	2.75 ± 2.63[c]	85.930	0.001*
Participation restriction	21.79 ± 8.60[a]	10.21 ± 5.39[b]	5.79 ± 3.12[c]	48.425	0.001*
HRQoL (SF-12)					
Scales -					
PF	30.36 ± 25.68[a]	63.10 ± 18.90	75.00 ± 15.383[c]	46.721	0.001*
RP	95.00 ± 12.47[a]	78.75 ± 17.41[b]	90.00 ± 16.10[a]	11.401	0.001*
BP	65.00 ± 20.82[a]	77.14 ± 20.79[b]	88.57 ± 12.08[c]	20.201	0.001*
HP	40.89 ± 19.25[a]	82.32 ± 16.86[b]	82.85 ± 15.48[a]	66.102	0.001*
EF	52.14 ± 22.67[a]	84.2919.13[b]	86.4320.41[c]	31.440	0.001*
SF	86.61 ± 12.70[a]	75.89 ± 4.73[b]	75.00 ± 0.00[b]	20.481	0.001*
RL	90.00 ± 16.10[a]	65.00 ± 0.000[b]	66.25 ± 6.61[b]	57.463	0.001*
MH	59.85 ± 12.55[a]	68.57 ± 6.75[b]	70.00 ± 4.63[b]	11.341	0.001*
Domain					
MHD	72.15 ± 4.72[a]	73.445.28[a]	74.42 ± 4.32[a]	1.911	0.167
PHD	57.81 ± 8.99[a]	`75.33 ± 9.01[b]	84.12 ± 8.84[c]	84.497	0.001*

Superscripts ([a,b,c]).For a particular variable, mean values with different superscript are significantly ($p < 0.05$) different. Mean values with same superscripts are not significantly ($p > 0.05$) different. The pair of cell means that is significant has different superscripts.*Significant difference; *QVAS* Quadruple Visual Analogue Scale, *RMDQ* Roland Morris Disability Questionnaire, *OLBPS* Oswestry Low-Back Pain Scale, *HRQoL* Health-Related Quality of Life, *HP* Health perception, *PF* Physical function, *RP* Role Limitation –physical, *RE* Role limitation – emotional, *SF* Social functioning, *MH* Mental health, *BP* Bodily pain, *EF* Energy fatigue, *MHD* Mental health domain, *PHD* Physical health domain

higher mean. Similarly, there were no significant differences in the treatment outcome (mean change) between both groups at the end of the 8th week of the study (i.e., the difference between week eight outcomes and baseline), except for item MH on the SF-12 where the SMT group had significantly higher effect. There is lack of studies comparing any form of SMT with telerehabilitation interventions in LBP. However, some earlier studies have compared SMT and other forms of physiotherapy interventions, among which is electrotherapy. Akhtar et al. [47] established that MT is a more helpful therapeutic approach in the conservative management of long-standing LBP as compared to the more traditionally practiced electrotherapeutic modalities. The main finding was that MT is a superior treatment approach for managing patient's condition. Moreover, it was found that MT helps in improvements in pain intensity and activities of daily living, including sitting, lifting, standing, walking, personal care, sleeping, sexual life, social life, and travelling in a much better way in patients with chronic LBP as compared to electrotherapy [47].

It is also common in the literature for researchers to compare different forms of SMT techniques [48]. Largely, the trend of results indicated that most techniques are comparable in their effects on different LBP outcomes [49]. In other studies, MT has been shown to have immediate effects in reducing pain, regardless of whether a randomly assigned or therapist-selected technique was used [50]. In contrast, Aureet al.[51] compared groups receiving either MT or exercise therapy, and found significantly greater improvements in the MT group, although both groups showed improvements. In the study setting, the most common MT of choice is VOP. Preference for the type of SMT often employed in clinical settings and research is often based on available reports of efficacy and also competency. Nonetheless, common concerns about the implementation or use of SMT for LBP are bothered by the lack of skills in the technique and the shortage of faculties, especially in rural areas [19]. These concerns call for alternative and innovative approaches to ameliorating the menace of LBP.

Telerehabilitation, which encompasses the use of smartphones, telemonitoring and remote monitoring

Table 5 Comparison of the participants' treatment outcomes (mean change) at week four of the study ($N=49$)

	SMT ($n=21$)	TBMT ($n=28$)		
	$\bar{x} \pm SD$	$\bar{x} \pm SD$	t	*p*-value
Pain intensity (QVAS)				
Current	1.86 ± 1.65	1.79 ± 0.99	0.188	0.852
Average	2.05 ± 1.69	1.93 ± 0.90	0.318	0.752
Least	1.57 ± 0.93	2.46 ± 1.95	-1.935	0.059
Worst	2.14 ± 1.42	2.96 ± 1.93	-1.640	0.108
QVAS score	20.2 ± 12.80	22.3 ± 10.90	-0.618	0.539
Activity limitation (RMDQ)	6.14 ± 4.36	6.75 ± 5.73	-0.405	0.687
Participation restriction (OLBPS)	8.81 ± 6.49	11.5 ± 7.08	-1.399	0.168
HRQoL (SF-12)				
PF	26.9 ± 23.3	39.3 ± 31.5	-1.507	0.139
RP	11.7 ± 16.9	15.0 ± 17.6	0.666	0.508
BP	20.9 ± 20.8	14.1 ± 20.1	1.159	0.252
HP	25.4 ± 35.5	43.0 ± 24.2	-2.058	0.045
EF	26.7 ± 20.3	35.7 ± 26.3	1.309	0.197
SF	10.7 ± 12.7	10.7 ± 12.5	0.000	1.000
RL	20.0 ± 17.7	27.5 ± 14.6	1.621	0.112
MH	8.57 ± 13.8	7.05 ± 13.8	0.378	0.707
Domain				
MHD	1.13 ± 7.33	1.28 ± 6.51	-0.080	0.937
PHD	15.4 ± 12.1	17.5 ± 12.6	-0.578	0.566

* Significant difference; *QVAS* Quadruple Visual Analogue Scale, *RMDQ* Roland Morris Disability Questionnaire, *OLBPS* Oswestry Low-Back Pain Scale, *HRQoL* Health-Related Quality of Life, *HP* Health perception, *PF* Physical function, *RP* Role Limitation –physical, *RE* Role limitation – emotional, *SF* Social functioning, *MH* Mental health, *BP* Bodily pain, *EF* Energy fatigue, *MHD* Mental health domain, *PHD* Physical health domain

Table 6 Comparison of the participants' treatment outcomes (mean change) at week eight of the study ($N=49$)

	SMT ($n=21$)	TBMT ($n=28$)		
	$\bar{x} \pm SD$	$\bar{x} \pm SD$	t	*p*-value
Pain intensity (QVAS)				
Current	3.76 ± 2.32	3.96 ± 1.79	0.344	0.732
Average	3.90 ± 1.64	4.14 ± 1.56	-0.518	0.607
Least	2.05 ± 1.24	2.96 ± 1.71	-2.076	0.043
Worst	3.95 ± 1.53	4.71 ± 1.57	-1.690	0.098
QVAS score	38.7 ± 15.4	42.7 ± 14.5	-0.933	0.356
Activity limitation (RMDQ)	10.4 ± 5.48	9.14 ± 5.22	0.835	0.408
Participation restriction (OLBPS)	14.7 ± 9.02	16.0 ± 7.02	-0.561	0.577
HRQoL (SF-12)				
PF	35.7 ± 24.8	48.8 ± 24.8	-1.826	0.074
RP	5.00 ± 12.5	8.75 ± 20.4	0.740	0.463
BP	21.4 ± 24.3	25.0 ± 15.3	-0.629	0.53
HP	42.6 ± 32.1	42.6 ± 23.9	-0.007	0.99
EF	37.1 ± 34.8	36.4 ± 29.8	-0.077	0.939
SF	15.4 ± 12.4	11.6 ± 12.6	-1.065	0.292
RL	23.3 ± 16.9	26.2 ± 15.4	0.628	0.533
MH	17.4 ± 14.5	8.72 ± 11.4	2.359	0.023*
Domain –				
MHD	3.94 ± 8.73	2.27 ± 7.29	0.723	0.468
PHD	23.6 ± 16.8	26.2 ± 9.00	0.698	0.488

* Significant difference; *QVAS* Quadruple Visual Analogue Scale, *RMDQ* Roland Morris Disability Questionnaire, *OLBPS* Oswestry Low-Back Pain Scale, *HRQoL* Health-Related Quality of Life, *HP* Health perception, *PF* Physical function, *RP* Role Limitation –physical, *RE* Role limitation – emotional, *SF* Social functioning, *MH* Mental health, *BP* Bodily pain, *EF* Energy fatigue, *MHD* Mental health domain, *PHD* Physical health domain

devices/apps, mobile apps and online platforms, and videoconferencing systems has been reported to be effective in various patient populations [52]. It is used to educate patients, caregivers, and health professionals about diseases, promote healthy living in the general public, as well as offera digital platform for communication and feedback between patients and healthcare providers. Some emerging systematic reviewsconfirm the effectiveness of telerehabilitation [52, 53]. However, there is still a paucity of evidence of clinical benefit from such technologies, thereby making it of research interest. Although there are significant variety of differences among studies in terms of methodologies, sample populations, client settings, and outcomes measured, most of the studies have reported comparable or superior clinical outcomes for telerehabilitation compared to conventional interventions. No studies reported worse outcomes with telerehabilitation [52, 54]. Small, downloadable programmes called "apps" have become increasingly popular with the rise of smartphones, combining phone features with handheld computer technologies [55]. Also, there is an abundance of commercially available applications offered for pain management. However, one of the main issues with existing apps is their lack of adherence to established guidelines and scientifically proven concepts [56, 57], as well as limited evidence for improvement in general health when thesesmartphoneappsare used. Furthermore, Vardehet al.[58] submitted that minimal data exists to determine the effectiveness of mobile interventions for pain.

The McKenzie MDT promotes the use of extension protocol in managing LBP and also supportsactive or self-care. Although several studies have established the efficacy of the McKenzie method, however, evidence of the telerehabilitation application of this method is just emerging. The comparability between the VOP and TBMT group at 4th and 8th week of this study supports the opinions that digital health will not wholly substitute the traditional in-service care and interaction with a health-care professional [58]. However, the findings of

this study seem to be consistent with the views that telerehabilitation is a viable link that may enable healthcare providers to remotely engage and provide healthcare services, and overcome geographic hindrances of distance- and travel, as well as the barrier of time to access care [59, 60]. In particular, this study's finding supports that the TBMT group may be a beneficial alternative to the VOP, perhaps other forms of SMT considering that skills and experience following proper evaluation are *sine qua non* to effective implementation of SMT [61].

The study's finding on the higher effect of TBMT on vitality or energy can be attributed to the fact that while VOP is exclusively a passive procedure, TBMT is an active intervention. Thus, an active intervention will directly or indirectly improve vitality compared to a passive one. In sum, it is adducible that higher energy/vitality reports associated with TBMT are because the intervention is an active protocol that involves some level of movement of the spine by the patient; however, VOP is a passive procedure. This study highlights telerehabilitation's role as a supplementary patient care platform. Adoption of telerehabilitation may help reduce the frequency and cost of clinic attendance and bridge the access gap to rehabilitation services. This study has potential limitations. Blinding the therapist to the treatment allocation was not possible, and there could be a risk of performance bias. Also, a non-telerehabilitation McKenzie therapy group was not included, considering that earlier studies have found both conventional and digital methods of the technique comparable in their effects on clinical outcomes [19, 24, 46]. Based on ethical concerns, a non-treatment or placebo control group was not included in this study, which also can be considered a limitation. In addition, the TBMT is limited to the McKenzie extension technique only and cannot be generalised to other forms of the McKenzie protocols.

The MT approach used in this study was limited to VOP, a form of posterior-anterior unilateral pressure. It cannot be generalised to all forms of MT to the spine. However, the lack of parity in skills and competence which are often associated with manual therapy outcomes was limited in this study as the same physiotherapist provided the VOP. Both the TBMT and VOP groups received back care education instructions, which may have influenced the treatment outcomes. Additionally, the use of ice after VOP was intended to reduce tissue reactions such as muscle soreness, increased pain intensity, and inflammation, but it may also be a confounding factor for the intervention. Future studies are therefore needed to explore these limitations. Though, only patients who were receiving physiotherapy for chronic LBP participated in this study, however, for ethical reasons, individual patients were excluded if they were at risk from the research, and not justifiably on use of medications such as NSAIDs before or during the trial [62, 63].

Conclusion

Telerehabilitation-based McKenzie methods and SMT are effective in managing patients with chronic NSLBP, with TBMT leading to significantly higher improvement in health perception in the long term.

Acknowledgements
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Authors' contributions
All authors read and approved the final manuscript.

Availability of data and material
The datasets used and/ or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Ethical approval was obtained from the Ethical Review Committee, Institute of Public Health, Obafemi Awolowo University, Ile-Ife, Nigeria (IPHOAU/12/1046).

Consent for publication
Not applicable.

Competing interests
No competing interests to declare.

Author details
[1]Department of Health Professions, Manchester Metropolitan University, Manchester, UK. [2]Crumpsall Vale Intermediate Care, Manchester Community Response Service, Manchester, UK. [3]Department of Physiotherapy, Osun State University Teaching Hospital, PMB 5000, Osogbo 230221, Nigeria. [4]Department of Medical Rehabilitation, Obafemi Awolowo University, Ile-Ife, Nigeria. [5]Department of Physiotherapy, Federal Teaching Hospital, Ido-Ekiti, Nigeria. [6]Royal Liverpool University Hospital, Prescot Street, Liverpool, UK.

Received: 7 June 2024 Accepted: 12 July 2024
Published online: 06 November 2024

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