Title: Supervising Core Stabilization and Neurodynamic EXERCISES in Patients with Chronic Non-Specific Low Back Pain Using a Mobile Application: A Pilot Randomized Clinical Trial

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Abstract:

Introduction: Exercises aimed at lumbar stability, along with neurodynamic exercises, are beneficial in addressing low back pain. One of the most important factors of the effectiveness of these exercises is teaching patients how to do exercises correctly. The objective of this research was to evaluate the impact of administering lumbar stability exercises and neurodynamic exercises through a smartphone application compared to the booklet method in patients suffering from non-specific chronic low back pain.

Method: 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, dynamics of the nervous system, neuromuscular control, satisfaction levels, and adherence to exercise. Both groups received therapeutic exercise included neurodynamic exercises and lumbar stabilization exercises. The control group were given a booklet containing pictures and explanations of the exercises, and the treatment group were given a special application.

Results: Statistically significant enhancements were noted in the intensity of low back pain, 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 between the groups ($P<0.05$).

Conclusion: The findings of this research 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 suffering from nonspecific low back pain.

Key words: Remote rehabilitation, Chronic low back pain, Smartphone rehabilitation application, Stabilization exercises, Neurodynamic exercises.

Highlights

• Both Core stability and neurodynamic exercises are useful to management of the nonspecific LBP

• The utilization of smartphones can significantly contribute to the learning of stabilization and neurodynamic exercises for patients experiencing nonspecific low back pain.

Plain Language Summary

Therapeutic exercise, guided by a therapist, is advised in European guidelines as the primary treatment option for individuals suffering from chronic low back pain. Core stability and neurodynamic exercises are widely recognized and beneficial for the management of nonspecific low back pain (LBP). Nonetheless, the effectiveness of these exercises in individuals suffering from LBP is contingent upon the quality of learning and execution of the exercises by the 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 the use of a mobile application for educating patients on core stabilization and neurodynamic exercises is as effective as the traditional booklet method.

1.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 suffering from chronic low back pain (LBP) (3). If the exercises are performed under supervision, it increases the effect of the exercises and improves the pain and function of the patients significantly (3).

Core stability and Neurodynamic techniques (NDT) can be common and useful therapeutic exercise to management of the nonspecific LBP (4). Core stability exercises establish an effective connection between the muscles responsible for stability and the central nervous system therefore preventing 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). Neurodynamic techniques (NDT) enhance the biomechanics of nerve systems through the positioning and movement of joints, thereby facilitating either neural tensioning or sliding (9-11). According to the recent systematic review in LBP patients, 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 it 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 very important role. A large percentage of patients do not adhere to the 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 is improved. This allows therapists to provide remote patient care outside of the clinical setting (16). Tele-rehabilitation is the opportunity to continue physiotherapy in the patient's own social and professional environment that it may leads to more functional results. Smart phone applications with home exercise programs are 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 not only for the therapist but also for the patients themselves (16).

Chronic LBP has a long treatment process and creates difficult conditions for patients who cannot participate in many physiotherapy sessions. The utilization of mobile phones and remote rehabilitation applications for instructing exercise therapy to individuals suffering from chronic low back pain (LBP) has demonstrated a beneficial impact on alleviating pain, enhancing the quality of life, and increasing patient satisfaction among those with chronic LBP (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 aimed at treating low back pain, alongside the recognition of the significance of core stability and neurodynamic exercises in alleviating the symptoms experienced by patients with LBP, there is a pronounced absence 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 LBP patients. 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. The objective of this research is 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 suffering from non-specific low back pain (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 experiencing non-specific LBP.

2. Materials and Methods

2.1. Study Design

This research constituted a pilot study of a single-blinded randomized clinical trial, which involved two parallel groups aimed at evaluating 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 low back pain (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 (IRCT20210316050727N2) and was carried out at the physiotherapy clinic of the Faculty of Rehabilitation Sciences following the ethics committee's approval from Tabriz University of Medical Sciences (IR.TBZMED.REC.1400.126). The research commenced in March 2022 and concluded in September 2022.

2.2. Participants

Participants (age range 20-60 years) referred by orthopedic and physical medicine specialists to the physiotherapy were recruited. Inclusion criteria for participants were having mild to moderate back pain (Typically, if the pain intensity ranges from 2 to 6 on the Visual Analog Scale (VAS)) and referred lower extremity pain for at least the past three months, ODI score ≥ 10%. Additionally, the capacity to read the Persian language, the capability of utilizing a smartphone operating on the Android system, and a willingness to engage in the study were included as criteria for participation in the research (20, 22). Participants were excluded if they had: (1) history of inflammatory, metabolic, infectious, and malignant spine diseases; (2) osteoporosis; (3)

ankylosing spondylitis; (4) vertebral fracture and history of spinal surgery; (5) Any limitation in the range of motion of the knee and hip joints. Before entering the study, each participant provided written consent (23-26).

2.3. Sample Size

The sample size was established according to the variable of the OSWESTRY functional disability questionnaire, considering $\alpha = 0.05$ and $\beta = 0.05$ (95% power). According to previous studies, with the help of G. Power v.3.1.6 software, 10 people were situated within 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 and interference of treatment time with their work time. Finally, 20 patients completed the treatment process.

2.4. 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 (with 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 provide general warm-up exercises, neuro mobilization exercises (slider and tensioner neurodynamic exercises in the slumped and supine positions) and stabilization exercises to the patients. (Figure 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 to 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 the clinical symptoms and the patient's condition permitted, 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, they were resolved. Also, patients' adherence to treatment was assessed with 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, this software had the ability to 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, they were solved. Every day, the patient specified the number of times to perform the exercises in the applications. 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.

2.5. 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. Four balanced blocks were utilized for the purpose of randomization. As each patient enters, an independent researcher selects and opens one of the envelopes. According to the number written in it and the predetermined blocks, the patient is 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 had to refrain from disclosing any information that could have been representative of their treatment group. This may have minimized bias in the data collection process.

2.6. Primary Outcome

The main outcome measures included the intensity of low back pain (LBP) and functional disability, which were assessed using the Visual Analog Scale (VAS) and the Persian version of the Oswestry Disability Questionnaire. These questionnaires have already been validated and reliable (28, 29).

2.7. 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 administration of the SLR test, the patient is positioned supinely without a pillow supporting the head. The examiner elevates the patient's leg while ensuring that the knee remains in a completely extended posture. The examiner proceeds to elevate the patient's leg until the patient expresses discomfort or cramping in the lumbar spine region or the posterior aspect of the leg. The angle of hip flexion is assessed using a goniometer and documented. Each leg is evaluated separately, with the healthy leg being assessed first (30).

To conduct the DLL test, the patient is positioned supine, and a pressure cuff inflated to 40 mmHg is positioned beneath the lumbar spine. The examiner raises both legs of the patient to a 90 degrees 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 lower both legs. If the pressure on the

cuff decreases, the test has been halted, and the angle of the hip joint in relation to the ground is assessed using a goniometer. All outcomes have been measured in the first and last sessions (31).

The valid and reliable Persian version of patient "satisfaction" and "exercise adherence" questionnaires have been used to measure the amount of patient's satisfaction and adherence of participant in both groups (32, 33). Patient's satisfaction and adherence were collected in the last intervention treatment.

2.8. Statistical Analysis

The SPSS software version 29.1.1 was utilized 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, while the Mann-Whitney test was used for the intergroup analysis of variables that did not conform to a normal distribution.

3. Results

Kolmogorov-Smirnov test showed that two variables (OSWESTRY disability questionnaire criteria and Double Leg Lowering) have normal distribution and other variables do not have normal distribution. Demographic information of age, height and weight variables (mean and standard deviation) related to the members of both groups are shown in Table 1.

The 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, are presented in Table 2. Additionally, Table 2 includes the level of satisfaction with the treatment as well as the degree of adherence to the treatment after its completion.

Prior to the intervention, both groups exhibited statistical similarity regarding background variables (age, weight, and height) as well as research variables (VAS, SLR, DLL, and OSWESTRY Disability Index score) ($P<0.05$).

There was no statistically significant difference 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 group and the booklet group ($P>0.05$). The results from the intra-group comparison indicated that the intervention had a significant impact on all research variables in both groups ($P< 0.05$).

Table 1: Demographic information

Variables	applications Group	booklet Group	P value
	Mean (SD)[1]	Mean (SD)	
Age	51.60 (8.08)	52.20 (9.84)	0.88
Weight	80.30 (12.27)	83.90 (9.97)	0.48
Height	168.40 (8.78)	167.50 (10.17)	0.83

1: Standard Deviation.

Table 2: Variables related to pain intensity, functional disability, neurodynamic function of the nervous system, neuromuscular control of the back-stabilizing muscles before and after treatment. Additionally, the degree of satisfaction with the treatment and the extent of adherence to the treatment following its completion.

Variables	applications Group				booklet Group				Between Groups	
	Before	After	Within Group		Before	After	Within Group			
	Mean (SD)[1]	Mean (SD)	P value	Effect size	Mean (SD)	Mean (SD)	P value	Effect size	P value	Effect size
VAS[2]	6.00 (1.15)	2.20 (0.92)	0.00*	3.60	6.10 (1.66)	2.70 (1.42)	0.00*	2.18	0.36	0.42
SLR[3]	67.70 (17.62)	87.50 (11.56)	0.00*	1.27	64.80 (15.29)	87.00 (8.11)	0.00*	1.67	0.91	0.05
DLL[4]	62.20 (14.09)	34.00 (15.14)	0.00*	1.92	59.60 (14.02)	28.80 (22.72)	0.00*	1.55	0.55	0.27
OSWESTRY	49.20 (7.78)	18.60 (8.22)	0.00*	3.82	44.40 (10.74)	17.60 (12.21)	0.00*	2.32	0.83	0.1
Satisfaction	-	5.53 (0.29)	-		-	5.31 (0.72)	-		0.39	0.40
Adherence	-	54.40 (2.99)	-		-	49.30 (9.29)	-		0.12	0.74

1: Standard Deviation, 2: Visual Analogue Scale, 3: Straight Leg Raising, 4: Double Leg Lowering.

4. Discussion

Recently, the use of smart phones has become common in the field of health. Advances in the world of 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 the patient's compliance with exercise programs (35).This method gives the patient a sense of personal independence and empowerment (36). Although there are several studies on use of applications in treatment and improving communication between patients and physiotherapists, but studies on specific patients and on specific exercises are limited (37, 38). This was the first study to apply neurodynamic exercises through an app in LBP patients

According to the result of this study, significant improvements in disability and pain was found in both groups, so using the mobile application to educate the core stabilization and neurodynamic

exercise as effective as booklet method. Education of stabilization exercise takes time and energy for physiotherapist and in other hand the correct execution of exercises by the patient has a great impact on the effectiveness of the exercises. The patient's relationship with the therapist is a strong predictor of the patient's adherence during the treatment, and a correct and effective communication with the health therapists improves the effects of the treatment. Physiotherapy exercises that are prescribed through smartphone technology they may facilitate this communication by increasing patient participation in specific treatment programs with greater learning and memorization capabilities.

The findings of our research 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), which 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 when 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 research, 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 the study of 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 the enhancement of pain relief (41). Also, in the study of Amorim et al. (2019), even though the improvement of pain and disability favored 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 Ozden et al. (2022), after 8 weeks of exercise in both the applications and booklet groups, improvement in pain intensity and functional disability was seen (43). This improvement was statistically greater in the applications group. In another study conducted by Chhabra et al. (2018), participants in the applications 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 receiving standard physical therapy (45). It should be mentioned that in the existing software, specific back exercises are not considered, and general exercises are provided to patients. In addition to this, the software designed in this study was also capable of further monitoring the patient's exercise performance.

In this study, with the aim of patients benefiting 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 the majority of 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 is only by learning the exercises in the physical therapy center, so that we can know the main effect of using tools to prepare home exercises.

In individuals suffering from chronic conditions, compliance with treatment is regarded as a crucial element for long-term success. The findings of the research 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 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 "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, due to the use of the software required literacy in the use of technology, we had limitations in the entry of patients into this group. Another limitation of this study is the numbers of participations. A randomized clinical trial with a large sample size is needed for better substantiate the results obtained.

5. Conclusion

Utilizing the mobile application along with the exercise booklet to deliver stabilization and neurodynamic exercises at home for patients suffering from non-specific chronic back pain has notably enhanced their symptoms, leading to high levels of patient satisfaction and adherence to the treatment regimen. Consequently, the mobile application has proven to be as effective in facilitating patient recovery as the exercise booklet.

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This study was funded by Tabriz University of Medical Sciences.

7. Author’s contributions

Study designing: Hadi khani khosrowshahi, Abbas Soltani, Taha Samad Soltani

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Manuscript drafting: Hadi Khani Khosrowshahi, Zahra Salahzadeh, Jalal Ahadi, Zahra Chakeri

8. Conflict of interest

The authors declare that there were no conflicts of interest.

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General lumbar exercises			
First week			
	Single knee to chest	Duble knee to chest	Hip flexors stretching
Second week			
	Hamstring stretching	Hamstring stretching	Piriformis stretching
Third week			
	Heel slide	Bridging	
Forth week			
	Partial curl up	Diagonal curl up	Leg cycling

Figure1: General warm-up exercises.

Neurodynamic exercises			
			
Sliding technique	sliding neurodynamic technique (hands behind the back)	Tension technique	Stretching in slump position

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

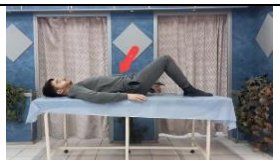
Segmental stabilization exercises				
The first week of exercises				
	In the crooklying position, pulling the abdomen inward	In the prone position, pulling the abdomen inward	Isolated contraction of lumbar multifidus	In the sitting position, pulling the abdomen inward
The second week of exercises				
	In the static standing position, pulling the abdomen inward		In the bridging position, pulling the abdomen inward	
The third week of exercise				
	In the squat position, pulling the abdomen inward		In the crook lying position, pulling the abdomen inward and moving arms and legs	
The fourth week of exercises				
	In the sitting position, pulling the abdomen inward and moving the arms and legs		In the standing position, pulling the abdomen inward with leg movement	

Figure3: Stabilization exercises for patient.

CONSORT

TRANSPARENT REPORTING of TRIALS

CONSORT 2010 Flow Diagram