Effectiveness of perioperative pain science education on pain, psychological factors and physical functioning : a systematic review

TITLE PAGE

Effectiveness of Perioperative Pain Science Education on Pain, Psychological Factors and Physical Functioning: a Systematic Review

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ABSTRACT

Objective To synthesize the evidence on the effectiveness of pain science education on pain, psychological factors and physical functioning in adults who underwent surgery.

Data sources A systematic literature search of English articles using PubMed/Medline, Embase, Web of Science Core Collection and Cochrane Library.

Review methods The search strategy was constructed as follows: *[((pain) AND (education)) OR (pain education)] AND (surgery).* Only controlled quantitative studies in adults reporting outcome(s) on pain, psychological factors and/or physical functioning were included. Risk of bias was assessed using the Cochrane risk of bias tools. P-values and corresponding effect sizes for interaction-effect (time x group) portrayed the difference in change over time between groups were of interest. The last search was conducted on February 28, 2021.

Results Nine papers (n=1,078) were deemed eligible for this review. Two randomized controlled trials showed significant interaction effects. Breast cancer patients who had received one preoperative pain science education session showed a significant increase in postoperative *pain* compared to controls (P-value=0.0394). Furthermore, p*sychological factors* (pain catastrophizing and kinesiophobia) decreased in participants who had received pain science education before total knee arthroplasty, while this was not the case in the control group (P-value<0.001, η2p:0.11).

Conclusions Overall, pain science education did not result in any significant postoperative effects on pain, psychological factors and/or physical functioning compared to

controls. There is currently no strong evidence for the implementation of pain science education in the perioperative period.

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BODY OF ARTICLE

Introduction

Pain is a frequent problem after surgery, with serious consequences on both an individual as a societal level if insufficiently controlled. Between 58-86% of patients experience pain immediately after surgery.[1, 2] At that point in time, pain is normal and serves as a protection mechanism to promote tissue healing. However, in 10-50% of patients, pain persists after tissues have healed and develops into a chronic state.[3-7]

There are several risk factors for chronic postsurgical pain, including **pain** (preoperative pain, higher intensity of acute postsurgical pain, acute postsurgical pain lasting more than five days), **psychological factors** (fear or anxiety, depression, pain catastrophizing) and **physical functioning** (worse pain interference).[3, 4] Although these factors inform us about patients at risk for chronic postsurgical pain, they could present potential cues for preventive and curative therapies.

Apart from improvements in surgical techniques, multimodal pharmacotherapy and physical rehabilitation, recent years have witnessed a growing academic interest in educational interventions in the management of pain.[8-10] New insights have led to a biopsychosocial educational intervention that broadens the scope on the pain experience, not only explaining it from a biomedical or structural perspective, but also considering possible psychosocial contributing factors.[11-15] *Pain science education* explains *how* pain is produced. The patient is educated that pain is not always a true representation of the actual state of the tissues, but it is *the nervous system's interpretation of the threat of their injury*, which in turn is subject to various psychological factors, including fear avoidance, catastrophizing, expectations, cognitions and beliefs.[16]

Several systematic reviews and meta-analyses on pain science education in chronic musculoskeletal pain populations have reported evidence for, among other things, improving pain ratings, pain knowledge, disability, pain catastrophizing, kinesiophobia, attitudes regarding pain and physical movement.[17-19] However, to achieve clinically important improvements, education should be combined with physical interventions.[16-18, 20]

Considering the aforementioned risk factors for chronic postsurgical pain and their overlap with factors targeted in pain science education, it could be beneficial to look at the possible attenuating effect of perioperative pain science education (preoperative and early postoperative) at different time points post-surgery. If patients understand at an early stage that pain may not only result from tissue damage, but also from increased nerve sensitivity (and could thus be overprotective), they can adjust their beliefs, attitudes, behaviors, treatment and lifestyle choices, which in turn might positively influence their current and future pain experience.

For this purpose, the aim of this systematic review was to look at the effect of perioperative pain science education in adults on pain, psychological factors and physical functioning compared to controls.

Methods

This systematic review was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[21] Before the start of the review, a detailed protocol had been registered at the International Prospective Register of Systematic Reviews (PROSPERO: ID 161267, registration number CRD42020161267). We followed the Committee on Publication Ethics (COPE) international standards for authors to ensure integrity of this manuscript.[22]

Table 1 presents the pre-specified criteria for inclusion and exclusion of articles.

A comprehensive literature search was conducted with the help of a biomedical information specialist (T.V.). Electronic searches were performed in the databases PubMed (including MEDLINE; 1946 – 2021) Embase (1974 – 2021), Web of Science Core Collection (1955 – 2021) and the Cochrane Library (Cochrane Database of Systematic Reviews (1995 – 2021) and Cochrane Central Register of Controlled Trials (no inception date)) to identify relevant studies.

The search strategy *[((pain) AND (education)) OR (pain education)] AND (surgery)* was adapted for each database. For PubMed, Embase and the Cochrane Library, indexterms (MeSH –terms and Emtree-terms) were included and combined with free textwords to search in title, abstract and keywords. The full search strategy for PubMed is set out in *Appendix II*. The search was performed on February 28, 2021.

After deduplication in Endnote, two independent raters (E.V.d.G. and L.D.) first screened the included titles and abstracts for eligibility in Rayyan,[23] using the above-mentioned eligibility criteria. Disagreements regarding the selection of studies were resolved through discussion until the raters reached consensus. Full texts were obtained for all citations that could potentially fit the eligibility criteria. During the second screening performed by the same raters, full text papers of studies that did not to meet the eligibility criteria were rejected and the reasons for exclusion reported (*Figure 1*).

The following information was extracted from the included studies: 1) study characteristics (author, year of publication, country in which the study was conducted, study design), 2) sample characteristics (type of surgery, sample size, eligibility criteria), 3) patient characteristics (age, gender ratio, baseline pain), 4) treatment characteristics (timing, delivery

mode), 5) outcomes on pain, psychological factors and physical functioning (time points, outcome measures), 6) results (statistical analysis, statistical significance).

Data extraction was performed by E.V.d.G. and L.D. Any disagreement was resolved by either consensus or consultation of an independent third reviewer (M.M.). Authors of studies of which important data was missing were contacted by email.

E.V.d.G. and L.D. independently verified the risk of bias (outcome level) of all included papers, after which any disagreements were discussed until they reached consensus. Risk of bias in randomized trials was assessed using the second version of the revised Cochrane risk-of-bias tool for randomized trials (RoB 2).[24] The resulting overall risk of bias represents the following five domains: randomization process, deviations from the intended interventions, missing outcome data, measurement of the outcome and selection of the reported result. We used the Risk Of Bias In Non-Randomized Studies – of Interventions (ROBINS-I) assessment tool (version for cohort studies) to assess risk of bias in the results of non-randomized studies.[25] The final overall risk of bias represents the following seven domains: confounding, selection of participants into the study, classification of interventions, deviations from intended interventions, missing data, measurement of outcomes and selection of the reported result.

P-values for interaction effect (time x group) portrayed the difference in change over time between groups. The common effects for both intervention groups (unless otherwise specified) over time were presented with p-values for time-effect, as this value could clarify on the result of a possible interaction effect. We chose not to depict p-values for group-effect, since they would not have contributed to the scope of this review (i.e. p-values for group-effect would inform us on whether two groups differ in general, not taking into account the

course over time of this difference). Effect sizes were reported if available from the original study.

Results

Following deduplication, the search yielded 9,001 publications (*Figure 1*). After screening the titles/abstracts and full texts against the eligibility criteria, nine publications reporting eight studies were included (one publication reported on long-term follow-up of a study that had already been included).[26, 27]

Seven randomized controlled trials and one controlled clinical trial were included. Study characteristics are summarized in *Table 2*. Sample sizes ranged from 31 to 402 with a total of 1,078 unique participants, 468 of whom received pain science education. Eight studies included patients with moderate to severe pain at baseline (Visual Analogue Scale ≥ 35mm or Numeric Rating Scale ≥ 4[28, 29]),[26, 27, 30-35] among which five[26, 27, 30, 32, 34, 35] reported duration of preoperative pain (mean = 4.36 years).

Table 3 presents details on the timing and delivery mode of treatment in both groups (intervention and control). The following names were given to the interventions by the authors of the original studies: pain neuroscience education (n=5)[26, 27, 30, 34, 35], education (n=1)[33], behavioral pain medicine (n=1)[36], patient education based on cognitive behavioral therapy (n=1)[31] and pain coping skills (n=1)[31]. Six papers implemented a preoperative pain science education intervention,[26, 27, 30, 34-36] two an intervention containing both preoperative and postoperative sessions[31, 32] and one paper investigated the effect of a postoperatively delivered pain science education.[33]

Table 4 provides a brief description of the content categories that were included as part of pain science education interventions. A more elaborated description of treatment content

in both groups (as provided by the authors of the original publications) can be found in *Appendix III*.

Pain, psychological factors and physical functioning were evaluated with a wide range of self-reported outcome measures, for which both disease-specific and general questionnaires were used (*Table 2*). Two randomized controlled trials showed a significant interaction effect (i.e. a significant difference in outcomes between groups over time) on pain and psychological factors.[34, 36] No statistically significant interaction effects were reported for outcomes on physical functioning.

In the first randomized controlled trial with a significant interaction effect, breast cancer patients who had received a digital behavioral pain medicine intervention reported an increase in average postoperative **pain**, which was not observed in the control group whom had been informed on general health via text.[36] The authors did not calculate effect sizes to measure the strength of this significant interaction effect.

In the second randomized controlled trial with a significant interaction effect on **psychological factors**, pain catastrophizing and kinesiophobia decreased in participants who had received four pain science education sessions combined with knee mobilization before undergoing total knee arthroplasty.[34] Over the same period of time (i.e. three months after surgery), the values in the control group remained unchanged. A medium effect size, calculated as the partial eta squared (η2p:0.11), was reported for both the interaction effects of pain catastrophizing and kinesiophobia.

An overview of the risk of bias can be found in *Table 5*. The vast majority of included studies (n=6) were at high risk of bias.[27, 31-34, 36]

Discussion

The purpose of this systematic review was to synthesize the literature on the effect of perioperative pain science education. Although significant interaction effects were present in two studies, there was no conclusive evidence for an overall effect on pain, psychological factors nor physical functioning.

In the first study with a significant interaction effect, breast cancer patients who had received one preoperative pain science education session showed a significant increase in postoperative **pain** compared to controls.[36] This is an interesting finding as this result was the opposite of the effect we had anticipated. It should be pointed out why we have to be careful drawing conclusions from this study to answer our research question. First of all, it was only a pilot randomized controlled trial on feasibility and acceptability of the educational program, with pain intensity as a secondary outcome. The authors also created a composite postsurgical measure for pain intensity (averaging pain intensity over all the postsurgical follow-up assessments) because they had not found evidence of an interaction effect on either one of the follow-up time-points (two-, four-, eight- and 12-week after surgery) and only p-values without effect sizes were reported. Lastly, the distinction between this study and the others was twofold. First, breast cancer surgery is not a surgery for a painful condition, so this was the only study including participants without preoperative pain. This raises the additional research question whether pain science education can serve a preventive role, compared to a curative role in the other studies. Second, breast cancer patients were the only oncological population included (compared to musculoskeletal surgeries). It might be feasible that pain science education results in different effects in oncological populations, as the specific contexts of their pain experiences differs.

Regarding the impact on **psychological factors**, only the study by Lluch et al. showed a significant interaction effect of pain science education on both pain catastrophizing and kinesiophobia after total knee arthroplasty.[34] In the intervention group that had received four one-on-one sessions, pain catastrophizing and kinesiophobia decreased compared to baseline, while values for the control group remained the same. This beneficial effect was in line with previous research in chronic pain populations, showing that pain science education by itself has minor effects and should be combined with physical exercises.[18, 37-40] The study by Lluch et al. was among the two included studies that had indeed implemented an additional controlled physical intervention (knee mobilization physiotherapy sessions), similar for both the intervention and control group.[34, 35] Three other studies described whether or not patients in both groups were referred for postoperative physical therapy, though this could have been unevenly distributed among intervention and control groups.[30-32]

There are several **possible explanations** to why no overall beneficial effects of perioperative pain science education were found.

The first one is that most studies were conducted in subjects who underwent surgery for a painful condition, which was reflected in moderate to severe pain at baseline.[26, 27, 30-35] Therefore, we cannot rule out a general pain-reducing effect of surgery and postoperative use of pain medication, irrespective of group allocation. Indeed, all studies in populations with preoperative pain showed a decrease in postoperative pain over time up to three months post-surgery in both the control and intervention group, which did not depend on group allocation.[26, 27, 30-35]

An alternative explanation for the lack of significant differences in post-surgical pain levels is that the post-surgical healing process is painful because of tissue injury (to promote

healing) rather than (bio)psychological factors addressed in the pain science education. In this particular population, short-term pain relieving effects can be expected to be less but it may be more valuable to look at long-term effects for prevention of chronification.

Furthermore, it might not be surprising that we did not find an effect on pain, as pain science education targets a reconceptualization of pain through knowledge.[16] Although patients see their pain in a different light, they can still experience pain. However, through pain science education, the knowledge per se that pain can be overprotective could encourage patients to change their behavior and result in a better well-being and quality of life. In future research, this might be a reason to select studies based on outcomes other than pain, e.g. pain-related functioning.

In addition, it is possible that positive findings for pain science education in chronic pain populations cannot directly be translated to patients undergoing surgery. In previous research[17-19, 41], chronic pain patients receiving pain science education without surgery were guided through the stages of behavioral change, resulting in active self-management of their problem without the "time pressure" of a scheduled surgery or notion that surgery is their only valid option for a pain-free life. Behavioral change is typically nonlinear and people continuously change through a cyclical process, which can result in a long process.[42-44] In contrast, most participants included for this review (who were likely experiencing chronic pain, as their preoperative pain duration averaged four years[26, 30-35]), were taught about the importance of biopsychosocial factors as possible contributors to their pain *after* their decision to undergo surgery. According to the transtheoretical model of behavioral change, it is harder to trigger inherent motivation to change behavior once people have set their mind on a surgical remedy.[44] Apart from that, the postoperative circumstances and condition of the

tissues create a new context for the patient's interpretation of educational content. However, this reasoning should be interpreted with caution, as none of the authors reported evidence about behavioral change as a result of the interventions. It is possible that participants did, in fact, change behaviors and still experienced pain.

Furthermore, the format of the intervention should be discussed as an explanation for the results. Currently, there are no clear guidelines on intensity or amount of sessions, which may not be surprising as pain is characterized by strong inter-individual variability. Nonetheless, it may well be argued that a more elaborate educational approach is required to substantially change beliefs/cognitions and induce behavioral change in people who have been in pain for a while.[45] Changes in participants' pain knowledge before and after education could help us further unravel the optimal educational format for this population. However, none of the included studies evaluated whether participants comprehended the education provided.

Lastly, another question is whether we observed limited effects because most participants did not experience a significant effect (group level) or because most of them did not experience any benefits (non-responders), while others experienced a very pronounced effect (responders). In line with this train of thought, a possible explanation could be that we did not stratify on group level (e.g. diagnosis, dominant pain mechanism, level of anxiety, catastrophizing, kinesiophobia…).[3, 4] Future studies need to investigate whether the effect of pain science education might be more pronounced after stratification, by defining responders to perioperative pain science education. This can be done based on the known risk factors for development of chronic pain as described in the introduction.

To summarize, pain science education was not effective for reducing post-surgical pain, psychosocial factors and physical functioning, regardless of whether or not study participants reported pre-surgical pain. However, several more nuanced **clinical recommendations** can be made based on interpretation of the results of the individual studies.

For the above-mentioned reasons, it could be beneficial to educate patients in pain *before* the decision for surgery. This way, they could make an informed decision about whether or not, and why, they would want surgery or rather explore other possibilities, possibly resulting in less pain and disability without the side-effects of surgery. Perhaps, after being in pain for a long time, they might have expected surgery as the final magic bullet. Health care providers, in this case mostly surgeons and anesthesiologists, still often ignore the biopsychosocial paradigm of chronic pain, leading to informed consent for surgery based on incomplete information.

In patients without preoperative pain, pain science education does not seem the best option. It is plausible that pain science education triggers anxious behavior in this subgroup, for they do not experience any relatable pain when being educated on the matter. The question then rises whether people who are not in pain can be ready to change, as they cannot (yet) link any behavior to pain. Therefore, a possible recommendation could be to plan the educational session(s) whenever patients experience acute postoperative pain. Nevertheless, it is premature to draw such conclusions based on our results, as there was only one study included regarding preoperative pain science education in patients without pain.[36] Besides, this study in breast cancer patients was the only one using a none face-to-face educational format (90-minute video).

The generalizability of the results is subject to certain **limitations**. Firstly, the included studies were quite heterogeneous in terms of population (eligibility criteria, type of surgery, preoperative pain, exclusion of patients with low catastrophizing), intervention (amount of sessions, timing and mode of delivery, stand-alone treatment or in combination with others), outcome measures and comparators. Hence, it was not possible to conduct a meta-analysis. Secondly, the overall quality of the included studies was rather low, which compromises confidence that the results represent a true treatment effect. A possible explanation for this is that one of the questions in the risk of bias assessment tool was whether the assessors were blinded to intervention assignment. Because participants are considered assessors in case of patient-reported outcome measures, blinding for type of educational intervention is rather challenging. The assessment tool states that once one item is graded as high risk of bias, the whole paper is considered high risk of bias. Lastly, for the scope of this review, we wanted to look at the possible attenuating effect of perioperative pain science education on postoperative pain and other possible risk factors for chronic postsurgical pain. However, our eligibility criteria did not filter out patients with preoperative pain and there was no specification on minimal follow-up period. For these reasons, it was very difficult to look at a possible effect of pain science education on pain chronification on the long-term.

In general, perioperative pain science education in adults does not result in significant effects on pain, psychological factors or physical functioning compared to controls. Only one study indicated that subjects receiving pain science education after total knee arthroplasty (in combination with a physical therapy program) showed greater statistically significant improvements in pain catastrophizing and kinesiophobia. Further work needs to be done to determine the optimal timing of pain science education (before the decision to undergo surgery, before surgery or afterwards) in both people with and without existing pain, as well

as to define responders to pain science education so the effect of population-specific pain science education can be studied in the future. In addition, research on the effectiveness of pain science education should include a checklist to verify whether participants comprehended the educational content and follow-up periods should be long enough to study the effect on pain chronification.

CLINICAL MESSAGES

- Contrasting with the effectiveness of pain science education in chronic pain populations, there is currently no strong evidence for the implementation of pain science education in the perioperative period.
- In people with preoperative pain, pain science education has no harmful effects (but neither any benefits).

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author, E.V.d.G., upon reasonable request.

DECLARATION OF CONFLICTING INTERESTS

The Author(s) declare(s) that there is no conflict of interest.

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TABLES

Table 1. Eligibility criteria for inclusion and exclusion of studies, based on the PICOS-format (Patients, Intervention, Comparison, Outcome, Study design)

Patients	Adults (mean age ≥18 years) who will undergo or underwent surgery
Intervention	Pain science education - Consistent with the definition of pain science education as described by Louw and colleagues[17]: "(An) educational session(s) describing the neurobiology and neurophysiology of pain (processing) by the nervous system. Patients are educated that the nervous system's processing of their injury, in conjunction with various psychosocial aspects, determines their pain experience and that pain is not always a true representation of the status of the tissues." For the full definition, see *Appendix I*. - Delivered orally or written, individually or in group, isolated or in combination with other forms of treatment. - At least one session took place in the perioperative period (between one month prior to surgery and one month after surgery).
Comparison	The interventional group was compared to either: a) *a non-exposed control group* A group that did not receive an educational intervention (apart from the lack of education, the comparison group had to be treated the same way as the interventional group, so the effect of pain science education could be isolated) or b) *another intervention* A group that had received an alternative educational intervention (apart from the educational intervention, the comparison group had to be treated the same way as the interventional group, so the effect of pain science education could be isolated). This control intervention might have been a routine educational intervention that is accepted in the hospital and that patients would have received anyway (usual care), or an additional educational intervention rather focusing on pain as a reflection of tissue damage or injury (a biomedical focus instead of the broader biopsychosocial focus of pain science education).
Outcome	Studies that reported on at least one of the following outcome parameters: - Pain - Psychological factors (pain catastrophizing, kinesiophobia, self-efficacy, depression, anxiety and stress) - Physical functioning No limitations were set on the measurement tool used to examine the effect of pain science education on the outcomes.
Study design	Original studies: controlled quantitative study designs Full-text availability in Dutch or English

Table 2. Study characteristics

STUDY **Author** **Year** **Country** **Design**	**SAMPLE** **Type of surgery** **Sample size** (IG/CG) **Eligibility criteria**	**PATIENT CHARACTERISTICS** **Age (years)** *mean (SD)* **Gender ratio (♀/♂)** **Baseline pain** *mean (SD)*		**OUTCOMES** **Time points** **Outcome measures**	**RESULTS** **Statistical analysis** **Statistical significance** *p-value* (unless specified otherwise)
		IG	**CG**		
Lluch et al.[34] 2018 Spain RCT	Total knee arthroplasty N=54 (27/27) Inclusion - Knee osteoarthritis pain >3m Exclusion - Previous total knee arthroplasty/other lower limb surgery of the affected knee <6m - Inflammatory, metabolic or neurological comorbidities - Chronic widespread pain	67.7 (7.8) 59/41 Numeric Rating Scale (0-10) 6.2 (1.5)	72.8 (5.6) 68/32 5.4 (1.6)	- T0: preop - T1: after treatment (preop) - T2: 1m follow-up (preop) - T3: 3m postop **Pain and disability** - Western Ontario and McMaster Universities Arthritis Index **Psychological factors** - Pain Catastrophizing Scale - Tampa Scale for Kinesiophobia-11	PPA (22/22) **Pain and disability** - P int=0.35 - P time<0.0001*:↘ **Psychological factors** - P int<0.001* - P time CG(T0-T3) =/ns - P time EG(T0-T3) <0.001*:↘ - P int<0.001* - P time CG(T0-T3) =/ns - P time EG(T0-T3) <0.001*:↘
Núñez-Cortés et al.[35] 2019 Chile RCT	Carpal tunnel surgery N=31 (16/15) Inclusion - ≥18y Exclusion - Prior pain education	56.8 (8.4) 100/0 Visual Analogue Scale (0-100) 72.6 (22.1)	50.8 (17.7) 100/0 61.7 (21.6)	- T0: preop - T1: 4w postop - T2: 12w postop **Pain** - Visual Analogue Scale **Psychological factors**	PPA (15/15) <u>Composite measure</u>: mean value T1 and T2 **Pain** - P int=0.816 - P time=0.040*:↘ **Psychological factors**

	- Prior surgery on the extremity requiring carpal tunnel surgery			- Pain Catastrophizing Scale - Tampa Scale for Kinesiophobia-11 **Physical functioning** - Quick Disabilities of Arm, Shoulder and Hand questionnaire	- P int=0.510 - P time=0.510 - P int=0.717 - P time=0.278 **Physical functioning** - P int=0.506 - P time=0.024*:↗
Louw et al.[30] 2019 USA Controlled clinical trial	Total knee arthroplasty N=103 (49/54) Exclusion - Previous total knee arthroplasty - Scheduled for bilateral total knee arthroplasty	74.1 (9.5) 65/44 Numeric Rating Scale (0-10) 4.7 (2.2)	69.6 (10.6) 55/45 4.7 (2.2)	- T0: before education - T1: 1m postop - T2: 3m postop - T3: 6m postop **Pain** - Numeric Rating Scale **Psychological factors** - Pain Catastrophizing Scale - Tampa Scale for Kinesiophobia-11 **Physical functioning** - Western Ontario and McMaster Universities Arthritis Index	PPA (31/36) ITTA (only reported if different from PPA) **Pain** - P int=0.386 - P time(T0- T3) <0.001*:↘ **Psychological factors** - P int=0.819 - P time(T0-T3) <0.001*:↘ - P int=0.245 - P time(T0-T3) <0.001*:↘ **Physical functioning** - P int=0.222 - P time(T0-T3) <0.001*:↗
Louw et al.[26] 2014 USA RCT	Lumbar surgery for radiculopathy N=67 (35/32) Exclusion - <18y or >65y	49.59 (53/47) Numeric Rating Scale: low back (0-10) 4.57	49.65 (54/46) 5.12	- T0: preop - T1: 1m postop - T2: 3m postop - T3: 6m postop - T4: 12m postop **Pain** - Numeric Rating Scale: low back	PPA (28/33) and ITTA (only reported if different from PPA) **Pain** - P int>0.167

	- Instrumented lumbar surgery - Participation in formal back school or multidisciplinary pain management program - Chronic pain-related conditions - Symptoms of cord compression	Numeric Rating Scale: leg (0-10) 5.25		6.06	- Numeric Rating Scale: leg **Physical functioning** - Oswestry Disability Index	- P time(T0-T4) <0.002*: ↘ - P int>0.167 - P time(T0-T4) <0.002*:↘ **Physical functioning** - P int>0.167 - P time(T0-T4) <0.002*:↘
Louw et al.[27] 2016 USA RCT	See Louw et al. 2014	See Louw et al. 2014		See Louw et al. 2014	- T0: preop - T1: 1m postop - T2: 3m postop - T3: 6m postop - T4: 12m postop - **T5: 3y postop** **Pain** - Numeric Rating Scale: low back - Numeric Rating Scale: leg **Physical functioning** - Oswestry Disability Index	See Louw et al. 2014 **Pain** - P int=0.405 - P time(T0-T5) <0.001*:↘ - P int=0.665 - P time(T0-T5) <0.001*:↘ **Physical functioning** - P int=0.520 - P time(T0-T5) <0.001*:↘
Riddle et al.[32] 2019 USA RCT	Total knee arthroplasty N=402 (130/135/137) Inclusion - ≥45y - Diagnosed with osteoarthritis	62.6 (7.9) (72/28) Numeric Rating Scale: knee (0-10)	64.2 (8.5) (63/37)	62.7 (7.7) (64/36)	- T0: 1w preop - T1: 2m postop - T2: 6m postop - T3: 12m postop **Pain** - Western Ontario and McMaster Universities Arthritis Index: pain scale	ITTA **Pain** - P int=0.73 - P time<0.001*:↘

	- Pain Catastrophizing Scale ≥16 Exclusion - Scheduled for revision surgery - Hip or knee arthroplasty 6m prior to or after surgery - Self-reported diagnosis of inflammatory arthritis - Bilateral knee arthroplasty	6.0 (1.8)	6.0 (2.0)	6.2 (1.9)	- Numeric Rating Scale **Psychological factors** - Pain Catastrophizing Scale **Physical functioning** - Western Ontario and McMaster Universities Arthritis Index: physical function scale - Short Physical Performance Battery - 6 Minute Walk Test	- P int>0.05 - P time<2e-16*:↘ **Psychological factors** - P int>0.05 - P time(T0-T3) =<2e-16*:↘ **Physical functioning** - P int>0.05 - P time(T0-T3)=/*:↗ - P int>0.05 - P time=2.619e-10*:↗ - P int=0.96 - P time<2e-16*:↗
Darnall et al.[36] 2019 USA Pilot RCT	Breast cancer surgery N=127 (77/50) Inclusion - >18y - Scheduled for lumpectomy or mastectomy Exclusion - Pregnancy - Ongoing pain- or disability-related legal claim	51.27 (100/0) Numeric Rating Scale (0-5) 1.47 (0.12)		51.16 (100/0) 1.74 (0.13)	- T0 - T1: 2w postop - T2: 4w postop - T3: 8w postop - T4: 12w postop **Pain** - Numeric Rating Scale - Patient-Reported Outcome Measurement	PPA (36/32) No evidence of postop interaction effect (T1, T2, T3, T4). Measures were averaged to create a composite postsurgical measure. For each of the covariates, they specified a mixed-design ANOVA with treatment, time and treatment x time as predictors. **Pain** - P int=0.0394* - P time=0.0016*:↗ - P time IG=0.0002* - P time CG=0.4191 - P int>0.008 - P time>0.008

				Information System: pain interference **Psychological factors** - Pain Catastrophizing Scale - Patient-Reported Outcome Measurement Information System: anxiety and depression **Physical functioning** - Patient-Reported Outcome Measurement Information System	**Psychological factors** - P int=0.34 - P time=0.03*:↘ - P int>0.008 - P time>0.008 **Physical functioning** - P int>0.008 - P time>0.008
Glindvad and Jorgensen[33] 2007 Denmark RCT	Surgery for inguinal hernia N=234 (103/131) Inclusion - >18y Exclusion - Scheduled for laparoscopic and bilateral surgery	54.2 (17.7) (8/92) Visual Analogue Scale: rest (0-100) 3.0 Visual Analogue Scale: while moving (0-100) 11.0	54.0 (15.0) (6/94) 2.0 7.0	- T0: preop - T1: 1st day postop - T2: 3rd day postop - T3: 7th day postop **Pain** - Visual Analogue Scale: rest - Visual Analogue Scale: while moving	PPA **Pain** - P int=/ - P time(T0-T3)=/ - P int=ns - P time(T0-T3)=/
Birch et al.[31] 2020	Total knee arthroplasty N=60 (31/29)	66 (9) (69/31)	66 (10) (62/38)	- T0: preop - T1: 3m postop - T2: 12m postop **Pain**	ITTA **Pain**

Denmark RCT	Inclusion - Primary knee osteoarthritis - ≥18y - Pain Catastrophizing Scale>22 Exclusion - Severe depression - Contralateral total knee arthroplasty within 1y after surgery of interest	Visual Analogue Scale: during activity (0-100) 48 (18) Visual Analogue Scale: rest (0-100) 19 (14)	49 (21) 25 (17)	- Visual Analogue Scale: during activity - Visual Analogue Scale: rest **Pain and physical functioning** - Oxford Knee Score **Psychological variables** - Pain Catastrophizing Scale - Pain Self-Efficacy Scale **Physical functioning** - 6 Minute Walk Test - 30 Seconds Sit To Stand Test	- P int=/ns - P time(T0-T2)=/*:↘ - P int=/ns - P time(T0-T2)=/*:↘ **Pain and physical functioning** - P int=/ns - P time=/*:↗ **Psychological variables** - P int=/ns - P time=/*:↘ - P int=/ns - P time=/ns **Physical functioning** - P int=/ns - P time=/ns - P int=/ns - P time=/ns

*= significance in original study; /=p-values not shown in original manuscript; CG=control group; IG=intervention group; ITTA=intention-to-treat analysis; m=month(s); N=study sample (randomized); ns=non-significant; P int=P value interaction effect; PPA=per-protocol analysis; P time=P value for time effect; RCT=randomized controlled trial; SD=standard deviation; T0=baseline assessment; T1/2/3/…=assessment 1/2/3/…; w=week(s); y=year(s)

Table 3. Treatment timing and delivery mode

Study	Both groups	Intervention group	Control group
Lluch et al. (2018)[34]	**Knee mobilization sessions** - Preop - After each educational session	**Pain neuroscience education** - 2m-1m preop - 4 x (1/w) - 1st session 50-60', 2nd-4th session 20-30'	**Biomedical education** - 2m-1m preop - 4 x (1/w) - 1st session 50-60', 2nd-4th session 20-30'
	Delivery mode - PT - Intervention group: pain-guided - Control group: not pain-guided and non-threatening word choice	**Delivery mode** - One-on-one - PT - Verbally and visually with the aid of a computer	**Delivery mode** - One-on-one - PT - Verbally and visually with the aid of a computer
Núñez-Cortés et al. (2019)[35]	**Hand therapy** - 1w postop	**Pain neuroscience education** - 1 x 30' - 1w preop	**Usual care** - 1 x 30' - 1w preop
	Delivery mode - Verbal and written instructions - Home exercise program	**Delivery mode** - One-on-one - PT - Audio visual approach - Pictures, examples, metaphors, stories	**Delivery mode** - One-on-one - Audiovisual approach
Louw et al. (2019)[30]	**Traditional hospital education** - Preop	**Pain neuroscience education** - 1 x 30' - Preop - Prior to traditional hospital education	/
	Delivery mode - Group - Booklet 100% (n=103) of the patients received postop PT	**Delivery mode** - Group - PT - PowerPoint presentation - Booklet	/
Louw et al.	**Usual care** - Preop	**Pain neuroscience education** - 1 x 30'	/

(2014 and 2016)[26, 27]		- Preop		
	Delivery mode - Surgeons and staff	**Delivery mode** - One-on-one - PT - Verbal - Pictures, examples, metaphors and drawings - Booklet	/	
Riddle et al. (2019)[32]	Patients were routinely prescribed medications for pain control and are referred for physical therapy following total knee arthroplasty.	**Pain coping skills training** - 8 x 50' - 2w preop-6w postop **Delivery mode** - One-on-one - PT - 1st session in-person, other sessions via telephone - Written maintenance plan	**Arthritis education** - 8 x 50' - 2w preop-6w postop **Delivery mode** - One-on-one - Nurse - Presentation and discussion format - 1st session in-person, other sessions via telephone	**Usual care**
Darnall et al. (2019)[36]	/	**Behavioral pain medicine intervention** - 1 x 90' - Preop	**General health education** - Preop	
	/	**Delivery mode** - Website - Video on pain psychoeducation (including PowerPoint presentation)	**Delivery mode** - Digital text education	
Glindvad and Jorgensen (2007)[33]	**Routine information** - 1 x 5-10' - Preop	**Education** - 1 x 30-60' - Postop	**Discharge information** - Postop	

		- Follow-up telephone call 2d postop	
	Delivery mode - Oral - Ward nurse - 5 pamphlets	**Delivery mode** - One-on-one - Project nurse - Communication guide	**Delivery mode** - Oral
Birch et al. (2020)[31]	**Usual care** - 1w preop - 1w postop - 2, 4, 12w postop	**Patient education based on cognitive behavioral therapy** - 7/6 x 45' - 2w preop-3m postop - 3 x preop - 4 x postop	/
	Delivery mode - Multidisciplinary information meeting - Phone call - Control visits	**Delivery mode** - One-on-one - 2 PT's - PowerPoint - Handbook - Mp3 player	/

'=minutes; m=month; PT=physiotherapist; w=week(s); y=year(s)

Table 4. Educational content included as part of pain science education interventions
Basic neurophysiology and pain physiology[26, 27, 30-36]
Chronic pain physiology and central sensitization[26, 27, 30, 31, 34, 35]
Pain neuromatrix[31, 34-36]
Influencing/sustaining factors[26, 27, 30-36]
Multifactorial experience of pain[26, 27, 30-36]
Activity pacing[31-33]
Transfer knowledge about pain to an adaptive behavioral change[31-35]
Reconceptualization of pain[26, 27, 30-35]
Mindfulness/relaxation/breathing exercise[31-33, 36]

Table 5. Risk of bias assessment according to the revised Cochrane risk-of-bias tool for randomized trials (RoB 2) and the Risk Of Bias In Non-Randomized Studies – of Interventions (ROBINS-I) assessment tool.

RoB 2	**1**	**2**	**3**	**4**	**5**	**=**		
Birch 2020	-	+	+	-	+	-		
Darnall 2019	+	-	?	+	-	-		
Glindvad 2007	+	+	-	+	+	-		
Lluch 2018	+	-	+	+	+	-		
Louw 2014	+	+	+	+	+	+		
Louw 2016	+	-	?	+	?	-		
Núñez-Cortes 2019	+	?	+	+	+	?		
Riddle 2019	+	+	+	-	+	-		
ROBINS-I	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**=**
Louw 2019	+	+	+	+	+	?	+	+

RoB 2: risk of bias (1) arising from the randomization process, (2) due to deviations from the intended interventions, (3) due to missing outcome data, (4) in measurement of the outcome, (5) in selection of the reported result, (=) overall risk of bias

ROBINS-I: bias (1) due to confounding, (2) in selection of participants into the study, (3) in classification of interventions, (4) due to deviations from intended interventions, (5) due to missing data, (6) in measurement of outcomes, (7) in selection of the reported result, (=) overall risk of bias

(-) High risk

(+) Low risk

(?) Some concerns

FIGURES

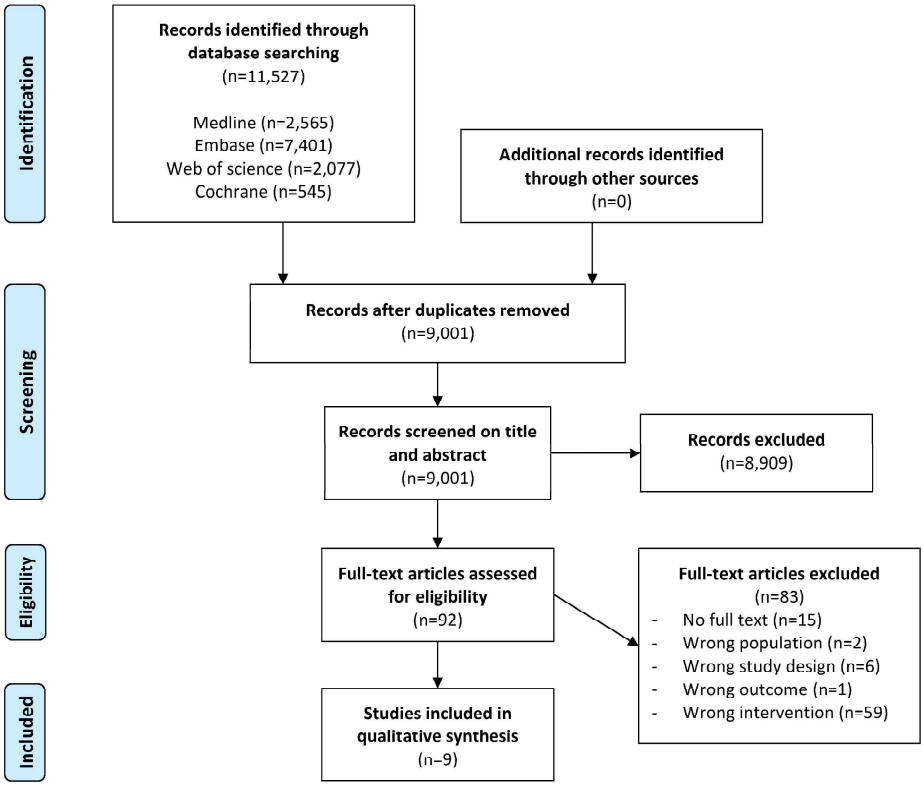

Figure 1. PRISMA flow diagram of study identification, screening and inclusion.

APPENDIX

Appendix I: Definition of pain science education as defined by Adrian Louw et al. (they used the term "neuroscience education")

Neuroscience education can be best described as an educational session or sessions describing the neurobiology and neurophysiology of pain, and pain processing by the nervous system. Instead of a traditional model of connecting tissue injury or nociception and pain, neuroscience education aims to describe how the nervous system, through peripheral nerve sensitization, central sensitization, synaptic activity, and brain processing, interprets information from the tissues and that neural activation, as either upregulation or downregulation, has the ability to modulate the pain experience. Patients are thus educated that the nervous system's processing of their injury, in conjunction with various psychosocial aspects, determines their pain experience and that pain is not always a true representation of the status of the tissues. By reconceptualizing their pain as the nervous system's interpretation of the threat of the injury, rather than an accurate measure of the degree of injury in their tissues, patients may be more inclined to move, exercise, and push into some discomfort. Depending on the timing of its administration, neuroscience education may be viewed as a preventive measure in acute pain situations and as a treatment/rehabilitation intervention in chronic pain situations.

Appendix II: search strategy for PubMed/Medline

((("Pain"[Mesh] OR pain*[tiab]) AND ("Health Education"[Mesh] OR “psychoeducation”[tiab] OR “Medical information”[tiab] OR "Education"[Mesh:NoExp] OR patient-education*[tiab] OR education-of-patient*[tiab] OR "Health Communication"[Mesh] OR “Health communication”[tiab] OR “patient communication”[tiab] OR communication-patient*[tiab] OR “Health literacy”[tiab] OR “Preoperative education”[tiab] OR ((informati*[tiab] OR educati*[tiab]) AND (brochure*[tiab] OR leaflet*[tiab] OR booklet*[tiab] OR pamphlet*[tiab])))) OR (“Pain education”[tiab] OR “Neuroscience education”[tiab] OR “Explain pain”[tiab] OR “Pain science education”[tiab] OR “Pain communication”[tiab] OR “Pain neuroscience approach”[tiab] OR “Pain physiology education”[tiab] OR “Pain neurophysiology education”[tiab] OR “Pain biology education”[tiab])) AND ("Specialties, Surgical"[Mesh] OR "Surgical Procedures, Operative"[Mesh] OR "surgery" [Subheading] OR operative-procedure*[tiab] OR operative-intervention*[tiab] OR operative-repair*[tiab] OR operative-restoration*[tiab] OR operative-treatment*[tiab] OR resection*[tiab] OR operation*[tiab] OR surger*[tiab] OR surgic*[tiab] OR "Postoperative Complications"[Mesh:NoExp] OR postop*[tiab] OR post-op*[tiab] OR preop*[tiab] OR pre-op*[tiab] OR periop*[tiab] OR peri-op*[tiab] OR mastectom*[tiab] OR mammectom*[tiab] OR lumpectom*[tiab] OR tylectom*[tiab] OR arthroplast*[tiab] OR bone-tunnel-enlargement*[tiab] OR bone-tunnel-widening*[tiab] OR alloarthroplast*[tiab] OR joint-reconstruction*[tiab] OR arthroscop*[tiab] OR arthroendoscop*[tiab] OR discectom*[tiab] OR diskectom*[tiab] OR laminectom*[tiab] OR laminoplast*[tiab] OR laminotom*[tiab] OR amputation*[tiab] OR arthrodes*[tiab] OR articular-process-fusion*[tiab] OR joint-fusion*[tiab] OR skeletal-fixation*[tiab] OR fracture-fixation*[tiab] OR fracture-reduction*[tiab] OR bone-fixation*[tiab] OR osteotom*[tiab] OR bone-section[tiab] OR

debridement[tiab] OR appendectom*[tiab] OR appendicectom*[tiab] OR cholecystectom*[tiab] OR hemorrhoidectom*[tiab] OR haemorrhoidectom*[tiab] OR hemorrhoid-excision*[tiab] OR hemorrhoidopex*[tiab] OR tonsillectom*[tiab] OR laparoscop*[tiab] OR celioscop*[tiab] OR peritoneoscop*[tiab] OR pelvic-endoscop*[tiab] OR videolaparoscop*[tiab] OR thoracotom*[tiab] OR pleura-incision*[tiab] OR pleural-incision*[tiab] OR pleuracotom*[tiab] OR pleurotom*[tiab] OR rethoracotom*[tiab] OR hysterectom*[tiab] OR colpohysterectom*[tiab] OR hysterocolpectom*[tiab] OR panhysterectom*[tiab] OR uterus-extirpation*[tiab] OR herniorrhaph*[tiab] OR hernia-repair*[tiab] OR hernioplast*[tiab] OR herniaplast*[tiab] OR saphenectom*[tiab] OR sternotom*[tiab] OR sternum-osteotom*[tiab] OR hip-replacement*[tiab] OR hip-joint-replacement*[tiab] OR knee-replacement*[tiab] OR knee-joint-replacement*[tiab] OR cesarean-section*[tiab] OR abdominal-deliver*[tiab] OR caesarean-section*[tiab] OR c-section*[tiab] OR postcesarean-section*[tiab] OR caesarean-birth[tiab] OR cesarean-deliver*[tiab] OR fetectom*[tiab] OR repeated-cesarotom*[tiab] OR section-caesarea[tiab] OR "Radiculopathy"[Mesh] OR radiculopath*[tiab] OR radiculiti*[tiab] OR neuroradiculitis[tiab] OR polyneuroradiculitis[tiab] OR polyradiculoneuropath*[tiab] OR radiculoneuropath*[tiab] OR nerve-root-disorder*[tiab] OR nerve-root-inflammation*[tiab] OR nerve-root-avulsion*[tiab] OR nerve-root-disease*[tiab] OR polyradiculopath*[tiab] OR radicular-neuropath*[tiab]) NOT (“animals”[Mesh] NOT “humans”[Mesh])

Appendix III: Study characteristics: detailed content of interventions

1. Lluch et al. (2018)

    a. **Knee joint mobilization**

    Knee joint mobilization was applied using Mulligan's mobilization with movement following the protocol from Takasaki. Mobilization with movement during active knee flexion and/or extension, depending on which was the limited/painful movements for each patient, was applied progressing from non-weight-bearing to weight-bearing positions. All the mobilizations were performed for three sets of 10 repetitions and patients were asked to perform self-applied mobilizations at home involving four series of 20 movement repetitions per day. Home treatment adherence was recorded by means of a diary. The mobilization with movement techniques used in this study are described elsewhere.

    b. **Biomedical education**

    The information was provided by the same physiotherapist performing pain neuroscience education (PNE) in the other group through visualization of several videos that were presented on a computer.

    - No reference to PNE or pain biology
    - Anatomy, physiology and biomechanics of the knee
    - Disease knowledge: normal course, etiology and clinical presentation of knee osteoarthritis
    - Principles of conservative management of KOA: exercise, physical activity, weight loss and drugs

- Surgical treatment for knee osteoarthritis and expected course of postoperative knee pain

c. **Pain neuroscience education**

Topics addressed included the physiology of the nervous system with special interest in the pain system, characteristics of acute versus chronic pain; how pain becomes chronic (plasticity of the nervous system, central sensitization, etc.); potential sustaining factors of central sensitization like emotions, stress, pain behavior and cognitions; surgical experiences and environmental aspects affecting nerve sensitivity; and reconceptualization of postoperative pain after knee joint replacement.

- No reference to pathoanatomical models
- Acute pain versus chronic pain, transition from acute to chronic pain Neurons, synapsis and action potentials Peripheral and central sensitization
- Descending inhibition and facilitation of pain
- Sustaining factors of central sensitization (i.e. emotions, stress, pain behavior, cognitions)
- The pain matrix in the brain
- Reconceptualization of pain as a normal brain response to perceived threat
- Surgical experiences and environmental aspects affecting nerve sensitivity
- (Re)conceptualization of postoperative pain
- Transfer knowledge about pain to an adaptive behavioral change

2. Núñez-Cortés et al. (2019)

    a. **Hand therapy**

    Instructions for a home exercise program that included active digital flexor tendon gliding; active thumb opposition; and active wrist range of motion (flexion and extension).

    b. **Usual care education**: Information about the medical, anatomical, and pathological aspects of carpal tunnel surgery.

        - Basic aspect of the anatomy of the wrist in general and of the carpal tunnel in particular.
        - Surgery procedures was explained and illustrated with pictures.
        - The objective of the education was to teach people about the surgery of carpal tunnel release.
        - There was up to 10 minutes extra time for questions for each participant.

    c. **Pain neuroscience education (PNE):** The key contents of the session included the neurophysiological and biopsychosocial aspects of pain and the concept of peripheral and central sensitization.

        - Basic physiology of the nervous system in general and of the pain system in particular.
        - The theoretic information was illustrated with pictures and examples. Metaphors and stories to help understand the biology of pain.
        - The objective of the education was to teach people about the multifactorial experience of pain.

- There was up to 10 minutes extra time for questions for each participant.

3. Louw et al. (2019)
    a. The **traditional hospital preoperative program** was consistent with current preoperative total knee arthroplasty protocols. Participants in both intervention groups received education covering anatomy of the knee joint, information about the joint replacement surgery, what to expect when they were admitted for surgery, what to expect immediately after surgery, pain medications, postoperative rehabilitation/physical therapy, and so on. All patients received a hospital-based booklet with this information.
    b. The **pain neuroscience education (PNE)** session was presented in the form of a PowerPoint presentation, prior to receiving the usual preoperative education program from the hospital. The PNE program used in this study was an adaptation of the PNE program developed for lumbar surgery (for content see Louw 2014). The educational material and content used in the spine surgery study were altered to reflect knee pain, knee osteoarthritis, and total knee arthroplasty. Patients also received a patient booklet specific to PNE containing the same information provided during the live lecture program.
4. Louw et al. (2014)
    a. **Usual care**: preoperative education from the surgeons and staff. To ensure all surgeons involved in this study provided relatively similar usual care, each surgeon was asked to complete the Spine Surgery Education Questionnaire (SSEQ) to determine if their treatment followed the usual care established in SSEQ study. Two investigators independently reviewed the surgeons'

responses to the SSEQ to ensure their preoperative education was in line with the findings of the SSEQ. All participating surgeons used usual care per the SSEQ.

Content SSEQ:

- Surgical procedure
- Complications
- Outcomes/expectations
- Anatomy
- Amount of postoperative pain expected
- Hospital stay
- How surgery will affect pain
- Precautions after surgery
- Infection
- Smoking

b. The content of the neuroscience education sessions as found in the systematic review on neuroscience education (Louw et al., 2011) was used to develop appropriate messages for patients considering surgery for lumbar radiculopathy (*Table 1*).

Table 1. Content of neuroscience education used in the development of the preoperative neuroscience educational program

Neurophysiology of pain
No reference to anatomical or patho-anatomical models
No discussion of emotional or behavioral aspects to pain
Nociception and nociceptive pathways
Neurons
Synapses

Action potential
Spinal inhibition and facilitation
Peripheral sensitization
Central sensitization
Plasticity of the nervous system

Preoperative **pain neuroscience education (PNE)** covered the sensitivity of the nervous system metaphorically described as an alarm system accompanied with drawings of action potentials was used to describe peripheral sensitization, central sensitization and plasticity of the nervous system. Material covered in the PNE included all of the following: (1) the decision to have lumbar surgery (LS); (2) the nervous system's physiology and pathways; (3) peripheral nerve sensitization; (4) surgical experiences and environmental issues effects on nerve sensitivity; (5) calming the nervous system; (6) recovery after lumbar surgery; (7) scientific evidence for the PNE booklet content; and (8) an opportunity to reflect and write questions to ask the surgeon prior to surgery. Patients in the experimental group received usual care in addition to the preoperative PNE program. PNE was provided by participating physical therapists in a one-on-one verbal format, with the use of pictures, examples, metaphors, and drawings as needed. This was done in a conversational and personal approach rather than a lecture format. To ensure a standardized PNE program, a systematic checklist was developed. The educational sessions averaged 30 minutes. Patients were additionally provided with a preoperative PNE booklet summarizing the educational content of the preoperative PNE session, including pictures, examples, and metaphors. Patients were asked to read the PNE booklet at least once before and once after their surgery.

5. Darnall et al. (2019)

a. **Health education**

Before surgery, patients received digital text education about health and nutrition that was framed in terms of their importance in enhancing recovery after surgery (this group received no 90-minute video).

b. **Digital behavioral pain medicine intervention**

Video content included information and skills to regulate cognition, emotion, and physiologic hyperarousal related to pain, including relaxation, thought reframing and behaviors that modulate attention and counteract helplessness about pain. During the video, learners were guided to self-tailor and apply the information by completing their Personalized Plan for Surgical Success.

Link to the video where the author explains part of the intervention: https://www.youtube.com/watch?v=-_xRM4fxoig

6. Riddle et al. 2019

a. **Usual care**

Patients in the usual care group only received care that they would have routinely received had they not been entered in the study. Patients were routinely prescribed medications for pain control and referred for physical therapy following total knee arthroplasty.

b. **Arthritis education**

Patients randomly assigned to the arthritis education arm received detailed information from a registered or licensed practical nurse educator about osteoarthritis and its treatment. The arthritis education intervention controlled for participation in a trial, time and clinician attention. The arthritis education sessions used a presentation and discussion format similar to that originally

described by Lorig for arthritis education (complete manuals of arthritis education and pain coping skills training intervention can be found on the Journal of Bone and Joint Surgery website: https://www.jbjs.org/). Figures and discussion sessions presented information on the nature of arthritis, the post-operative course of knee arthroplasty, treatment of osteoarthritis, the role of exercise, joint protection and making future treatment decisions.

c. Pain coping skills training (CST)

The (CST) protocol: (1) provided a rationale for the coping skills intervention; (2) trained patients in cognitive restructuring as well as a variety of skills that provide patients with opportunities to observe the impact of coping skills on changes in negative pain-related cognitions typical of pain catastrophizing (i.e. thoughts related to pain rumination, pain magnification, and helplessness in the face of pain); and (3) provided training in strategies for enhancing maintenance of gain following treatment.

Melzack and Wall's gate control model of pain was used to help patients reconceptualize their pain and emphasize their own abilities to control pain. The gate control model highlights the role that thoughts, feelings, and behaviors can play in influencing the transmission of noxious signals from the periphery to the brain. Training in pain coping skills was described as a way of changing thoughts, feelings, and behaviors that contribute to pain. Using techniques drawn from cognitive therapy, patients were taught how to identify irrational, maladaptive, and catastrophic pain-related thoughts and to replace these with alternative, rational, reassuring and adaptive thoughts. Self-instructional training was used to teach patients how to use calming self-

statements as a way of coping with pain flares. Activity-rest cycling and pleasant activity scheduling was used to help patients increase their activity level and observe the resultant impact on their pain-related cognitions. Activity-rest cycling teaches patients to target activities they tend to overdo (e.g. prolonged standing or walking while shopping) and learn to break these activities into periods of moderate activity (e.g. 30 minutes of shopping) followed by a limited rest break (e.g. 5 minutes of rest). Over time, the goal was to help patients raise their activity level by increasing the length of their activity and decreasing the length of their rest periods. In pleasant activity scheduling, patients learn how to identify activities they enjoy doing (e.g. reading, doing hobbies, and visiting friends) or that give them a sense of mastery (learning how to do something new such as typing or a new language) and then set and record weekly activity goals. Patients were also trained in three attention diversion methods that could be used to alter negative pain related cognitions: relaxation, imagery, and distraction. Progressive relaxation training helped patients learn to concentrate on muscle tension signals and use them as cues to relax. Patients were taught how to use pleasant imagery as a way to alter their pain-related thought patterns and foster relaxation. Distraction training involved training in how to focus on physical stimuli (e.g. a photograph or picture of a nature scene) or auditory stimuli (e.g. listening to music) when experiencing increased pain. Using pain science education prevention methods, each patient developed a written maintenance plan that included the list of pain coping skills learned during the study, potential high-risk situations, early warning signs of setbacks, and plans about how the patient might apply

these skills in dealing with future setbacks and challenges. *Table 2* highlights the key elements of the CST protocol.

Table 2. Components of the pain coping skills intervention

Training objective	Coping skill training methods
Altering Cognitions to Change Pain Catastrophizing	Cognitive Restructuring, Self-Instructional Training
Altering Activity Patterns To Change Pain Catastrophizing	Activity-Rest Cycling, Goal Setting
Using Attention Diversion to Change Pain Catastrophizing	Relaxation Training, Imagery, Distraction
Enhancing Maintenance	Relapse Prevention Training

7. Glindvad and Jorgensen (2005)
    a. **Routine information** took approximately 5-10 minutes to deliver. The *preoperative oral information* covered postoperative pain, postoperative stomach and bowel function and recommendations about lifting and sick leave. The *discharge oral information* covered prospective pain, administration of analgesics, lifting to the pain tolerance limit, postponing showers until 24 hours after the operation, avoiding baths and swimming baths until removal of sutures, removal of sutures and use of laxatives. Finally, *five pamphlets containing* information about anesthesia, the hospital stay and pre- and postoperative care were issued.
    b. The intervention group received *routine preoperative oral information and the same five pamphlets*. The discharge oral information was replaced by 30-60 minutes of individual **education** and a follow-up telephone call on the second postoperative day. The starting point of the education was the patient's earlier experiences with pain and knowledge of treatment of pain. A communication guide with 78 points was used, partly to aid the project nurse and partly to be

used after discharge as a checklist for patients to remind them of the main points of the conversation. Patients could check whether all points had been discussed and could use the checklist in the telephone call on the second postoperative day.

Content of the education:

- Pain: patients' experiences of pain to date, information about the risk and frequency of pain, its character and localization and the course of the pain. The project nurse included patients' earlier experiences of pain relating to illnesses, operations and accidents and also their own strategies in treating or controlling pain.
- Effect/side effects of analgesics.
- Administration of analgesics: it was stressed to patients that they should not delay treating pain, but should treat it as soon as it began.
- Physiology of pain, including which factors can increase or decrease pain.
- Instruction in change in posture, motion, lifting technique and when to resume sports.
- Wound care instructions.
- Complications: showing photographs of haematomas and cyanosis around the wound and scrotum and infection in the wound in order to give patients an idea of what to accept as expected reactions. Information on when to contact the hospital in the case of bleeding, seeping of fluid from the wound, haematoma or infection.

- Relaxation: patients' methods of relaxation were discussed. Yoga and meditation were included. Cassette tapes with relaxing music were offered.
- Advice on diet and prevention of constipation was given.
- Recommendations about resuming work were discussed (1–2 days of convalescence for light and sedentary work and 1–2 weeks for hard physical work). It was stressed that the degree of pain should be the only decisive factor in when to resume work.

8. Birch et al. (2020)
    a. Patients in the control group received **usual care**. Preoperatively this consisted of a multidisciplinary information meeting for patients and their relatives, approximately 1 week before the operation. Postoperative patients in the usual care group were offered a phone call after 1 week and 3 control visits after 2, 4, and 12 weeks with the nurse, physiotherapist and operating surgeon respectively. Further, some of the patients will receive physical rehabilitation in their local community.
    b. In addition to usual care the intervention group participated in **patient education based on cognitive behavioral therapy**, covering 3 main components: (1) education in pain and the interaction between cognition and pain perception; (2) training in cognitive and behavioral pain coping skills; and (3) training in how to apply the learned coping skills in real-life situations. The goal of the patient education was to teach the patients about pain to gain a better understanding of how cognitions and behavior affect the pain experience. We wanted them to understand the link between thoughts,

feelings, bodily reactions and behavior and to realize their own role in controlling their pain experience. The patients learned to use appropriate coping strategies such as activity pacing and pleasant activity scheduling to increase their activity level and observe the resultant impact on their pain related cognitions. Additionally, the patients were trained in cognitive restructuring. Using techniques drawn from cognitive therapy the patients were taught how to identify irrational, maladaptive and catastrophic related thoughts that contribute to pain and how to replace them with alternative rational and more positive thoughts. Each patient learned about their own early warning signs of setbacks and potential high risk situations and how to use the coping skills learned in the seven sessions to deal with future challenges. The content of each of the seven sessions is described in *Table 3*.

In the first session, the patient were handed out a patient hand-book containing all the key points from the sessions and material for the homework. Further, they received an mp3 player with different relaxation and mindfulness exercises and a pain diary.

Table 3. An overview of the content of each of the seven sessions in the cognitive-behavioral intervention

Session/time	Focus and skills
1. Session 2 weeks preoperative	Introduction to the patient education. Causes and consequences of pain. Different types of pain. Introduction to the cognitive triangle – The link between thoughts, feelings, bodily reactions and behavior. *Homework*: Identify and write down thoughts in relation to painful or stressful situations.
2. Session 1 week preoperative - relatives are invited to participate	Active and passive coping strategies. How to cope with pain and distress in relation to family, relatives and work. The consequences of fear avoidance and the link between activity and pain. Relaxation and mindfulness exercise. *Homework*: Identify and write down your own coping strategies when in pain or distress. Relaxation and mindfulness exercise.
3. Session 3–5 days preoperative	Appropriate activity management – activity pacing. Pleasant activity scheduling. Goal setting.

	Introduction to pain diary. *Homework*: Identify five activities you used to enjoy and would like to do again.
4. Session During hospitalization 1-2 days postoperative	Summary of learned skills from previous sessions. Goal setting for the next 14 days. Appropriate rest and activity. *Homework*: Use the pain diary the next 14 days.
5. Session 14 days postoperative	The cognitive triangle – The link between thoughts, feelings, bodily reactions and behavior. Learning how to change negative automatic thoughts and catastrophic pain-related thoughts into more realistic thoughts by using cognitive restructuring techniques Pleasant activity scheduling and activity pacing. *Homework*: Use pacing techniques and pleasant activity scheduling to restart daily activities and hobbies. Write down how it affects your mood and pain level. Identify and write down troubled thoughts and how they affect your feelings, bodily reactions and behavior. Consider alternative realistic thoughts.
6. Session 4 weeks postoperative	Restructuring of inappropriate thoughts. Working with the patient's individual problems. Goal setting for the next 2 months. *Homework*: Identify catastrophic and negative thoughts and try to change them to alternative more realistic thoughts.
7. Session 3 months postoperative	Brush up from the 6 previous sessions and a reflection of which coping techniques and cognitive techniques the patient can and will use in the future How to manage and control flare-ups Plan for the future
All sessions begins with questions and a talk about the homework from the previous session	