EFFECTIVENESS OF PAIN NEUROSCIENCE EDUCATION COMBINED WITH THERAPEUTIC EXERCISE IN PEOPLE WITH CHRONIC PAIN

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INTRODUCTION

Chronic pain is a complex process, defined as "an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage" (1). It is a highly prevalent clinical entity, with a rate of 25.9% in Spain and an average duration of 6.83 years, highlighting its significant health and social impact (2).

Among the different manifestations of chronic pain, chronic low back pain (CLBP) is the most frequent location in the Spanish population, affecting 58.1% of people with chronic pain between 18 and 85 years of age (2). It is noteworthy that in 27.1% of cases, it is not possible to identify a clear cause explaining this clinical condition, which complicates its diagnostic and therapeutic management. Its epidemiological relevance lies in its high functional and occupational impact, being one of the leading causes of physical limitation and temporary disability in Spain (2).

Similarly, fibromyalgia (FM) represents a type of nonspecific chronic pain affecting 10.4% of individuals suffering from chronic pain in Spain (2), also without a clear organic cause. It is characterized by widespread musculoskeletal pain accompanied by symptoms such as fatigue, sleep disturbances, and emotional impairment. Unlike CLBP, fibromyalgia is considered a generalized dysfunction syndrome affecting multiple body regions. Nevertheless, both clinical entities share the absence of a clear organic cause and represent the diagnostic and therapeutic complexity of nonspecific chronic pain in the Spanish population.

Chronic pain, specifically in the lumbar region and in individuals with FM, may occur at all stages of life, although its prevalence varies according to age. In children and adolescents, a

prevalence of 20.8% has been reported (3), while in adults aged 15–34 years it is around 11.66% (4), and in older adults over 60 years, variability ranges between 21% and 68% depending on the study (5). Age is also related to pain threshold, meaning that it tends to increase progressively with aging, requiring stimuli of greater intensity for pain perception in older individuals (6). However, chronic pain is more frequent from middle age onward, as it is associated with degenerative diseases such as osteoarthritis and low back pain (7).

For the reasons described above, studies addressing pain, both in FM and CLBP, should consider the effect of age in their analyses (8), as well as the effect of interventions due to the various conditioning factors involved, such as physiological, functional, and even educational factors influencing pain experience and its therapeutic management (9).

From a physiological perspective, aging is associated with significant changes in the musculoskeletal system and body composition (10). Among these, the progressive loss of muscle mass stands out, estimated at between 3% and 8% per decade from the third decade of life onward, accelerating notably after the age of 60–65 years (11). This reduction predominantly affects type II fibers, responsible for strength and power, increasing the risk of developing sarcopenia (12). However, younger populations exhibit greater anabolic capacity (13), a superior hypertrophic response, and a more efficient neuromuscular system, leading to faster and more pronounced adaptations to training stimuli (14). Likewise, bone mass also differs considerably between both groups, as adults over 65 years present a progressive decline in bone mineral density, unlike young adults who are generally at their peak bone mass (15,16).

Beyond structural changes, the process of central sensitization (CS) may explain the persistence of pain without a clear cause. This is a pathological process affecting the central nervous system and characterized by sustained hyperexcitability of pain-processing neurons (17). This results in a lower pain threshold and a reduction in the natural inhibitory mechanisms of pain (17). If this process persists, it may lead to the establishment of chronic pain, as the central nervous system becomes responsible for maintaining and amplifying pain signals, even when the original cause has disappeared or is minimal (17).

Given the impact of chronic pain on quality of life and functionality, numerous efforts have been made to identify effective treatments capable of reducing the intensity and duration of chronic pain. One of the main non-pharmacological treatments received by these patients is therapeutic exercise (TE), as evidence has demonstrated its ability to reduce pain and its impact on the functionality of affected individuals (18,19). However, the benefits of TE on these

variables do not show long-term clinical significance (18). This is often related to poor adherence and the barriers to engaging in physical exercise, associated with pain itself, psychological factors, social factors, and other external factors (20,21), such as educational level.

Educational level should be considered, since younger adult populations tend to present higher educational levels and greater digital and health literacy (22,23). A good educational level is associated with better understanding of and adherence to a therapeutic exercise program (24). Therefore, the same exercise protocol does not necessarily have the same mechanical implications (25) nor produce equivalent osteogenic stimuli in each group (26,27).

In recent years, interest has increased in interventions that provide patients with knowledge about their own condition in order to improve treatment adherence (28), such as educational approaches aimed at explaining to patients the neurophysiological mechanisms underlying their pain experience, as well as the multidimensional nature of pain, and translating this knowledge into adaptive behavioral change (28). This strategy allows both pain and associated psychological factors to be addressed, facilitating greater long-term adherence to exercise. Several studies have evaluated the effect of combining these treatments both in individuals suffering from CLBP (29,30) and in individuals with FM (31,32).

To date, there is no evidence demonstrating that the combination of pain neuroscience education (PNE) and therapeutic exercise (TE) may have a positive effect on pain and promote a reduction in perceived disability in patients with chronic musculoskeletal pain, such as fibromyalgia. Although the study by Adriaan Louw et al. (2016) (33) observed that a PNE program improved function and reduced disability, in that study PNE was combined with neuromuscular stimulation rather than therapeutic exercise to address chronic musculoskeletal disorders. Other studies have reported positive effects on variables such as pain intensity, disability, and associated cognitive-emotional factors when combining PNE with TE or other physiotherapy modalities, as concluded in the systematic review and meta-analysis by Sánchez-Robalino, A., et al. (2025) (34). However, none of the studies included in the meta-analysis involved a sample of individuals with fibromyalgia; instead, they included conditions such as chronic low back pain, chronic temporomandibular disorders, neck pain, radius fractures, cervicogenic headaches, migraines, carpal tunnel syndrome awaiting surgery, or knee osteoarthritis.

Particularly, the study by Traeger, A. C., et al. (2015) (35), focused on individuals with chronic low back pain (not fibromyalgia), showed that PNE alone helped reduce fear, anxiety, worry, pain catastrophizing, and even healthcare utilization. However, the PNE intervention was not combined with active programs such as TE, which may have a greater impact on physical capacities.

In this regard, there are no previous studies specifically analyzing the combined effect of PNE and TE on kinematic variables of spinal movement during the performance of functional activities, despite the fact that it is known, on the one hand, that TE alone may be effective in improving pain and function, but does not directly address the cognitive factors influencing motor behavior, such as catastrophizing or fear of movement. Conversely, PNE has been shown to be effective in modifying these variables, as it promotes a reduction in the perceived threat of movement and a better reconceptualization of pain. Therefore, the combination of both interventions could generate a synergy that facilitates safer exposure to movement and promotes deeper changes in movement patterns. Given that kinematic alterations are present both in individuals with chronic low back pain and in those with fibromyalgia, and that these alterations are influenced not only by physical but also cognitive factors, complementing PNE with TE in the study could provide relevant information about the mechanisms underlying clinical improvement.

OBJECTIVES/HYPOTHESES

The hypothesis of this study is that implementing a pain neuroscience education (PNE) intervention can enhance the effect of therapeutic exercise (TE) on pain and functionality in individuals with chronic low back pain (CLBP) and those with fibromyalgia (FM). Furthermore, it is hypothesized that PNE combined with TE may have a different effect in young and older adults.

Therefore, the main objective is to test the effectiveness of a PNE intervention combined with TE compared to TE applied in isolation in individuals with chronic pain. The specific objectives are to analyze the impact of adding a PNE intervention to a TE program on:

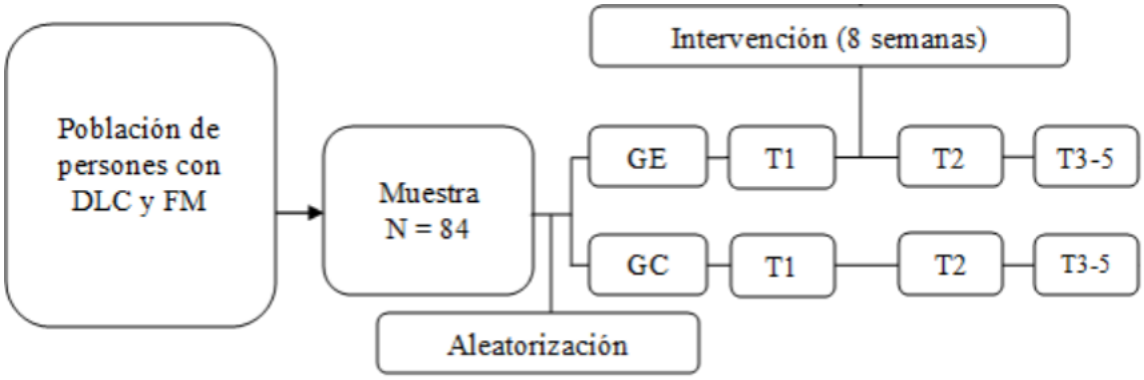
Pain, catastrophizing, pain sensitivity and sensitization, as well as on functionality, disability, the degree of anxiety and/or depression, and finally, the degree of fear and/or avoidance of movement in people with CLBP and people with FM.

Secondarily, the study aims to analyze, on the one hand, whether age influences the effectiveness of the intervention and, on the other hand, whether educational level influences understanding of pain education.

METHODOLOGY

DESIGN

The study design is a four-arm, age-stratified randomized clinical trial that will include participants with CLD or FM. Participants will be categorized by age into those under 65 years and those over 65 years. Participants will be assessed before the intervention (T1) and after the intervention (T2). In addition, to assess the durability of the effects, follow-up assessments will be conducted four, twelve, and twenty-four weeks after the intervention ends (T3, T4, and T5, respectively). Figure 1 shows the study design.



CG: Control group; EG: Experimental group; T1: Pre-intervention assessment; T2: Post-intervention assessment; T3: Follow-up assessment (4 weeks); T4: Follow-up assessment (12 weeks); T5: Follow-up assessment (24 weeks).

Figure 1. Research design diagram. Created by the authors.

PARTICIPANTS

Information about the project will be disseminated through various associations related to chronic pain in the cities of Valencia and Alcoy. The associations involved will be the Chronic Fatigue Syndrome Association of the Valencian Community, the Valencian Association of People with Fibromyalgia (AVAFI), and the Alcoy Fibromyalgia Association (ASFIAL). Potential participants who are interested will be contacted by phone or email. After verifying that they meet the inclusion and exclusion criteria, they will be given a detailed explanation of

the assessment and intervention procedures to be carried out during the study, as well as its duration and expected results.

Volunteers who agree to participate will be invited to Laboratory 2 (a laboratory equipped with a motion capture system) to sign the informed consent form and undergo the initial assessment (T1). Subsequently, a researcher not involved in the assessment or intervention processes will conduct the randomization of participants to avoid potential bias in the study.

Participants will initially be divided into two groups based on their age (under or over 65 years old) and their condition (DLC or FM):

- GDLCA (Chronic Lower Back Pain Group for Adults)
- GDLCJ (Chronic Lower Back Pain Group for Young Adults)
- GFMA (Fibromyalgia Group for Adults)
- GFMJ (Fibromyalgia Group for Young Adults)

Once this division into groups of participants younger and older than 65 years, and into patients with CLBP or patients with FM, has been completed, participants will be randomly assigned into two subgroups according to the pathology and intervention allocated:

- Experimental Group (EG): PNE intervention and TE program.
- Control Group (CG): placebo PNE intervention and TE program.

The specific details of each intervention are described in the "Intervention Protocols" section. Before the first assessment, volunteers will be invited to receive a detailed explanation of the evaluation and intervention protocol procedures and to formally sign the informed consent form. The first assessment (T1) will include the collection of demographic and clinical data, as well as the administration of a battery of tests, assessments, and questionnaires described in the "Evaluation Procedures" section.

Once these data have been collected, participants' schedules will be organized so that they attend the laboratory once per week and connect synchronously twice per week for eight weeks in order to carry out the intervention. Upon completion of the intervention, the T2 assessment will be performed, replicating the same procedures used in the T1 assessment. Finally, assessments T3, T4, and T5 will be conducted four, twelve, and twenty-four weeks after the end of the intervention, respectively.

The collected data will be stored in strict compliance with confidentiality provisions according to the Organic Law on Personal Data Protection (LOPD) 3/2018, of December 5. Participant coding will be safeguarded in a separate encrypted database to ensure information security.

For individuals with CLBP, the inclusion criteria will be as follows: a) experiencing pain for at least the last 3 months, b) with a frequency of 3 or more days per week, c) located between the ribs and the gluteal folds, d) without any previous surgical intervention, and e) having the ability to understand instructions (Mini-Mental State Examination [MMSE] > 23 points) (36). The exclusion criteria will be as follows: a) changes in medication during the month prior to the study and b) disorders affecting the central or peripheral nervous system.

For individuals with FM, the inclusion criteria will be as follows: a) diagnosis of FM according to the 2016 criteria of the American College of Rheumatology (37,38), and b) having the ability to understand instructions (Mini-Mental State Examination [MMSE] > 23 points) (36). The exclusion criteria will be as follows: a) changes in medication during the month prior to the study and b) disorders affecting the central or peripheral nervous system.

The assessments and interventions will primarily be conducted at the Universitat de València Faculty of Physiotherapy, specifically in Laboratory 2 (assessments) and in the Physiotherapy and Physical Exercise Laboratory (interventions). Participants belonging to each sample group (CLBP and FM) will be divided into the previously mentioned groups (G1 and G2). The stratified randomization process will be carried out using the Random Allocation Software computer program.

Sample size calculation will be performed using G*Power software. Effect size will be calculated using the observed differences in the variable "Functionality," measured with the Roland Morris Disability Questionnaire (RMDQ), between the two groups in the study by Rabiei et al. (39) after an intervention similar to that proposed in this project. This study was selected as the reference because it included the largest sample among previously published similar clinical trials. In addition, the RMDQ was selected as the reference measure because it evaluates different functional activities. The resulting effect size was large (Cohen's d = 0.5), combined with a statistical power of 80% to minimize false negatives and a type I error probability of 0.05. Considering that participants will be divided into two groups (according to the intervention received) and that a total of five measurements will be performed, the sample size calculation resulted in a total of 42 participants with CLBP and 42 participants with FM.

REVIEWS

To carry out the assessments, participants will be asked to attend wearing comfortable clothing, including shorts and appropriate footwear, to facilitate the performance of the tests. They will also be instructed to refrain from performing intense physical exercise on the day prior to the evaluations in order to ensure that the results are not influenced by fatigue or exhaustion.

During the first visit, eligible volunteers will receive a detailed explanation of all study procedures and will have the opportunity to clarify any doubts or questions before signing the informed consent form. During this initial session, anthropometric, demographic, and clinical data will be collected through interviews and measurements. This step is essential in order to control, if necessary, for any confounding factors that may influence the study results, thereby ensuring the accuracy and rigor of subsequent analyses. Some of the data will be collected pre- (T1) and post-intervention (T2); their specifications are described in greater detail in section 3.5. Anthropometric and demographic data will include:

- Height (measured using a stadiometer).
- Weight (measured using a Tanita scale). This measurement will be performed pre- (T1) and post-intervention (T2).
- Age: this variable will classify participants as younger or older than 65 years.
- Sex.
- Educational level.
- Physical activity level measured using the International Physical Activity Questionnaire (IPAQ) (40).
- Type of sport practiced (the amount of time spent practicing the sport will be recorded).
- Previous knowledge regarding Pain Neuroscience Education.
- Central sensitization, assessed using the Spanish version of the Central Sensitization Inventory (CSI) (41).

Clinical data (assessed by healthcare professionals at the hospital or primary healthcare center from which the volunteer is recruited) will include a report indicating:

- Previous pathologies.
- Medication currently being taken and medication taken during the previous month.

In addition, to verify compliance with the inclusion and exclusion criteria, a neurological examination will be conducted, including the assessment of osteotendinous reflexes and tactile and pain sensitivity. The procedure is as follows:

Assessment of the following reflexes: biceps (C5), brachioradialis (C6), triceps (C7), quadriceps/patellar (L4), and Achilles (S1). Reflexes will be assessed following the reflex examination guidelines provided by the Stanford University School of Medicine (42). Reflex status will be determined using the Muscle Stretch Reflex Scale of the National Institute of Neurological Disorders and Stroke (NINDS) (43,44). The assessment will be performed using a reflex hammer and an examination table, with patient positioning varying according to the reflex being evaluated:

- **Biceps reflex (C5):** the patient will be seated on the examination table with the arm relaxed and the elbow slightly flexed. The physiotherapist will strike the biceps brachii tendon using the reflex hammer.
- **Brachioradialis reflex (C6):** the patient will be seated on the examination table with the arm relaxed and the forearm in a neutral pronation-supination position. The physiotherapist will strike the radial styloid process using the reflex hammer.
- **Triceps reflex (C7):** the patient will be seated on the examination table with the arm relaxed over the physiotherapist's hand and the shoulder abducted to 90°. The physiotherapist will strike the triceps brachii tendon with the elbow flexed.
- **Quadriceps or patellar reflex (L4):** the patient will be seated on the examination table with the knees flexed at 90° and feet not touching the floor. The physiotherapist will strike the quadriceps tendon using the reflex hammer.
- **Achilles reflex (S1):** the patient will lie prone on the examination table with both feet extending beyond the edge of the table. The physiotherapist will strike the Achilles tendon with the foot in dorsiflexion.

Sensitivity assessment will be performed at all evaluation time points (T1 to T5). On the one hand, tactile sensitivity will be assessed using the Semmes-Weinstein Monofilament Test (SWMT) (45), and on the other hand, pain sensitivity will be assessed using the Pinprick test (46), in which a sterile needle will be used to apply a sharp stimulus to the dermatomes of the lower limbs. This procedure will follow the International Standards for Neurological Classification of Spinal Cord Injury (47) and will consider the following dermatomes:

- **L1:** inguinal region and upper medial thigh.
- **L2:** middle and lateral anterior thigh.
- **L3:** medial knee region.
- **L4:** medial leg and ankle.

- **L5:** dorsum and medial aspect of the great toe.
- **S1:** dorsum and lateral aspect of the little toe.
- **S2:** posterior thigh and popliteal fossa.

For sensitivity assessment, the patient will be seated on an examination table with the knees flexed at 90° and feet supported on the floor while the physiotherapist performs the examination.

For tactile sensitivity, Semmes-Weinstein monofilaments will be used. These filaments vary in thickness, and the objective is for the filament to bend when applied perpendicularly to the patient's skin. The thinnest filament perceived by the patient will be considered valid.

For pain sensitivity, the pointed end or pin of the reflex hammer will be applied bilaterally over each dermatome. Patients will be asked to indicate, first, when they perceive the pinprick stimulus and, second, whether the sensation is perceived equally on both sides. Patients will be informed that a non-harmful sharp stimulus will be applied.

A data collection form including all the previously mentioned information will be used. If the volunteer meets all the criteria to participate in the study, they will be assigned to an intervention group (G1 or G2) using a simple blinded randomization method according to whether they present CLBP or FM and according to age group.

During the first visit, a pre-treatment assessment will be conducted by an investigator blinded to group allocation (T1). The evaluation procedure will be repeated by the same investigator at the end of the 8-week treatment period (T2), and four (T3), twelve (T4), and twenty-four (T5) weeks after the end of the intervention. The different assessment procedures carried out during the T1 to T5 evaluation sessions, as well as the variables extracted from them, are described below.

1. Medication Review

Medication use will be reviewed at each assessment using the Medication-Related Problems Detection Questionnaire (PRM) (48). Medication taken pre-intervention (T1), post-intervention (T2), and during follow-up assessments (T3, T4, and T5) will be recorded. For T1, medication intake during the previous week will be documented, whereas for the remaining assessments, medication intake since the previous evaluation will be recorded. This questionnaire consists of 39 questions, 18 of which relate to the medications taken by the patient, including dosage, administration schedule, route, relation to meals, among others.

2. Pain Catastrophizing Scale (49,50)

This scale consists of 13 items rated on a Likert scale from 0 to 4 points, where higher scores indicate greater levels of catastrophizing. It will be used to assess the level of catastrophizing experienced by the patient. The scale evaluates three distinct aspects of the pain experience: helplessness, magnification, and rumination.

- **Helplessness:** refers to the negative evaluation a person makes regarding their ability to cope with pain. It includes items 1, 2, 3, 4, 5, and 12.
- **Magnification:** refers to the exaggeration of the threatening value of pain. It includes items 6, 7, and 13.
- **Rumination:** refers to the individual's constant concern about pain and their inability to inhibit pain-related thoughts. It includes items 8, 9, 10, and 11.

3. Conditioned Pain Modulation Test (51)

This test is used to assess the condition of the nervous system. The procedure is as follows:

The test stimulus will be applied using an algometer to assess pressure pain threshold at the tibialis anterior muscle (5 cm distal to the tibial tuberosity). The patient will verbally indicate the point at which pressure becomes painful (the average of 3 consecutive measurements will be recorded).

Subsequently, a conditioning stimulus will be applied using a blood pressure cuff inflated to a constant pressure of 240 mmHg for 120 seconds (52).

Finally, the pressure pain threshold at the tibialis anterior muscle will be reassessed.

4. Functional Assessment of the Lumbar Spine

4.1 Clinical Assessment

Two tests will be used for the functional evaluation of the lumbar spine:

On the one hand, the Biering-Sørensen Test (53), which is a functional test measuring the strength and isometric endurance of the trunk extensor musculature, particularly in the lumbar spine.

To perform the test, the patient will be positioned prone with the trunk extending beyond the examination table, while the pelvis and legs are secured using straps. The arms must remain crossed over the chest.

The objective of the test is for the patient to maintain the horizontal position for as long as possible. Therefore, the test will end when fatigue or pain appears, or when the trunk drops below the horizontal position.

The test duration will be measured using a stopwatch, and surface electromyography (EMG) will be used to assess muscle activation. Electrodes will be placed over the longissimus and iliocostalis muscles, as these muscles are part of the erector spinae group and show the highest activation during the test, as indicated in the study by Shaw, J., et al. (2024) (54). The electrodes will measure 20 mm and will be placed over the iliocostalis muscle, 3–4 cm lateral to the midline at the L2–L4 level.

On the other hand, the Finger-to-Floor Distance Test (55,56) will be used to measure spinal mobility and flexibility, especially in the lumbar region. During this test, the patient will stand upright with feet together and knees extended and will be instructed to bend forward attempting to touch the floor with the fingertips. The physiotherapist will measure the distance between the right middle finger and the floor using a standard tape measure. Patients will also be asked whether the movement is limited by pain, stiffness, or both. In addition to the previously mentioned variables, the finger-to-floor distance in centimeters will also be recorded.

4.2 Kinematics

Using a motion capture system located in the Motion Capture Laboratory of the Universitat de València Faculty of Physiotherapy, the following variables will be analyzed:

On the one hand, spinal range of motion (ROM), specifically flexion-extension, lateral bending, and rotation movements. Each movement will be performed five times at a comfortable speed (for example, similar to arm movement during walking). Participants will be instructed to move to the limit of their range of motion. The movements will be as follows:

Rotations

- **Starting position:** The participant will sit on a stool with the spine in a neutral position, hips and knees flexed at 90°, feet supported on the floor, and hands placed on the waist in a “cup” position.
- **Movement execution:** The participant will rotate the trunk to both sides without bringing the elbows forward or flexing the shoulders, while maintaining a neutral spinal position.

Lateral bending

- **Starting position:** The participant will sit on a stool with the spine in a neutral position, hips and knees flexed at 90°, feet supported on the floor, and arms in a "cup" position.
- **Movement execution:** The participant will laterally bend the trunk to both sides while maintaining a neutral spinal position.

Flexion-extension

- **Starting position:** The participant will stand upright with feet shoulder-width apart, arms in a "cup" position, and knees slightly flexed.

Flexion and extension movements will be performed consecutively five times.

- **Movement execution:** The participant will flex the trunk as far as possible, reaching maximal flexibility range, and then extend the trunk backward as far as possible.

Additionally, the Five Times Sit-to-Stand Test (5TST) (57) will be performed. This test provides a method for quantifying lower limb functional strength and/or identifying the movement strategies used by a patient to complete transitional movements.

The patient will sit upright with hands placed on the hips in a "cup" position. A height-adjustable examination table will be used to maintain hips and knees at 90°, always using the same height across all evaluations. The table will not be positioned against the wall. The participant will stand up and sit down five times as quickly as possible. Timing will begin on the command "Go" and will stop when the buttocks touch the examination table after the fifth repetition. No assistance may be provided during the test, and timing will be recorded manually.

Finally, a functional task will be performed in which the participant will lift a standardized 5 kg weight (using a medicine ball) and repeat the movement five times, lifting it from the floor, turning, and simulating placement on an examination table. The test will have three assessment objectives and will be divided into three parts, as described by Von Arx, M., et al. (2021) (58):

Free Movement

The participant will begin in a standing position and perform the lifting task freely without receiving any specific instructions. Trunk flexion is expected.

Instruction to the participant: "Lift the weight in the way you consider appropriate using both hands and simulate placing it on the examination table."

Deadlift Movement

The participant will begin standing and perform the lifting task by bending forward with clear spinal and hip flexion (hinge movement) while keeping the knees as straight as possible.

Instruction to the participant: “Lift the weight from the floor without bending your knees and place it on the examination table.”

Squat Movement

The participant will begin standing and perform the lifting task while keeping the back as straight as possible, with the arms positioned inside the knees and primarily flexing the knees and hips so that the quadriceps generate the pushing force.

Instruction to the participant: “Performing a squat, lift the weight and place it on the examination table.”

All movements will be performed for five repetitions (the middle three repetitions will be analyzed). Marker locations will be predefined, with larger markers used for the trunk and head. A total of 36 markers will be placed over the body except on the hands.

The variables extracted from all tasks will include:

- Maximum pain using a Visual Analogue Scale (VAS) from 0–10.
- Maximum range of each movement.
- Velocity.
- Movement smoothness.
- Compensatory movements.

5. Anxiety and Depression Assessment (59)

The Hospital Anxiety and Depression Scale (HADS) is a self-assessment instrument used to identify anxiety and depression in patients with medical conditions requiring hospital care. The HADS consists of two subscales: HADS-A for anxiety assessment and HADS-D for depression assessment, each containing 7 items. Each item has 4 Likert-type response options ranging from 0 to 3, where higher scores indicate greater presence or severity of symptoms. Each subscale is scored separately, ranging from 0 to 21, while the total combined score ranges from 0 to 42 points.

Interpretation of scores is as follows:

- **0–7 points:** not considered a case of anxiety or depression.
- **8–10 points:** possible case of anxiety or depression.
- **11–21 points:** case of anxiety or depression.

6. Pain (60)

Pain will be assessed during all photogrammetry tests using a VAS ranging from 0 to 10.

Additionally, for the CLBP group, the following functional disability scales will be used:

7. Functional Disability for Low Back Pain

On the one hand, the Oswestry Low Back Pain Disability Scale, also known as the Oswestry Disability Index (ODI) (61), which is a questionnaire validated in Spanish that quantifies the degree of functional disability due to low back pain. This self-administered questionnaire contains 10 questions assessing pain intensity, positions such as standing, sleeping, or walking, as well as basic activities of daily living.

Each question is answered on a Likert scale from 0 to 5 points, where higher scores indicate greater disability. The total score is expressed as a percentage, allowing classification of functional impairment from minimal disability to severe disability or bedridden status.

On the other hand, the Roland-Morris Disability Questionnaire (62,63) is an assessment instrument consisting of 24 items designed to measure the degree of physical disability in patients with low back pain. Its main focus is to determine how back pain affects daily activities, evaluating aspects such as physical capacity, sleep, psychosocial factors, household management, eating, and pain frequency. The total score ranges from 0 to 24.

8. Fear and Avoidance

The Fear-Avoidance Beliefs Questionnaire (FABQ) (64) will be used. This questionnaire specifically focuses on how patients' fear-avoidance beliefs regarding physical activity and work may affect and contribute to their low back pain (i.e., the cognitive/affective components of pain that differ from specific tissue damage, injury, and nociception) and the resulting disability.

It is a self-administered questionnaire composed of 16 questions scored on a scale from 0 to 6 (maximum score of 96; higher scores indicate greater fear-avoidance behaviors). The first 5 questions refer to physical activity, whereas the remaining 11 refer to work. The Physical

Activity subscale (FABQ-PA, range: 0–24) is calculated as the sum of items 2 to 5. The Work subscale (FABQ-W, range: 0–42) is calculated as the sum of items 6, 7, 9, 10, 11, 12, and 15.

Finally, participants in the FM group will complete the Revised Fibromyalgia Impact Questionnaire, and to verify whether diagnostic criteria are met, the corresponding assessments will be conducted: the Widespread Pain Index (WPI) and the Symptom Severity Scale (SSS).

Currently, the diagnostic criteria used for fibromyalgia are those proposed by the American College of Rheumatology and revised in 2016 (65). These criteria include the following conditions:

- Generalized pain must be present in at least 4 of 5 body regions.
- Symptoms must have been present at a similar level during the previous 3 months.
- The Widespread Pain Index (WPI) and Symptom Severity Scale (SSS) (66) must present the following scores: WPI ≥ 7 and SSS ≥ 5, or WPI 4–6 and SSS ≥ 9.
- The presence of fibromyalgia is compatible with other medical diagnoses; therefore, diagnosis may be established independently of comorbidities, although these must still be considered.

9. Revised Fibromyalgia Impact Questionnaire (67)

The Revised Fibromyalgia Impact Questionnaire aims to assess function, overall impact, and fibromyalgia symptoms during the previous 7 days. It was specifically developed for patients with fibromyalgia and is designed for patient self-completion. It includes 21 items: 9 related to function, 2 related to overall impact, and 10 related to symptoms.

INTERVENTION

The treatment will last 8 weeks for both groups:

- **G1:** TE + PNE
- **G2:** TE + placebo PNE

Therapeutic Exercise (TE)

The intervention will consist of approximately 40–50 minutes and will include an exercise protocol aimed at the treatment of low back pain. Three TE sessions per week will be performed. The intervention will include a 5-minute warm-up, 10 minutes of CORE stabilization exercises, 15 minutes of functional exercises, and finally 6 minutes of stretching

exercises. Rest periods of 1 minute between exercises will be allowed depending on the patient's needs. (APPENDICES)

Pain Neuroscience Education (PNE)

One weekly session lasting between 20–40 minutes will be conducted. The sessions will follow the structure below:

BLOCK 1. Fundamentals of Pain Neuroscience (Sessions 1–3)

- **Session 1:** What is pain? Types of pain (acute/chronic).
- **Session 2:** The alarm system in chronic pain and the role of central sensitization.
- **Session 3:** Factors influencing pain.

BLOCK 2. Myths, Beliefs, and Movement (Sessions 4–5)

- **Session 4:** Myths about low back pain.
- **Session 5:** Fear of movement (kinesiophobia), gradual exposure to movement, and the importance of physical activity.

BLOCK 3. Coping Strategies and Self-Care (Sessions 6–7)

- **Session 6:** Stress, sleep, and nervous system regulation in pain.
- **Session 7:** Catastrophizing and negative thoughts.

BLOCK 4. Consolidation and Relapse Prevention (Session 8)

- **Session 8:** Review of learning outcomes.

Placebo Pain Neuroscience Education (Placebo PNE)

Sessions will focus on back anatomy and biomechanics.

BLOCK 1. Fundamentals of Anatomy (Sessions 1–4)

- **Session 1:** Bone structure and joints.
- **Session 2:** Muscular system.
- **Session 3:** The spinal cord.
- **Session 4:** The central and peripheral nervous systems.

BLOCK 2. Back Biomechanics (Sessions 5–6)

- **Session 5:** Biomechanics of the cervical spine.
- **Session 6:** Biomechanics of the lumbar spine.

BLOCK 3. Strategies for Back Care (Session 7)

- **Session 7:** Posture and balance.

BLOCK 4. Consolidation of Learned Concepts (Session 8)

- **Session 8:** Review of learning outcomes.

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