Original Article

JHSMR Journal of Health Science and Medical Research

Effects of a Core Stabilization Exercise Program with the Abdominal Drawing-In Maneuver Technique in Chronic Non-Specific Low Back Pain with Lumbar Instability Using Telerehabilitation: A Randomized Controlled Trial

Chutimon Kongsa, M.Sc.[1,2,3], Torkamol Hunsawong, Ph.D.[1,2], Rungthip Puntumetakul, Ph.D.[1,2], Thiwaphon Chatprem, Ph.D.[1,2], Lugkana Mato, Ph.D.[1,2], Papangkorn Meekaew, M.D.[3]

[1]School of Physical Therapy, Faculty of Associated Medical Sciences, Khon Kaen University, Mueang, Khon Kaen 40002, Thailand.
[2]The Research Centre in Back, Neck, Other Joint Pain and Human Performance (BNOJPH), Khon Kaen University, Mueang, Khon Kaen 40002, Thailand
[3]Faculty of Medicine, Mahasarakham University, Mueang, Mahasarakham 44000, Thailand.

Received 23 October 2025 ● Revised 27 March 2026 ● Accepted 20 April 2026 ● Published online 28 October 2026

Abstract:

Objective: Despite the increasing use of telerehabilitation, few studies have examined its effectiveness for core stabilization exercises in chronic non-specific low back pain (CNSLBP) with lumbar instability (LI). This study compared telerehabilitation-based versus clinic-based delivery of core stabilization exercise with abdominal drawing-in maneuver (CSE with ADIM) on pain, functional disability, lumbar joint repositioning error (LJRE), quality of life, and satisfaction in individuals with CNSLBP and LI.

Material and Methods: A single-blind randomized controlled trial that included 30 participants with CNSLBP and LI, randomized to telerehabilitation-based (n=15) or clinic-based (n=15) groups. Both groups completed 7 weeks of CSE with ADIM; the telerehabilitation-based group received training via video calls, while the clinic-based group received in-person training. Pain, functional disability, quality of life, and LJRE were measured at baseline and post-intervention; satisfaction was assessed at completion.

Results: Both groups demonstrated significant within-group reductions in pain (numerical rating scale [NRS]) and functional disability scores (Oswestry Disability Index [ODI] and Roland-Morris Disability Questionnaire [RMDQ]; p-value<0.05),

Contact: Torkamol Hunsawong, Ph.D.
School of Physical Therapy, Faculty of Associated Medical Sciences,
Khon Kaen University, Mueang, Khon Kaen 40002, Thailand.
E-mail: tkmhun@kku.ac.th

J Health Sci Med Res
doi: 10.31584/jhsmr.20261485
www.jhsmr.org

© 2026 JHSMR. Hosted by Prince of Songkla University.
This is an open access article distributed under the CC BY-NC-ND 4.0 license
(http://www.jhsmr.org/index.php/jhsmr/about/editorialPolicies#openAccessPolicy)

with no significant between-group differences. Telerehabilitation-based delivery improved most SF-36 domains except the social function domain, whereas clinic-based training improved most domains except the physical function domain. LJRE had no significant changes within and between groups. Training adherence was high (96%) with high satisfaction (telerehabilitation-based: 4.94±0.08; clinic-based: 4.87±0.20). No adverse events occurred.

Conclusion: Telerehabilitation-delivered CSE-ADIM is an effective alternative to clinic-based care for reducing pain and improving functional disability and quality of life in CNSLBP with LI.

Keywords: core stability, exercise therapy, low back pain, spinal instability, telerehabilitation

Introduction

Low back pain (LBP) is a prevalent musculoskeletal disorder with substantial global impact, contributing to reduced physical activity, psychosocial distress, and rising healthcare costs[1]. Approximately 90% of cases are non-specific, lacking an identifiable pathological cause[2]. Chronic non-specific LBP (CNSLBP) presents considerable treatment challenges and is often associated with lumbar instability (LI)[3], which may result from poor posture, degeneration, injury, or surgery[4]. LI affects 12–83.7% of LBP patients[5,6].

Exercise interventions such as yoga, Pilates, and core stabilization exercises (CSE) are recommended for chronic LBP and LI[7]. Among these, CSE is preferred for specifically activating deep core muscles essential for spinal stability. Puntumetakul et al. developed a CSE protocol incorporating the abdominal drawing-in maneuver (ADIM), which co-activates the lumbar multifidus (LM) and transversus abdominis (TrA) to enhance stability[8,9]. This program has shown benefits in pain reduction, deep muscle activation, and proprioception in sub-acute NSLBP with LI when delivered with adequate patient adherence and professional supervision. Barriers such as limited facilities, time, and cost often restrict access to supervised exercise, especially in remote areas, thus creating gaps in rehabilitation.

Telerehabilitation, which provides professional supervision via technology, offers a potential solution to overcome these barriers by improving accessibility and continuity of care[10]. Evidence supports its effectiveness in chronic LBP; for example, an 8-week trial of McKenzie therapy found comparable clinical outcomes between clinic-based and telerehabilitation delivery[11]. Likewise, Özden et al. (2022) reported greater improvements in pain, function, quality of life, and adherence with telerehabilitation compared to home exercise[12]. However, evidence supporting telerehabilitation delivery of CSE with ADIM in patients with CNSLBP and LI remains limited.

To our knowledge, no prior study has specifically investigated telerehabilitation delivery of CSE with ADIM in patients with CNSLBP and LI. This represents a critical knowledge gap, particularly given the potential advantages of remote delivery. Unlike traditional home programs that rely on static pamphlets or manuals with limited professional supervision, telerehabilitation approaches provide real-time guidance through video calls and high-definition video demonstrations. This interactive supervision allows therapists to monitor exercise technique, provide real-time feedback on ADIM performance, and modify the program based on individual progress—capabilities not available in conventional unsupervised home exercise programs. However, evidence directly comparing the effectiveness

of telerehabilitation and clinic-based delivery of CSE with ADIM in this population remains limited. Establishing this evidence would support broader access to supervised rehabilitation for those with limited access to clinical care. Therefore, this study compared the effectiveness of telerehabilitation versus clinic-based delivery of CSE with ADIM on pain, functional disability, lumbar joint repositioning error (LJRE), quality of life, and satisfaction in patients with CNSLBP and LI.

Material and Methods

Study design

A single-blind randomized controlled trial was conducted with 30 participants with CNSLBP and LI at the Physical Therapy Unit, Suddhavej Hospital, Faculty of Medicine, Mahasarakham University, Thailand. Ethical approval was obtained from the Human Research Ethics Committees of Khon Kaen University (HE662176) and Mahasarakham University (490-488/2566). The trial was registered at ClinicalTrials.gov (NCT06321393; March 14, 2024). All participants received study information and provided written informed consent.

Sample size calculation

The sample size was determined based on data from Chalermsan et al. (2016)[9], utilizing the pooled standard deviation of post-treatment pain intensity. With an assumed two-tailed α of 0.05, 80% power, a correlation coefficient of 0.5, and a mean between-group difference of 2.31, a minimum of 7 participants per group was required. To account for an anticipated 30% dropout rate and the potential dilution of treatment effects in the intention-to-treat analysis, the sample size was adjusted using the formula[13]: $n_{adj}=n/(1-R)^2$, where n was the initial sample size (7 participants) and R was the anticipated dropout rate (0.3). The final sample size was 15 participants per group, for a total of 30 participants.

Participants

Adults aged 18–60 years with CNSLBP (>12 weeks) were enrolled. Participants were screened for lumbar instability using the Thai-version 14-item lumbar instability screening questionnaire[6], applying a cutoff score of ≥6/14, as established for sub-threshold clinical lumbar instability[5], along with ≥2 positive clinical tests (painful catch, aberrant movement, or prone instability test)[14,15]. Further inclusion criteria comprised pain intensity 3–7/10 on a numerical rating scale (NRS) at rest, no CSE treatment in the past 3 months, ability to use a smartphone/tablet with LINE, and Thai fluency. Exclusion criteria comprised serious spinal pathology (fracture, malignancy, infection), osteoporosis, ankylosing spondylitis, spondyloarthritis, prior spinal/lower limb surgery, cauda equina syndrome, ≥2 neurological deficits (diminished reflexes, sensory loss, or muscle strength <grade 3)[16], pregnancy or breastfeeding, and BMI >30 kg/m^2.

Procedures

After screening and informed consent, baseline assessments were performed by a physical therapist blinded to group allocation. Measures included pain (NRS), functional disability (measured by the Oswestry Disability Index [ODI] and Roland-Morris Disability Questionnaire [RMDQ]), quality of life (SF-36), and LJRE. Randomization was conducted via sealed opaque envelopes using stratified block randomization (gender: male/female; age: 18–39/40–60) from https://www.sealedenvelope.com. Participants were assigned to telerehabilitation or clinic-based groups. The same assessor, who remained blind to group allocation, re-evaluated all outcomes after the 7-week intervention. Satisfaction was measured using a 5-point Likert scale questionnaire at post-intervention. Of 45 screened, 11 failed inclusion and 4 declined. Thirty participants were randomized equally (n=15 per group). No dropouts occurred; all completed the trial and were included in the final analysis (Figure 1: CONSORT flow diagram).

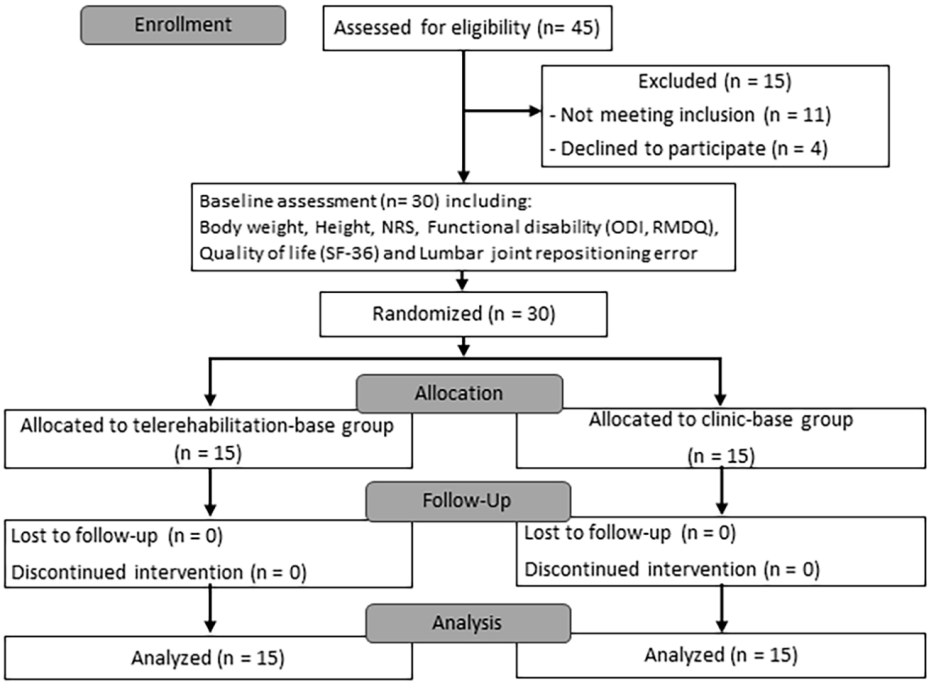

Figure 1 CONSORT flow diagram

Interventions

All participants completed a 7-week core stabilization exercise (CSE) program with the abdominal drawing-in maneuver (ADIM)[9], 20 minutes per session, three times weekly. Each session consisted of 8 sets of 10 repetitions, holding each for 10 seconds. Prior to group allocation, all participants received individualized training from an experienced physical therapist to ensure correct ADIM technique and lumbar multifidus activation. Training was conducted in the prone position using a pressure biofeedback device inflated to 70 mmHg under the lower abdomen. Participants were instructed to draw the abdominal wall 'up and in' with simultaneous pelvic floor contraction, reducing pressure by 4–10 mmHg while maintaining normal breathing and avoiding spinal or pelvic motion. Proficiency was verified two days later, prior to group allocation. Participants were also taught to independently monitor TrA activation through self-palpation with finger placement 2 cm medial to the anterior superior iliac spine (ASIS), and LM activation with finger placement adjacent to the L5 spinous process.

Telerehabilitation-based group

Participants in this group underwent a 7-week CSE-ADIM program delivered through a telerehabilitation framework. This approach was characterized by its integration of real-time supervision and synchronous video calls with the main researcher. To support exercise accuracy, video demonstrations were provided, enabling participants to follow the movements simultaneously during their sessions. Specifically, the first session of each week was directly supervised via video call to ensure the correct technique and safety. The first session of each week was supervised by the researcher via video call. At the start of each session, participants performed the previous week's exercises for a proficiency check. Competency was

confirmed by the researcher through observation of neutral spinal alignment—avoiding excessive lumbar lordosis or kyphosis—and correct ADIM execution without breath-holding or compensatory maneuvers. If the exercises were performed correctly, the program progressed to the next level; otherwise, participants continued with the current exercises. Participants were instructed to position their cameras approximately 2 meters away to ensure full-body visibility throughout each session. Each weekly supervised session comprised participant review of exercise demonstration videos, a question-and-answer (Q&A) segment, and 20 minutes of supervised practice with real-time feedback. In the event of technical disruptions lasting more than 5 minutes, this session was terminated and rescheduled for the following day via telephone or instant messaging. For the remaining sessions each week, participants exercised independently with asynchronous support provided via the LINE application. Adherence was monitored using exercise logbooks in which participants recorded each 10-second ADIM contraction. Each set consisted of 10 repetitions, with eight sets performed per session. Exercise adherence was calculated as the percentage of successfully completed repetitions relative to the total prescribed repetitions during the 7-week intervention (3 sessions per week).

Clinic-based group

For the clinic-based group, the first session of each week involved a scheduled appointment with the main researcher. During these one-on-one clinic-based sessions, the researcher supervised the prescribed weekly exercises. Before progressing to new exercises, the researcher manually palpated the TrA and LM muscles to verify proficiency in the previous week's program and confirm the proper ADIM technique. If the exercises were performed correctly, the program progressed to the next level; otherwise, participants continued with the current exercises. Following each weekly supervised session, participants performed the prescribed exercises as a daily home program. Exercise adherence was monitored using the same logbook method as the telerehabilitation group.

Outcome assessment

All outcomes were assessed at baseline and post-intervention (7 weeks). Patient satisfaction was evaluated at the post-intervention assessment.

Pain intensity was assessed using the 11-point Numeric Rating Scale (NRS, 0–10) at rest. Participants verbally reported their pain level, where 0 represented no pain and 10 was the worst pain imaginable. A change of ≥2.5 points on this scale is considered a clinically significant difference for chronic low back pain (LBP)[17].

Secondary outcomes

The Oswestry Disability Index (ODI), a 10-item questionnaire, was used to measure disability and participation restrictions. Each item is scored from 0 to 5, resulting in a maximum total score of 50. A higher score signifies a greater level of disability. The Thai version 1.0 of the ODI has been shown to have good internal consistency (Cronbach's α=0.81)[18].

The Roland-Morris Disability Questionnaire (RMDQ), a 24-item tool with a yes/no response format, was used to measure activity limitations in daily living. The questionnaire yields a total score from 0 to 24, where a higher score signifies a greater degree of disability. The Thai version of the RMDQ, which showed good reliability (Cronbach's α=0.83), was implemented for this study[19].

The Short-Form 36 (SF-36), a patient-reported outcome measure, was used to evaluate quality of life (QoL) across eight health dimensions. Scores range from 0 (poorest quality of life) to 100 (highest quality of life). The Thai version of the SF-36, with physical and mental component reliability coefficients of 0.93 and 0.92, respectively, was used in this study[20].

Lumbar Joint Repositioning Error (LJRE): LJRE was used to evaluate lumbar proprioception[8]. A laser pointer, mounted on a stable tripod, was positioned 50 cm from the chair where the participant remained in a seated position[21], with the tripod height adjusted to align with the S1 level for each participant. Participants sat with their hips and knees at 90 degrees, feet flat on the floor, and arms resting on their thighs. The assessor manually guided the lumbar spine into an upright neutral position—defined as the midpoint between anterior and posterior pelvic tilt—by leveling the anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS). A 10-cm tape measure was affixed to the S1 spinous process with its midpoint (5 cm) centered over S1, serving as the reference point (0 cm). Participants were instructed to memorize this neutral position and then perform two practice trials of maximal anterior and posterior pelvic tilting to ensure correct movement and minimize compensatory strategies. After the practice trials, three formal measurement trials were conducted with one-minute rest intervals between each trial. Repositioning error was recorded as the laser deviation from the reference point on the tape measure in centimeters. The average of the three trials was calculated for analysis[8]. Prior to data collection, the intra-rater reliability of the lumbar joint repositioning error (LJRE) measurement was evaluated in individuals without low back pain who were not included in the main study. The test was administered by a blinded licensed physical therapist with more than three years of musculoskeletal clinical experience (researcher 1). Intra-rater reliability was assessed using the intraclass correlation coefficient model ($ICC_{3,3}$) based on the mean of three repeated trials. The results demonstrated good to excellent reliability ($ICC_{3,3}$= 0.923, p-value<0.001, 95% CI: 0.705 to 0.981).

Post-intervention, participant satisfaction was assessed using a 5-point Likert scale questionnaire. The instrument measured satisfaction across five domains: (1) usability and appropriateness of the exercise program, (2) demonstration materials used for program delivery, (3) physical therapist's program delivery, (4) communication and appointment scheduling, and (5) provision of answers and additional guidance. Scores ranged from 1 (very dissatisfied) to 5 (most satisfied), with higher scores indicating greater satisfaction.

Statistical analysis

Statistical analyses were performed using SPSS 28.0 (IBM Corp., Armonk, NY, USA) with an intention-to-treat approach. Normality of distributions was assessed using the Shapiro-Wilk test. Descriptive data are presented as mean±S.D. or median (IQR), as appropriate. Baseline demographic characteristics were compared between groups using the independent t-test for normally distributed data (age and BMI) and the Mann-Whitney U test for non-normally distributed data (weight, height, lumbar instability screening score, and low back pain duration). Categorical variables (gender) were compared using Fisher's exact test. For baseline comparisons, all outcome measures (NRS, ODI, RMDQ, LJRE, and quality of life) were compared between groups using independent t-tests. Within-group pre–post changes were examined using paired t-tests for all outcome measures. Post-intervention between-group comparisons were analyzed using analysis of covariance (ANCOVA) with baseline values as covariates to adjust for initial differences. Participant satisfaction at post-intervention was compared between groups using independent t-tests. Effect sizes were reported as Cohen's d for t-tests (small: 0.20–0.49; medium: 0.50–0.79; large: ≥0.80) and partial eta-squared (ηp^2) for ANCOVA (small: 0.01; medium: 0.06; large: 0.14)[22]. Statistical significance was set at p-value<0.05.

Results

Baseline characteristics were comparable between the telerehabilitation and clinic-based groups (p-value>0.05; Table 1). Exercise adherence was high (96%), with no

serious adverse events reported; only mild, transient muscle soreness occurred in the first week, resolving with rest, and no treatment or analgesics were required. Overall satisfaction was high in both groups (telerehabilitation: 4.94±0.08; clinic-based: 4.87±0.20; p-value>0.05). The highest ratings were observed for 'provision of answers and additional guidance' (telerehabilitation: 5.00±0.00; clinic-based: 4.97±0.13). The lowest-rated domains differed by group: telerehabilitation participants rated 'exercise program usability and appropriateness' lowest (4.87±0.30), while clinic-based participants rated 'demonstration materials' lowest (4.60±0.55).

After the 7-week CSE with the ADIM program, both groups demonstrated significant within-group improvements in pain (NRS; p-value<0.001) and disability (ODI and RMDQ; p-value<0.001). These improvements were supported by large effect sizes for pain and disability, and most SF-36 domains (p-value<0.05), except social function (telerehabilitation-based) and physical function (clinic-based). LJRE did not change significantly in either group (telerehabilitation-based: p-value=0.80; clinic-based: p-value=0.36). No significant between-group differences were observed post-intervention for NRS (p-value=0.93), ODI (p-value=0.06), RMDQ (p-value=0.11), LJRE (p-value=0.80), or SF-36 domains (p-value>0.05) (Tables 2–4).

Discussion

This study demonstrated that a 7-week CSE program with ADIM significantly improved pain and functional disability, enhancing most domains of quality of life in patients with CNSLBP and LI, with no differences between telerehabilitation-based and clinic-based delivery.

These findings, which show no significant difference in pain reduction between the groups, align with prior research. For example, Akhtar et al. (2017) also reported a significant decrease in CLBP from CSE delivered in a clinic-based setting[23]. Similarly, Kwon et al. (2020) found that lumbar stabilization exercises were more effective at reducing pain for CLBP patients in a clinic-based context[24]. The comparable outcomes between the two delivery methods suggest that the primary mechanism for pain reduction is likely due to the CSE with the ADIM program itself. This mechanism is thought to involve enhanced co-contraction and the activity of TrA and LM muscles, which increases spinal stability and reduces compressive forces, thereby reducing pain[15].

Similarly, significant within-group improvements in functional disability (RMDQ, ODI) were consistent with studies by Noormohammadpour et al. (2018)[25] and Suh et al. (2019)[26], both of which utilized CSE protocols with home-based components in patients with CLBP. Improved

Table 1 Participants' characteristics

Variables	Telerehabilitation-based (n=15)	Clinic-based (n=15)	p-value
Age (years)	37.67 (11.60)	36.53 (11.28)	0.79[a]
Weight (kg)	61.57 (9.19)	64.07 (8.58)	0.30[b]
Height (cm)	160.20 (8.22)	161.20 (7.67)	0.71[b]
BMI (kg/m^2)	23.96 (2.62)	24.64 (2.56)	0.48[a]
Lumbar instability screening score (score)	8.27 (1.58)	7.93 (2.08)	0.19[b]
Low back pain duration (months)	4.93 (2.49)	3.93 (1.58)	0.18[b]
Gender, n (%) of female	12 (80%)	12 (80%)	0.67[c]

[a]Independent t-test, [b] Mann-Whitney U test, [c] Fisher's Exact test
Data are presented as mean (standard deviation), number (%), as appropriate.

Table 2 Differences in outcome measures at baseline within and between groups

Outcome variable	group	Baseline Mean (S.D.)	Post -intervention Mean (S.D.)	Mean difference (95% CI)	p-value	Effect Size[c]
NRS at rest (score)	Telerehabilitation-based	5.00 (1.69)	2.40 (1.96)	2.60 (1.37 to 3.84)	<0.001[b]	1.42
	Clinic-based	5.20 (1.27)	2.53 (1.72)	2.67 (1.74 to 3.60)	<0.001[b]	1.76
	p-value	0.69[a]				
ODI (%)	Telerehabilitation-based	24.27 (5.39)	14.00 (8.07)	10.27 (6.84 to 13.69)	<0.001[b]	1.50
	Clinic-based	28.00 (9.59)	9.87 (6.39)	18.13 (12.00 to 24.26)	<0.001[b]	2.22
	p-value	0.20[a]				
RMDQ (score)	Telerehabilitation-based	7.53 (3.94)	2.53 (2.67)	5.00 (3.58 to 6.42)	<0.001[b]	1.49
	Clinic-based	8.67 (5.95)	1.53 (1.30)	7.13 (3.80 to 10.47)	<0.001[b]	1.66
	p-value	0.54[a]				
Lumbar joint repositions sense (cm)	Telerehabilitation-based	0.64 (0.36)	0.61 (0.37)	0.036 (-0.26 to 0.34)	0.80[b]	0.08
	Clinic-based	0.67 (0.30)	0.58 (0.30)	0.089 (-0.11 to 0.29)	0.36[b]	0.30
	p-value	0.86[a]				

[a]Independent groups t-test, [b]Paired t-test, [c]Cohen's d effect size, NRS=numerical rating scale, ODI=Oswestry Disability Index, RMDQ=Roland-Morris Disability Questionnaire

Table 3 Differences in SF-36 outcome measures at baseline within and between groups

SF-36	group	Baseline Mean (S.D.)	Post intervention Mean (S.D.)	Mean difference (95% CI)	p-value	Effect Size[c]
PF (%)	Telerehabilitation-based	65.00 (20.35)	85.00 (11.95)	-20.00 (-27.10 to -12.90)	<0.001[b]	1.20
	Clinic-based	67.00 (20.07)	80.07 (23.75)	-13.07 (-27.81 to 1.69)	0.08[b]	0.59
	p-value	0.79[a]				
RP (%)	Telerehabilitation-based	30.00 (27.06)	81.67 (24.03)	-51.67 (-68.60 to -34.74)	<0.001[b]	2.02
	Clinic-based	33.33 (32.28)	70.00 (38.03)	-36.67 (-62.76 to -10.57)	0.009[b]	1.04
	p-value	0.86[b]				
RE (%)	Telerehabilitation-based	37.00 (34.87)	75.53 (38.81)	-38.53 (-61.62 to -15.45)	0.003[b]	1.04
	Clinic-based	37.80 (37.60)	71.07 (39.64)	-33.27 (-62.03 to -4.51)	0.03[b]	0.86
	p-value	0.97[b]				
V (%)	Telerehabilitation-based	54.00 (12.28)	67.33 (12.52)	-13.33 (-20.41 to -6.26)	0.001[b]	1.07
	Clinic-based	56.00 (12.56)	66.00 (11.83)	-10.00 (-18.63 to -1.37)	0.03[b]	0.82
	p-value	0.66[a]				

Table 3 (continued)

SF-36	group	Baseline Mean (S.D.)	Post intervention Mean (S.D.)	Mean difference (95% CI)	p-value	Effect Size[c]
EWB (%)	Telerehabilitation-based	68.27 (13.81)	79.20 (10.05)	-10.93 (-18.58 to -3.28)	0.008[b]	0.91
	Clinic-based	65.87 (14.41)	76.53 (11.79)	-10.67 (-19.15 to -2.18)	0.02[b]	0.81
	p-value	0.65[a]				
SF (%)	Telerehabilitation-based	60.07 (16.46)	71.07 (21.38)	-11.00 (-27.85 to 5.85)	0.18[b]	0.58
	Clinic-based	59.40 (18.53)	71.07 (18.03)	-28.53 (-43.59 to -13.47)	0.001[b]	0.64
	p-value	0.91[a]				
BP (%)	Telerehabilitation-based	41.33 (17.59)	69.47 (17.63)	-28.13 (-39.93 to -16.33)	<0.001[b]	1.60
	Clinic-based	42.53 (19.17)	64.20 (17.45)	-21.67 (-33.80 to -9.53)	0.002[b]	1.82
	p-value	0.86[a]				
GH (%)	Telerehabilitation-based	43.43 (16.68)	73.00 (12.22)	-20.33 (-26.20 to -14.46)	<0.001[b]	2.02
	Clinic-based	45.67 (17.61)	71.00 (10.72)	-25.33 (-36.96 to -13.71)	<0.001[b]	1.74
	p-value	0.27[a]				

[a]Independent groups t-test, [b]Paired t-test, [c]Cohen's d effect size, PF=physical function, RP=role limitations due to physical health, RE=role limitations due to emotional problems, V=vitality, EWB=emotional well-being, SF=social function, BP=bodily pain, GH=general health

functional ability in this study may be a result of reduced chronic pain, which is often linked to weakened abdominal and back muscles. This can lead to postural instability and functional limitations[27]. This study demonstrates that a 7-week program of CSE with ADIM enhances activation of the TrA and LM muscles, and their co-contraction reduces spinal compressive forces while improving lumbar stability. Consequently, this intervention contributes not only to pain reduction but also to improved functional performance. Therefore, these findings indicate that both telerehabilitation and clinic-based delivery of CSE with ADIM result in comparable reductions in functional disability.

Both groups showed significant QoL improvements. In the telerehabilitation group, most SF-36 domains improved, except social functioning. This limited change may be due to reduced social interaction from performing home-based exercises. In the clinic-based group, most domains improved, but physical functioning did not, possibly because travel and walking to the clinic exacerbated back pain. These findings are consistent with Puntumetakul et al. (2013), who reported that a 10-week core stabilization exercise (CSE) program produced greater physical component summary improvements than trunk stretching and hot pack therapy in patients with lumbar instability, maintained over 3 months[15]. Similarly, Ota et al. (2011) found QoL gains after 3 and 6 months of lumbar stabilization in chronic low back pain[28], and Noormohammadpour[25] et al. (2018) reported significant SF-36 improvements in nurses with chronic non-specific low back pain following CSE compared with a non-exercise control.

In contrast to previous research by Puntumetakul et al. (2018)[8] and Saiklang et al. (2025)[29], our study found no

Table 4 Comparison of outcomes measures at post-intervention between groups

Outcome variable	Telerehabilitation-based (n=15)			Clinic-based (n=15)			Adj mean difference between groups (95% CI)	*F*	p-value[a]	Effect size[b]
	Baseline mean (S.D.)	Post-intervention		Baseline mean (S.D.)	Post-intervention					
		mean (S.D.)	Adj mean		mean (S.D.)	Adj mean				
NRS at rest(score)	5.00 (1.69)	2.40 (1.96)	2.44	5.20 (1.27)	2.53 (1.72)	2.49	-0.06 (-1.39 to 1.28)	0.007	0.93	<0.001
ODI (%)	24.27 (5.39)	14.00 (8.07)	14.51	28.00 (9.59)	9.87 (6.39)	9.36	5.16 (-0.32 to 10.63)	3.74	0.06	0.12
RMDQ (score)	7.53 (3.94)	2.53 (2.67)	2.63	8.67 (5.95)	1.53 (1.30)	1.44	-1.188 (1.58 to 3.67)	2.717	0.11	0.091
Lumbar joint repositions sense (cm)	0.64 (0.36)	0.61 (0.37)	0.61	0.67 (0.30)	0.58 (0.30)	0.58	0.032 (-0.22 to 0.28)	0.067	0.80	0.002
SF-36										
- PF (%)	65.00 (20.35)	85.00 (11.95)	85.40	67.00 (20.07)	80.07 (23.75)	79.67	5.73 (-7.26 to 18.71)	0.82	0.37	0.029
- RP (%)	30.00 (27.06)	81.67 (24.03)	81.97	33.33 (32.28)	70.00 (38.03)	69.70	12.27 (-11.69 to 36.23)	1.10	0.30	0.039
- RE (%)	37.00 (34.87)	75.53 (38.81)	75.63	37.80 (37.60)	71.07 (39.64)	70.97	4.66 (-24.51 to 33.83)	0.11	0.75	0.004
- V (%)	54.00 (12.28)	67.33 (12.52)	67.66	56.00 (12.56)	66.00 (11.83)	65.68	1.98 (-6.83 to 10.78)	0.21	0.65	0.008
- EWB (%)	68.27 (13.81)	79.20 (10.05)	78.88	65.87 (14.41)	76.53 (11.79)	76.85	2.03 (-5.85 to 9.90)	0.28	0.60	0.010
- SF (%)	60.07 (16.46)	71.07 (21.38)	71.07	59.40 (18.53)	71.07 (18.03)	71.07	0.004 (-15.09 to 15.10)	<0.001	1.00	<0.001
- BP (%)	41.33 (17.59)	69.47 (17.63)	69.63	42.53 (19.17)	64.20 (17.45)	64.04	5.58 (-7.28 to 18.45)	0.79	0.38	0.029
- GH (%)	43.43 (16.68)	73.00 (12.22)	72.11	45.67 (17.61)	71.00 (10.72)	71.89	0.22 (-8.07 to 8.51)	0.003	0.96	<0.001

[a]Analysis of covariance (ANCOVA), [b]Partial eta-squared (ηp^2) effect size, NRS=numerical rating scale, ODI=Oswestry Disability Index, RMDQ=Roland-Morris Disability Questionnaire, PF=physical function, RP=role limitations due to physical health, RE=role limitations due to emotional problems, V=vitality, EWB=emotional well-being, SF=social function, BP=bodily pain, GH=general health, Adj Mean=mean adjusted for pre-intervention values

significant within-group or between-group changes in LJRE. This discrepancy is likely attributed to the significantly lower baseline LJRE values of our participants (telerehabilitation: 0.64±0.36 cm; clinic-based: 0.67±0.30 cm) compared to those in the aforementioned studies (Puntumetakul et al.: 0.8±0.4 cm; Saiklang et al.: 0.98±0.43 cm). The lower initial values in our cohort may have limited the potential for further improvement. Additionally, Saiklang et al. (2025) reported greater LJRE gains in participants with lower baseline BMI and pain scores, whereas higher BMI is known to increase mechanical loading and muscle deconditioning, thereby aggravating lumbar instability and impairing proprioception. Although our study demonstrated significant reductions in pain and disability, these changes did not translate into significant improvements in LJRE.

A systematic review by Amin et al. (2022) indicates that both patients and professionals are generally satisfied with telerehabilitation for musculoskeletal disorders[30], while Özden et al. (2022) reported high satisfaction in telerehabilitation groups[12]. In the present study, both groups demonstrated excellent overall satisfaction with no significant between-group difference (p-value>0.05), consistently rating 'provision of answers and additional guidance' highest, underscoring that accessible therapist communication remains critical regardless of delivery approach. Descriptively, the lowest-rated domains differed: telerehabilitation participants rated exercise usability lowest (4.87±0.30), potentially reflecting challenges in self-assessing motor control remotely, while clinic-based participants rated demonstration materials lowest (4.60±0.55), suggesting varied experiences with live demonstrations and printed materials. Building on these successful outcomes, insights from these patterns suggest potential refinements for future implementations: providing clinic-based programs with standardized digital video access and strengthening telerehabilitation with self-palpation training modules to further enhance patient experience. Nevertheless, all domain scores remained very high (≥4.60/5.0), and equivalent clinical outcomes confirm that both approaches effectively deliver CSE-ADIM, supporting telerehabilitation as a viable, well-received alternative method.

This study demonstrates that telerehabilitation significantly reduced pain while improving functional disability and quality of life, serving as a viable alternative to clinic-based care. For effective clinical integration, three steps are essential: (1) initial in-person training using pressure biofeedback and manual palpation to ensure the correct ADIM technique; (2) readiness confirmation of self-monitoring competence and technology access; and (3) structured remote follow-up via video supervision and accessible communication channels (e.g., LINE). Suitable patients include those with chronic NSLBP, adequate technology literacy, stable internet access, and motivation for independent exercise. Telerehabilitation may be unsuitable for those requiring hands-on manual therapy, with complex comorbidities necessitating close monitoring, or lacking reliable technology. Common implementation challenges—internet connectivity issues and difficulty self-assessing ADIM—can be addressed through asynchronous video submissions and enhanced self-palpation training protocols, respectively.

This study has several limitations that warrant consideration. First, the modest sample size (n=15 per group) may have limited statistical power to detect small-to-moderate between-group differences, particularly for secondary outcomes (SF-36, LJRE). Future studies with larger samples are needed to confirm these findings and detect smaller effect sizes that may be clinically meaningful. Second, while the use of a widely accessible communication platform (LINE) demonstrated feasibility and contributed to high adherence and satisfaction, this approach limited

real-time exercise monitoring and standardized progress tracking compared to specialized telehealth platforms. Third, the study design lacked interim assessments during the intervention period, which restricted understanding of treatment response patterns over time. Finally, no long-term follow-up was conducted to evaluate the sustainability of treatment effects beyond the 7-week period.

Future research should consider incorporating specialized telerehabilitation platforms with enhanced monitoring capabilities while maintaining accessibility, including interim assessments to monitor treatment progression, and conducting long-term follow-up evaluations to assess the durability of effects and strengthen the evidence base for telerehabilitation effectiveness in this population.

Conclusion

Telerehabilitation-delivered core stabilization exercise with abdominal drawing-in maneuver demonstrates equivalent effectiveness to clinic-based care for chronic non-specific low back pain with lumbar instability. Both delivery methods achieved clinically meaningful reductions in pain and disability scores, with telerehabilitation additionally improving multiple quality of life domains. High adherence rates and satisfaction scores indicate strong patient acceptance of the remote delivery approach. These findings support telerehabilitation as a viable alternative for expanding access to evidence-based care, particularly for patients in remote areas, those with transportation barriers, or healthcare systems with limited clinic capacity.

Acknowledgement

The authors would like to express their sincere gratitude to the participants for their valuable contributions to this study.

Funding sources

This work was supported by a grant for thesis research from the Faculty of Associated Medical Sciences, Khon Kaen University, Thailand.

Conflict of interest

There are no conflicts of interest to declare.

References

1. Olafsson G, Jonsson E, Fritzell P, Hägg O, Borgström F. A health economic lifetime treatment pathway model for low back pain in Sweden. J Med Econ 2017;20:1281-9. doi: 10.1080/13696998.2017.1372252.
2. Koes BW, van Tulder MW, Thomas S. Diagnosis and treatment of low back pain. BMJ 2006;332:1430-4. doi: 10.1136/bmj.332.7555.1430.
3. Hides JA, Jull GA, Richardson CA. Long-term effects of specific stabilizing exercises for first-episode low back pain. Spine (Phila Pa 1976) 2001;26:E243-8. doi: 10.1097/00007632-200106010-00004.
4. Ibarz E, Más Y, Mateo J, Lobo-Escolar A, Herrera A, Gracia L. Instability of the lumbar spine due to disc degeneration: a finite element simulation. Adv Biosci Biotechnol 2013;4:548-56. doi: 10.4236/abb.2013.45072.
5. Leungbootnak A, Puntumetakul R, Kanpittaya J, Chatprem T, Boucaut R. Validity of a screening tool for patients with a sub-threshold level of lumbar instability: a cross-sectional study. Int J Environ Res Public Health 2021;18:12151. doi: 10.3390/ijerph182212151.
6. Chatprem T, Puntumetakul R, Boucaut R, Wanpen S, Chatchawan U. A screening tool for patients with lumbar instability: a criteria-related validity of Thai version. Spine (Phila Pa 1976) 2020;45:e1431-8. doi: 10.1097/BRS.0000000000003617.
7. Batıbay S, Külcü DG, Kaleoğlu Ö, Mesci N. Effect of Pilates mat exercise and home exercise programs on pain, functional level, and core muscle thickness in women with chronic low back pain. J Orthop Sci 2021;26:979-85. doi: 10.1016/j.jos.2020.10.026.
8. Puntumetakul R, Chalermsan R, Hlaing SS, Tapanya W, Saiklang P, Boucaut R. The effect of core stabilization exercise on lumbar joint position sense in patients with subacute non-specific low back pain: a randomized controlled trial. J Phys Ther Sci 2018;30:1390-5. doi: 10.1589/jpts.30.1390.

9. Chalermsan R, Puntumetakul R, Dornpunha W, Kamolrat T, Chatchawan U, Pitak R, et al. Effects of core stabilization exercise in subacute non-specific low back pain: pilot study. J Nurs Sci Health 2016;39:48-60.
10. Shem K, Irgens I, Alexander M. Getting started: mechanisms of telerehabilitation. In: Telerehabilitation. Philadelphia, PA: Elsevier; 2022;p.5-20. doi: 10.1016/B978-0-323-86112-8.00001-4.
11. Mbada CE, Olaoye MI, Dada OO, Ayanniyi O, Johnson OE, Odole AC, et al. Comparative efficacy of clinic-based and telerehabilitation application of McKenzie therapy in chronic low-back pain. Int J Telerehabil 2019;11:41-58. doi: 10.5195/ijt.2019.6270.
12. Özden F, Sarı Z, Karaman ÖN, Aydoğmuş H. The effect of video exercise-based telerehabilitation on clinical outcomes, expectation, satisfaction, and motivation in patients with chronic low back pain. Ir J Med Sci 2022;191:1229-39. doi: 10.1007/s11845-021-02768-0.
13. Wu MC, Fisher MR, DeMets DL. Sample sizes for long-term medical trials with time-dependent dropout and event rates. Control Clin Trials 1980;1:111-23. doi: 10.1016/0197-2456(80)90036-9.
14. Kumar SP. Efficacy of segmental stabilization exercise for lumbar segmental instability in patients with mechanical low back pain: a randomized placebo controlled crossover study. N Am J Med Sci 2011;3:456-61. doi: 10.4297/najms.2011.3456.
15. Puntumetakul R, Areeudomwong P, Emasithi A, Yamauchi J. Effect of 10-week core stabilization exercise training and detraining on pain-related outcomes in patients with clinical lumbar instability. Patient Prefer Adherence 2013;7:1189-99. doi: 10.2147/PPA.S51658.
16. Macedo LG, Latimer J, Maher CG, Hodges PW, Nicholas M, Tonkin L, et al. Motor control or graded activity exercises for chronic low back pain? A randomised controlled trial. BMC Musculoskelet Disord 2008;9:65. doi: 10.1186/1471-2474-9-65.
17. Ostelo RW, de Vet HC. Clinically important outcomes in low back pain. Best Pract Res Clin Rheumatol 2005;19:593-607. doi: 10.1016/j.berh.2005.03.003.
18. Sae-jung S, Hunzavong T, Jirarattanapochai K. Reliability of Thai version of Oswestry Questionnaire for the evaluation of low back pain patients. Srinagarind Med J 2002;17:247-53.
19. Jirarattanaphochai K, Jung S, Sumananont C, Saengnipanthkul S. Reliability of the Roland-Morris Disability Questionnaire (Thai version) for the evaluation of low back pain patients. J Med Assoc Thai 2005;88:407-11.
20. Jirarattanaphochai K, Jung S, Sumananont C, Saengnipanthkul S. Reliability of the medical outcomes study short-form survey version 2.0 (Thai version) for the evaluation of low back pain patients. J Med Assoc Thai 2005;88:1355.
21. Hlaing SS, Puntumetakul R, Khine EE, Boucaut R. Effects of core stabilization exercise and strengthening exercise on proprioception, balance, muscle thickness and pain related outcomes in patients with subacute nonspecific low back pain: a randomized controlled trial. BMC Musculoskelet Disord 2021;22:998. doi: 10.1186/s12891-021-04858-6.
22. Richardson JT. Eta squared and partial eta squared as measures of effect size in educational research. Educ Res Rev 2011;6:135-47. doi: 10.1016/j.edurev.2010.12.001.
23. Akhtar MW, Karimi H, Gilani SA. Effectiveness of core stabilization exercises and routine exercise therapy in management of pain in chronic non-specific low back pain: a randomized controlled clinical trial. Pak J Med Sci 2017;33:1002-6. doi: 10.12669/pjms.334.12664.
24. Kwon SH, Oh SJ, Kim DH. The effects of lumbar stabilization exercise on transversus abdominis muscle activation capacity and function in low back pain patients. Isokinet Exerc Sci 2020;28:147–52. doi: 10.3233/IES-192191.
25. Noormohammadpour P, Kordi M, Mansournia MA, Akbari-Fakhrabadi M, Kordi R. The role of a multi-step core stability exercise program in the treatment of nurses with chronic low back pain: a single-blinded randomized controlled trial. Asian Spine J 2018;12:490-9. doi: 10.31616/asj.2018.12.3.490.
26. Suh JH, Kim H, Jung GP, Ko JY, Ryu JS. The effect of lumbar stabilization and walking exercises on chronic low back pain: a randomized controlled trial. Medicine (Baltimore) 2019;98:e16173. doi: 10.1097/MD.0000000000016173.
27. Porwal S, Rizvi MR, Sharma A, Ahmad F, Alshahrani MS, Raizah A, et al. Enhancing functional ability in chronic nonspecific lower back pain: the impact of EMG-guided trunk stabilization exercises. Healthcare (Basel) 2023;11:2009. doi: 10.3390/healthcare11142009.
28. Ota M, Kaneoka K, Hangai M, Koizumi K, Muramatsu T. Effectiveness of lumbar stabilization exercises for reducing

chronic low back pain and improving quality of life. J Phys Ther Sci 2011;23:679–81. doi: 10.1589/jpts.23.679.

29. Saiklang P, Chatprem T, Saiklang P, Puntumetakul R, Yeowell G. The effect of abdominal drawing-in manoeuvres and abdominal bracing techniques via telerehabilitation on lumbar repositioning error in seated sedentary participants with chronic low back pain and lumbar instability: a randomised controlled trial. Hum Mov 2025;26:101–14. doi: 10.5114/hm.2024.132512.
30. Amin J, Ahmad B, Amin S, Siddiqui AA, Alam MK. Rehabilitation professional and patient satisfaction with telerehabilitation of musculoskeletal disorders: a systematic review. Biomed Res Int 2022;2022:7366063. doi: 10.1155/2022/7366063.