Research Paper

Supervising Core Stabilization and Neurodynamic Exercises in Patients With Chronic Non-specific Low Back Pain Using a Mobile Application

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Citation Khani Khosrowshahi H, Salahzadeh Z, Ahadi J, Samad-Soltani T, Chakeri Z, Soltani A. Supervising Core Stabilization and Neurodynamic Exercises in Patients With Chronic Non-specific Low Back Pain Using a Mobile Application. Physical Treatments. 2026; 16(Special Issue: Exercise Therapy in Action):445-456. http://dx.doi.org/10.22034/ptj.specialissue.243.3

http://dx.doi.org/10.22034/ptj.specialissue.243.3

Article info:
Received: 21 Oct 2024
Revised: 14 Jul 2025
Accepted: 25 Oct 2025

Keywords:
Remote rehabilitation, Chronic low back pain (LBP), Smartphone rehabilitation application, Stabilization exercises, Neurodynamic exercises.

ABSTRACT

Purpose: Exercises aimed at lumbar stability, along with neurodynamic exercises, are beneficial in addressing low back pain (LBP). One of the most important factors in the effectiveness of these exercises is teaching patients how to do exercises correctly. This study aimed to evaluate the impact of administering lumbar stability and neurodynamic exercises through a smartphone application compared to the booklet method in patients with non-specific chronic LBP.

Methods: Twenty patients were randomly assigned to two groups: treatment group (application group) and control group (booklet group). The main outcome measures included pain intensity, while the secondary outcomes encompassed functional disability, nervous system dynamics, neuromuscular control, satisfaction levels, and exercise adherence. Both groups received therapeutic exercises, including neurodynamic and lumbar stabilization exercises. The control group was given a booklet containing pictures and explanations of the exercises, and the treatment group was given a special application.

Results: Statistically significant improvements were noted in the intensity of LBP, functional disability, single-leg raising (SLR) angle, double-leg lowering test (DLL), patient satisfaction, and exercise adherence across both groups ($P<0.05$). However, no statistically significant differences were found in any of the variables when comparing the groups ($P<0.05$).

Conclusion: The findings of this study indicated that the utilization of smartphone applications can enhance patients' symptoms to a degree comparable to traditional approaches, such as the use of exercise booklets. It appears that smartphones may have a unique function in facilitating the learning of stabilization and neurodynamic exercises for patients with nonspecific LBP.

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Highlights

- Both core stability and neurodynamic exercises are useful for the management of nonspecific LBP.
- Smartphone use can significantly contribute to learning stabilization and neurodynamic exercises for patients with nonspecific LBP.

Plain Language Summary

Therapeutic exercises guided by a therapist are recommended in European guidelines as the primary treatment option for individuals with chronic low back pain (LBP). Core stability and neurodynamic exercises are widely recognized and beneficial for the management of nonspecific LBP. Nonetheless, the effectiveness of these exercises in individuals suffering from LBP is contingent upon the quality of learning and execution by patients. This research aimed to compare the efficacy of mobile applications versus booklets in delivering exercise instructions on the symptoms, disability, and adherence of patients with nonspecific LBP. The findings of this study revealed that both groups experienced significant improvements in disability and pain, indicating that using a mobile application to educate patients on core stabilization and neurodynamic exercises is as effective as the traditional booklet method.

Introduction

The exact mechanisms underlying non-specific low back pain (LBP) remain unclear. One proposed mechanism for non-specific LBP is the disruption of stability in the lumbar spine [1, 2]. Therapeutic exercise, conducted under the guidance of a therapist, is advised in European guidelines as the primary treatment option for individuals with chronic LBP [3]. If the exercises are performed under supervision, this increases their effectiveness and significantly improves patients' pain and function [3].

Core stability and neurodynamic techniques (NDT) are common and useful therapeutic exercises for the management of nonspecific LBP [4]. Core stability exercises establish an effective connection between the muscles responsible for stability and the central nervous system; therefore, they prevent recurrent LBP [5]. The effectiveness of stabilization exercises has been approved and reported in previous studies [5-7]. In these exercises, patients receive initial education from a therapist to facilitate muscle recruitment during basic tasks. As the patient's skills improve, the exercises are advanced to more complex and functional tasks [1, 8]. NDT enhances the biomechanics of nervous systems through joint positioning and movement, thereby facilitating neural tensioning or sliding [9-11]. According to the recent systematic review in patients with LBP, NDT effectively improves function and reduces pain [1].

Core stability and neurodynamic exercises may be used as a unique treatment or as part of a multifaceted treatment program, and they can be prescribed face-to-face under the supervision of a therapist or include an exercise program at home [12, 13]. In LBP patients, the success of exercise therapy is contingent upon the patient's compliance with the recommended physiotherapy exercises. "Home-based "exercises also play a crucial role. A large percentage of patients do not adhere to the exercises prescribed in physiotherapy [14, 15].

The development of technology has made it possible for health professionals to provide health services in a new and remote way [16]. With the expansion of tele-rehabilitation, the continuity of patient care at home has improved. This allows therapists to provide remote patient care outside clinical settings [16]. Tele-rehabilitation is an opportunity to continue physiotherapy in the patient's own social and professional environment, which may lead to more functional results. Smartphone applications with home exercise programs are a new way to provide physical therapy that promotes the active participation of the patient during the treatment period. Using technology to provide rehabilitation services has many benefits for both therapists and patients [16].

Chronic LBP has a long treatment process and creates difficult conditions for patients who cannot participate in many physiotherapy sessions. The use of mobile phones and remote rehabilitation applications to instruct exercise therapy for individuals with chronic LBP has demonstrated a beneficial impact on alleviating pain, enhancing quality of life, and increasing patient satis-

faction [17]. The rate of patient retention for therapeutic exercises at home has shown a significant improvement with the use of smartphone applications [8, 18, 19].

With the progress of technology and the development of specialized software applications for treating LBP, as well as the recognition of the significance of core stability and neurodynamic exercises in alleviating the symptoms experienced by patients with LBP, there is a notable lack of evidence-based software solutions for LBP treatment. This is particularly true for supervised software applications that incorporate core-stabilizing and neurodynamic exercises tailored for patients with LBP. Consequently, our research team has resolved to create a supervised software application that focuses on core-stabilizing and neurodynamic exercises appropriate for individuals suffering from LBP. Following this, we will conduct a study to assess the impact of this application on patients diagnosed with LBP. This research represents a pilot study aimed at evaluating feasibility, refining protocols, and recognizing potential obstacles prior to the execution of a subsequent study. This study aimed to utilize supervised applications and booklets alongside physical therapy sessions to assess the impact of these two home exercise methods on the symptoms and performance of individuals with non-specific LBP. Based on the findings of the literature review, this study could potentially be the inaugural investigation into the effects of supervised neurodynamic and core stabilization exercises delivered through applications and booklets on patients with non-specific LBP.

Materials and Methods

Study design

This pilot study was designed for a single-blind randomized clinical trial involving two parallel groups to evaluate the effects of a therapeutic exercise program delivered through both application and booklet formats, in conjunction with physical therapy sessions, for patients experiencing non-specific LBP. The study focused on various outcomes, including pain intensity, functional disability, neurodynamic function of the nervous system, neuromuscular control of the back stabilizing muscles, as well as treatment satisfaction and adherence. This study was registered with the Iranian Randomized Clinical Trial (IRCT) and was conducted at the physiotherapy clinic of the Faculty of Rehabilitation Sciences following Ethics Committee Approval from Tabriz University of Medical Sciences. The research commenced in March 2022 and concluded in September 2022.

Participants

Participants (age range: 20-60 years) who were referred to physiotherapy by orthopedic and physical medicine specialists were recruited. Inclusion criteria for participants were mild to moderate back pain (typically, pain intensity ranging from 2 to 6 on the visual analog scale [VAS]) and lower extremity pain for at least the past three months, with an Oswestry disability index score ≥10%. Additionally, the capacity to read Persian, the ability to use an Android smartphone, and willingness to participate in the study were included as criteria for participation in the research [20- 22]. Participants were excluded if they had a history of inflammatory, metabolic, infectious, and malignant spine diseases; osteoporosis; ankylosing spondylitis; vertebral fracture and history of spinal surgery; and any limitation in the range of motion (ROM) of the knee and hip joints. Before entering the study, each participant provided written consent [23-26].

Sample Size

The sample size was established according to the Oswestry functional disability questionnaire, considering α=0.05 and β=0.05 (95% power). According to previous studies, using G.*Power v.3.1.6 software, 10 participants were included in each group. Throughout the research study, three patients from the control group and two patients from the treatment group were excluded due to various problems, such as transportation issues and treatment time conflicts with work. Finally, 20 patients completed the treatment process.

Interventions

Prior to the commencement of the study, patients were assessed regarding pain intensity, functional disability, neurodynamic function of the nervous system, and neuromuscular control of the lumbar stabilizing muscles. Both groups underwent 10 sessions of physical therapy over a period of four weeks (three sessions per week during the initial three weeks and a single session in the fourth week). Each physiotherapy session included 30 minutes of electrotherapy (TENS, hot pack, and US) and 20 minutes of exercise therapy (lumbar stabilization exercises and neurodynamic exercises) [9, 27].

In the initial session following electrotherapy, participants in the application group received exercise therapy utilizing the specialized software developed for this study, whereas the control group engaged in therapeutic exercises as outlined in a home booklet. To replicate and ensure that the control group received a comparable

treatment, the structure, content, or progression of the exercises was the same in both groups. These exercise programs provided general warm-up exercises, neuro mobilization exercises (slider and tensioner neurodynamic exercises in the slumped and supine positions), and stabilization exercises to the patients (Figures 1, 2 and 3).

Before the main exercises, the patients were given stretching exercises to warm up. For neurodynamic exercises, 4 exercises were considered, and each exercise was performed in a set of 20 exercises per day. Each stability exercise was performed for 5-10 seconds and 10 repetitions per day. In each physiotherapy session, a new exercise was added to the prescribed exercises so that the patient received all the relevant exercises in 4 weeks.

Patients were evaluated by a physiotherapist in each session, and the possibility of progressing to the next exercises was examined. If clinical symptoms and the patient's condition permitted, at the end of each session, the exercises specific to that session were taught to patients in both groups and marked in the application or booklet. If there was a problem in performing the exercises at home, it was resolved. Also, patients' adherence to treatment was assessed using an adherence questionnaire.

In the application group, a software program was installed on their smartphone, which offered the patient a video demonstrating the correct way to perform the exercises. In addition, the software could remind the patient to do the exercises at a certain time. At the end of each session, the exercises specific to that session were taught to the patients of both groups and marked in the application or booklet. Also, if there was a problem in performing the exercises at home, it was addressed. Every day, the patient specified the number of times to perform the exercises in the application. In the application, there was a section called "Sending the daily report"; at the end of that day, the number of exercises performed in this section of the software was written by the patient.

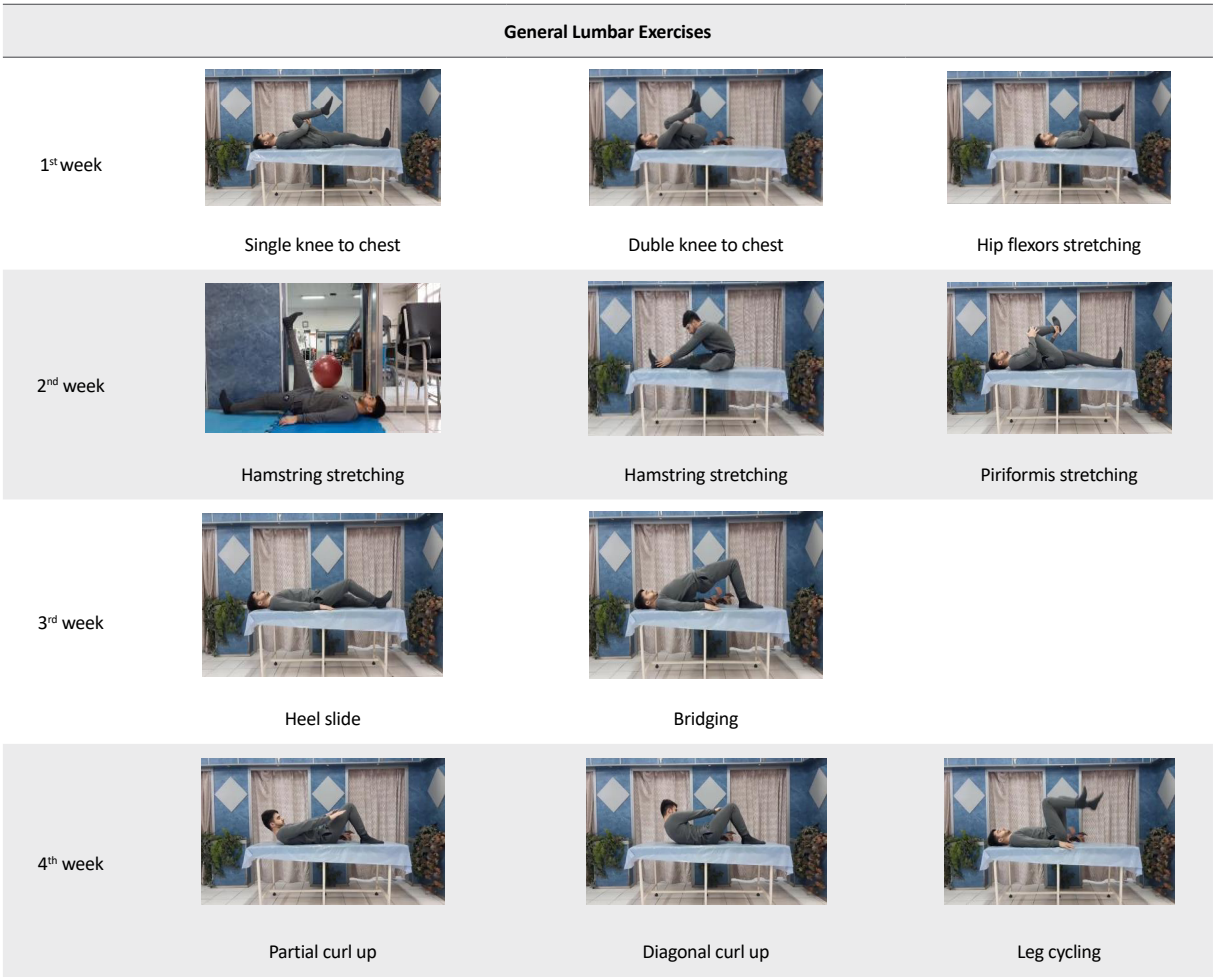

Figure 1. General warm-up exercises

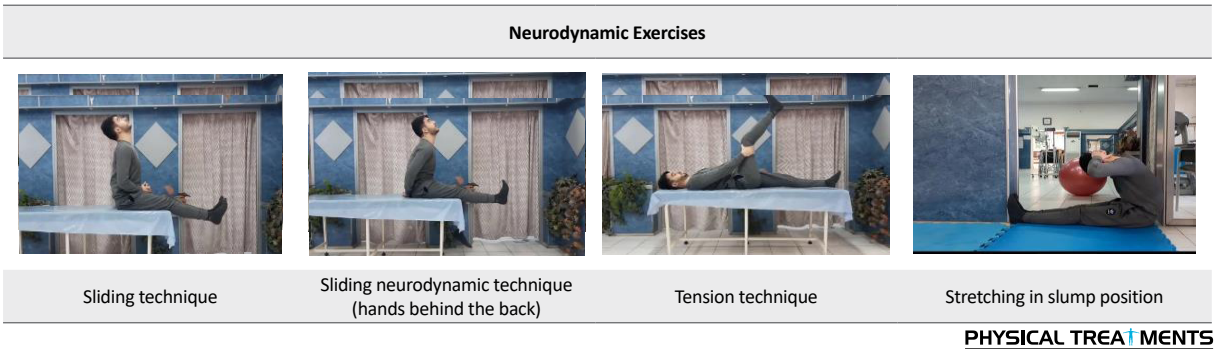

Figure 2. Neuro mobilization exercises (slider and tensioner neurodynamic exercises in the slumped and supine positions)

Randomization and masking

A total of 20 participants took part in the study and were randomly assigned to either the applications group or the control group (Figure 4). Four balanced blocks were used for randomization. As each patient entered, an independent researcher selected and opened one of the envelopes. According to the number written in it and the predetermined blocks, the patient was placed in one of the treatment groups. A total of 10 participants were randomly assigned to the applications group, while another 10 were assigned to the control group. The assessor and the person analyzing the results were blind to the subjects' assignments during the treatment. Given the characteristics of the intervention, the participants were not blinded to the study. During the evaluation process, participants were asked to refrain from disclosing any information that could have indicated their treatment group. This may have minimized bias in the data collection process.

Figure 3. Stabilization exercises for patient

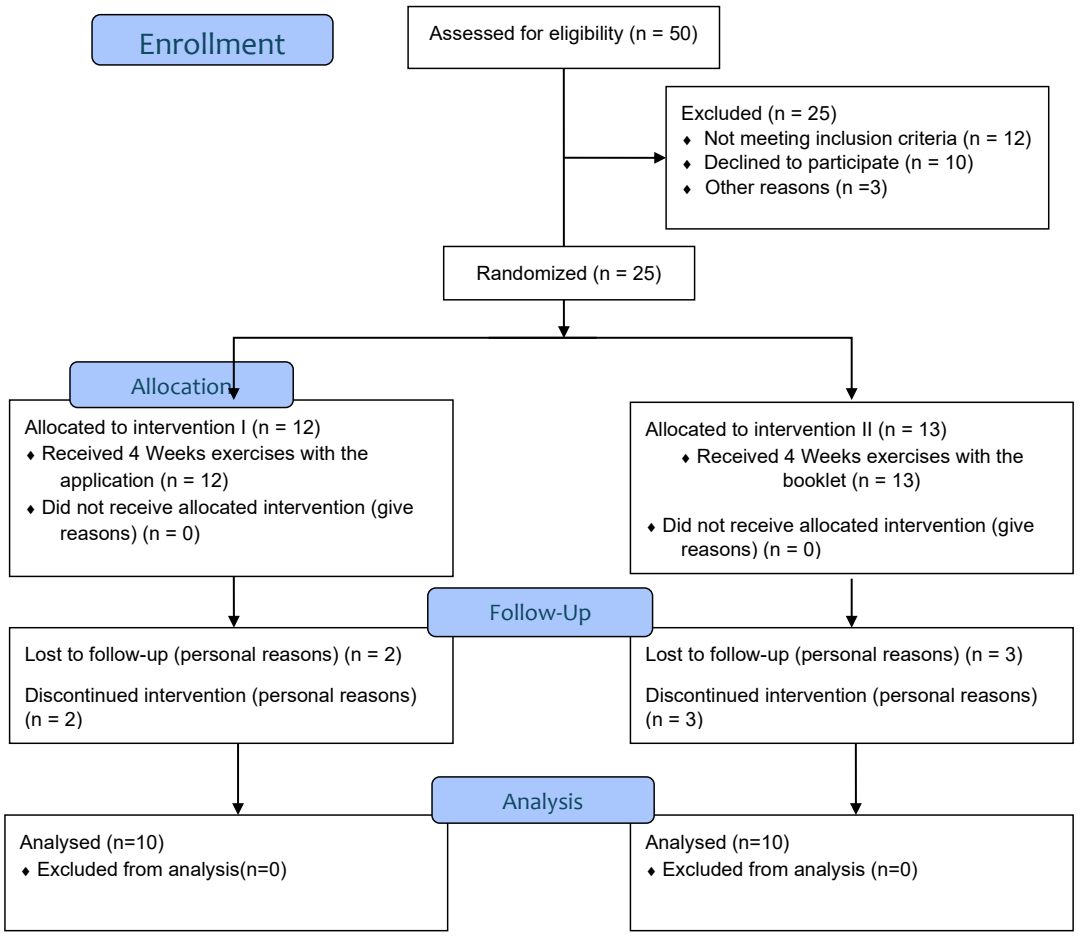

Figure 4. CONSORT flow diagram of participant recruitment, allocation, follow-up, and analysis PHYSICAL TREATMENTS

Primary outcome

The main outcome measures included the intensity of LBP and functional disability, which were assessed using the VAS and the Persian version of the Oswestry disability questionnaire. These questionnaires have been validated and are reliable [28, 29].

Secondary outcomes

The secondary outcome measures were single-leg raising (SLR) angle as the lumbar neurodynamic test and double-leg lowering test (DLL) as the lumbar neuromuscular control score. During the SLR test, the patient was positioned supine without a pillow supporting the head. The examiner elevated the patient's leg while ensuring that the knee remained fully extended. The examiner elevated the patient's leg until the patient expressed discomfort or cramping in the lumbar spine region or the posterior aspect of the leg. The angle of hip flexion was assessed using a goniometer and documented. Each leg was evaluated separately, with the healthy leg being assessed first [30].

To conduct the DLL test, the patient was positioned supine, and a pressure cuff was inflated to 40 mm-Hg and positioned beneath the lumbar spine. The examiner raised both legs of the patient to a 90-degree angle while keeping the lumbar spine on the floor. The patient was asked to maintain the pressure of the cuff by contracting the lower abdominal muscles and lowering both legs. If the pressure on the cuff decreased, the test was halted, and the angle of the hip joint in relation to the ground was assessed using a goniometer. All outcomes have been measured in the first and last sessions [31].

The valid and reliable Persian versions of patient "satisfaction" and "exercise adherence" questionnaires were used to measure the amount of patient satisfaction and adherence of participants in both groups [32, 33]. Patient's satisfaction and adherence were collected in the last intervention treatment.

Statistical analysis

SPSS software, version 29.1.1 was used to conduct all statistical analyses. The Kolmogorov-Smirnov test was employed to assess the normality of the data distribution. A paired t-test was applied for the intra-group analysis of variables exhibiting a normal distribution. For variables lacking a normal distribution within the group, the non-parametric Wilcoxon test was utilized. The independent t-test was conducted for the intergroup analysis of variables with a normal distribution. In contrast, the Mann-Whitney test was used for the intergroup analysis of variables that did not conform to a normal distribution.

Results

Kolmogorov-Smirnov test showed that two variables (Oswestry disability questionnaire criteria and double leg lowering) have a normal distribution, and the other variables do not have a normal distribution. Table 1 presents demographic information of age, height, and weight variables (Mean±SD) related to the members of both groups.

Table 2 presents variables associated with pain intensity, functional disability, neurodynamic function of the nervous system, and neuromuscular control of the back-stabilizing muscles, both prior to and following treatment. Additionally, Table 2 includes satisfaction with the treatment and adherence to the treatment after its completion.

Prior to the intervention, both groups exhibited statistical similarity regarding background variables (age, weight, and height) and research variables (VAS, SLR, DLL, and Oswestry disability index scores) ($P<0.05$).

No statistically significant difference was observed in the background variables and the study variables prior to the intervention. Additionally, the variables did not exhibit significant differences ($P>0.05$) in the between-group comparison following the intervention. The patients in both groups reported a high level of satisfaction with the treatment received (92% in the applications group versus 88% in the booklet group), and the adherence rates among subjects in both groups were also elevated (85% in the applications group compared to 77% in the booklet group). Nevertheless, there was no significant difference in satisfaction and adherence levels between the applications and booklet groups ($P>0.05$). The results from the intra-group comparison indicated that the intervention had a significant impact on all research variables in both groups ($P<0.05$).

Discussion

Recently, smartphones have become common in the field of health. Advances in technology, especially smartphone applications, have created a suitable environment for health professionals to communicate and treat different groups of patients [34]. This technology reduces costs and time for the patient and increases their compliance with exercise programs [35]. This method gives the patient a sense of personal independence and empowerment [36]. Although there are several studies on the use of applications in treatment and improving

Table 1. Demographic information

Variables	Mean±SD		P
	Applications Group	Booklet Group	
Age (y)	51.6±8.08	52.20±9.84	0.88
Weight (kg)	80.3±12.27	83.9±9.97	0.48
Height (cm)	168.4±8.78	167.5±10.17	0.83

Table 2. Comparison of study outcomes between the application and booklet groups

Variables	Applications Group				Booklet Group				Between Group	
	Mean±SD		Within Group		Mean±SD		Within Group			
	Before	After	P	Effect Size	Before	After	P	Effect Size	P	Effect Size
VAS	6±1.15	2.2±0.92	0.00*	3.6	6.1±1.66	2.7±1.42	0.00*	2.18	0.36	0.42
SLR	67.7±17.62	87.5±11.56	0.00*	1.27	64.8±15.29	87±8.11	0.00*	1.67	0.91	0.05
DLL	62.2±14.09	34±15.14	0.00*	1.92	59.6±14.02	28.8±22.72	0.00*	1.55	0.55	0.27
Oswestry	49.2±7.78	18.6±8.22	0.00*	3.82	44.4±10.74	17.6±12.21	0.00*	2.32	0.83	0.1
Satisfaction	-	5.53±0.29	-		-	5.31±0.72	-		0.39	0.4
Adherence	-	54.4±2.99	-		-	49.3±9.29	-		0.12	0.74

Abbreviations: VAS: Visual analog scale; SLR: Straight leg-raising; DLL: Double leg-lowering.
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*Statistically significant at P<0.05.

communication between patients and physiotherapists, studies on specific patients and specific exercises are limited [37, 38]. This was the first study to apply neurodynamic exercises through an app in LBP patients.

According to the results of this study, significant improvements in disability and pain were found in both groups; therefore, using a mobile application to educate core stabilization and neurodynamic exercises was as effective as the booklet method. Stabilization exercise education takes time and energy from physiotherapists, whereas the patient's correct execution of exercises has a great impact on the effectiveness of the exercises. The patient's relationship with the therapist is a strong predictor of adherence during treatment, and correct, effective communication with health therapists improves treatment outcomes. Physiotherapy exercises prescribed through smartphone technology may facilitate this communication by increasing patient participation in specific treatment programs, with greater learning and memorization capabilities.

Our findings align with those of Hou et al. (2019), who examined the impact of utilizing applications versus booklets over a brief duration. Their study did not reveal a significant difference between the groups regarding the enhancement of pain intensity and functional disability [39]. The findings of our research align with those of Hou et al. (2019), who examined the impact of utilizing applications in conjunction with standard care treatment. Their study demonstrated that, at the 24-month mark, the applications group experienced improvements in pain severity and functional disability compared to the usual care group. However, it is important to note that this difference between the two groups was not statistically significant in the short term [39]. In our study, the absence of a notable difference in pain intensity and functional disability between the two groups could also be attributed to the relatively brief period of exercise utilization.

In the research conducted by Cui et al. (2023), the effects of a digital care program compared to conventional physiotherapy on patients with chronic back pain were examined. Both groups exhibited significant improvements in disability and pain, with no statistically significant differences observed [40]. Furthermore, in a study by Mbada et al. (2019), the impact of face-to-face McKenzie therapy, when compared to executing McKenzie exercises with applications, did not reveal a notable difference in pain relief [41]. Also, in the study by Amorim et al. (2019), although pain and disability improved more in the application group, this difference was not statistically significant [42].

In other studies, contradictory results have been obtained compared to the present study. In the study of Lopez-Marcos et al. (2024), McGill's exercises within the application group demonstrated superior outcomes compared to in-person interactions [13]. In the study of Özden et al. (2022), after 8 weeks of exercise in both the application and booklet groups, improvement in pain intensity and functional disability was observed [43]. This improvement was statistically greater in the application group. In another study conducted by Chhabra et al. (2018), participants in the application group experienced statistically better recovery [44]. Also, in the study by Yang et al. (2018), individuals in the physiotherapy group who engaged in exercise through applications demonstrated a notable enhancement in pain intensity and functional disability when compared to those receiv-

ing standard physical therapy [45]. It should be mentioned that existing software does not consider specific back exercises, and general exercises are provided to patients. In addition, the software designed in this study was also capable of further monitoring the patient's exercise performance.

In this study, to ensure patients benefited from the positive effects of all therapeutic exercises, the types of exercises performed in both groups were similar. For this reason, although both groups demonstrated a satisfactory improvement relative to their condition prior to treatment, in most instances, no significant difference was noted between the two groups concerning the measured variables. In future studies, it is suggested that the application or booklet be considered only for the treatment group, and the control group should learn the exercises in the physical therapy center, so that we can determine the main effect of using tools to prepare home exercises.

In individuals with chronic conditions, compliance with treatment is regarded as a crucial element for long-term success. The findings indicated that both cohorts expressed a high level of satisfaction with the treatment and demonstrated strong adherence to the home exercise regimen, with no notable differences observed between the two groups. High adherence to treatment indicates high acceptance of home exercise therapy. Similarly, high levels of satisfaction by patients in both groups further strengthened participant acceptance. This was in line with Cui's study, which found that patients showed high adherence to the digital care program [40].

The absence of automated monitoring of home exercises within the functional groups can be identified as a limitation of the current study. This limitation was slightly removed by considering the "sending the daily report" section in the applications. However, only a few patients in this group submitted their daily reports irregularly. Another problem in this research was the lack of an IOS version for this software. In addition, because the software required technology literacy, we had limitations in enrolling patients in this group. Another limitation of this study is the number of participants. A randomized clinical trial with a large sample size is needed to better substantiate the results obtained.

Conclusion

Using a mobile application, along with the exercise booklet, to deliver stabilization and neurodynamic exercises at home for patients with non-specific chronic back pain has notably improved symptoms, leading to high patient satisfaction and adherence to the treatment regimen. Consequently, the mobile application was as effective in facilitating patient recovery as the exercise booklet.

Ethical Considerations

Compliance with ethical guidelines

This study was registered with the Iranian Randomized Clinical Trial (IRCT), Tehran, Iran (Code: IRCT20210316050727N2) and was conducted at the physiotherapy clinic of the Faculty of Rehabilitation Sciences following Ethics Committee Approval from Tabriz University of Medical Sciences, Tabriz, Iran (Code: IR.TBZMED.REC.1400.126).

Funding

This study was supported by the Faculty of Rehabilitation at Tabriz University of Medical Sciences, Tabriz, Iran.

Authors' contributions

Study design and data collection: Hadi Khani Khosrowshahi, Abbas Soltani, Taha Samad Soltani; Data analysis: Zahra Salahzadeh, Jalal Ahadi, and Zahra Chakeri; Writing: Hadi Khani Khosrowshahi, Zahra Salahzadeh, Jalal Ahadi, Zahra Chakeri.

Conflict of interest

The authors declared no conflict of interest.

Acknowledgments

The authors would like to express their sincere gratitude to the Faculty of Rehabilitation at Tabriz University of Medical Sciences for its valuable support in conducting this study.

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