Received: 11 February 2024 | Revised: 2 July 2024 | Accepted: 3 July 2024

DOI: 10.1002/ejp.4700

EJP European Journal of Pain

ORIGINAL ARTICLE

# Short- and medium-term effects of a single session of pain neuroscience education on pain and psychological factors in patients with chronic low back pain. A single-blind randomized clinical trial

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## Abstract

**Introduction:** Biopsychosocial approach in patients suffering chronic low back pain (CLBP) promotes pain self-management strategies. Current evidence recommends high dose of Pain Neuroscience Education (PNE) for clinically significant differences. However, the workload and time constraints experienced by healthcare providers impede the application of the recommended treatment regimen. In fact, Back School with a biomechanical model is the main approach to manage CLBP in public systems.

**Objective:** The objective of this study is to explore the effect of a 60 min single session of PNE as an adjunct to back school on pain intensity and psychological variables patients with CLBP.

**Methods:** A double-blind, two-arm randomized controlled clinical trial was conducted in patients with CLBP who attended back school sessions held in a Spanish public hospital. A total of 121 patients were randomized into control group, who received the Back School program during 5 weeks, and intervention group, who additionally received a single session of PNE. Patient-reported outcomes were the Numerical Pain Rating Scale, Central Sensitization Inventory, Pain Catastrophizing Scale, and Tampa Scale of Kinesiophobia, with a 12-week follow-up.

**Results:** A total of 113 patients were analysed. Intervention and control group presented similar effects on pain and kinesiophobia. At follow-up, intervention group exhibited reduced sensitization and catastrophism scores compared with control, including the subscales. Additionally, PNE reduced the percentage of participants classified as having central sensitization compared with control.

**Conclusions:** Adding a single PNE session in the back school program did not reduce pain but improved psychological factors as central sensitization and pain catastrophizing at medium-term. This study highlights the potential of PNE to

  

optimize treatment strategies for CLBP, especially in public health centres where time resources are scarce.

**Significance Statement:** Adding a single PNE session in the back school program did not reduce pain but improved psychological factors as central sensitization and pain catastrophism at medium-term.

## 1 | INTRODUCTION

Low back pain is still being one of the most common health problems worldwide (Chen et al., 2022). The incidence of LBP escalates in the third decade of life and the overall prevalence increases with age up to 60–65. LBP is one of the main reasons for healthcare seeking, with approximately 5%–10% of cases becoming chronic over time, according to the previous criteria (beyond 3 months) (Meucci et al., 2015).

The aetiology of chronic low back pain (CLBP) is unknown in approximately 85% of cases. Current literature proposes nociplastic pain as a clinical term for pain conditions in which nociception is altered; however, there is no clear evidence tissue or lesion of the somatosensory system causing the pain (Kosek et al., 2016). This could be the case of CLBP patients, due to the lack of tissues injury or somatosensory lesion and the presence of pain processing disorder, such hypersensitivity to a large number of stimuli or dysfunction of endogenous descending inhibitory system (Keedy et al., 2014). In those cases, the pain perceived by the patient is disproportionate in relation to the nature and extent of the injury and shows a diffuse distribution pattern (Nijs et al., 2011). It is theoretically proposed that this altered pain processing could be caused by a central sensitization, a potentiation of the nociceptive pathway in the central nervous system (Kosek et al., 2016). However, it has not been demonstrated in humans because central sensitization cannot be directly measured (Schuttert et al., 2021).

In recent years, there has been a growing recognition of the significance of psychosocial factors involved in the experience of pain (Keedy et al., 2014). This underlines the importance of a biopsychosocial model of chronic pain, which acknowledges a range of factors, including physical dysfunction, beliefs, coping strategies, distress, social interactions, and pathological behaviours, as contributors to the pain experience (Vlaeyen & Linton, 2000). Thus, it is not surprising to find an often association between negative psychological behaviours, such as kinesiophobia (fear of movement) and pain catastrophizing (Louw et al., 2016; Watson et al., 2019).

According to the biopsychosocial approach, a cornerstone in the management of patients suffering from chronic pain is to promote pain self-management (Moseley, 2002). In this regard, pain neuroscience education (PNE) is one of most widespread educational techniques that have been described for the treatment of chronic pain conditions (Moseley, 2002). Cognitive-behavioural interventions frequently incorporate PNE to reconceptualize misconceptions about chronic pain and how to promote positive coping styles (Watson et al., 2019). PNE has shown to improve pain, disability and psychosocial factors, such as catastrophizing and kinesiophobia, on patients with chronic pain (Louw et al., 2016; Suso-Martí et al., 2022). In addition, current evidence indicates that these programs should be accompanied by graded physical activity and targeted therapeutic exercise (Galan-Martin et al., 2020).

Until recently, the optimal dosage of PNE in patients with CLBP remained unclear (Watson et al., 2019). Currently, several systematic reviews and meta-analyses have established a dose–response relationship for PNE, indicating that high doses could be more effective. Núñez-Cortés et al. (2024) found that 150–200 min of PNE, added to an exercise programme, could be the minimal dose required to achieve a clinical reduction in pain intensity and disability (Núñez-Cortés et al., 2024). Salazar-Méndez et al., 2023 reported a linear dose–response relationship for psychosocial variables in chronic musculoskeletal pain, with 100 min being the minimum effective dose surpassing clinically important differences (Salazar-Méndez et al., 2023). However, a recent study using moderator analyses found no association between dosage and PNE efficacy on pain and psychosocial variables (Romm et al., 2021). Finally, another meta-analysis on LBP found that only a single PNE session was sufficient to reduce pain intensity in the short-term (Ma et al., 2023). The controversial results underscore the need for further evidence.

Currently, in Spanish public health system, some educational programmes are delivered in patients with CLBP (Paolucci et al., 2017). In most cases, the popular model used for years is the Back Schools (BS) (Straube et al., 2016), that are educational and training programs for patients based on anatomy and biomechanics (Straube et al., 2016). However, this approach is currently considered inadequate and inconsistent for chronic pain patients, focusing solely on postural and biomechanical aspects, contrary to the essential biopsychosocial framework

(García-Martínez et al., 2022; Louw et al., 2016). In addition, although therapeutic exercise is an evidence-based recommendation for CLBP patients (Qaseem et al., 2017), it is not yet widely prescribed in many clinical centres, which continue to promote education on postural hygiene and even limit physical or work-related activities (García-Martínez et al., 2022). Moreover, to the prevailing biomedical approach to patient education, strategies for education and self-management of symptoms in CLBP patients are very poor. This deficiency is due to the heavy workload and lack of time available to support physiotherapy patients in many public health centres (Carmona-Barrientos et al., 2020).

Considering the dynamics of the current public health system, the prevailing standard treatment for CLBP typically involves back school programs based on anatomical and biomechanical approaches. Although PNE at high doses (100–400 min) is recommended in combination with exercise as the first line of treatment for CLBP, the practical implementation of such intensive interventions is complicated. The demanding workload and time constraints experienced by healthcare providers impedes the application of the recommended treatment regimens. In light of these constraints, our study aims to explore the potential impact of adding a single session to the existing standard treatment protocol for CLBP. By investigating the efficacy of this approach, we seek to address the practical limitations associated with implementing prolonged PNE interventions within the constraints of real-world clinical practice. Then, the aim of this study was to assess the impact of a single session of PNE on pain, central sensitization inventory, kinesiophobia and catastrophizing in patients suffering CLBP who are on the waiting list for the back school (BS) protocol as physiotherapy treatment in a public hospital in the southeast of Spain.

## 2 | METHODS

### 2.1 | Design

A single-blind, two-arm randomized controlled clinical trial was designed following the recommendations of the Consolidated Standards of Reporting Trials CONSORT (Schulz et al., 2010), with a 12-week follow-up and a 1:1 assignment ratio with pre- and post-treatment evaluations at the Hospital Clínico Universitario Sant Joan d'Alacant (Spain).

Due to the nature of the intervention, it was not possible to blind either the intervention or the physiotherapists who applied it; however, the latter did not participate in the patient assessment process. The evaluator was blinded. In addition, an external biostatistician blinded to group treatment allocation performed the statistical analysis. The treatment assignment was kept hidden by informing participants of their involvement in the study without revealing the existence of two treatment groups or their allocation, thus ensuring blinding throughout the treatment assignment process.

The study was approved by the Ethics Committee of Ethics Committee of the Department of Health of Sant Joan d'Alcant on April 30, 2019 (code: 19/317) and the participants gave their written consent before starting the study. The trial protocol was recorded in ClinicalTrials.gov (NCT03964389).

### 2.2 | Participants

Subjects aged between 18 and 65 years, with a clinical diagnosis of chronic nonspecific low back pain from their doctor (rehabilitation or orthopaedic specialist), who were enrolled in the Physiotherapy Back School (BS) group were invited to participate in the study. Chronic pain was defined as persistent pain that lasts longer than 3 months (Loeser & Treede, 2008).

The exclusion criteria were acute low back pain, concomitant neurological or oncological diseases, previous back surgeries, severe cognitive impairments and pregnancy.

All patients were instructed not to take any new medications during the study and not to undergo other rehabilitation therapy (those who did so dropped out of the study).

### 2.3 | Intervention

The study was conducted from July 1 to December 31, 2022. The BS protocol involved five one-hour group-based sessions spread over a month and a half, once a week.

The purpose of first session was to make patients aware about their pathological condition. Thus, patients received information about general spinal anatomy, its functions, and ergonomic postures in daily life. After this session, patients interested in participating in the study were recruited, signed the informed consent and were randomly assigned to one of the study groups (BS or BS + PNE) using the Oxford Minimisation and Randomisation (OxMaR) system. They provided written informed consent before attending subsequent sessions (Figure 1).

In the second, third, and fourth sessions, patients received therapeutic exercise training (Figure 1). They practiced different exercises and received feedback corrections if needed, following the hospital clinical guidelines established by physiotherapists (Qaseem

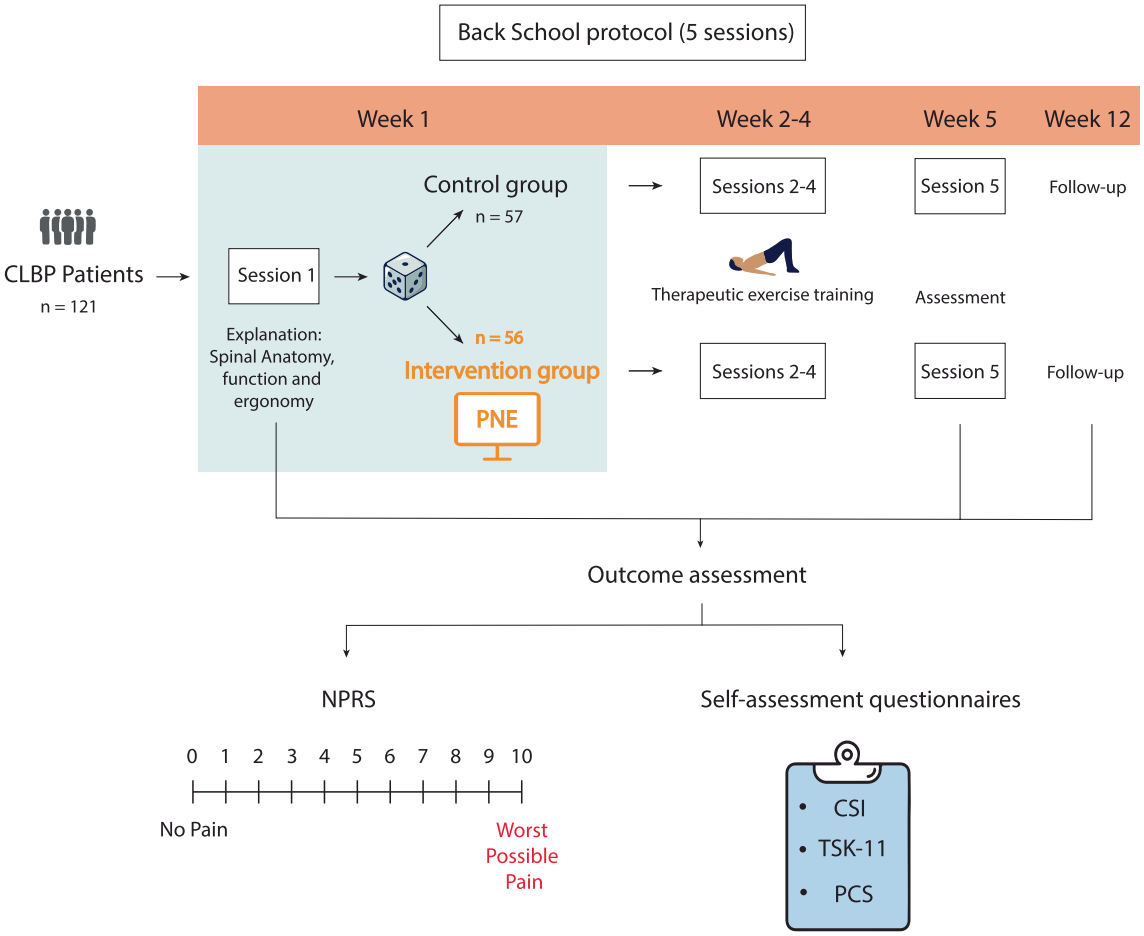


**FIGURE 1** Graphical representation of experimental design. It is represented the intervention and control protocols and the outcome measures. CLBP, chronic low back pain; PNE, pain neuroscience education; NPRS, numeric pain rating scale; CSI, central sensitization inventory; TSK-11, Tampa Scale of kinesiophobia 11 items; PCS, Pain Catastrophizing Scale.

et al., 2017). The exercises included: diaphragmatic breathing exercises (sets of 10 cycles), pelvic tilt exercise (10 repetitions), abdominal work (different muscles 10 repetitions), cervical stretches (3 times each side, 10 s), and proprioceptive postural correction exercises (10 repetitions). A more detailed description, graphic material and information on ergonomic tips for daily activities were also provided (Supporting Information S1). Summary according to the Consensus on Exercise Reporting Template (CERT) for the exercise programme is found in Supporting Information S2.

In the fifth session, both groups were assessed to monitor progress, filling out the questionnaires completed at baseline. Three months later, patients attended once more, coinciding with their doctor's check-up, and completed the same questionnaires for a third time (Figure 1).

Only the intervention group received an extra single session based on a 1-h of Patient Neuroscience Education (PNE), 2 days after the first BS session and before the second session. This PNE session provided a psychosocial approach to pain, aiming to reconceptualize perceptions, beliefs and avoidance behaviours related to pain, to finally perceive it as less threatening. Thus, PNE covered how thoughts, beliefs, and emotions can modify painful experiences, as well as addressing myths, taboos, and existing fears related to chronic pain. The content of this talk was based on the basic principles of the 'Explain Pain' book (Butler & Moseley, 2013). The structure of each session was designed to allow for a 5-min introduction, a 15-min exploration of pain physiology, a 20-min examination of the role of sensory factors and a 20-min explanation of pain modulating systems. However, we would like to clarify that we cannot assure that all sessions had the same time distribution. The supporting material used in the PNE session is found in Supporting Information S3.

## 2.4 | Outcome measures

During the baseline assessment, demographic variables were taken from patients, including gender, age,

weight, and height. Outcome measures were evaluated at three time points: basal conditions, after completing the intervention (5 weeks) and at the 12-week follow-up (Figure 1).

The primary outcome measure was pain intensity. It was evaluated using the numerical pain rating scale (NPRS), a segmented numeric version of the visual analogue scale (0–10 with 0 representing "no pain" and 10 indicating the "worst pain"). The minimal clinically important difference (MCID) of NPRS is 2 points (Salaffi et al., 2004).

Other self-reporting instruments, validated and cross-culturally adapted to Spanish, were also used:

Central sensitization inventory (CSI) (Cuesta-Vargas et al., 2016). This instrument is proposed to identify a potential CS syndrome in patients and to assess comorbidities associated with chronic pain, according to the IASP criteria. It contains 25 items scored on a *Likert*-type scale from 0 to 4. Total score ranges from 0 to 100, with a set cut-off of 40 points to differentiate subjects with and without potential CS or to confirm the presence of pain comorbidities (sensitivity: 85%, specificity: 75%) (Neblett et al., 2017). Recently, severity ranges have been proposed for CSI: subclinical (0–29), mild (30–39), moderate (40–49), severe (50–59) and extreme (60–100) (Neblett et al., 2017).

Tampa Scale of Kinesiophobia (TSK-11). It assesses the fear of a patient related with suffering a re-injury again during movement through 11 items. With a score range of 11 to 44, the TSK-11 has demonstrated acceptable internal consistency and validity. A 4-point reduction optimally identifies a significant reduction in the fear of the patient associated with the movement (Woby et al., 2005).

Pain Catastrophizing Scale (PCS) (Campayo et al., 2008). This self-reported outcome measure asks about negative thoughts related to pain. Based on the painful experiences of patients, the tool assesses the extent of certain thoughts and feelings using 13 items scoring from 0 (never) to 4 (always). Items are classified into 3 subgroups: rumination (constant worry, inability to inhibit pain-related thoughts), helplessness (loss of hope to achieve something, concerns about health) and magnification (the exaggeration of the unpleasantness of pain). Higher scores indicate increased catastrophizing. Total score ranges from 0 to 52 points (Rumination: 0–16 points; Helplessness: 0–24 points; Magnification: 0–12 points). A PCS score $\geq 30$ indicates a clinically relevant level of catastrophizing (Sullivan, 2009).

The minimal clinically important difference (MCID) threshold from the TSK scale and PCS have been previously reported previously in the literature, with values greater than 6 (Monticone et al., 2017) and 8 points, respectively (Monticone et al., 2022).

## 2.5 | Sample size calculation

Considering a mean effect size ($f = 0.20$) on the primary outcome (pain intensity), according to Cohen's definition, an alpha error of 5% and a power of 90%, leads to a minimum sample size of 108 participants when considering longitudinal data. We have estimated a 10% of dropouts, which brings us to a total sample of 120 participants.

## 2.6 | Statistics

Descriptive analysis was performed to detect possible outliers. Data distribution and normality was studied with the Kolmogorov-Smirnoff test.

Continuous variables are expressed as means and standard deviations, whereas categorical variables are expressed as counts and percentages. To compare categorical variables, we used the chi-squared test and to compare continuous variables between groups we used the t-test, due to central limit theorem allows us to ensure the normality of the sample means. The homogeneity of variances was analysed using Levene's test. We assessed the effect size using Cohen's *d*.

Generalized linear models, specifically Generalized Estimating Equations (GEE), for analysing longitudinal data were used. Within these models, we calculated the Robust Effect Size Index (RESI) as proposed by Vandekar et al. (2020). This involved estimating two variants of RESI: longitudinal RESI (L-RESI) and cross-sectional, per-measurement RESI (CS-RESI). The longitudinal RESI accounts for the specified clustering, whereas the cross-sectional RESI is derived from a model treating each measurement as its own cluster. Additionally, we incorporated the Overall RESI to compare the model with an intercept-only model (Vandekar et al., 2020).

The values of $p < 0.05$ were considered statistically significant. Unless otherwise indicated, data are presented as mean $\pm$ standard deviation. The dropouts were included in the analysis (intention to treat analysis). The statistical analysis was conducted using the free R software, version 4.0.5 (Free Software Foundation, Inc., Boston, MA).

# 3 | RESULTS

Of the 284 patients who were on the Rehabilitation Service waiting list for BS, 123 failed to meet the inclusion criteria and 40 declined to participate in the study. The remaining 121 patients (ITT sample) were randomized into two groups using a simple 1:1 randomization system: a control and intervention group. There were 8 dropouts due to different causes (2 oncological processes,

1 fracture, 2 surgeries, 1 stroke, 1 pregnancy, and 1 incontinence). In the control group (BS) were patients only attending the group sessions usually carried out at the hospital ($n = 57$, 67% women, mean age = 57.5 ± 13, BMI = 28.5 ± 5.7, NPRS = 7 ± 1.6), whereas the treatment group (BS + PNE) included patients who performed the same sessions as the control group and also a single 1-h face to face session of pain neuroscience education ($n = 56$, 73% women, mean age = 53.9 ± 14.1, BMI = 26.4 ± 5.1, NPRS = 6.7 ± 1.9). Table 1 shows that there are no differences in the physical characteristics of the sample after randomization.

A total of 113 patients completed the study. Fifty-seven were assigned to the control BS group and, 56 in the experimental PNE group (BS + PNE). The CONSORT flow chart is depicted in Figure 2.

Baseline comparisons of outcome variables (NRPS, CSI, TSK-11, PCS) revealed similar symptomatology and psychological features in both groups at the start of the study (Table 2). Post-intervention (week 5) comparisons showed no significant differences between the groups (Table 2). However, at follow-up (week 12), the intervention group exhibited reduced CSI and PCS scores compared with the control group (Table 2; Figure 3). Notably, the average CSI score in the intervention group fell below the cut-off (40 points) at follow-up (Figure 3). A detailed analysis revealed a decrease in the percentage of participants classified as having central sensitization (>40) in the intervention group compared with the control group (Table 3).

To further understand the PCS score reduction on intervention group at follow-up, an analysis of the subscales (helplessness, magnification and rumination) was carried out. Consistently, all three subscales demonstrated reduced scores in the intervention group compared with the control group (Figure 4).

The analysis using adjusted GEE models corroborated these findings, showing significant between-group differences for CSI ($p = 0.006$), PCS ($p = 0.012$), Helplessness ($p = 0.009$), Magnification ($p = 0.009$) and Rumination ($p = 0.007$) (Table 4).

Exploring within-group differences using adjusted GEE models revealed a time-related decrease in all variables except for TSK (Table 4; Figure 3). Importantly, the time-group interaction was not significant for any variable and was consequently omitted from the fitted model.

## 4 | DISCUSSION

The results of the present study show that including only a single PNE session in a traditional BS program conducted in a physiotherapy service of a public hospital is not able to modify pain intensity of patients with CLBP; however, it is sufficient to modify psychological factors as decrease the CSI and PCS. Remarkably, those effects are present, even higher, during the 12-week follow-up, showing a medium-term impact. It is also important to mention that pain and all psychological factors, excepting for kinesiophobia, were decreased at the 12-week follow-up in both control and intervention group.

Although the efficacy of the combination of exercise and PNE is well established in physiotherapy field of research (Núñez-Cortés et al., 2024; Watson et al., 2019), it is not included in the clinical practice of a great number of countries such as Spain (Torralba et al., 2014). This is evidenced by the main public clinical approach to manage CLBP patients: BS programmes with a predominantly

**TABLE 1** Descriptive characteristics of the sample.

| ITT sample | Control ($n = 60$) | Intervention ($n = 61$) | Total ($n = 121$) |
|---|---|---|---|
| Sex, women | 41 (68%) | 45 (74%) | 86 (71%) |
| Age, years | 57.4 ± 12.9 | 54.8 ± 14.2 | 56.1 ± 13.6 |
| Mass, kg | 75.6 ± 15.2 | 73.9 ± 15.8 | 74.8 ± 15.4 |
| Height, cm | 164.0 ± 9.4 | 166.5 ± 9.6 | 165.3 ± 9.5 |
| BMI | 28.3 ± 5.7 | 26.6 ± 5.0 | 27.4 ± 5.4 |
| Final sample | Control ($n = 57$) | Intervention ($n = 56$) | Total ($n = 113$) |
| Sex, women | 38 (67%) | 41 (73%) | 81 (72%) |
| Age, years | 57.5 ± 13.0 | 53.9 ± 14.1 | 55.7 ± 13.6 |
| Mass, kg | 76.5 ± 14.9 | 73.6 ± 16.3 | 75.1 ± 15,6 |
| Height, cm | 164.3 ± 9.5 | 166.5 ± 9.4 | 165.4 ± 9.5 |
| BMI | 28.5 ± 5.7 | 26.4 ± 5.1 | 27.5 ± 5.5 |

*Note*: Data are mean ± standard deviation unless indicated otherwise.

Abbreviations: BMI, body mass index; ITT, intention to treat.

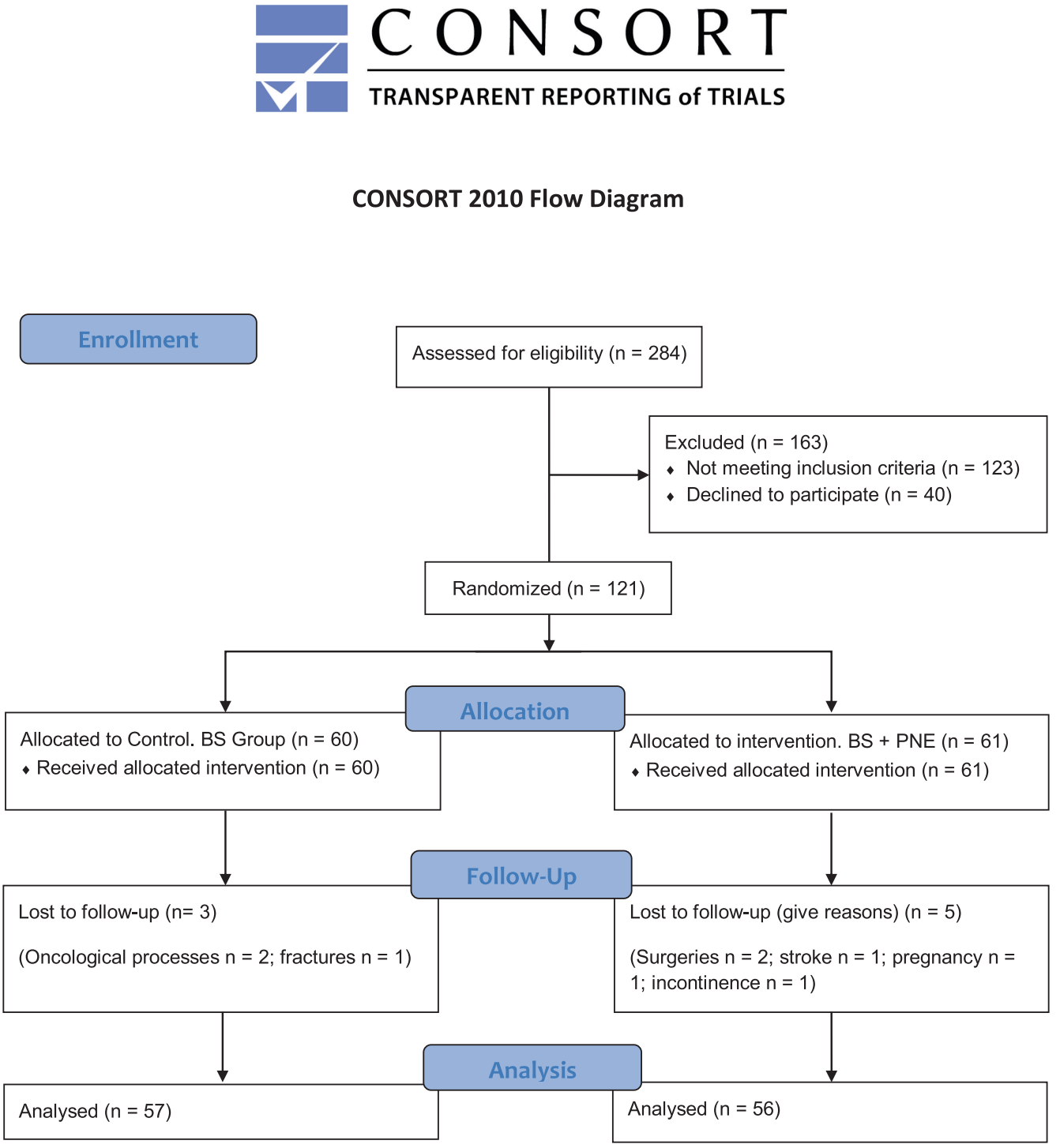


**FIGURE 2** Participants Consort flow-chart diagram for dropouts and sample management. PNE, pain neuroscience education; BS, Back School.

biomechanical nature (Paolucci et al., 2017; Straube et al., 2016). One of the explanations that limits the PNE inclusion on public healthcare system is the lack of time for physiotherapists. Additionally, that time limitation overlaps with lack of knowledge about the recent evidence around prescribing high dosage of PNE (Núñez-Cortés et al., 2024; Salazar-Méndez et al., 2023). For those reasons, the context of resource-constrained healthcare systems needs to optimize treatment strategies for CLBP that are both feasible and effective. Thus, we have proposed supplementing current CLBP management (BS) with a single session (60 min) of PNE, feasible in terms of economic and time resources and resulting in some relevant clinical changes.

**TABLE 2** Mean and standard deviation observed over time for each of the variable scales recorded in the control group and in the intervention group.

| | Control $n=57$ | Intervention $n=56$ | Total $n=113$ | $p$-value | Effect size |
|---|---|---|---|---|---|
| NPRS | | | | | |
| Baseline | 7.0 ± 1.6 | 6.7 ± 1.9 | 6.8 ± 1.7 | 0.314 | 0.19 |
| Follow-up 5 weeks | 6.1 ± 2.2 | 5.6 ± 1.9 | 5.8 ± 2.1 | 0.213 | 0.24 |
| Follow-up 12 weeks | 4.2 ± 2.6 | 3.8 ± 2.3 | 4.0 ± 2.5 | 0.407 | 0.16 |
| Central Sensitization Inventory (CSI) | | | | | |
| Baseline | 46.0 ± 18.9 | 43.2 ± 17.3 | 44.6 ± 18.1 | 0.406 | 0.16 |
| Follow-up 5 weeks | 43.9 ± 20.2 | 38.5 ± 17.6 | 41.2 ± 19.1 | 0.134 | 0.28 |
| Follow-up 12 weeks | 40.1 ± 22.0 | 31.0 ± 19.9 | 35.6 ± 21.4 | 0.023* | 0.43 |
| TSK-11 | | | | | |
| Baseline | 29.0 ± 7.4 | 28.8 ± 6.6 | 28.9 ± 7.0 | 0.871 | 0.03 |
| Follow-up 5 weeks | 31.7 ± 7.0 | 29.8 ± 6.4 | 30.7 ± 6.7 | 0.125 | 0.29 |
| Follow-up 12 weeks | 30.7 ± 9.3 | 28.1 ± 9.7 | 29.4 ± 9.5 | 0.151 | 0.27 |
| PCS | | | | | |
| Baseline | 26.5 ± 12.1 | 23.8 ± 13.2 | 25.2 ± 12.7 | 0.256 | 0.21 |
| Follow-up 5 weeks | 20.4 ± 11.2 | 19.8 ± 11.1 | 20.1 ± 11.1 | 0.795 | 0.05 |
| Follow-up 12 weeks | 20.6 ± 12.0 | 14.4 ± 9.9 | 17.5 ± 11.4 | 0.003* | 0.57 |
| Helplessness | | | | | |
| Baseline | 11.2 ± 5.6 | 10.6 ± 6.3 | 10.9 ± 6.0 | 0.604 | 0.10 |
| Follow-up 5 weeks | 9.3 ± 5.2 | 7.6 ± 4.7 | 8.4 ± 5.0 | 0.075 | 0.34 |
| Follow-up 12 weeks | 9.3 ± 5.4 | 7.0 ± 5.1 | 8.2 ± 5.3 | 0.021* | 0.44 |
| Magnification | | | | | |
| Baseline | 5.5 ± 2.8 | 5.0 ± 2.7 | 5.3 ± 2.7 | 0.293 | 0.20 |
| Follow-up 5 weeks | 5.0 ± 2.9 | 4.4 ± 2.4 | 4.7 ± 2.7 | 0.319 | 0.19 |
| Follow-up 12 weeks | 5.0 ± 3.5 | 3.6 ± 2.5 | 4.3 ± 3.2 | 0.023* | 0.43 |
| Rumination | | | | | |
| Baseline | 9.4 ± 4.9 | 8.8 ± 5.0 | 9.1 ± 4.9 | 0.521 | 0.12 |
| Follow-up 5 weeks | 7.6 ± 3.6 | 7.0 ± 3.8 | 7.3 ± 3.7 | 0.363 | 0.17 |
| Follow-up 12 weeks | 7.7 ± 4.8 | 5.1 ± 3.8 | 6.4 ± 4.5 | 0.002** | 0.60 |

*Note*: Data are mean ± standard deviation. *$p < 0.05$, **$p < 0.01$, independent $t$-test.

Abbreviations: NPRS; Numerical Pain Rating Scale; PCS, Pain Catastrophizing Scale; TSK-11, Tampa Scale of Kinesiophobia.

Respect to the primary outcome, the addition of a single session of PNE to BS programme did not reduce the pain intensity. Although, both groups showed a pain reduction and we noticed a tendency to observe a greater average improvement for the PNE + BS group (0.5 points at 5 weeks and 0.4 at 12 weeks). Although the literature supports the analgesic effect of PNE (Suso-Martí et al., 2022) and its combination with exercise (Siddall et al., 2022), our results on pain intensity are negative. This could be explained mainly by the low dose of our intervention (a single session of 60 min) compared with the minimal dose found to be effective on the intensity of musculoskeletal pain (100–150 min) (Núñez-Cortés et al., 2024; Salazar-Méndez et al., 2023). Then, our dose could be not sufficient to impact on pain intensity. Additionally, we must take in account that the effect of PNE on pain intensity often reports a small effect size (Moseley et al., 2003; Suso-Martí et al., 2022) and that several works find no effect on pain (Lepri et al., 2023).

Contrary to our results, recently, it has been reported preliminarily evidence about dose-effect relationships for PNE intervention on CLBP patients. It has been found that only single PNE session duration was associated with a greater reduction in pain (Ma et al., 2023). Another pilot study found the same analgesic effect with a single PNE session in patients with persistent pain (Sillevis et al., 2021). We can suggest some explanations to understand the discrepancies in our results and literature. Remarkably, the analgesic effect of one single session is found when the duration of PNE intervention is exceeding

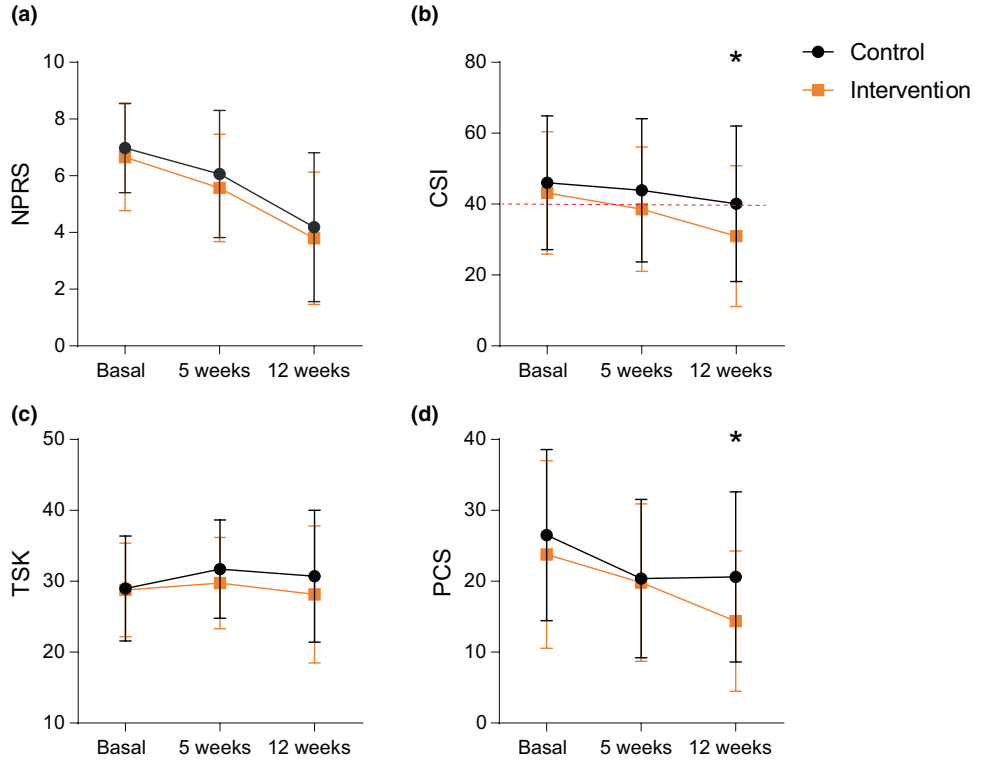


**FIGURE 3** Pain and psychological scales averages evolution between groups. NPRS, numeric pain rating scale; CSI, central sensitization inventory; TSK-11, Tampa Scale of kinesiophobia 11 items; PCS, Pain Catastrophizing Scale. (mean ± SD). *$p < 0.05$.

**TABLE 3** Percentage of participants with a CSI above cut-off by groups.

| % of participants CSI >40 points | Control ($n = 57$) | Intervention ($n = 56$) | $p$-value |
|---|---|---|---|
| Basal | 68.42 | 51.79 | 0.107 |
| 5 weeks | 61.4 | 44.64 | 0.110 |
| 12 weeks | 56.14 | 30.36 | 0.010** |

*Note*: Data are mean ± standard deviation unless indicated otherwise.

Abbreviations: BMI, body mass index; ITT, intention to treat.

**$p < 0.001$.

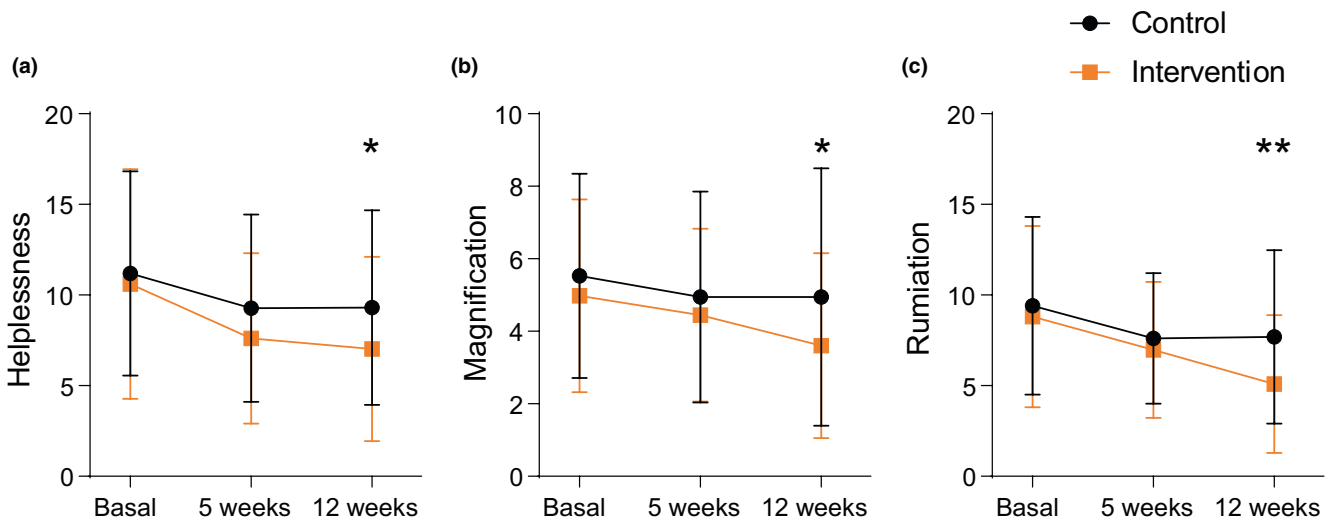


**FIGURE 4** Subscales of the PCS averages evolution between groups. (mean ± SD). *$p < 0.05$, **$p < 0.01$.

**TABLE 4** Generalized Estimating Equations model adjusted for each scale.

| NPRS | β (CI95%) | *p*-value | L.RESI | CS-RESI | Overall RESI |
|---|---|---|---|---|---|
| (Intercept) | 7.02 (6.65, 7.39) | <0.001 | 3.48 | 2.01 | 0.97 |
| Intervention | −0.40 (−0.85, 0.04) | 0.077 | 0.17 | 0.10 | |
| Follow-up 5 weeks | −1.00 (−1.5, −0.5) | <0.001 | 0.37 | 0.21 | |
| Follow-up 12 weeks | −2.83 (−3.38, −2.27) | <0.001 | 0.94 | 0.54 | |
| **CSI** | **β (CI95%)** | ***p*-value** | **L.RESI** | **CS-RESI** | |
| (Intercept) | 47.47 (43.5, 51.44) | <0.001 | 2.20 | 1.27 | 0.39 |
| Intervention | −5.77 (−9.87, −1.68) | 0.006 | 0.26 | 0.15 | |
| Follow-up 5 weeks | −3.36 (−8.16, 1.43) | 0.169 | 0.13 | 0.07 | |
| Follow-up 12 weeks | −9.05 (−14.13, −3.97) | <0.001 | 0.33 | 0.19 | |
| **TSK-11** | **β (CI95%)** | ***p*-value** | **L.RESI** | **CS-RESI** | |
| (Intercept) | 29.66 (28.09, 31.23) | <0.001 | 3.49 | 2.01 | 0.21 |
| Intervention | −1.58 (−3.24, 0.07) | 0.061 | 0.18 | 0.10 | |
| Follow-up 5 weeks | 1.86 (0.08, 3.64) | 0.041 | 0.19 | 0.11 | |
| Follow-up 12 weeks | 0.57 (−1.59, 2.73) | 0.607 | 0.05 | 0.03 | |
| **PCS** | **β (CI95%)** | ***p*-value** | **L.RESI** | **CS-RESI** | |
| (Intercept) | 26.73 (24.17, 29.28) | <0.001 | 1.93 | 1.11 | 0.52 |
| Intervention | −3.16 (−5.63, −0.7) | 0.012 | 0.24 | 0.14 | |
| Follow-up 5 weeks | −5.06 (−8.16, −1.97) | 0.001 | 0.30 | 0.17 | |
| Follow-up 12 weeks | −7.63 (−10.71, −4.55) | <0.001 | 0.46 | 0.26 | |
| **Helplessness** | **β (CI95%)** | ***p*-value** | **L.RESI** | **CS-RESI** | |
| (Intercept) | 11.66 (10.46, 12.85) | <0.001 | 1.79 | 1.04 | 0.44 |
| Intervention | −1.52 (−2.66, −0.38) | 0.009 | 0.24 | 0.14 | |
| Follow-up 5 weeks | −2.45 (−3.87, −1.03) | 0.001 | 0.32 | 0.18 | |
| Follow-up 12 weeks | −2.73 (−4.18, −1.27) | <0.001 | 0.34 | 0.20 | |
| **Magnification** | **β (CI95%)** | ***p*-value** | **L.RESI** | **CS-RESI** | |
| (Intercept) | 5.65 (5.06, 6.24) | <0.001 | 1.76 | 1.02 | 0.33 |
| Intervention | −0.8 (−1.39, −0.2) | 0.009 | 0.24 | 0.14 | |
| Follow-up 5 weeks | −0.56 (−1.26, 0.14) | 0.118 | 0.15 | 0.08 | |
| Follow-up 12 weeks | −0.97 (−1.73, −0.22) | 0.012 | 0.24 | 0.14 | |
| **Rumination** | **β (CI95%)** | ***p*-value** | **L.RESI** | **CS-RESI** | |
| (Intercept) | 9.74 (8.73, 10.75) | <0.001 | 1.78 | 1.03 | 0.48 |
| Intervention | −1.28 (−2.2, −0.35) | 0.007 | 0.25 | 0.15 | |
| Follow-up 5 weeks | −1.81 (−2.94, −0.67) | 0.002 | 0.29 | 0.17 | |
| Follow-up 12 weeks | −2.71 (−3.92, −1.5) | <0.001 | 0.41 | 0.24 | |

*Note*: Coefficient (95% confidence interval); *p*-value; longitudinal, cross-sectional and overall robust effect size index.

Abbreviations: CSI, central sensitization inventory; NPRS, numeric pain rating scale; PCS, Pain Catastrophizing Scale; TSK-11, Tampa Scale of kinesiophobia 11 items.

60 min (Ma et al., 2023); meanwhile, our PNE maximal duration was 1 h. This result is consistent with some studies showing longer individual sessions to be more effective than shorter ones (Neblett et al., 2017). Therefore, our PNE session duration could be too short to produce consistent effects on pain. Additionally, studies that apply one-single PNE session assess the immediate analgesic effect (Ma et al., 2023; Sillevis et al., 2021); meanwhile, we evaluate the medium-term effects over pain intensity after 5 weeks and 12 weeks after the PNE intervention.

One of the most relevant findings in this work is the reduction of CSI values adding a single session PNE to

the BS programme. At baseline, the mean values in both groups were above 40 points (the set cut-off), while they had fallen below specially in most of patients at intervention group at 12 weeks. The CSI score has been associated with clinical variables such as pain intensity or hyperalgesia (Coronado & George, 2018). Current literature supports that PNE targets the cognitive-emotional system that could activate the descending inhibitory pathways, inducing pain analgesia (Van Oosterwijck et al., 2013). This could also be supported by previous studies reporting the direct influence of emotional state on pain perception and the ability to modulate the activation of cerebral areas (dorsolateral prefrontal cortex, anterior cingulate cortex, etc.) associated with pain processing (Bushnell et al., 2013). Importantly, these areas modulated by emotional state also send projections to one of the main nuclei of the descending inhibitory system: the periaqueductal grey area (Bushnell et al., 2013). Curiously, in this study, we observed changes in the CSI but not in pain intensity. Although this may seem contradictory, this also could make sense considering the poor correlation found between CSI and pain intensity (Schuttert et al., 2023).

In relation to kinesiophobia, our results revealed that a single session of PNE showed no effects this variable. Additionally, we did not observe any evolution in TKS scores within-groups. In reference to literature, it is surprising the limited number of studies that have used TSK-11 as an outcome measure when evaluating the effects of PNE in patients with low CLBP (Pardo et al., 2018; Pires et al., 2015). According to our results, one of these studies reported non-significant differences in the degree of kinesiophobia between PNE intervention and control group on CLBP patients (Pires et al., 2015). Regarding about the lack of effects, we have noticed that none of the participants presented a high degree of kinesiophobia (>37 points) (Woby et al., 2005), may be patients with higher degree of kinesiophobia could be benefit from PNE.

With regard to catastrophizing, the present study reveals that the addition of a single PNE session produces a greater reduction of PCS score compared with control BS group. This effect is resulting from decreasing all its subscales (rumination, helplessness and magnification). Specifically, the PNE intervention reduced 4 points for helplessness ($p < 0.001$), 2.5 for magnification ($p > 0.001$) and 2.5 for rumination ($p = 0.003$). This finding is consistent with the positive effects found different studies conducted in patients with chronic low back pain (Amer-Cuenca et al., 2020; Louw et al., 2016; Pardo et al., 2018). However, our catastrophizing results are not in line with a recent meta-analysis which established 400 min as a minimum effective dose surpassing clinically important differences for catastrophizing between others psychosocial variables in chronic musculoskeletal pain (Salazar-Méndez et al., 2023). To explain the discrepancy between our results and the literature recommendations, we propose that a key point may not only be attributed to the dosage of PNE, but also to its content. Although many studies delve into the theoretical aspects of pain neurophysiology, our approach integrates this knowledge with active engagement. Our study combines an explanation of the neurophysiology of pain with practical applications, which will be integrated in the BS program. Consequently, our PNE intervention could modify the experience of the entire BS program, potentially reducing catastrophizing. However, we must mention that the catastrophizing baseline levels of the participants were low (PCS total score < 30 points).

In an integrated consideration, on the one hand, the concurrent reduction of both CSI and PCS is not surprising, as previous studies have reported an association between these two variables (Koh et al., 2022). As CSI evaluates comorbid psychosocial symptoms, it is expected to find an association between both measures (Neblett et al., 2017). On the other hand, the independent tendency of TSK-11 values from PCS changes also presents an interesting observation. This could be explained by recognizing that these measures assess distinct psychological constructs. Although TSK-11 quantifies fear of movement due to beliefs about physical harm, PCS involves the magnification of pain-related thoughts and feelings of helplessness. Consequently, it is conceivable that certain patients may continue to exhibit fear of movement even as their pain catastrophizing decreases.

Summarizing, our study demonstrated clinical improvements at medium-term mainly at psychosocial factors as central sensitization inventory and catastrophizing with adding a brief intervention in a single session during a BS programme, achieving improvements similar to those with longer PNE interventions. This work supports the suitability of including a PNE intervention, to reconceptualizing pain, making the current BS programs more efficient, increasing the engaging of patients with exercise. These findings may help to improve the much-needed adherence of primary health care providers to the biopsychosocial model (García-Martínez et al., 2022), since relevant benefits have been found with this brief intervention, which could motivate health authorities and health teams to implement this intervention regularly (Wood & Hendrick, 2019). In addition, extra material for the 1-h PNE session is provided publicly at Supporting information, which could help other professionals who wish to implement PNE in their clinical practice. Even so, this educational approach needs to be supplemented with other interventions such as physical activity and therapeutic exercise (Louw et al., 2016).

Understanding the limitations of this study is essential for a nuanced interpretation of the results. The variables studied have been collected with self-reported tools, with the biases that this may entail, especially in patients with pain. However, even while being subjective measures, they reflect the perspective of the patient with chronic pain. Additionally, we did not evaluate the pain knowledge of the patients after the PNE intervention to assess if the session was effective to reconceptualize beliefs. Also, we highlight that due to the nature of the intervention, we cannot guarantee that blinding will be successful; therefore, the intervention expectations were not controlled. Finally, patients were recruited from only one healthcare centre, which limits the external validity of the results.

In summary, the addition of a single PNE session combined with a traditional BS program conducted in a Spanish public hospital did not result in a pain intensity improvement. However, it was sufficient to reduce psychological factors as central sensitization inventory and catastrophizing, which were maintained at the three-month follow-up. This work highlights the potential of PNE as a valuable adjunctive approach in the management of chronic low back pain.

## ACKNOWLEDGEMENTS

The authors thank the physiotherapists of the Hospital de San Juan for their collaboration in this Project; also, Alicia Amorós Sánchez and Raquel Rodrigo Masanet for providing the graphic material, and the Colegio Oficial de Fisioterapeutas de la Comunidad Valenciana for the proofreading and language editing support. Jose V. Segura acknowledges the financial support from the Generalitat Valenciana under project PROMETEO/2021/063.

## CONFLICT OF INTEREST STATEMENT

The authors declared no conflicts of interest.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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## SUPPORTING INFORMATION

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**How to cite this article:** Tomás-Rodríguez, M. I., Asensio-García, M. D. R., García, R. N., Delicado-Miralles, M., Sánchez, S. H., & Segura-Heras, J. V. (2024). Short- and medium-term effects of a single session of pain neuroscience education on pain and psychological factors in patients with chronic low back pain. A single-blind randomized clinical trial. *European Journal of Pain*, *00*, 1–14. https://doi.org/10.1002/ejp.4700