

Effects of a 4-week training program on people with low back pain: Comparison of core stability training and McKenzie exercises

GUIDO BELLI¹, MARIO MAURO^{2*}, CRISTIAN ESPOSITO³, ALIN LARION⁴, ELENA LUPU⁵,
PASQUALINO MAIETTA LATESSA⁶, LUCA RUSSO⁷

^{1,7}Department of Theoretical and Applied Sciences, eCampus University, 22060 Novedrate (CO), ITALY

^{2,6}Department of Science for Life Quality Studies, University of Bologna, 47921 Rimini, ITALY

³University of Bologna, 40126 Bologna, ITALY

⁴Faculty of Physical Education and Sport, Ovidius University of Constanta, 900029 Constanta, ROMANIA

⁵Department of Motor Activities, Petroleum Gas University Ploiesti, 100600 Ploiesti, ROMANIA

Published online: April 30, 2026

Accepted for publication: April 15, 2026

DOI:10.7752/jpes.2026.04068

Abstract:

Chronic non-specific low back pain (NCLBP) is one of the main spinal disorders that impairs many daily activities and limits functional skills. The role of exercise in NCLBP is well documented, although the debate over the most effective type of training. This study aims to investigate the effects of a 4-week specific training program on pain, trunk mobility, and muscle flexibility in adults with this condition. Thirty people (aged 30-50 years) were recruited for the study. All participants were untrained and affected by NCLBP. Participants were divided into two groups, each consisting of 15 people: the Core Stability Training (CST) group (46.67% female) and the McKenzie exercises (MCK) group (53.33% female). Both groups trained twice a week for four weeks (eight sessions in total), with each session lasting 30 minutes, and repeated the exercises at home (two times per week). All participants were assessed pre- and post-training to evaluate pain intensity (Numerical Rating Scale – NRS), posterior chain muscles flexibility (Forward Bending Test - BEND) and trunk mobility (Schober Test – SCHOB). NRS and SCHOB improved significantly in both CST and MCK, whereas no difference was observed for BEND. The interaction effect comparison showed significance for NRS, with greater improvements observed in CST (-56.84%). Previous results suggest that both types of training are effective for reducing pain and improving lumbar spine mobility. Since Core Stability exercises led to better outcomes in NCLBP symptomatology after four weeks of specific training, combining both types of exercises could be helpful for people with NCLBP.

Key Words: physical exercise; core training; adaptation; health

Introduction

Low back pain (LBP) is one of the major disorders of the spine. It seriously impairs many daily activities and limits functional skills, representing a leading cause of disability worldwide (Urits et al., 2019; Van Middelkoop et al., 2011). LBP can be defined as “pain located in the area of the posterior aspect of the body, extending from the lower margin of the twelfth ribs to the lower gluteal folds; this pain may or may not radiate into one or both lower limbs and must persist for a minimum duration of one day” (Hoy et al., 2014). Annually, the prevalence of LBP in the United States adult population is about 10-30%, and the lifetime prevalence is 65-85% (Longo et al., 2010). In 2020, there were more than half a billion prevalent cases of LBP worldwide, and by 2025, a 36.4% increase is globally expected (Ferreira et al., 2023). Among the different types of LBP, the chronic non-specific low back pain (NCLBP) is the most common form of this pathology and represents a global disease independent of age and sex (Cheng et al., 2025). The aetiology of NCLBP is mainly myofascial pain (related to mechanical and musculoskeletal factors), lasting more than 12 weeks, without a clear underlying cause defined by medical tests (injury, tissue damage, and structural deficits) (Pergolizzi & LeQuang, 2020). In this regard, it is imperative to manage symptoms and improve primary, secondary, or tertiary prevention programs to reduce functional limitations and healthcare costs (George et al., 2021; Pergolizzi & LeQuang, 2020). The conservative treatment of NCLBP primarily focuses on pharmacological therapy, physical therapy, massage and manual therapy, specific exercises, and behavioural and educational strategies provided by healthcare professionals within a multidisciplinary approach (Pergolizzi & LeQuang, 2020; Urits et al., 2019; Van Middelkoop et al., 2011). In particular, the role of exercise in NCLBP management has been widely investigated to understand the effectiveness of different types of training across several populations (García-Moreno et al., 2022; Hayden et al., 2021; Li et al., 2023). Exercises for NCLBP are promoted to improve global muscular strength and endurance, increase trunk muscle activation and movement control, enhance trunk mobility and aerobic fitness (George et al., 2021; Hayden et al., 2021; Wang et al., 2012). Recently, the review of Li et al. (Li et al., 2023) reported that core stability exercises, Yoga, Pilates, Thai Chi and motor control

exercises improve physical function in people with NCLBP. In addition, the review by Hayden et al. (Hayden et al., 2021) underscores that there is moderate-certainty evidence that exercise can reduce pain and functional limitations compared with no treatment or other conservative treatments. However, more high-quality studies are needed to strengthen these conclusions. Among various exercise and methodology approaches, core stability training (CST) and the McKenzie Method (MCK) have been investigated and promoted over the last few years. The purpose of CST is to enhance lumbar-pelvic stability and motor control between the trunk and pelvis, thereby reducing mechanical loads on the spine and facilitating efficient muscular coordination (Belli et al., 2022; Ghorbanpour et al., 2018; Kumar et al., 2015; Marshall et al., 2011; Wang et al., 2012). CST seems to be more effective than general training in reducing pain and improving physical function in people with NCLBP in the short term (Wang et al., 2012). Kumar et al. (2015) demonstrated that a 6-week CST program focused on trunk strength and lumbar flexibility is an effective treatment for individuals with NCLBP, regardless of pain duration (more or less than one year). Similarly, Ghorbanpour et al. (2018) found greater improvements in pain, functional limitations, and lumbar range of motion after applying a specific CST protocol compared with conventional exercises during the same training period. On the other hand, the McKenzie Method involves repeated movements or sustained positions, accompanied by manual mobilisation and overpressure from a trained specialist (Mann et al., 2025). MCK is a system of mechanical diagnosis and management of spinal pain and is commonly used during physiotherapy for acute and chronic LBP (Alhakami et al., 2019; Hosseinfar et al., 2013; Machado et al., 2010; Mujić Skikić & Trebinjac, 2003; Szulc et al., 2015). The review by Alhakami et al. (2019) found that both CST and MCK exercises are superior to conventional exercises for reducing functional disability in people with NCLBP. Contrarily, Hosseinfar et al. (2013) found superior benefits of CST compared to MCK after 6 weeks of individual training sessions on pain, disability and lumbar musculature thickness.

Although the benefits of CST and MCK have been reported, their effectiveness remains debated (Mannion et al., 2012; Saragiotto et al., 2016). In particular, a comparison between the two approaches for pain and disability management, especially in the short term, could be useful for healthcare professionals. Therefore, the present work aims to investigate the effects of a 4-week training program on lumbar pain, trunk mobility and global muscular flexibility in adults with NCLBP. It's hypothesised that CST could yield better improvements than MCK.

Material & methods

Subjects and study design

This is a longitudinal randomised study design with a 4-week duration and two evaluation times (pre and post). Participants were recruited from Torre Lasie Medical Centre (Imola, Bologna, Italy). The selection criteria included a diagnosis of chronic non-specific low back pain, a medical prescription for exercises issued by a physician, and an age range of 30 to 50 years. Exclusion criteria were neurological or other orthopaedic disease in the last 12 months. No gender restrictions were defined. All participants were informed and gave voluntary consent to participate in the study. They were randomly allocated to one of two groups: the Core Stability Training group (CST, n=15; seven males and eight females) and the McKenzie group (MCK, n=15; eight males and seven females). No nutritional information was collected. The research was approved by the Ethics Committee of Ovidius University of Constanta (Approval code nr. 45, 23rd January 2024) in accordance with the Declaration of Helsinki.

Test and functional evaluation

The pre- and post-training evaluations were conducted the week before and after the training period, respectively. Tests were run in a single session before and after the treatment in the medical centre with a comfortable temperature of 20° and humidity of 51% and lasted about 20' for each participant (Russo, Belli, et al., 2023). All testing was performed in the afternoon, between five p.m. and eight p.m., due to participants' availability, as with training sessions. The following tests were selected (Hjermstad et al., 2011; Muyor et al., 2014; Russo, Panessa, et al., 2023): the Numerical Pain Rating Scale (NRS) for pain assessment, the Forward Bending test (BEND) for posterior muscular chain flexibility, and the Schober Test (SCHOB) for lumbar spine mobility. Before performing each test, participants were instructed by a trained physiotherapist who explained the procedure in detail and ensured it was accurate and safe. No specific preparation or warm-up of the patients was requested for the test session. The tests were conducted in the following order: NRS, BEND and SCHOB. A single measure for each test was performed, and five minutes of rest were allowed between BEND and SCHOB (Muyor et al., 2014). The participant was examined wearing underpants and barefoot, and the assessment phase lasted 20 minutes. A physiotherapist with more than 15 years of experience in LBP and two kinesiologists performed all tests.

Numerical Pain Rating Scale

The Numerical Pain Rating Scale (NRS) is a practical and valuable test for pain assessment (Stratford & Spadoni, 2001). It is widely used in several medical fields, and literature reports that NRS provides sufficient discriminative power for chronic pain patients to describe their pain intensity (Hjermstad et al., 2011; Russo, Panessa, et al., 2023). Consensus-based studies indicate that researchers and clinicians prefer this quantitative scale to other instruments for measuring pain intensity in LBP (Chiarotto et al., 2019). NRS is a 10-point scale in

which 0 represents the absence of pain and 10 the maximum level of pain. Patients were asked to mark the number corresponding to their pain intensity on that day with a pen.

Forward Bending Test

The Forward Bending test (BEND) is a standard, quick test to evaluate global flexibility (Muyor et al., 2014). It allows a qualitative and quantitative assessment of trunk and lower-body muscular flexibility and movement patterns (Esola et al., 1996). The current literature describes this test as the “Toe-touch test” or “Stand and reach test” to distinguish it from other flexibility tools performed in different positions (e.g., the Sit and Reach test; Jankowicz-Szymańska et al., 2022; La Greca et al., 2022; López-Miñarro & Rodríguez-García, 2010; Russo, Montagnani, et al., 2023). The participant was asked to stand on a step connected to a vertical measuring bar, with the reference point “0” at the height of the feet’ contact surface; positive values indicated the direction toward the floor, and negative values indicated the opposite direction. Then, the subject bent their trunk forward, keeping the knees, arms, and fingers extended, and trying to touch the lowest point on the numerical scale with their hands. The feet were positioned at shoulder’s width, and the palm of the dominant hand was placed on the dorsal side of the other hand. Once the participant reached the further point on the measuring bar, the position was held for 3 seconds to collect the correct number (López-Miñarro & Rodríguez-García, 2010).

Schober Test

The Schober test (SCHOB) is a practical and quick test to determine the range of lumbar flexion (Hershkovich et al., 2022). It allows analysis of lumbar spine flexibility during the forward bending test by comparing changes in lumbar length from standing to the bending position. Historically, several versions of the test have been proposed to better quantify this parameter (Tousignant et al., 2005; Williams et al., 1993). In this study, the original version of SCHOB was performed (Jankowicz-Szymańska et al., 2022). Subjects were asked to stand in the same position as BEND during the starting assessment. Then, two points were marked on the lower back: the S1 spinous process and a point 10 cm above it, using a metric ruler. After the points marker, the participant performed a forward bend, as in the previous test. In the bending position, the distance between the two points was measured again, and the change in this distance was compared with the standing distance. Normal range of motion in the lumbar spine should expect a five cm improvement (Williams et al., 1993).

Training protocol

CST and MCK were submitted to a four-week training protocol. Training frequency was two sessions per week, and the total number of sessions was eight, according to previous research demonstrating benefits for pain and functional outcomes after a short time period (Hayden et al., 2021; Szulc et al., 2015). The duration of each session was 30’ and was performed with a 1:1 ratio between the physical therapist and patients. Two specialised kinesiologists supported the physical therapist during work. This choice allowed us to guarantee the quality of training and the correct execution of each exercise. The time of rest between each training session was 72 hours (training days were Monday or Tuesday, Thursday or Friday in the afternoon, ranging between 5.00 and 7.00 PM). Figures 1 and 2 show the training protocol exercises for the MCK and CST groups, respectively.

MCK protocols (Fig. 1) consisted of six exercises focusing on static and dynamic trunk mobility, lumbar spine flexibility, and antalgic positions (Hosseiniifar et al., 2013; Mann et al., 2025). Each exercise lasted between 3’ and 5’ and was progressed during the training period. The number of repetitions for dynamic exercises ranged between 5 and 10 in relation to individual condition, while the static postures time was increased by 1’ every three sessions (Ghorbanpour et al., 2018; Mujić Skikić & Trebinjac, 2003). The CST protocol (Fig. 2) consisted of 7 exercises focused on core muscle activation and trunk stabilisation (Machado et al., 2010; Marshall et al., 2011). Static and dynamic exercises were performed for 3 sets with an individual progression from 15s to 30s and from 10 to 15 repetitions, respectively (Anderson et al., 2016; Mannion et al., 2012). During the testing session, each subject received specific information about the training protocol (type of exercises, equipment, duration) from the two specialised kinesiologists. Since the individual sessions were held twice per week, participants were encouraged to repeat the exercises at home. They were instructed to continue the same weekly program for two additional sessions per week and received written details (exercise, set, repetitions, rest). They were requested to perform 100% of home sessions in addition to physiotherapy, and were directly monitored by the kinesiologists during this part.



Figure 1. The McKenzie protocol exercises.



Figure 2. The Core Stability Training protocol exercises.

Statistical Analysis

A priori sample size estimation was computed according to the following parameters: type I error = 5%, type II error = 20%, tested effect between-within variance of 0.125 ($\delta = 0.56$), number of groups = 2, number of repeated measures = 2, correlation between repeated measures = 0.2. The estimated sample size was 28 (14 per group). A 10% participant was added to avoid sample attrition and bias the effect size. Descriptive statistics, such as mean and standard deviation, have been calculated. The distributions of the dependent variables and the residuals have been checked using the Shapiro-Wilk test. The Cook distance was used for the presence of outliers. The sphericity error was checked and adjusted using the Geisser-Greenhouse epsilon. The repeated-measures ANOVA was used to test the full and reduced models. Interaction, main and simple contrasts were computed.

All statistical analyses were conducted with Stata 18 (64-bit, Windows edition).

Results

Table 1 presents summary statistics and adjusted repeated-measures ANOVA results for the McKenzie and Core groups at both pre- and post-evaluations.

Table 1. Repeated-measures ANOVA table.

	McKenzie		Core		treatment		time		Interaction	
	Mean	SD	Mean	SD	F _(1, 56)	p	F _(1, 56)	p	F _(3, 52)	P
Bending					0.37	0.544	1.76	0.19	0.360	0.552
pre	-3.33	6.41	-3.30	16.80						
post	-1.47	4.92	1.63	6.84						
Schober					14.48	<0.001*	13.89	<0.001*	0.24	0.624
pre	15.10	1.83	13.71	1.88						
post	16.87	1.55	15.07	1.10						
NRS					10.46	0.002*	41.22	<0.001*	16.05	<0.001*
pre	6.07	0.94	6.33	1.29						
post	5.23	0.98	2.73	1.91						

Figure 3 shows longitudinal variations between CST and MCK for the forward bending test, Schober and the numerical pain rating scale. While no significant differences emerged between groups and time in the bending test, CST showed a steeper trend, 5.25% greater than McKenzie, with a contrast of 3.1 (95% CI: -6.82, 13.02). The contrast between McKenzie pre and post was 1.87 (95% CI: -8.05, 11.78), whereas for Core it was 4.93 (95% CI: -4.98, 14.85).

Concerning the Schober test (Figure 3 B), the McKenzie and Core groups reported different baseline levels (95% CI: -2.57, -0.2), but similar trends over time, with a contrast at post of -1.8 (95% CI: -2.99, -0.61).

Whilst the Schober score varied by 11.7% from pre to post within McKenzie, the Core participants increased by 9.99%. Marginal linear predictions reported significant results for McKenzie post vs pre ($F_{(1, 56)} = 8.9$, $p = 0.004$, 95% CI of contrast: 0.58, 2.95) and Core post vs pre ($F_{(1, 56)} = 5.22$, $p = 0.004$, 95% CI of contrast: 0.17, 2.54).

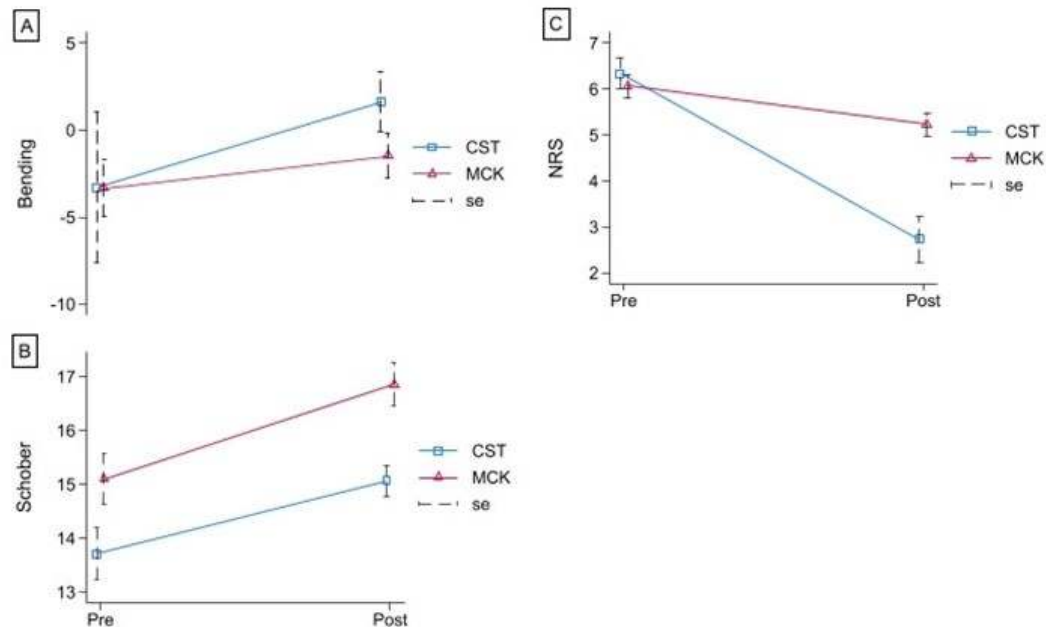


Figure 3. Longitudinal means plots for Bending test (A), Schober test (B) and NRS (C).

Regarding NRS (Fig. 3C), treatments showed different slopes over time, with mean reductions of 13.74% and 56.84% in McKenzie and Core, respectively (Table 1). When corrected by the Bonferroni method, McKenzie post vs pre did not report significant differences (95% CI of contrast: -1.81, 0.14), while Core training showed an essential contrast of 3.6 (95% CI: -4.58, -2.62; $F_{(1, 56)} = 54.36$, $p < 0.001$). Whilst no significant difference appeared between McKenzie and Core at pre (95% CI of contrast: -1.07, 1.60), relevant changes emerged at post (95% CI of contrast: -3.83, -1.16; $F_{(2, 52)} = 13.26$, $p < 0.001$).

Discussion

The current study aimed to analyse the effects of a 4-week training program on pain and flexibility in NCLBP. The main findings indicate that both McKenzie and Core Stability improve lumbar spine mobility, posterior muscular chain flexibility, and pain, with a significant difference reported in the post vs pre comparison in favour of CST. The debate over the efficacy of both methods for NCLBP treatment remains in the literature (Alhakami et al., 2019; Ghorbanpour et al., 2018; Hosseinifar et al., 2013; Kumar et al., 2015; Machado et al., 2010; Mann et al., 2025; Mannion et al., 2012; Marshall et al., 2011; Mujić Skikić & Trebinjac, 2003; Russo, Belli, et al., 2023; Saragiotto et al., 2016; Szulc et al., 2015; Wang et al., 2012). Hosseinifar et al. compared the effects of CST and MCK on pain, disability, and the thickness of the transverse and multifidus muscles (Hosseinifar et al., 2013). After 18 individual sessions (3 times per week over 6 weeks), the authors found similar results for pain and superior benefits of CST on disability and muscular thickness in adults with NCLBP. The protocol focused on 6 MCK exercises and a specific progression of core segmental control (CST) exercises in a similar sample (15 participants per group). Recently, the systematic review by Alhakami et al. concluded that there is insufficient evidence to support the superiority of MCK or CST over pain and disability in NCLBP management and found that both methods are more efficient than conventional exercises (Alhakami et al., 2019).

The hypothesis of the present study is partially confirmed with relevant practical and operational implications. Core Stability Training not only proved non-inferior to the McKenzie Method in lumbar mobility as measured by the Forward Bending Test and Schober Test, but also demonstrated significant superiority in pain control ($p < 0.001$). Pain reduction for the CST group was 56.84% compared to 13.74% measured in the McKenzie group, supporting the role of physical exercise as a primary, secondary, and tertiary prevention factor for low back pain, an aspect discussed in reviews but not always scientifically evident due to study quality issues (Alhakami et al., 2019; Belli et al., 2024). This result is of considerable importance for professional and daily practice because it challenges the traditional paradigm that favours approaches focused exclusively on segmental mobility, highlighting the need for more global movement approaches conducted by qualified kinesiologists and physical therapists. The data obtained confirm findings from other meta-analyses, showing that core training produces improvements in pain and disability superior to those of general exercise in the short term (Frizziero et

al., 2021; Wang et al., 2012). This efficacy could be explained by specific motor control mechanisms favoured by training deep muscles oriented toward spinal stabilisation, which could promote better management of repetitive mechanical stresses on vulnerable tissues. In this way, the aim is to interrupt the vicious cycle of pain-motor dysfunction-pain typical of LBP (George et al., 2021; Marshall et al., 2011).

Looking at the results in detail, although the statistical analysis did not reveal a significant superiority of CST in the Forward Bending Test, there is an evident trend of greater improvement (+5.25%) in CST compared to MCK. This pattern suggests a potential effect that may not be fully apparent in the present study due to two main factors: the reduced sample size and the intervention duration. This consideration is rational and supported by the scientific literature, which suggests that longer periods (8-12 weeks) are required to manifest the desired neuromuscular adaptations (Frizziero et al., 2021; Niederer & Mueller, 2020). Conversely, the 4-week period in the present study may not have been sufficiently long and may have captured only the initial phase of this adaptive process. The substantial equivalence between CST and the McKenzie Method in the Schober Test must be interpreted in light of the test's well-documented methodological limitations (Hershkovich et al., 2022; Taheri et al., 2024). Furthermore, the minimal detectable change of 1 cm represents 15-20% of the typical total excursion, limiting the test's ability to discriminate minor differences that could actually be clinically relevant (Tousignant et al., 2005). The minimal difference observed between the two methods in the pre-post results of the Schober Test must also be analysed from a rational perspective. The results obtained are perfectly coherent with the typical characteristics of the interventions. McKenzie exercises focus specifically on segmental lumbar mobility, using repeated movements in preferential directions (extension and flexion). It is reasonable to assume that this stimulation optimises articular range of motion during a test of lumbar flexion (Lam et al., 2018; Namnaqani et al., 2019). In contrast, CST favours a more global approach, promoting active stabilisation and neuromuscular control rather than range of motion. Based on these considerations, it appears logical and potentially expected that MCK would show marginal advantages on a specific lumbar mobility test. At the same time, it must be underlined that what was previously highlighted regarding the test's validity limitations.

The central result of this study, which supports Core Stability Training as the elective approach for short-term management of NCLBP, is a 56.84% reduction in pain in the CST group compared with 13.74% in the McKenzie group ($p < 0.001$). From an operational and scientific perspective, this is not exclusively a statistical datum; instead, it should be interpreted as a global improvement in the quality of life of study participants. This result aligns perfectly with the international consensus on primary outcomes in low back pain (Chiarotto et al., 2015). This document highlights that the three domains to consider as outcomes in studies of NCLBP are pain intensity, physical functioning, and health-related quality of life. It is noteworthy to emphasise that range of motion was not included in the core outcome set of this international consensus, highlighting that pain control and functional recovery have clinical priority over segmental mobility. This dismantles the traditional conceptual assumption that improving ROM is necessary or sufficient for pain reduction.

Limitations

The current study presents several limitations that should be addressed to improve the interpretation of results and guide future quality research. First, the reduced sample size ($n=30$; 15 participants per group) must be considered, which can significantly limit the statistical power of the results. A larger sample could have better generalised the results, but given the difficulty in recruiting subjects, a lower number had to be chosen. The second aspect to highlight is the short intervention duration (4 weeks), which may not have captured all potential benefits. The choice of a brief time period reflected the usual time patients spend in a medical centre during the initial exercise approach, led by physical therapists supported by kinesiologists. In addition, the lack of a follow-up period at the medium- to long-term (3-6 months) should also be noted. This is a significant gap because it prevents evaluating the maintenance of results and identifying potential relapses. Unfortunately, it was not possible to carry out this procedure due to organisational reasons of the facility where the activities were conducted. Finally, the absence of functional disability and quality-of-life evaluation (e.g., the Roland-Morris Disability Questionnaire), as well as the limits of the chosen tests and home training, must be evidenced.

Conclusions

Core Stability Training and McKenzie exercises may reduce pain intensity and improve flexibility in adults with chronic non-specific low back pain. Core stability Exercises could better reduce pain after only four weeks of individual training integrated with home exercises under the lead of physical therapists and specialised kinesiologists.

Since both approaches are characterised by specific exercises and focus on different elements, the combination of core stability and McKenzie training may be a helpful support in the management of chronic non-specific low back pain.

Data availability statement The dataset is freely available at the following DOI: 10.17605/OSF.IO/QFAM6

Conflicts of interest - Authors declare no conflict of interest.

Use of Generative AI statement: Authors declare no use of AI in the writing of the article

References:

- Alhakami, A. M., Davis, S., Qasheesh, M., Shaphe, A., & Chahal, A. (2019). Effects of McKenzie and stabilization exercises in reducing pain intensity and functional disability in individuals with nonspecific chronic low back pain: a systematic review. *Journal of Physical Therapy Science*, 31(7), 590–597. <https://doi.org/10.1589/JPTS.31.590>
- Anderson, G. S., Deluigi, F., Belli, G., Tentoni, C., & Gaetz, M. B. (2016). Training for improved neuromuscular control of balance in middle aged females. *Journal of Bodywork and Movement Therapies*, 20(1), 10–18. <https://doi.org/10.1016/J.JBMT.2015.01.007>
- Belli, G., Marini, S., Mauro, M., Maietta Latessa, P., & Toselli, S. (2022). Effects of Eight-Week Circuit Training with Core Exercises on Performance in Adult Male Soccer Players. *European Journal of Investigation in Health, Psychology and Education*, 12(9), 1244–1256. <https://doi.org/10.3390/EJHPE12090086>
- Belli, G., Russo, L., Mauro, M., Toselli, S., & Maietta Latessa, P. (2024). Relation between Photogrammetry and Spinal Mouse for Lumbopelvic Assessment in Adolescents with Thoracic Kyphosis. *Healthcare (Basel, Switzerland)*, 12(7). <https://doi.org/10.3390/HEALTHCARE12070738>
- Cheng, M., Xue, Y., Cui, M., Zeng, X., Yang, C., Ding, F., & Xie, L. (2025). Global, Regional, and National Burden of Low Back Pain: Findings From the Global Burden of Disease Study 2021 and Projections to 2050. *Spine*, 50(7), E128–E139. <https://doi.org/10.1097/BRS.0000000000005265>
- Chiarotto, A., Deyo, R. A., Terwee, C. B., Boers, M., Buchbinder, R., Corbin, T. P., Costa, L. O. P., Foster, N. E., Grotle, M., Koes, B. W., Kovacs, F. M., Lin, C. W. C., Maher, C. G., Pearson, A. M., Peul, W. C., Schoene, M. L., Turk, D. C., van Tulder, M. W., & Ostelo, R. W. (2015). Core outcome domains for clinical trials in non-specific low back pain. *European Spine Journal: Official Publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 24(6), 1127–1142. <https://doi.org/10.1007/S00586-015-3892-3>
- Chiarotto, A., Maxwell, L. J., Ostelo, R. W., Boers, M., Tugwell, P., & Terwee, C. B. (2019). Measurement Properties of Visual Analogue Scale, Numeric Rating Scale, and Pain Severity Subscale of the Brief Pain Inventory in Patients With Low Back Pain: A Systematic Review. *The Journal of Pain*, 20(3), 245–263. <https://doi.org/10.1016/J.JPAIN.2018.07.009>
- Esola, M. A., McClure, P. W., Fitzgerald, G. K., & Siegler, S. (1996). Analysis of lumbar spine and hip motion during forward bending in subjects with and without a history of low back pain. *Spine*, 21(1), 71–78. <https://doi.org/10.1097/00007632-199601010-00017>
- Ferreira, M. L., De Luca, K., Haile, L. M., Steinmetz, J. D., Culbreth, G. T., Cross, M., Kopec, J. A., Ferreira, P. H., Blyth, F. M., Buchbinder, R., Hartvigsen, J., Wu, A. M., Safiri, S., Woolf, A. D., Collins, G. S., Ong, K. L., Vollset, S. E., Smith, A. E., Cruz, J. A., ... March, L. M. (2023). Global, regional, and national burden of low back pain, 1990–2020, its attributable risk factors, and projections to 2050: a systematic analysis of the Global Burden of Disease Study 2021. *The Lancet. Rheumatology*, 5(6), e316–e329. [https://doi.org/10.1016/S2665-9913\(23\)00098-X](https://doi.org/10.1016/S2665-9913(23)00098-X)
- Frizziero, A., Pellizzon, G., Vittadini, F., Bigliardi, D., & Costantino, C. (2021). Efficacy of Core Stability in Non-Specific Chronic Low Back Pain. *Journal of Functional Morphology and Kinesiology*, 6(2). <https://doi.org/10.3390/JFMK6020037>
- García-Moreno, J. M., Calvo-Muñoz, I., Gómez-Conesa, A., & López-López, J. A. (2022). Effectiveness of physiotherapy interventions for back care and the prevention of non-specific low back pain in children and adolescents: a systematic review and meta-analysis. *BMC Musculoskeletal Disorders*, 23(1). <https://doi.org/10.1186/S12891-022-05270-4>
- George, S. Z., Fritz, J. M., Silfies, S. P., Schneider, M. J., Beneciuk, J. M., Lentz, T. A., Gilliam, J. R., Hendren, S., Norman, K. S., Beattie, P. F., Bishop, M. D., Goertz, C., Hunter, S., Olson, K. A., Rundell, S. D., Schmidt, M., Shepard, M., Vining, R., Buzzanca, K. E., ... Sundaram, M. (2021). Interventions for the Management of Acute and Chronic Low Back Pain: Revision 2021. *The Journal of Orthopaedic and Sports Physical Therapy*, 51(11), CPG1–CPG60. <https://doi.org/10.2519/JOSPT.2021.0304>
- Ghorbanpour, A., Azghani, M. R., Taghipour, M., Salahzadeh, Z., Ghaderi, F., & Oskouei, A. E. (2018). Effects of McGill stabilization exercises and conventional physiotherapy on pain, functional disability and active back range of motion in patients with chronic non-specific low back pain. *Journal of Physical Therapy Science*, 30(4), 481–485. <https://doi.org/10.1589/JPTS.30.481>
- Hayden, J. A., Ellis, J., Ogilvie, R., Malmivaara, A., & van Tulder, M. W. (2021). Exercise therapy for chronic low back pain. *The Cochrane Database of Systematic Reviews*, 9(9). <https://doi.org/10.1002/14651858.CD009790.PUB2>
- Hershkovich, O., Grevitt, M. P., & Lotan, R. (2022). Schober Test and Its Modifications Revisited-What Are We Actually Measuring? Computerized Tomography-Based Analysis. *Journal of Clinical Medicine*, 11(23). <https://doi.org/10.3390/JCM11236895>
- Hjermstad, M. J., Fayers, P. M., Haugen, D. F., Caraceni, A., Hanks, G. W., Loge, J. H., Fainsinger, R., Aass, N., & Kaasa, S. (2011). Studies comparing Numerical Rating Scales, Verbal Rating Scales, and Visual

- Analogue Scales for assessment of pain intensity in adults: a systematic literature review. *Journal of Pain and Symptom Management*, 41(6), 1073–1093. <https://doi.org/10.1016/J.JPAINSYMMAN.2010.08.016>
- Hosseiniifar, M., Akbari, M., Behtash, H., Amiri, M., & Sarrafzadeh, J. (2013). The Effects of Stabilization and McKenzie Exercises on Transverse Abdominis and Multifidus Muscle Thickness, Pain, and Disability: A Randomized Controlled Trial in NonSpecific Chronic Low Back Pain. *Journal of Physical Therapy Science*, 25(12), 1541–1545. <https://doi.org/10.1589/JPTS.25.1541>
- Hoy, D., March, L., Brooks, P., Blyth, F., Woolf, A., Bain, C., Williams, G., Smith, E., Vos, T., Barendregt, J., Murray, C., Burstein, R., & Buchbinder, R. (2014). The global burden of low back pain: estimates from the Global Burden of Disease 2010 study. *Annals of the Rheumatic Diseases*, 73(6), 968–974. <https://doi.org/10.1136/ANNRHEUMDIS-2013-204428>
- Jankowicz-Szymańska, A., Kawa, J., Wódka, K., Smola, E., Bibro, M. A., & Bac, A. (2022). The Scores and Manner of Performing the Stand and Reach Test in Girls and Boys of Different Body Weight. *Bioengineering (Basel, Switzerland)*, 9(10). <https://doi.org/10.3390/BIOENGINEERING9100538>
- Kumar, T., Kumar, S., Nezamuddin, M., & Sharma, V. P. (2015). Efficacy of core muscle strengthening exercise in chronic low back pain patients. *Journal of Back and Musculoskeletal Rehabilitation*, 28(4), 699–707. <https://doi.org/10.3233/BMR-140572>
- La Greca, S., Rapali, M., Ciaprini, G., Russo, L., Vinciguerra, M. G., & Di Giminiani, R. (2022). Acute and Chronic Effects of Supervised Flexibility Training in Older Adults: A Comparison of Two Different Conditioning Programs. *International Journal of Environmental Research and Public Health*, 19(24). <https://doi.org/10.3390/IJERPH192416974>
- Lam, O. T., Strenger, D. M., Chan-Fee, M., Pham, P. T., Preuss, R. A., & Robbins, S. M. (2018). Effectiveness of the McKenzie Method of Mechanical Diagnosis and Therapy for Treating Low Back Pain: Literature Review With Meta-analysis. *The Journal of Orthopaedic and Sports Physical Therapy*, 48(6), 476–490. <https://doi.org/10.2519/JOSPT.2018.7562>
- Li, Y., Yan, L., Hou, L., Zhang, X., Zhao, H., Yan, C., Li, X., Li, Y., Chen, X., & Ding, X. (2023). Exercise intervention for patients with chronic low back pain: a systematic review and network meta-analysis. *Frontiers in Public Health*, 11. <https://doi.org/10.3389/FPUBH.2023.1155225>
- Longo, U. G., Loppini, M., Denaro, L., Maffulli, N., & Denaro, V. (2010). Rating scales for low back pain. *British Medical Bulletin*, 94(1), 81–144. <https://doi.org/10.1093/BMB/LDP052>
- López-Miñarro, P. A., & Rodríguez-García, P. L. (2010). Hamstring muscle extensibility influences the criterion-related validity of sit-and-reach and toe-touch tests. *Journal of Strength and Conditioning Research*, 24(4), 1013–1018. <https://doi.org/10.1519/JSC.0B013E3181C7C60D>
- Machado, L. A. C., Maher, C. G., Herbert, R. D., Clare, H., & McAuley, J. H. (2010). The effectiveness of the McKenzie method in addition to first-line care for acute low back pain: a randomized controlled trial. *BMC Medicine*, 8. <https://doi.org/10.1186/1741-7015-8-10>
- Mann, S. J., Stretanski, M. F., & Singh, P. (2025). McKenzie Back Exercises. In *StatPearls*. StatPearls Publishing. <https://www.ncbi.nlm.nih.gov/books/NBK539720/>
- Mannion, A. F., Caporaso, F., Pulkovski, N., & Sprott, H. (2012). Spine stabilisation exercises in the treatment of chronic low back pain: a good clinical outcome is not associated with improved abdominal muscle function. *European Spine Journal: Official Publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 21(7), 1301–1310. <https://doi.org/10.1007/S00586-012-2155-9>
- Marshall, P. W. M., Desai, I., & Robbins, D. W. (2011). Core stability exercises in individuals with and without chronic nonspecific low back pain. *Journal of Strength and Conditioning Research*, 25(12), 3404–3411. <https://doi.org/10.1519/JSC.0B013E318215FC49>
- Mujić Skikić, E., & Trebinjac, S. (2003). The effects of McKenzie exercises for patients with low back pain, our experience. *Bosnian Journal of Basic Medical Sciences*, 3(4), 70–75. <https://doi.org/10.17305/BJBMS.2003.3497>
- Muyor, J. M., Vaquero-Cristóbal, R., Alacid, F., & López-Miñarro, P. A. (2014). Criterion-related validity of sit-and-reach and toe-touch tests as a measure of hamstring extensibility in athletes. *Journal of Strength and Conditioning Research*, 28(2), 546–555. <https://doi.org/10.1519/JSC.0B013E31829B54FB>
- Namnaqani, F. I., Mashabi, A. S., Yaseen, K. M., & Alshehri, M. A. (2019). The effectiveness of McKenzie method compared to manual therapy for treating chronic low back pain: a systematic review. *Journal of Musculoskeletal & Neuronal Interactions*, 19(4), 492–499. <https://pubmed.ncbi.nlm.nih.gov/31789300/>
- Niederer, D., & Mueller, J. (2020). Sustainability effects of motor control stabilisation exercises on pain and function in chronic nonspecific low back pain patients: A systematic review with meta-analysis and meta-regression. *PloS One*, 15(1). <https://doi.org/10.1371/JOURNAL.PONE.0227423>
- Pergolizzi, J. V., & LeQuang, J. A. (2020). Rehabilitation for Low Back Pain: A Narrative Review for Managing Pain and Improving Function in Acute and Chronic Conditions. *Pain and Therapy*, 9(1), 83–96. <https://doi.org/10.1007/S40122-020-00149-5>

- Russo, L., Belli, G., Blasio, A. Di, Lupu, E., Larion, A., Fischetti, F., Montagnani, E., Arrivabene, P. D. B., & De Angelis, M. (2023). The Impact of Nordic Walking Pole Length on Gait Kinematic Parameters. *Journal of Functional Morphology and Kinesiology*, 8(2). <https://doi.org/10.3390/JFMK8020050>
- Russo, L., Montagnani, E., Pietrantonio, D., D'Angona, F., Fratini, T., Di Giminiani, R., Palmeri, S., Ceccarini, F., Migliaccio, G. M., Lupu, E., & Padulo, J. (2023). Self-Myofascial Release of the Foot Plantar Surface: The Effects of a Single Exercise Session on the Posterior Muscular Chain Flexibility after One Hour. *International Journal of Environmental Research and Public Health*, 20(2). <https://doi.org/10.3390/IJERPH20020974>
- Russo, L., Panessa, T., Bartolucci, P., Raggi, A., Migliaccio, G. M., Larion, A., & Padulo, J. (2023). Elastic Taping Application on the Neck: Immediate and Short-Term Impacts on Pain and Mobility of Cervical Spine. *Journal of Functional Morphology and Kinesiology*, 8(4). <https://doi.org/10.3390/JFMK8040156>
- Saragiotto, B. T., Maher, C. G., Yamato, T. P., Costa, L. O. P., Menezes Costa, L. C., Ostelo, R. W. J. G., & Macedo, L. G. (2016). Motor control exercise for chronic non-specific low-back pain. *The Cochrane Database of Systematic Reviews*, 2016(1). <https://doi.org/10.1002/14651858.CD012004>
- Szulc, P., Wendt, M., Waszak, M., Tomczak, M., Cieřlik, K., & Trzaska, T. (2015). Impact of McKenzie Method Therapy Enriched by Muscular Energy Techniques on Subjective and Objective Parameters Related to Spine Function in Patients with Chronic Low Back Pain. *Medical Science Monitor : International Medical Journal of Experimental and Clinical Research*, 21, 2918–2932. <https://doi.org/10.12659/MSM.894261>
- Taheri, N., Becker, L., Reitmaier, S., Muellner, M., Schömig, F., Pumberger, M., & Schmidt, H. (2024). Schober test is not a valid assessment tool for lumbar mobility. *Scientific Reports*, 14(1). <https://doi.org/10.1038/S41598-024-54787-2>
- Stratford, P. W., & Spadoni, G. (2001). The reliability, consistency, and clinical application of a numeric pain rating scale | Request PDF. *Physiother Can*, 53, 88–91. https://www.researchgate.net/publication/284632149_The_reliability_consistency_and_clinical_application_of_a_numeric_pain_rating_scale
- Tousignant, M., Poulin, L., Marchand, S., Viau, A., & Place, C. (2005). The Modified-Modified Schober Test for range of motion assessment of lumbar flexion in patients with low back pain: a study of criterion validity, intra- and inter-rater reliability and minimum metrically detectable change. *Disability and Rehabilitation*, 27(10), 553–559. <https://doi.org/10.1080/09638280400018411>
- Urits, I., Burshtein, A., Sharma, M., Testa, L., Gold, P. A., Orhurhu, V., Viswanath, O., Jones, M. R., Sidransky, M. A., Spektor, B., & Kaye, A. D. (2019). Low Back Pain, a Comprehensive Review: Pathophysiology, Diagnosis, and Treatment. *Current Pain and Headache Reports*, 23(3). <https://doi.org/10.1007/S11916-019-0757-1>
- Van Middelkoop, M., Rubinstein, S. M., Kuijpers, T., Verhagen, A. P., Ostelo, R., Koes, B. W., & Van Tulder, M. W. (2011). A systematic review on the effectiveness of physical and rehabilitation interventions for chronic non-specific low back pain. *European Spine Journal : Official Publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society*, 20(1), 19–39. <https://doi.org/10.1007/S00586-010-1518-3>
- Wang, X. Q., Zheng, J. J., Yu, Z. W., Bi, X., Lou, S. J., Liu, J., Cai, B., Hua, Y. H., Wu, M., Wei, M. L., Shen, H. M., Chen, Y., Pan, Y. J., Xu, G. H., Chen, P. J., & Eldabe, S. (2012). A meta-analysis of core stability exercise versus general exercise for chronic low back pain. *PloS One*, 7(12). <https://doi.org/10.1371/JOURNAL.PONE.0052082>
- Williams, R., Binkley, J., Bloch, R., Goldsmith, C. H., & Minuk, T. (1993). Reliability of the modified-modified Schober and double inclinometer methods for measuring lumbar flexion and extension. *Physical Therapy*, 73(1), 26–37. <https://doi.org/10.1093/PTJ/73.1.26>