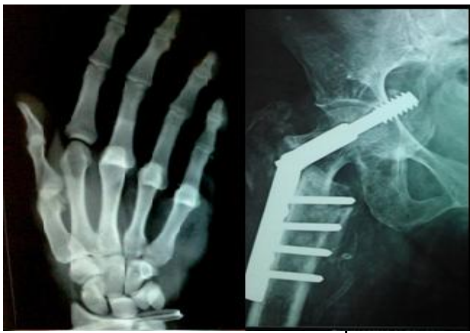

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# Telehealth-based pain neuroscience education in individuals with musculoskeletal pain: A narrative review

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## Abstract
**Background:** Chronic musculoskeletal pain can impair both cognition and physical function. Pain Neuroscience Education (PNE) addresses these challenges by reshaping pain-related beliefs. When delivered via telehealth, PNE provides accessible and cost-effective care, promoting self-management and improving outcomes through multidisciplinary, patient-centered approaches.
**Objective:** This narrative review aims to synthesize current research on the effectiveness of telehealth-based Pain Neuroscience Education for individuals with musculoskeletal pain.
**Methods:** A comprehensive literature search was conducted in PubMed/MEDLINE, the Cochrane Library, and Google Scholar in July 2025. Eligible studies included randomized controlled trials (RCTs), non-randomized trials, pilot RCTs, quasi-RCTs, and double-blind, placebo-controlled RCTs investigating PNE interventions delivered via telerehabilitation. The methodological quality of the controlled studies was assessed using the Physiotherapy Evidence Database (PEDro) scale.
**Results:** Nine studies, including a total of 1.130 participants, were reviewed. Most studies reported reductions in pain intensity, with mixed results regarding disability and functional outcomes. The mode of delivery appears to play a key role in the intervention's effectiveness. A consistent benefit of telehealth-based PNE lies in its ability to improve psychological variables such as kinesiophobia, catastrophizing, and pain self-efficacy.
**Discussion:** The findings suggest that PNE delivered via telehealth reduces pain and maladaptive pain beliefs in individuals with musculoskeletal conditions. Although effects on function are variable, factors such as delivery format and patient engagement influence outcomes. Future research should aim to enhance methodological quality and adapt digital PNE approaches to diverse populations and clinical needs.
**Conclusions:** Telerehabilitation incorporating PNE is effective in reducing pain and improving psychological outcomes, although its impact on physical function remains inconsistent. The integration of emerging technologies may improve personalization and accessibility, supporting further research to optimize digital pain management.

**Keywords:** Pain neuroscience education, tele-health, musculoskeletal pain

## Introduction
Pain is one of the most common reasons patients seek medical care [1], with persistent musculoskeletal pain constituting a clinical challenge worldwide [2]. Individuals who experience chronic pain are prone to develop inappropriate pain cognitions, such as kinesiophobia and pain catastrophizing [3, 4]. Chronic pain, in general, can lead to significant neurocognitive alterations and impairments in executive functions (e.g., attention, working memory and cognitive flexibility), which create maladaptive neuroplastic changes in the brain [5]. Those changes remain modifiable through targeted therapeutic interventions designed to promote adaptive plasticity [5] and a multidisciplinary care, including engagement of psychologists, neurologists, physical therapists etc. [6].
Noninvasive methods are constantly gaining popularity, with emphasis on educational and self-management means [7].

Research suggests that Pain neuroscience education (PNE) is an efficient strategy to manage persistent musculoskeletal pain [2]. PNE aims to inform people about pain neuroscience and the principal role of the brain [1] and on factors contributing to pain, while motivating them to become more active in the rehabilitation process [8]. It has been shown that patients that have better understanding of pain neuroscience have less pain and disability [1].

Nevertheless, the quality of health care may be affected by the patient's geographic location, race/ethnicity and other cultural aspects of pain [6]. Postponed health care can negatively impact outcomes, potentially resulting in lower health-related quality of life, increased stress and anxiety, diminished treatment effectiveness and reduced trust to the healthcare system [7]. Digital and mobile health can help overcome those limitations, while also take into account the time and availability of the patients involved [6]. Telehealth can provide numerous benefits as complimentary or stand-alone intervention [9], enhancing self-management, improving treatment adherence, and reducing health care costs at the same time [10]. This narrative review aims to summarize the current research findings on the effectiveness of PNE telehealth systems in musculoskeletal pain rehabilitation.

## Materials and Methods

### Information Sources and Search

A systematic literature search was conducted in PubMed/MEDLINE, the Cochrane Library and Google Scholar. The databases were searched in July 2025. The search strategy employed the following keywords: ("pain neurophysiology education" OR "pain physiology education" OR "pain biology education" OR "pain neuroscience education" OR "PNE") AND (telehealth OR telerehabilitation OR tele-exercise OR "e-rehabilitation" OR "remote training" OR tele-physiotherapy OR telemedicine OR mHealth OR "mobile Health"). No filters were applied. Only journal articles were included, while books, conference abstracts, and encyclopedic entries were excluded.

### Study selection

The inclusion criteria for this review were as follows: (a) participants with a history of musculoskeletal pain, regardless of age, sex, severity, or chronicity; (b) implementation of pain neuroscience education intervention; and (c) the intervention must have been delivered via tele-rehabilitation. Eligible study designs included randomized controlled trials (RCTs), non-randomized trials, pilot RCTs, quasi-randomized trials, and double-blind, randomized, placebo-controlled trials. Exclusion criteria included: (a) studies not published in English; (b) studies involving healthy populations; (c) studies lacking full-text availability or relevant outcome data; and (d) studies unrelated to the scope of this review.

Two reviewers (K.N.M., P.E.) independently screened the search results using the criteria mentioned above initially through title and abstract review. Articles deemed potentially relevant were subsequently screened in full text. In cases of disagreement between the two reviewers, a third reviewer (M.A.M.) resolved the discrepancies. Zotero software was used to manage references.

The methodological quality of the controlled trials was assessed using the Physiotherapy Evidence Database (PEDro) scale. Studies scoring 9-10 points were classified as "excellent," those scoring 6-8 as "good," 4-5 as "moderate," and studies scoring below 4 were considered "poor" quality [9]. The results of the quality assessment are presented in Table 1.

**Table 1:** Methodological quality assessment of the included controlled trials.

| | Pedro Items | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Study** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **Total** |
| Egerton *et al*., 2022 [11] | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | 1 | 8 |
| Núnez-Cortés *et al*., 2023 [12] | 1 | 1 | 1 | 1 | | | 1 | 1 | | 1 | | 6 |
| McReynolds, 2024 [13] | 1 | 1 | 1 | 1 | | | | 1 | | 1 | 1 | 5 |
| Supe *et al*., 2023 [14] | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 9 |
| Garcia *et al*., 2021 [15] | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 10 |
| Feng *et al*., 2025 [16] | 1 | 1 | 1 | 1 | | | | 1 | 1 | 1 | 1 | 7 |
| Sitges *et al*., 2022 [17] | 1 | | | 1 | | | 1 | 1 | | 1 | 1 | 5 |
| Barbosa *et al*., 2025 [18] | 1 | 1 | 1 | | | | 1 | 1 | 1 | 1 | 1 | 7 |
| Okudan *et al*., 2023 [19] | 1 | 1 | | | | | 1 | 1 | | 1 | 1 | 5 |

1 = eligibility criteria; 2 = random allocation; 3 = concealed allocation; 4 = baseline comparability; 5 = blind subjects; 6 = blind therapists; 7 = blind assessors; 8 = adequate follow-up; 9 = intention to-treat analysis; 10 = between-group comparisons; 11 = point estimates and variability.

## Results

A flow diagram illustrating the study selection process is presented in Figure 1. The initial database search yielded 1.403 records. After the removal of duplicate entries, titles and abstracts were screened for relevance. A total of 98 full-text articles were assessed for eligibility, of which 88 were excluded based on the inclusion criteria. The remaining 9 articles were included in the qualitative synthesis.

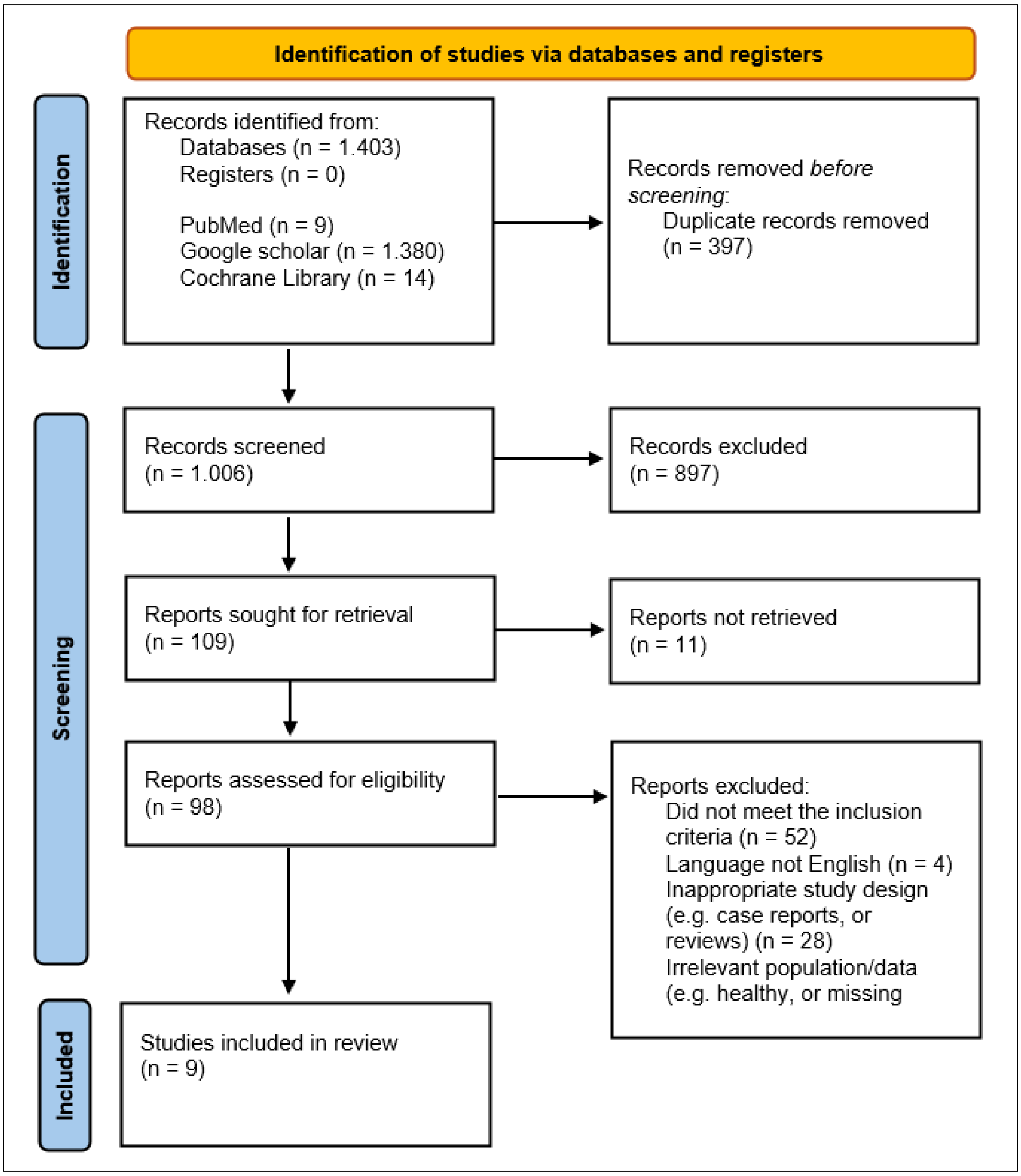


**Fig 1:** PRISMA flow diagram

Table 2 presents the characteristics of the 9 studies included in this review, comprising a total of 1.130 participants. Sample sizes across studies ranged from 9 to 296 individuals.

**Table 2:** Participant characteristics of the included studies.

| Study | N | | Age (years) | | Intervention | | Intervention duration | Outcome measures | Key findings |
|---|---|---|---|---|---|---|---|---|---|
| | E | C | E | C | E | C | | | |
| Egerton *et al.*, 2022 [11] | 296 | 293 | 55 (50-62) | 54 (50-61) | 12-min video presented evidence-based knee OA information Focus on empowerment and participation | 12-min video similar information Provides disease and impairment-based information and advice | 30-45 min (per session)/single online survey | Arthritis Self-Efficacy Scale pain subscale (range 0-10) Brief Fear of Movement Scale for OA Expectation about prognosis and physical activity benefits, future, level of concern and perceived need for surgery. | Compared to control group, Experimental group showed: -Self efficacy for managing OA pain: Mean difference = 0.4 [95% CI: 0.2-0.6] -Kinesiophobia: Mean difference -1.6 [95% CI: -1.1 to -2.0] Secondary outcomes: -Overall improvements: Experimental group demonstrated greater improvements in all secondary outcomes apart from hopefulness, which was high in both groups |
| Núnez-Cortés *et al.*, 2023 [12] | 15 | 15 | 45.9±7.5 | 43.6±8.1 | PNE+ exercise | Exercise | 30 min/d, 3d/wk, 6wks E: +three 40min PNE sessions/15, 6wks 132 min (120 min of synchronous pain education and 12 min of asynchronous material). | NRPS PCS TSK-11 BCTQ HADS EQ-5D EQ-VAS PGICS | Between-group differences: -KInesiophobia: Significant time × group interaction: $F = 6.67$, $p = 0.005$, $\eta p^2 = 0.225$ (large effect size), -Symptom severity: Significant time × group interaction: $F = 4.82$, $p = 0.013$, $\eta p^2 = 0.173$ (large effect size), favoring PNE+Exercise group. -Self-Perceived Improvement: Significant difference after treatment ($p < 0.05$), favoring PNE+Exercise group. -Pain intensity and catastrophizing: significant and clinically relevant within-group improvements in the PNE+Exercise group, with no significant between group differences. -Other variables: No significant time × group interaction ($p>0.05$) |
| McReynolds, 2024 [13] | 10 | 9 | 19.60 + 1.43 | 19.11 + 1.54 | Online PNE video | Educational anatomy video related to patellofemoral joint | A single video session | FABQ YBT | Within-Group Effects: -FABQ Score: No statistically significant change ($p = 0.076$) -YBT Composite: No statistically significant change ($p = 0.260$) Between-Group Differences: -FABQ Score: No statistically significant difference ($p = 0.458$) -YBT Composite: No statistically significant difference ($p = 0.420$) |
| Supe *et al.*, 2023 [14] | 35 | 35 | 58.34 +5.80 | 58.51 +5.66 | Conventional exercises (followed every day for two weeks) + | Conventional exercises (followed every day for two | Session 1: Baseline testing and ~ 30 min of PNE. Session 2 (after two weeks): ~ 20 min of PNE and follow-up | PCS PSFS NRPS | All outcome measures were significantly increased in the PNE group. Significant between-group differences were revealed for PCS (mean difference 11.4) and NPRS |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Online PNE in groups (Verbal explanation with a visual presentation on power point) | weeks) | testing. | | (mean difference 1.20), No mean difference was found in the patient function (PSFS) between groups. |
| Garcia *et al.*, 2021 [15] | 89 | 90 | 51.5 (13.5) | 51.4 (12.9) | Ease VRx (3D immersive skills training and experience) | Sham VR (2D nonimmersive content with no skills training) | 56 d (2-16 min each/average 6 min) | DVPRS<br>DVPRS-II<br>PGIC<br>PROMIS<br>PCS<br>PSEQ-2<br>CPAQ-8<br>Satisfaction (6-point scale 0-5)<br>Likelihood to recommend VR (0-10)<br>Likelihood to continue using VR (0-10)<br>SUS<br>Cybersickness (0-3)<br>OCT<br>MME | Between-Group Differences:<br><br>-User Satisfaction: higher in EaseVRx group (p<0.001)<br>-Primary Outcomes: all favored EaseVRx [highest p<0.009; between-group Cohen's d = 0.40-0.49 (moderate clinical relevance)]<br>-Physical Function: favoring EaseVRx (p = 0.022)<br>-Sleep disturbance: favoring EaseVRx (p = 0.013)<br>-Over-the-Counter Analgesic Use: Reduced in EaseVRx group (p<0.01), no significant change in Sham VR<br><br>*No other significant between-group differences were observed |
| Feng *et al.*, 2025 [16] | 39 | 39 | 27 (21-34) | 22 (21-37) | App-based exercise therapy, patient education and WeChat video-based health coaching | Paper-based exercise therapy and app-based patient education | 8 wk (24 sessions)<br>The experimental group included:<br>- 40 min app-based exercise therapy 3 times per week<br>-10 min patient education 1 time per week<br>-20 min WeChat video-based health coaching, 1 time per week.The control group's interventions included:<br>-40 min paper-based exercise therapy, 3 times per week<br>-10 min app-based patient education 1 time per week (same as E, but unable to access the exercise therapy section in the app) | RMDQ<br>NRS<br>DASS21<br>SF-12<br>TUG<br>EARS | Significant Between-Group differences at 8 weeks:<br><br>-Disability (estimated value: −3.96, 95% CI: −5.45 to −2.47, P < 0.001)<br>-Pain (estimated value: −1.69, 95% CI: −2.14 to −1.24, P < 0.001) -The physical health dimensions of quality of life (esti- mated value: 4.5, 95% CI: 1.29 to 7.71, P = 0.006).<br>Within- Group differences at 8 weeks:<br>-Mental health status (estimated value: −3.81, 95% CI: −4.99 to −2.63, P < 0.001), -Mental health dimensions of quality of life (estimated value: 5.01, 95% CI: 2.9 to 7.13, P < 0.001)<br>-Walking ability (estimated value: −0.92, 95% CI: −1.17 to −0.68, P < 0.001)<br>-Exercise adherence (Z: 1.91, P = 0.06) |
| Sitges *et al.*, 2022 [17] | 23 | 27 | 45.00 (9.13) | 48.63 (7.54) | Self-manage mobile app (BAckFit app) | Face-to-Face Same programme supervised | 2 d/wk *4 wk (8 sessions) | EEG<br>Digital algometer pain sensitivity<br>ODI | Within-group Effects (pre-post intervention):<br>Resting-state EEG activity increased:<br>-Beta-2 (16-23 Hz): 0.0020 vs. 0.0024 (p = 0.02)<br>-Beta-3 (23-30 Hz): 0.0013 vs. 0.0018 (p = 0.03) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | POMS<br>Edinburgh Handedness Inventory<br>State-Trait Anxiety Inventory<br>TSK-11<br>PCS<br>FABQ | Source analysis revealed increased power density in:<br>-Beta (16-30 Hz): Anterior cingulate cortex<br>-Alpha (8-12 Hz): Postcentral gyrus<br>-Decreased delta: (2-4 Hz): Cuneus and precuneus<br>Clinical outcomes (both groups improved):<br>-Depression: 7.74 vs. 5.15 (p = 0.01)<br>-Kinesiophobia: 22.91 vs. 20.87 (p = 0.002)<br>-Activity avoidance: 14.49 vs. 12.86 (p < 0.001)<br>-Helplessness: 6.38 vs. 4.74 (p = 0.02)<br>-Fear-avoidance beliefs: 35 vs. 29.11 (p = 0.03)<br>-Avoidance of physical activity 12.07 vs. 9.28 (p = 0.01)<br>-Dissability score: Increased (6.08 vs. 7.5 (p = 0.01)<br>No significant between-groups differences were found. |
| Barbosa *et al.*, 2025 [18] | 35 | 35 | 29.2 (9.0) | 28.9 (8.6) | Video conferencing exercise program<br>+<br>digital self-care booklet | Digital self-care booklet | E: 2d/wk, 45 min/session, 6 wk<br>C: 6wk | NDI<br>NRS<br>CPSS<br>SF-12<br>SF-36<br>TSK<br>Global Perceived effect | Between-group differences:<br>At 6-week follow-up:<br>-Functional disability: 10.3 points, (95% CI: 4.8-15.7)<br>-Pain intensity: 2.8 points (95% CI: 1.4-4.1)<br>-Global Perceived effect: -2.38 points (95% CI: -3.77 to -0.98)<br>-Self efficacy: -24.75 points (95% CI: -41.09 to -8.41)<br>At 3-month follow-up:<br>-Global Perceived effect: -2.0 points (95% CI: -3.4 to -0.6)<br>-Self efficacy: -26.31 points (95% CI: -42.82 to -9.80)<br>*telerehabilitation group had better outcome across all outcome measures |
| Okudan *et al.*, 2023 [19] | Exercise Group: 15<br>Exercise +PNE Group: 15 | 15 | Exercise Group: 52.27±5.03<br>Exercise +PNE Group: 52.93±4.94 | 50.80±4.69 | Exercise Group:<br>One-to-one telerehabilitation<br>Exercise +PNE Group:<br>Same exercise<br>PNE (Power Point, screen sharing, conversation, photographs, analogies, stories) | Maintain daily routine | 2d/wk, 6 wks<br>Exercise Group:<br>45min/session<br>Exercise +PNE Group:<br>30min exercise + 15 min PNE/session | NPRS<br>ODI<br>PBQ<br>SF-12v2<br>GROC | Between-Group differences (Group × Time interaction):<br>-NPRS at Rest: F = 4.276, p = 0.021<br>-NPRS during Activity: F = 12.327, p = 0.0001<br>-ODI: 23.122, p = 0.0001<br>-Organic Pain Beliefs: F = 39.708, p = 0.0001;<br>Further ANOVA showed significant improvement only in the exercise + PNE group (p = 0.0001)<br>GROC:<br>-Improvement reported by all groups<br>-Higher improvement in intervention groups |

E = Experimental group; C = Control group; OA = osteoarthritis; PNE = Pain Neuroscience Education; NRPS = Numeric Rating Pain Scale; NRS = Numerical Rating Scale for pain; PCS = Pain Catastrophizing Scale; TSK-11 = Tampa Scale for Kinesiophobia (11-item version); BCTQ = Boston Carpal Tunnel Questionnaire; HADS = Hospital Anxiety and Depression Scale; EQ-5D = EuroQol 5-Dimension; EQ-VAS = EuroQol Visual Analogue Scale; PGICS = Patient Global Impression of Change Scale; FABQ = Fear-Avoidance Beliefs Questionnaire; YBT = Y Balance Test; PSFS= Patient-Specific Functional Scale; DVPRS = Defense and Veterans Pain Rating Scale; PROMIS = Patient-Reported Outcomes Measurement Information System; PSEQ-2 = Pain Self-Efficacy Questionnaire-2-item version; CPAQ-8 = Chronic Pain Acceptance Questionnaire-8-item version; SUS = System Usability Scale; OCT = Over-the-Counter Medication Use; MME = Morphine Milligram Equivalent; RMDQ = Roland-Morris Disability Questionnaire; DAS-21 = Depression Anxiety Stress Scales (short form); SF-12 = Short Form Health Survey-12 items; SF-36 = Short Form Health Survey-36 items; TUG = Time Up and Go Test; EARS = Exercise Adherence Rating Scale; EEG = Electroencephalography; ODI = Oswestry Disability Index; POMS = Profile of Mood States; NDI = Neck Disability Index; CPSS = Child PTSD Symptom Scale; GROC = Global Rating of Change Scale; PBQ = Pain Beliefs Questionnaire; VR = Virtual Reality.

Values are presented as mean (standard deviation) or mean (range) where available.

wk = week(s); d = day(s); min= minute(s).

The study by Egerton *et al*. [11] investigated the outcomes of two different types of videos with educational content on the pain, kinesiophobia and self-efficacy levels of patients with knee osteoarthritis. This online two-arm randomized controlled trial involved 589 people with knee osteoarthritis, aged 45 and above, who were divided into two groups, the control (n=293) and the experimental group (n=296). In the experimental group, two videos of educational content were provided to the participants. The content of these videos was focused on empowerment, active participation and engagement of the participants. Recommendations regarding treatment with exercise, based more on social cognitive theory and an information-motivation-behavioral skills model, were given to the participants rather than just information about the pathophysiology and other aspects of the disease itself. On the other hand, the control group watched a video whose aim was to inform participants about the pathophysiological aspects of the disease and its biomedical management. A main difference between the two groups was that, in the experimental group, the information was presented in a more entertaining and animated form—simpler and without medical definitions and diagrams. The control video, however, was based on figures and images about osteoarthritis. The main outcomes measured were self-efficacy for managing osteoarthritis pain, via the Arthritis Self-Efficacy Scale (ASES), and kinesiophobia, via the Brief Fear of Movement Scale for Osteoarthritis (BFMS). Furthermore, the Credibility/Expectancy Questionnaire was used to assess participants' expectations and the perceived effect of physical activity, along with other questions about awareness of knee osteoarthritis, the level of concern, and thoughts about the need for future surgery. The results of this trial showed that the educational video based on empowerment and active patient participation was more effective. Participants in the experimental group had better self-efficacy and kinesiophobia levels, as well as better results in the secondary outcomes. The researchers concluded that the experimental video was more effective for patients with knee osteoarthritis because it focused on participant engagement rather than solely on disease-related information.

In another study, Núnez-Cortes *et al*. [12] investigated the effects of a 6-week telerehabilitation program that combined exercise and pain neuroscience education in patients with carpal tunnel syndrome. In this randomized controlled trial, 30 patients aged 18-60 years with carpal tunnel syndrome were equally divided into two groups. Participants in both the experimental and control groups followed the same exercise program, which included aerobic training, neurodynamic home exercises, and auto stretching. The experimental group (n = 15) also received a pain neuroscience education session, delivered via videoconferencing by an experienced physiotherapist, along with supplementary videos and materials to reinforce the PNE concepts between sessions. Demographic data, physical activity levels, and analgesic intake were recorded. Other outcomes, such as pain intensity, pain catastrophizing, kinesiophobia, symptom severity and function, mental health, quality of life, and self-perception of improvement, were measured using the Numeric Pain Rating Scale (NPRS), the Pain Catastrophizing Scale (PCS), the Spanish version of the Tampa Scale for Kinesiophobia-11 (TSK-11), the Boston Carpal Tunnel Questionnaire (BCTQ), the Hospital Anxiety and Depression Scale (HADS), the EuroQol 5-Dimensions (EQ-5D), and the Patient Global Impression of Change Scale (PGICS), respectively. Assessments were conducted at baseline, post-intervention (6 weeks), and at follow-up (12 weeks). Of the 30 participants, 25 completed the follow-up. The results showed that a telerehabilitation program combining PNE and exercise can be effective for individuals with carpal tunnel syndrome. Participants in the experimental group had better outcomes in kinesiophobia and symptom severity than those in the control group. Other outcomes, such as pain intensity and catastrophizing, showed clinical improvement in both groups, but without statistically significant differences. According to the authors, combining PNE with exercise in a telerehabilitation format offers more short-term benefits than exercise alone.

In another study, McReynolds [13] aimed to test the outcomes of a PNE video on young adults with knee pain, compared to a simple video about the anatomy of the knee joint and region, and bracing options. Students at Western Kentucky University, aged 18-25 years, with unilateral knee pain during walking and squatting, participated in this non-certified randomized controlled trial. The 21 participants were divided into an experimental group (n = 10), which was assigned an educational online PNE video, and a control group (n = 11), which received a video about the knee joint anatomy and the use of braces to help reduce pain levels. Outcome measures assessed in both groups included fear, measured with the Fear-Avoidance Beliefs Questionnaire (FABQ), and balance, measured with the Y-Balance Test (YBT). These assessments were conducted at three time points: before the intervention, immediately after, and one-week post-intervention as a follow-up. Only 19 participants were included in the follow-up analysis (experimental group: n = 10; control group: n = 9). The results of this study were statistically non-significant regarding fear-avoidance and balance levels between the two groups, as well as overall. The investigator concluded that this study was unable to detect the benefits of PNE on these measures in an online format and suggested that further research is needed in this area. In another randomized controlled trial, Supe *et al*. [14] investigated the effectiveness of a PNE plus conventional physiotherapy telerehabilitation program in patients with knee osteoarthritis, as well as how patients perceived this intervention. Seventy patients were equally divided into two groups: the PNE group (n = 35) and the control group (n = 35). An exercise program based on conventional physiotherapy, focusing on strengthening and stretching, was provided to both groups. The PNE group also attended two PNE sessions via telerehabilitation, conducted by a single physiotherapist. Images, metaphors, and examples were used to explain pain-related concepts to the PNE group. Three outcomes were assessed in both groups at baseline and after 2 weeks: pain catastrophizing levels, measured using the Pain Catastrophizing Scale (PCS); self-reported function, measured using the Patient-Specific Functional Scale; and pain intensity, measured using the Numerical Pain Rating Scale (NPRS). The results showed significant improvement in all three outcomes in the PNE group after 2 weeks. While pain catastrophizing and pain intensity levels were significantly improved in the PNE group, there was no statistically significant difference in self-reported function between the PNE and control groups. In conclusion, a combined telerehabilitation program of PNE with conventional physiotherapy exercises appears more effective in reducing pain catastrophizing and pain intensity than an exercise program alone. It also improves self-reported function in individuals with knee osteoarthritis.

In the study of Garcia *et al*. [15], the efficacy of a self-administered, at-home, behavioral skills-based Virtual Reality (VR) program was investigated in individuals with self-reported nonmalignant chronic low back pain. This online, single-cohort, double-blinded, placebo-controlled randomized trial lasted 56 days, with 179 participants completing the study—89 in the treatment group and 90 in the sham group. Participants in the treatment group received a multimodal, skills-based, pain self-management VR program called EaseVRx, which incorporated Cognitive Behavioral Therapy and PNE principles. The main components of this program included pain education lessons, relaxation and interoception exercises and videos, pain distraction games, and dynamic breathing training. The sham group received 2D VR content featuring nature images and scenes. Outcome assessments were conducted through multiple surveys at three time points: before treatment (days -14 to 0), during treatment (days 1-55), and on the final day after treatment (day 56). The outcomes assessed included pain intensity (measured using the Defense and Veterans Pain Rating Scale, DVPRS), pain interference with activity, sleep, mood, and stress (DVPRS Interference Scale, DVPRS-II), the patient's global impression of change (via a specific question), physical function and sleep disturbance (PROMIS), pain catastrophizing (13-item Pain Catastrophizing Scale, PCS), pain self-efficacy (2-item Pain Self-Efficacy Questionnaire, PSEQ-2), chronic pain acceptance (8-item Chronic Pain Acceptance Questionnaire, CPAQ-8), satisfaction with treatment (via several items), and analgesic medication use (via specific questions). The results of this trial revealed that participants in the EaseVRx group showed significant improvements in pain intensity, sleep quality, and physical function, as well as in pain-related interference with activity, mood, and stress. However, other outcomes—such as pain catastrophizing, pain self-efficacy, pain acceptance, and medication use—did not differ significantly between the two groups. The researchers concluded that the EaseVRx program was better accepted by participants and improved pain levels and pain-related interference in important life domains compared to the sham group. They emphasized the importance of further research in this area to support the potential use of home-based VR programs for individuals with chronic low back pain, alongside other available treatment options.

In another nonrandomized controlled trial, Sitges *et al* [17]. investigated the impact of a self-managed educational and exercise-based mHealth intervention (BackFit app) on electroencephalographic and electrocardiographic activity, pressure pain thresholds (PPTs), pain, disability, and psychological and cognitive functioning in patients with chronic low back pain. Fifty patients with nonspecific CLBP were divided into two groups: the self-managed group (n = 23) and the face-to-face group (n = 27). The intervention was the same for both groups and was completed over 4 weeks, with a total of eight sessions. However, it was delivered differently: one group received the intervention through the app, and the other in a face-to-face format. The intervention protocol consisted of a pain education video, a follow-up question assessing whether the participant watched the video, and a 50-minute exercise program, which was also supported by an instructional video. The primary outcomes were electrophysiological data, recorded during electroencephalography using the Brain Vision Analyzer and heart rate via the electrocardiogram channel, as well as pain sensitivity measured with an algometer through PPTs. The secondary outcomes included handedness (Edinburgh Handedness Inventory), physical disability (Oswestry Disability Index, ODI), mood (Profile of Mood States, POMS), anxiety (State-Trait Anxiety Inventory), fear of movement (Tampa Scale for Kinesiophobia, TSK-11), pain catastrophizing (Pain Catastrophizing Scale, PCS), and fear-avoidance beliefs (Fear-Avoidance Beliefs Questionnaire, FABQ). All questionnaires were administered in their validated Spanish versions. Lastly, inference control was assessed using a modified computerized version of the Eriksen flanker task. The results of this study showed increased beta activity at rest and improvements in physiological functioning and PPTs in both groups; however, no statistically significant differences were found between them. The researchers acknowledged the limitations of their study and emphasized the need for further research in this area to strengthen the conclusions.

Another randomized controlled trial assessor blinded was conducted by Barbosa *et al*. [18] to investigate the effectiveness of a telerehabilitation exercise program on disability and pain in patients with chronic non-specific neck pain. The participants of this study were divided into two groups: the telerehabilitation group (n = 35) and the control group (n = 35). The telerehabilitation group completed an exercise program via video conferencing on the Google Meet platform, along with receiving educational material through a digital booklet. This booklet included information about chronic pain education, the benefits of being physically active, and additional lifestyle advice such as sleep and diet recommendations. The control group received only the online booklet and a text or email encouraging engagement in a healthy lifestyle. The treatment duration for both groups was six weeks. Outcome assessments were conducted at baseline, after 6 weeks, and at 3 months as follow-up. The Neck Disability Index was used to assess disability. Secondary outcomes included pain intensity (measured with the

Numerical Rating Scale, NRS), global perceived effect, self-efficacy (Chronic Pain Self-Efficacy Scale, CPSS), quality of life (Short-Form Survey, SF-12), and kinesiophobia (Tampa Scale for Kinesiophobia, TSK). Disability and pain intensity levels were statistically different between the two groups—favoring the telerehabilitation group—but only at the 6-week assessment. No significant difference was observed at the 3-month follow-up. Significant improvement was observed in the telerehabilitation group for global perceived effect and self-efficacy at both the 6-week and 3-month follow-up assessments. However, improvements in quality of life and kinesiophobia were not statistically different between the groups at any time point. The researchers concluded that the telerehabilitation program yielded better outcomes than a self-guided booklet intervention, particularly for disability and pain intensity (short-term), and self-efficacy (both short- and long-term), in individuals with non-specific chronic neck pain.

Finally, the study of Okudan *et al*. [19] investigated the effectiveness of telerehabilitation-based exercise combined with pain neuroscience education (PNE) for patients with low back pain (LBP) caused by facet joint arthrosis (FJA). In this randomized controlled trial, 45 patients with LBP due to FJA were equally divided into three groups. The exercise group (n = 15) completed a telerehabilitation exercise program guided by a physiotherapist, with two 45-minute sessions per week for six weeks. The exercise plus PNE group (n = 15) followed the same exercise protocol, along with a PNE telerehabilitation component, delivered using PowerPoint presentations, screen sharing, and one-on-one discussions with a physiotherapist. In this group, 45-minute sessions—consisting of 30 minutes of exercise and 15 minutes of PNE—were conducted twice a week for six weeks. Lastly, the control group (n = 15) was instructed to engage in daily routines recommended via telerehabilitation at baseline and was given access to the exercise program and videoconference details only after the six-week period. Pain intensity, disability, and pain beliefs were the primary outcomes, measured using the Numeric Pain Rating Scale (NPRS; at rest and during activity), the Oswestry Disability Index (ODI), and the Pain Beliefs Questionnaire (PBQ), respectively. Secondary outcomes included the Short Form-12v2 (SF-12v2) and the Global Rating of Change (GROC) score. A significant group-by-time interaction was observed for NPRS (both at rest and during activity), ODI, and organic pain beliefs. The only outcome that showed greater improvement in the exercise plus PNE group was organic pain belief, while both intervention groups had a more favorable effect on the GROC score. In conclusion, the study demonstrated that both PNE combined with exercise and exercise alone via telerehabilitation were effective in improving pain intensity, disability, and organic pain beliefs in individuals with LBP caused by FJA, compared to a control group.

## Discussion

This narrative review examined the effectiveness of telehealth-based PNE in individuals experiencing musculoskeletal pain. The findings from the analysis of nine clinical studies suggest that PNE delivered via telehealth can have a positive effect on the rehabilitation process. Telerehabilitation programs incorporating PNE consistently demonstrated short-term benefits in reducing pain intensity and severity across a range of musculoskeletal conditions. These findings align with a previously published systematic review and meta-analysis, which showed that PNE—even in a self-guided, web-based format—outperformed minimal interventions in reducing pain in the short to intermediate term.[7] Moreover, the consistency of pain-reducing effects demonstrated by PNE intervention regardless of the mode of delivery - whether through videos, virtual reality, or live sessions - supports the idea that PNE can be effectively translated into a variety of digital formats.

However, effects on disability and functional improvement were more mixed. Some studies, such as those by Feng *et al*. and Barbosa *et al*., reported significant improvements, while others found little or no effect. This variability may be due to differences in intervention duration, patient populations, or how functional outcomes were measured. It may also suggest that PNE is more reliable in addressing pain than physical disability when delivered remotely. It could, however, point to a more fundamental distinction: PNE primarily targets pain as a perceptual and cognitive process, aiming to reshape beliefs and reduce fear rather than directly modify physical function. As such, its effects on pain intensity and pain-related psychological outcomes may be more immediate and consistent, whereas improvements in disability — which have a stronger physical basis — may depend on sustained behavioral change (i.e., overcoming kinesiophobia and gradually increasing activity levels).[20] This may explain why the impact on physical functionality tends to be less robust and more variable when PNE is delivered as a standalone or short-term intervention.

A consistent strength of PNE-based telerehabilitation lies in its capacity to improve psychological variables such as kinesiophobia, catastrophizing, and pain self-efficacy. Studies by Egerton *et al*., Núñez-Cortés *et al*., and Supe *et al*. all found that digital PNE interventions effectively reduced maladaptive beliefs and increased patients' confidence in managing their pain. These outcomes are particularly relevant in chronic musculoskeletal conditions, where fear and avoidance behaviors can perpetuate disability. However, not all formats were equally effective. for example, Garcia *et al*. found that although VR-based PNE improved pain and function, it had limited impact on self-efficacy and catastrophizing. This may reflect differences in how cognitive content is experienced and internalized depending on the level of interactivity, personalization, and engagement.

The way educational content is delivered appears to play a central role in its effectiveness. Egerton *et al*. showed that simplified, animated video designed to promote patient empowerment was more effective than traditional biomedical video, despite both delivering factual information. Similarly, the EaseVRx program (Garcia *et al*.) led to high user satisfaction and significant improvements in pain-related outcomes, likely due to its immersive, skills-based design. In contrast, Sitges *et al*. found similar outcomes between a self-managed app and face-to-face sessions, suggesting that well-structured content can be effective regardless of delivery format, provided it is engaging and accessible. These findings highlight that clarity, interactivity, and emotional resonance may be as important as the information itself in digital health interventions.

Emerging technologies such as artificial intelligence and chatbots are opening new possibilities for delivering PNE at scale. While high-quality trials are still lacking, early acceptability studies suggest these tools may enhance engagement, particularly in younger populations. Telehealth formats also offer opportunities for inclusivity in pain education. For example, pilot research using sign language to deliver PNE showed promising results in improving pain knowledge and reducing fear-avoidance beliefs, underscoring the need for adaptable formats that reach individuals with sensory or cognitive limitations [22]. Telehealth allows for the integration of visual, auditory, and interactive elements that can improve understanding and accessibility. Such inclusive design should be a priority in future development.

Regarding the pediatric population there is not enough evidence and studies that examine more technologically engaging and effective means to manage chronic pain, and a need of reorientation is arising to address both the kid and the parents.

Despite the overall promise of PNE-based telerehabilitation, heterogeneity across studies remains a challenge. Variations in patient populations, intervention protocols, outcome measures, and follow-up duration limit direct comparisons and preclude definitive conclusions. Methodological gaps - such as missing long-term data, unblinded assessments, or incomplete reporting - further constrain interpretation. Future trials should prioritize methodological rigor, use standardized outcome measures, and assess both short- and long- term effects. Additionally, research is needed to explore which formats are most effective for specific populations and how digital tools can be optimized to improve psychological, functional, and behavioral outcomes in chronic pain rehabilitation.

## Conclusions

Pain neuroscience education (PNE) integrated into telerehabilitation demonstrates promising benefits in reducing pain intensity and improving related psychological outcomes in individuals with musculoskeletal conditions. However, its effects on disability and physical function are less consistent and may require longer-term engagement, behavioral reinforcement, or combined interventions to produce meaningful change. The mode of delivery - particularly formats that emphasize simplicity, engagement, and empowerment - portrays a crucial role in the intervention’s effectiveness. Emerging technologies, including virtual reality and AI-driven tools, offer promising possibilities for personalized, accessible, and scalable PNE interventions, though further high-quality research is needed to assess their efficacy. Ensuring inclusive design practices and adaptability across diverse populations should be a central consideration in both future development and research. As digital health continues to evolve, embedding PNE within telehealth frameworks presents a timely opportunity to reframe the pain experience and enhance patient-centered rehabilitation.

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