Received: 8 June 2023 | Revised: 3 November 2023 | Accepted: 23 November 2023

DOI: 10.1002/ejp.2221

EJP European Journal of Pain

REVIEW ARTICLE

The effect of self-management techniques on relevant outcomes in chronic low back pain: A systematic review and meta-analysis

C. Scholz[1] | **P. Schmigalle**[1] | **C. Y. Plessen**[1] | **G. Liegl**[1] | **P. Vajkoczy**[2] | **F. Prasser**[3] | **M. Rose**[1,4] | **A. Obbarius**[1,5]

[1]Department of Psychosomatic Medicine, Center for Internal Medicine and Dermatology, Charité – Universitätsmedizin Berlin, Berlin, Germany

[2]Department for Neurosurgery with Pediatric Neurosurgery, Center for Neurology, Neurosurgery und Psychiatry, Charité – Universitätsmedizin Berlin, Berlin, Germany

[3]Center of Health Data Sciences, Berlin Institut of Health at Charité – Universitätsmedizin Berlin, Berlin, Germany

[4]Department of Quantitative Health Sciences, Medical School, University of Massachusetts, Boston, Massachusetts, USA

[5]BIH Charité Digital Clinician Scientist Program, Berlin Institute of Health, Charité – Universitätsmedizin Berlin, BIH Biomedical Innovation Academy, Berlin, Germany

Correspondence
P. Schmigalle, Department of Psychosomatic Medicine, Center for Internal Medicine and Dermatology, Charité – Universitätsmedizin Berlin, Charitéplatz 1, 10117 Berlin, Germany.
Email: paul.schmigalle@charite.de

Funding information
Charité - Universitätsmedizin Berlin; Berlin Institute of Health at Charité

Abstract

Background and Objective: Among many treatment approaches for chronic low back pain (CLBP), self-management techniques are becoming increasingly important. The aim of this paper was to (a) provide an overview of existing digital self-help interventions for CLBP and (b) examine the effect of these interventions in reducing pain intensity, pain catastrophizing and pain disability.

Databases and Data Treatment: Following the PRISMA guideline, a systematic literature search was conducted in the MEDLINE, EMBASE, PsychInfo, CINAHL and Cochrane databases. We included randomized controlled trials from the last 10 years that examined the impact of digital self-management interventions on at least one of the three outcomes in adult patients with CLBP (duration ≥3 months). The meta-analysis was based on random-effects models. Standardized tools were used to assess the risk of bias (RoB) for each study and the quality of evidence for each outcome.

Results: We included 12 studies ($n=1545$). A small but robust and statistically significant pooled effect was found on pain intensity ($g=0.24$; 95% CI [0.09, 0.40], $k=12$) and pain disability ($g=0.43$; 95% CI [0.27, 0.59], $k=11$). The effect on pain catastrophizing was not significant ($g=0.38$; 95% CI [−0.31, 1.06], $k=4$). The overall effect size including all three outcomes was $g=0.33$ (95% CI [0.21, 0.44], $k=27$). The RoB of the included studies was mixed. The quality of evidence was moderate or high.

Conclusion: In summary, we were able to substantiate recent evidence that digital self-management interventions are effective in the treatment of CLBP. Given the heterogeneity of interventions, further research should aim to investigate which patients benefit most from which approach.

Significance: This meta-analysis examines the effect of digital self-management techniques in patients with CLBP. The results add to the evidence that digital

C. Scholz and P. Schmigalle—equally contributing first authors.

interventions can help patients reduce their pain intensity and disability. A minority of studies point towards the possibility that digital interventions can reduce pain catastrophizing. Future research should further explore which patients benefit most from these kinds of interventions.

1 | INTRODUCTION

Low back pain is a global health epidemic, which affects about one-third of the global population (Chen et al., 2022), and it is the leading cause of years lived with disability according to the Global Burden of Disease Study (Wu et al., 2020). Disability due to low back pain vastly affects individuals' quality of life including physical, psychological and social functioning, especially when pain has become chronic (Breivik et al., 2013). Besides the personal impact, low back pain's socioeconomic burden is huge. For example, in western countries, the financial burden of back pain is estimated at 1%–2% of the gross national product (Hansson & Hansson, 2005; Wenig et al., 2009). Eighty to ninety per cent of these costs are indirect costs, caused by loss of productivity and disability (Hartvigsen et al., 2018). Accordingly, there is an urgent need to improve the current therapy for patients with chronic low back pain (CLBP) and raise awareness for this global health issue.

A large number of treatment approaches exist for patients with CLBP, and many treatments have proven to be effective in clinical trials (Qaseem et al., 2017). Common approaches include, for example, lifestyle modifications, diet, education, physical therapy, pharmacologic treatments, psychotherapy and in some cases surgery (Foster et al., 2018). According to the American College of Physicians, patients are encouraged to try non-pharmacologic interventions such as self-management techniques as a first choice to treat their CLBP because these therapies are less harmful than pharmacologic options (Qaseem et al., 2017). Self-management refers to the individual's ability to manage the symptoms, treatment, physical and psychological consequences, and lifestyle changes associated with a chronic condition (Barlow et al., 2002).

According to a systematic review and meta-analysis (Du et al., 2017), self-management is effective for CLBP. Specifically, the authors found that self-management programmes had a moderate effect in relieving pain and a small-to-moderate effect in improving disability. However, factors such as distance, time, cost (Borrelli & Ritterband, 2015) and lack of information impede access to self-management programs for many patients (Gliddon et al., 2017).

Since the beginning of the digital age, new opportunities have arisen to establish new technologies for disease management (Borrelli & Ritterband, 2015). E-health describes a healthcare practice supported by information technologies to prevent disease, treat disease, and promote and maintain health status (Borrelli & Ritterband, 2015). If health information is provided via mobile devices, this is also known as m-health (Gliddon et al., 2017). There is the first evidence that e-health-based self-management programs are effective in improving pain intensity and disability in CLBP patients. In a meta-analytical review, the authors found small effects for the improvement of pain intensity and disability immediately after the treatment as well as for short-term outcomes (Foster et al., 2018). In this systematic review, we aim to address the following research questions: (1) What types of digital self-management interventions for adults with CLBP have been studied thus far? (2) What is the effectiveness of these interventions in reducing pain intensity, pain interference/pain disability,[1] and pain catastrophizing? (3) What characteristics define effective interventions? Answering these questions is crucial in developing digital interventions that can be tailored to individual patients with CLBP.

2 | METHODS

The systematic review and meta-analysis were reported based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021).

2.1 | Data sources and search strategy

The search for literature was performed in the databases Cochrane, Embase, Medline, CINAHL & PsychInfo on 23 March 2022. We additionally looked in the International Clinical Trials Registry (ICTRP) from the World Health Organization, to find studies not yet published. The search was limited to the last 10 years.

The search strategy consisted of keywords and Medical Subject Headings (MeSH). In addition, the Cochrane Highly Sensitive Search Strategy for randomized controlled trials (RCTs) was used for our search (Cumpston et al., 2019). As described in the protocol, using Web of Science, citation tracking was performed with the final selection of studies. The search terms are provided in Table 1.

TABLE 1 Search terms for systematic review and meta-analysis.

Category	Search terms
Back pain	back pain (MeSH[a]; ti,ab,kw.[b]) OR Low* Back pain (MeSH[a]; ti,ab,kw.[b]) OR chronic low* back pain (ti,ab,kw.[b]) OR chronic back pain
Self-management	self-management (MeSH[a]; ti,ab,kw.[b]) OR self-care (MeSH[a]; ti,ab,kw.[b]) OR patient ADJ2 education (MeSH[a]; ti,ab,kw.[b]) OR telerehabilitation (ti,ab,kw.[b]) OR coping (ti,ab,kw.[b]) OR skill* (ti,ab,kw.[b]) OR self-help (ti,ab,kw.[b]) OR self-administ* (ti,ab,kw.[b]) OR self-assist* (ti,ab,kw.[b]) OR self-instruct*(ti,ab,kw.[b])
Digital	internet (MeSH[a]; ti,ab,kw.[b]) OR mobile application (MeSH[a]; ti,ab,kw.[b]) OR telemedicine (MeSH[a]; ti,ab,kw.[b]) OR web* (ti,ab,kw.[b]) OR app* (ti,ab,kw.[b]) OR e-health (ti,ab,kw.[b]) OR m-health (ti,ab,kw.[b]) OR digital (ti,ab,kw.[b]) OR internet-based (ti,ab,kw.[b]) OR web-based (ti,ab,kw.[b])
RCT	Cochrane Highly Sensitive Search Strategy

Note: The MeSH terms varied in the different databases. All the search terms marked with MeSH could be found as such in at least one database. If the search term could not be found as a MeSH term, it was only searches in the categories title, abstract and keyword ti,ab,kw. = searched in the categories title (ti), abstract (ab) and keyword (kw).

Abbreviation: RCT, randomized controlled trial.

2.2 | Eligibility criteria

Studies meeting the following criteria were eligible for inclusion:

1. Patients reporting nonspecific CLBP, lasting ≥3 months
2. Age ≥18 years
3. Using a digital intervention (accessible via smartphone/smartwatch/tablet/computer or internet browser) that aims for reducing pain, disability, catastrophizing or pain-related impact on functioning in patients with CLBP
4. Using a self-management technique guided or unguided including psychological and behavioural therapy approaches, patient education, physical activity, physiotherapy, complementary and alternative treatments, interdisciplinary methods and multimodal programs
5. Comparison of intervention with a control group (e.g., waitlist, active control or treatment as usual)
6. Reported outcome at least pain intensity
7. Using a RCT design
8. Study was available as full text in English or German language

Two independent reviewers (C.S. and P.S.) screened all search results by title and abstract. For those studies that were not excluded, the full text was obtained and screened. If there was disagreement between the two reviewers after full-text screening, a third independent reviewer (A.O.) was consulted. The same process was performed for the studies found for citation tracking via Web of Science.

2.3 | Data extraction and management

Two authors (P.S. and C.S.) extracted the data separately using a structured table. After extracting all the data, both authors compared the extracted information and resolved inconsistencies. Extracted data included:

1. title, DOI, short description of the study
2. outcome and sample type, outcome measure, instrument type
3. the type of intervention, type of control group
4. mean and standard deviation of pain intensity before and after treatment
5. mean and standard deviation of pain catastrophizing before and after treatment
6. mean and standard deviation of pain disability before and after treatment
7. follow-up data of pain intensity, pain catastrophizing and pain disability
8. moderators such as format, country, age, percentage of women, duration of treatment and what kind of device supported the intervention (device support)

If the article did not provide data as mean and standard deviation, the given format (e.g., change score and standard error) was extracted and later converted into mean and standard deviation.

In Özden et al. (2022), pain intensity was only described separately for activity and rest periods. Therefore, we chose to use the mean of both values. In the three-armed trial by Irvine et al. (2015), both control groups were combined. Due to the low number of studies that reported follow-up data (only four studies), we decided to refrain from reporting any follow-up data.

2.4 | Risk of bias

The RoB was assessed by two authors individually (P.S. and C.S.). In the case of inconsistent ratings, the domain was rated by a third author (C.Y.P.). We used the RoB tool for randomized trials version 2 (RoB2; Sterne et al., 2019) for the assessment. The tool contains five domains, which can be rated separately as high risk, some concerns or low risk.

- Domain 1: RoB arising from the randomization process
- Domain 2: RoB due to deviations from the intended interventions (effect of assignment to intervention)
- Domain 3: RoB due to missing outcome data
- Domain 4: RoB in measurement of the outcome
- Domain 5: RoB in selection of the reported result

After rating the domains individually, the overall scores were calculated following the RoB2 algorithms.

2.5 | Quality of evidence

To assess the quality of evidence of each effect evaluated in this meta-analysis, we used the Grading of Recommendations Assessment, Development and Evaluation (GRADE) method.

With GRADE, quality of evidence is a evaluated according to the criteria defined by the GRADE Working Group for reviews in the healthcare sector, with the goal of better comparability (Schünemann et al., 2013).

Evaluation criteria include the following dimensions: RoB, inconsistency, indirectness, imprecision and publication bias. The extent of the limitations in each dimension can be rated as 'not serious', 'serious' and 'very serious'. Based on another similar study (Schütze et al., 2018), dimensions were rated based on the following criteria:

1. Risk of bias: less than 25% of the study participants are from studies rated as 'high/unclear RoB' by the RoB2 score.
2. Inconsistency: significant heterogeneity in pooled effect ($I^2 > 50\%$)
3. Indirectness: the interventions are not directly compared; it will not be possible to generalize from the results
4. Imprecision: <400 study participants
5. Publication bias: the funnel plot shows asymmetry and the funding of a large part of the studies to be evaluated is not presented transparently or comes from profit-oriented funding.

2.6 | Meta-analysis

We conducted separate meta-analyses for the outcomes pain intensity, pain catastrophizing, pain disability and one hierarchical meta-analysis for all outcomes combined to reflect the efficacy of the included interventions across all relevant outcomes. We calculated standardized mean differences with a small-study correction (Hedges' *g*) for post-intervention comparisons between interventions and control conditions. If only data on pre-post changes were available, we transformed those effect sizes to Hedges' *g*. For each individual domain, we pooled the effect sizes using random-effects models. The amount of heterogeneity (i.e., τ^2) was evaluated using the restricted maximum-likelihood estimator (Viechtbauer, 2005). In addition to the estimate of τ^2, the *Q*-test for heterogeneity (Cochran, 1954) and the I^2 statistic (Higgins & Thompson, 2002) were reported. In case, any amount of heterogeneity was detected (i.e., $\hat{\tau}^2 > 0$, regardless of the results of the *Q*-test), a prediction interval for the true outcomes was implemented as well (Riley et al., 2011). Tests and confidence intervals were computed using the Knapp and Hartung method (Knapp & Hartung, 2003). To examine whether studies may be outliers studentized residuals and Cook's distances are used (Viechtbauer & Cheung, 2010). Studies with a studentized residual larger than the $100 \times (1 - 0.05/(2 \times k))$ percentile of a standard normal distribution are considered potential outliers (i.e., using a Bonferroni correction with two-sided $\alpha = 0.05$ for k studies included in the meta-analysis). Studies with a Cook's distance larger than the median plus six times the interquartile range of the Cook's distances considered to be influential.

Additionally, we fitted a three-level meta-analysis, nesting the effect sizes of all three outcomes within the included studies to address effect size dependency. We constructed the confidence intervals with both the conventional three-level model (Assink & Wibbelink, 2016) and robust sampling variance estimation (Hedges et al., 2010).

All meta-analyses were carried out using R (version 4.1.2; R Core Team, 2020) and the metafor, meta and metapsyTools packages (Balduzzi et al., 2019; Harrer et al., 2022; Viechtbauer, 2010).

2.7 | Publication bias

The validity of meta-analyses can be compromised by publication bias. Publication bias occurs if negative study results (e.g., RCT without a response of the treatment group) are not published. We use recently suggested methods to control publication bias (Bartoš et al., 2022). We performed precision-effect tests and precision-effect estimates with standard errors (PET-PEESE), selection models and robust Bayesian meta-analysis. In addition, the contour-enhanced funnel plots were inspected. To examine funnel plot asymmetry, the rank correlation test (Begg & Mazumdar, 1994) and the regression test (Sterne & Egger, 2005) were used.

2.8 | Subgroup analysis

In the case of sufficient statistical power, we performed subgroup analyses based on the type of control condition, type of intervention and gender.

2.9 | Disclosure, preregistration and open science

All sample sizes, data exclusions, manipulations and measurements occurring in the analysis were disclosed. The protocol for this meta-analysis containing the search strategy, eligible criteria following the PICO scheme and other information on data extraction, RoB assessment, data synthesis and subgroup analysis was published before the database search on the PROSPERO platform (CRD42022319992). All data necessary for the reproducibility of the analysis will be made available via the Open Science Framework (https://osf.io/vks95/?view_only=07c1fda6c3a44c6d8c4d9e16dd652a10). The data meet the criteria of the FAIR guidelines for scientific data.

3 | RESULTS

3.1 | Search results

The search yielded 1572 results, of which 678 were duplicates. Therefore, titles and abstracts of the remaining 894 records were screened. Of these, 25 were found to be eligible for full-text screening. Eight were assessed as suitable for inclusion in the full-text screening. With these eight studies, we performed citation tracking via Web of Science. Citation tracking identified 10 additional studies, five of which were included after screening the full text.

Seven of 15 full texts were excluded due to inclusion of participants with other diagnoses than CLBP, such as neck pain or fibromyalgia (Baumeister et al., 2021; Darnall et al., 2020; Koppenaal et al., 2022; Malfliet et al., 2018; Sander et al., 2020; Selter et al., 2018; Weymann et al., 2015). Three studies had to be excluded because patients' back pain lasted less than 3 months at the time of recruitment (del Pozo-Cruz et al., 2012; Shebib et al., 2019; Toelle et al., 2019). Two studies did not have an intervention that was regarded as sufficiently digital (face-to-face teaching program taught by a physical therapy course professor, interactive voice programs via telephone; Bianchi et al., 2014; Heapy et al., 2017). One study did not use a randomized controlled study design (Valenzuela-Pascual et al., 2015). Another study had to be excluded because of a measurement scale that was not suitable (Sandal et al., 2021). One study (Riva et al., 2014) would have been suitable for inclusion, because the data provided in the paper was sufficient to calculate the effect sizes. Unfortunately, we were not able to obtain the necessary data from the authors of the study.

The PRISMA flow chart is provided in Figure 1.

3.2 | Description of studies

Table 2 shows a summary of the 12 included studies. The studies included in the meta-analyses were published between 2012 and 2022. Of the 12 included studies seven were conducted in the United States (Amorim et al., 2019; Barone Gibbs et al., 2018; Carpenter et al., 2012; Garcia et al., 2021; Irvine et al., 2015; Krein et al., 2013; Zadro et al., 2019) one was conducted in India (Chhabra et al., 2018), one in Turkey (Özden et al., 2022) and three in China (Yang et al., 2019; Zheng, Liu, et al., 2022; Zheng, Zheng, et al., 2022). All studies, except one, followed a two-armed design with one control group. Irvine et al. compared their intervention with both an active (emails with informative content) and an inactive (treatment as usual) control group. Most studies chose pain intensity and/or pain disability as their primary outcome. Three studies (Garcia et al., 2021; Irvine et al., 2015; Özden et al., 2022) did not define a specific primary outcome. Various secondary outcomes were collected in the studies, most frequently physical activity and self-efficacy. One study assessed pain interference (Garcia et al., 2021), whereas 10 studies assessed pain disability (with RMDQ [Roland-Morris Disability Questionnaire]: Amorim et al., 2019; Carpenter et al., 2012; Krein et al., 2013; Yang et al., 2019; Zadro et al., 2019; Zheng, Liu, et al., 2022; Zheng, Zheng, et al., 2022); with ODI [Owestry Disability Index]: Barone Gibbs et al., 2018; Özden et al., 2022; with MODI [Modified Disability Index]: Chhabra et al., 2018). Four studies assessed pain catastrophizing as an outcome

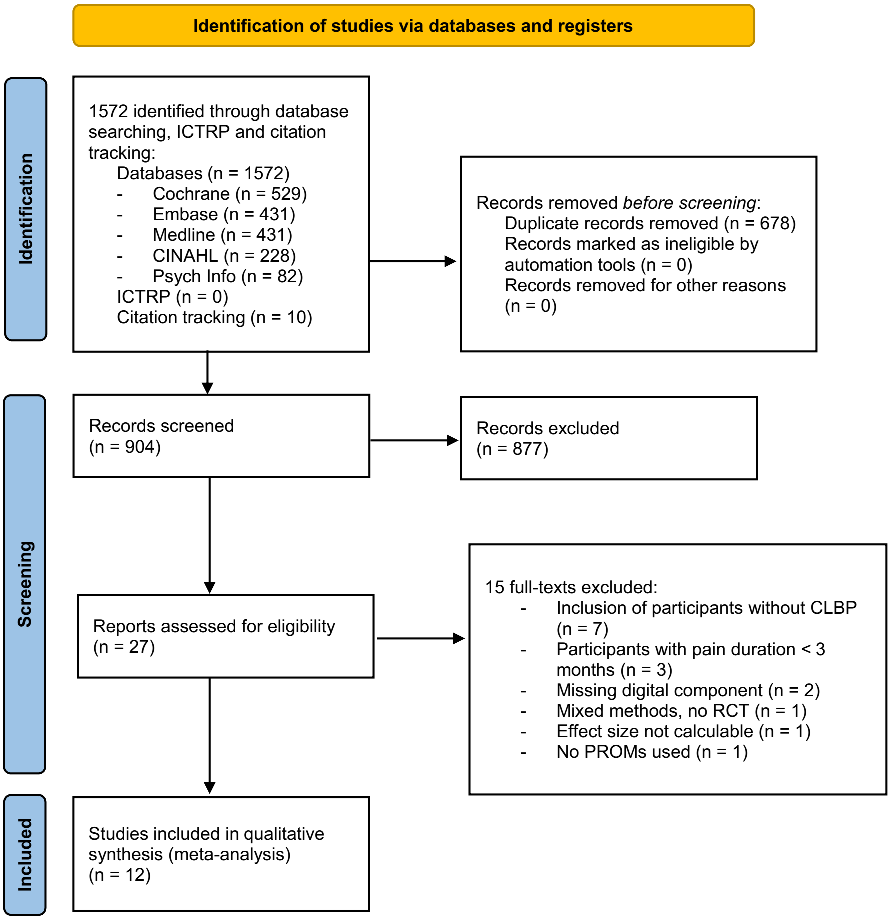

FIGURE 1 Flowchart of the literature search and study selection. CINAHL, Cumulative Index to Nursing and Allied Health Literature; ICTRP, International Clinical Trial Registry Platform; n, number of studies; PROM, patient-reported outcome measures. *Source*: From Page et al. (2021).

(Carpenter et al., 2012; Garcia et al., 2021; Irvine et al., 2015; Zheng, Liu, et al., 2022).

Seven of 12 studies in this meta-analysis examined the efficacy of a self-management intervention that was developed based on cognitive behavioural therapy (CBT) in combination with exercise. Three studies designed a merely exercise-based intervention, and two only provided CBT content to patients in the intervention group. Seven studies used inactive control groups; this included wait-list control or treatment as usual. As described above, Irvine et al. (2015) conducted a three-armed study with active and inactive control groups. The remaining four studies established an active control group, each modifying the actual intervention and making it less detailed and patient-centred. The digital formats were limited to web-based, app-based interventions and virtual programs, such as gaming and virtual reality. The average duration of the interventions was 14 weeks (standard deviation = 14.1). The shortest intervention duration (3 weeks) was used in the study by Carpenter et al. (2012), whereas Krein et al. (2013) used the intervention with the longest duration, which was 48 weeks.

3.3 | Participants

There were 1545 participants studied in total, with trial samples ranging from 8 to 597 people. Two studies were not included in determining the proportion of women because the gender distribution was not stated in the publication (Chhabra et al., 2018) or no distinction was made between the intervention and control group (Carpenter et al., 2012). Therefore, only 1295 participants could be considered for the calculation of the proportion of women. In addition, three studies disclosed only the sex, but not the gender, of the study participants (Carpenter et al., 2012; Zadro et al., 2019; Zheng, Zheng, et al., 2022). The mean age across all study participants was 48.3, the range was 34.5–68.3. Mean age was reported in all studies except for Carpenter et al. (2012), which did not differentiate the age of intervention and control groups, and Irvine et al. (2015), which did not report age at all. Baseline pain intensity scores were available for 11 studies. The mean baseline score was 3.7 (Standard deviation = 2.1) on a 11-point scale (0 = no pain, 10 = maximum pain). Demographic findings of the study population are summarized in Table 3.

TABLE 2 Characteristics of included studies.

First author (year)	Sample size (number)	Gender women (%)	Age (years)	Study duration (weeks)	Intervention	Intervention content	Control group	Control type	Digital format	Primary outcome and instrument
Amorim (2019)	68 (I: 34; C: 34)	50% (I: 44%; C: 56%)	I: 59.5; C: 57.1	24	*CBT* + Exercise	Physical activity booklet and activity tracker, *face-to-face and telephone-based health coaching sessions*, internet-based application	tau	Inactive	App	Care seeking, pain levels (NRS), activity limitation
Barone Gibbs (2018)	27 (I: 13; C: 14)	78% (I: 85%; C: 71%)	I: 52; C: 51	24	*CBT* + Exercise	Sit-stand desk, activity prompter; *behavioural counselling*	wlc	Inactive	App	Pain intensity (VAS) and pain disability via Owestry Disability Index (ODI)
Carpenter (2012)	141(I: 70; C: 71)	83% (no differentiation)	I & C: 42.5	3	*CBT*	*Online Self-help CBT* via *Wellness Workbook*	wlc	Inactive	Web	Survey of Pain Attitudes (SOPA-32)
Chhabra (2018)	93 (I: 45; C: 48)	Not specified	I: 41.4; C: 41.0	12	*CBT* + Exercise	'Snapcare App' with back and aerobic exercises and *motivational, promoting and guiding content* + pain medication prescription	tau	Inactive	App	Pain intensity (NRS) and pain disability via Modified Owestry Disability Index (MODI)
Garcia (2021)	188 (I: 94; C: 94)	77% (I: 75%; C: 78%)	I: 51.5; C: 51.4	8	*CBT*	*Immersive pain relief skills VR program*	sham vr	Active	Virtual	*No specific primary outcome*
Irvine (2015)	597 (I: 199; C1: 199; C2: 199)	60% (I: 58.3%; C1: 58.8%; C2: 62.8%)	Not specified	8	*CBT* + Exercise	Education and behavioural strategies: exercises, *text articles, videos, self-care activities*	tau + ac	Both	App	*No specific primary outcome*
Krein (2013)	229 (I: 111; C: 118)	13% (I: 19.8%; C: 27%)	I: 51.2; C: 51.9	48	*CBT* + Exercise	Pedometer, *website with walking goals, feedback, motivational messages*, e-community	tau	Inactive	Web	Pain-related disability via RDMQ and pain-related function measure from MOS (Medical Outcomes Study)
Özden (2022)	54 (I: 27; C: 27)	60% (I: 56%; C: 64%)	I: 40.1; C: 42.3	8	Exercise	Video-based exercise training (Fizyoweb)	ac	Active	Web	*No specific primary outcome*
Yang (2019)	8 (I: 5; C: 3)	50% (I: 25%; C: 100%)	I: 35; C: 50.33	4	Exercise	Self-management program via app; reminder of exercises & pain diary	ac	Active	App	Pain intensity (VAS), Pain Self-Efficacy Questionnaire (PSEQ), RMDQ, Short Form Health Survey (SF36)
Zadro (2019)	60 (I: 30;C: 30)	52% (I: 30%; C: 21.7%)	I: 68.8; C: 67.8	8	Exercise	'Wii Fit U' flexibility, strengthening and aerobic exercises, fortnightly calls from a physical therapist	tau	Inactive	Virtual	Pain self-efficacy and care-seeking
Zheng (2022)	40 (I: 20;C: 20)	76% (I: 73.7; C:77.8)	I: 31.5; C: 39.2	4	*CBT* + Exercise	m-health-based exercise and *self-compassion training*	ac	Active	App	Roland-Morris Disability Questionnaire (RMDQ) and Pain intensity (NRS)
Zheng (2022)	40 (I: 20; C: 20)	65% (I: 70%; C: 60%)	I: 34; C: 34.9	6	*CBT* + Exercise	m-health-based exercise (via guidance *plus education*)	ac	Active	App	Roland-Morris Disability Questionnaire (RDMQ) and Pain Intensity (NRS)

Abbreviations: ac, active control; CBT, cognitive behavioural therapy; NRS, numeric rating scale; sham vr, sham virtual reality; tau, treatment as usual; VAS, visual analogue scale; wlc, wait-list control.

3.4 | Risk of bias

The RoB assessment shows that the studies included have mixed 'RoB' with a tendency towards 'high RoB'. The results of the quality assessment for RoB through RoB2 are provided in Figure 2.

Four of the studies included show serious RoB. Two studies (Carpenter et al., 2012; Özden et al., 2022) showed bias in domain 2 (Bias due to deviations from intended intervention) and two studies (Zadro et al., 2019; Zheng, Liu, et al., 2022) showed bias in domain 5 (bias in selection of reported results). The poor rating of domain 2 occurred mainly because Carpenter et al. (2012) and Özden et al. (2022) analysis did only include cases that completed the intervention, and the attrition rates of these two studies were greater than 5%. The high-risk scores in domain 5 occurred in both Zadro et al. (2019) and Zheng, Liu, et al. (2022) because there were deviations from the protocol. In both studies outcomes in the final study were modified after creating the protocol.

Most of the studies (Amorim et al., 2019; (Chhabra et al., 2018; Garcia et al., 2021; Krein et al., 2013; Yang et al., 2019) show some concerns in domain 3 (bias due to missing outcome data). Domain 3 was rated with 'some concerns' because one could only suspect that the missing data were depending on the true value. We did not find any RoB for the studies (Barone Gibbs et al., 2018; Irvine et al., 2015; Zheng, Zheng, et al., 2022).

3.5 | Quality of evidence

Because our study did not synthesize results from pharmacological trials, only the quality of evidence assessment and not the strength of recommendation of the GRADE rating was meaningful for this meta-analysis. The quality of evidence of the outcome pain intensity and of the combined outcome was rated as high. The quality of evidence of the outcomes pain disability and pain catastrophizing was rated as moderate because one category in each certainty assessment was rated as serious. In the case of the outcome pain catastrophizing, the inconsistency was rated as serious because I^2 was 78% and thus well exceeded the cut-off >50%. For the outcome pain disability, the RoB

TABLE 3 Characteristics of study participants.

Characteristics	Total sample	Control group	Intervention group
Number of patients—*N*	1545	877	668
Gender/sex female—*N* (%)	698 (54)	414 (55)	284 (52)
Age in years—*M* (SD)	48.3 (12.6)	48.6 (11.6)	49.7 (10.9)
Duration of intervention in weeks—*M* (SD; range)	14 (14.1; 4–48)	14 (14.1; 4–48)	14 (14.1; 4–48)
Baseline pain intensity 11-point numeric rating scale—*M* (SD)	3.7 (2.1)	4.1 (2.2)	3.4 (1.9)

Abbreviations: M, mean; N, number; SD, standard deviation.

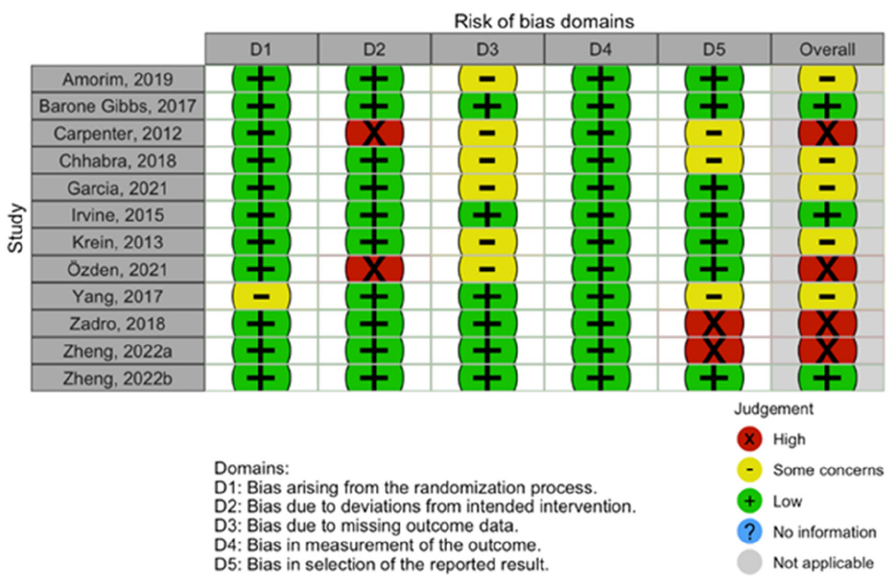

FIGURE 2 Risk of Bias assessment of included studies.

category was rated as serious because 31% (cut-off >25%) of the participants originated from studies that were classified as having high RoB. The GRADE rating results are provided in Table 4.

3.6 | Meta-analysis

3.6.1 | Pain intensity

A total of $k=12$ studies were included in the analysis. The results of the meta-analysis indicate a significant difference between the intervention and control groups, with a pooled summary effect size of Hedges' $g=0.24$, 95% CI [0.09, 0.40], indicating a small effect in favour of the intervention group ($p=0.0052$). The observed standardized mean differences ranged from −0.07 to 0.88, with the majority of estimates being positive (83%). Figure 3 shows the forest plot for the studies observing the pain intensity.

According to the Q-test, the heterogeneity of the true pain intensity outcomes was not significant, $Q(11)=15.05$, $p=0.1800$, $\hat{\tau}^2=0.02$, $I^2=33\%$. The 95% prediction interval for the true outcomes ranges from −0.11 to 0.59. This means that although the average effect was estimated to be positive, the true outcome may actually be negative in some studies.

An examination of the studentized residuals revealed that none of the studies had a value larger than ±2.87, which means that there was no evidence of outliers in this model. According to Cook's intervals, one study (Carpenter et al., 2012) may be overly influential.

3.6.2 | Pain catastrophizing

The results of the meta-analysis on pain catastrophizing based on four studies found a statistically non-significant difference between the intervention and control groups, with a pooled effect size of Hedges' $g=0.38$, 95% CI [−0.31, 1.06], $p=0.1790$. Observed results ranged from −0.00 to 1.04, with three out of four estimates being positive (75%). Figure 4 shows a forest plot with the observed results and the estimate based on the random-effects model.

According to the Q-test, the true outcomes seem to be heterogeneous [$Q(3)=15.89$, $p=0.0012$, $\hat{\tau}^2=0.13$, $I^2=84\%$]. The 95% prediction interval for the true outcomes lies between −1.43 and 2.18. Thus, although the average outcome was estimated to be positive, the true outcome may actually be negative in some studies.

An inspection of the student residuals revealed that none of the studies had a value greater than ±2.5, which means that there was no indication of outliers in this

TABLE 4 GRADE evidence table.

	Certainty assessment							No. of patients		
Outcome	No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other factors	Digital self-management interventions	Control group	Certainty
Pain intensity	12	Randomized controlled trial	Not serious	Not serious	Not serious	Not serious	None	668	877	⊕⊕⊕⊕ High
Pain disability	11	Randomized controlled trial	Serious[a]	Not serious	Not serious	Not serious	None	460	470	⊕⊕⊕◯ Moderate
Pain catastrophizing	4	Randomized controlled trial	Not serious	Serious[b]	Not serious	Not serious	None	383	583	⊕⊕⊕◯ Moderate
Pain outcomes combined	12; $k=27$	Randomized controlled trial	Not serious	Not serious	Not serious	Not serious	None	668	877	⊕⊕⊕⊕ High

[a]31% of participants high risk of bias.

[b]$I^2>50\%$.

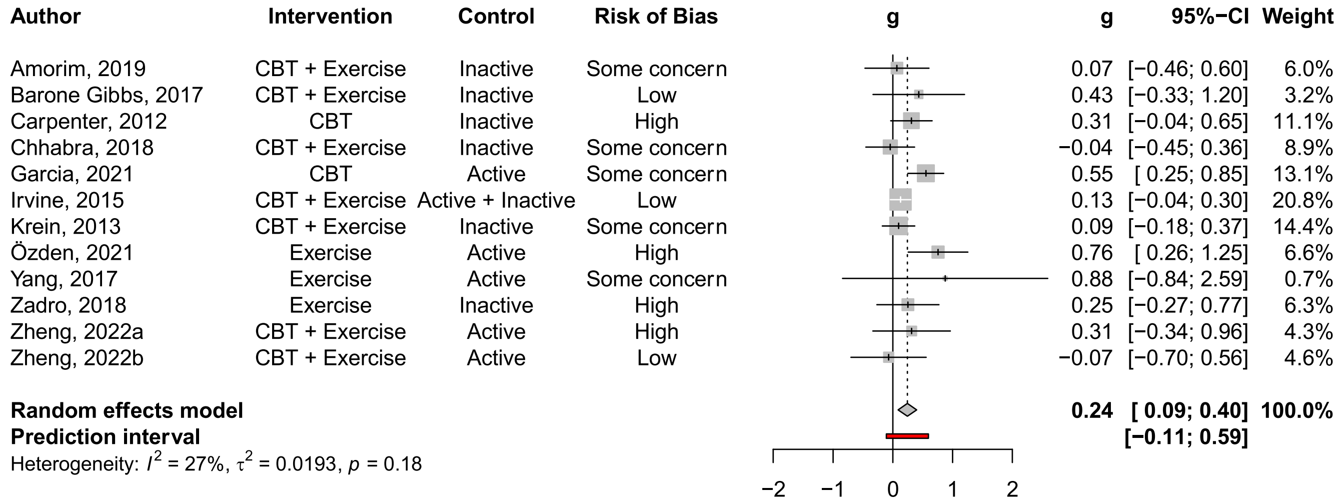

FIGURE 3 Forest plot showing the observed outcomes and the estimate of the random-effects model for pain intensity.

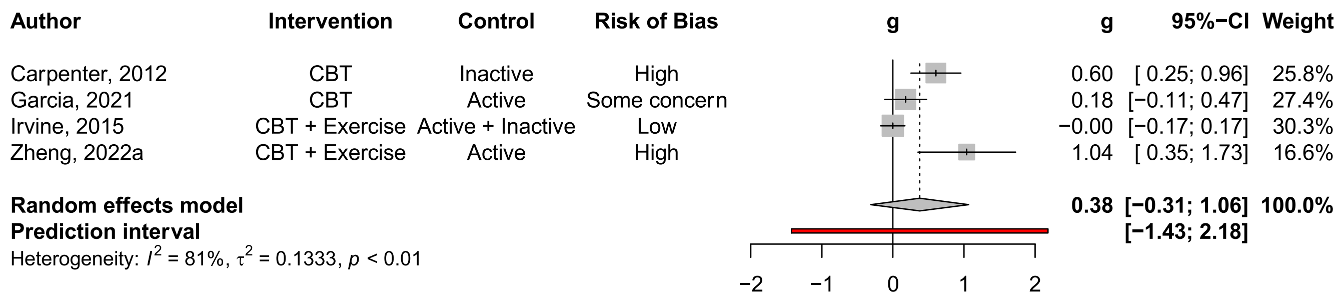

FIGURE 4 Forest plot showing the observed outcomes and the estimate of the random-effects model for pain catastrophizing.

model. According to Cook's distances, none of the studies could be considered overly influential.

3.6.3 | Pain disability

The meta-analysis including 11 studies on pain disability found a significant difference between the intervention and control groups, with a pooled summary effect size of Hedges' $g = 0.43$ 95% CI [0.27, 0.59], indicating a small-to-medium effect in favour of the intervention group ($p = 0.0001$). Observed standardized mean differences ranged from −0.26 to 1.28. Most of the results were positive, with 91% of the estimates having a positive outcome. Figure 5 shows the forest plot for the studies observing the pain disability.

No significant heterogeneity was detected [$Q(10) = 12.31$, $p = 0.2600$, $\hat{\tau}^2 = 0.0000$, $I^2 = 19\%$]. A 95% prediction interval for the true outcomes ranges from 0.28 to 0.57.

One study (Garcia et al., 2021) had a relatively large weight compared with the other studies (i.e., a weight at least three times as large as an equal weight for all studies). An examination of the student residuals revealed that none of the studies had a value greater than ±2.8376. Thus, there was no evidence of outliers in this model. According to Cook's intervals, none of the studies could be considered overly influential.

3.6.4 | Combined outcomes

The results of a three-level meta-analysis, nesting all 27 effect sizes within the 12 included studies for the combination of all three pain outcomes (Figure 6), found a significant difference between the intervention and control groups, with a pooled effect size of Hedges' $g = 0.33$, 95% CI [0.17, 0.49], indicating a small-to-moderate effect in favour of the intervention group ($p < 0.001$). The robust variance estimation yielded similar results with $g = 0.31$, 95% CI [0.14, 0.49]. The observed outcomes for all $k = 27$ effect sizes ranged from −0.26 to 1.28, with the majority of estimates being positive (85%).

According to the Q-test, the true outcomes appear to be heterogeneous [$Q(26) = 52.47$, $p = 0.0016$, $\hat{\tau}^2_{\text{between}} = 0.042$, $\hat{\tau}^2_{\text{within}} = 0.0455$, $I^2 = 50\%$]. The 95% prediction interval for the true outcomes ranged from −0.14 to 0.80, indicating that although the average effect was estimated to be

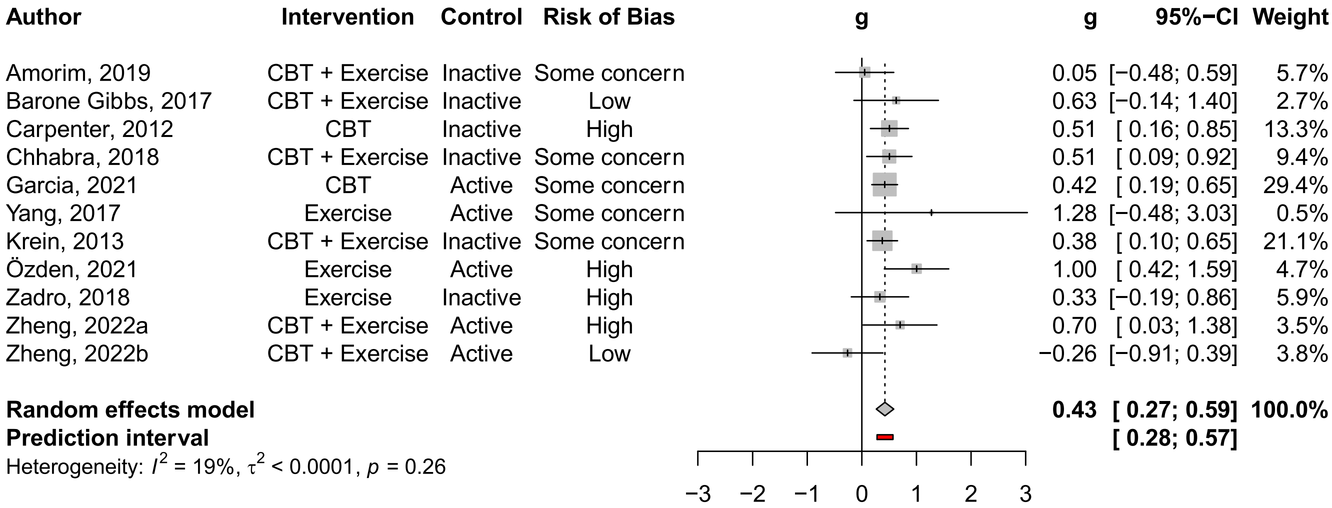

FIGURE 5 Forest plot showing the observed outcomes and the estimate of the random-effects model for pain interference.

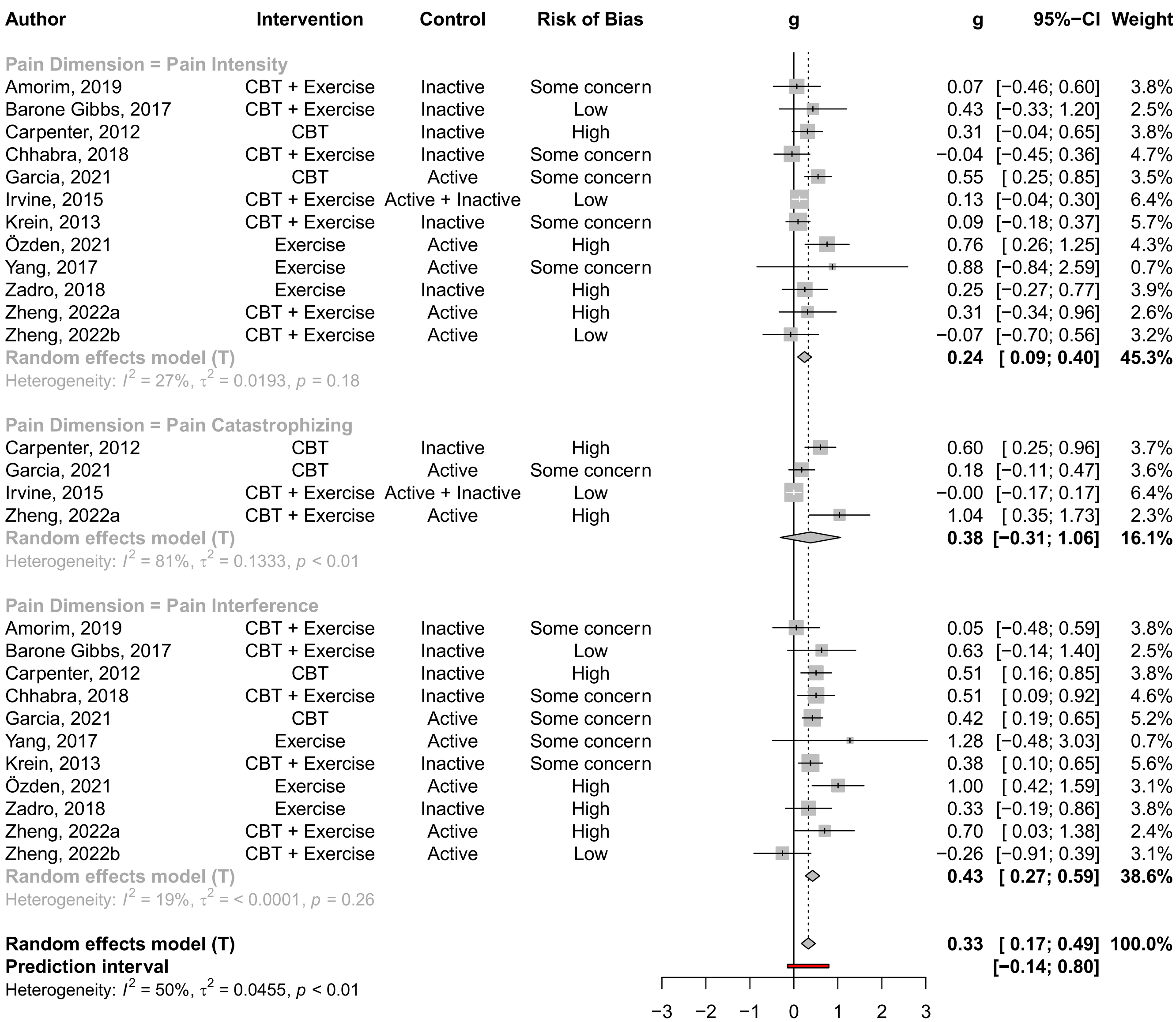

FIGURE 6 Forest plot showing the observed outcomes and the estimate of the three-level model for all pain domains (pain intensity, pain catastrophizing and pain interference).

positive, that the true outcome may be negative in some studies.

An examination of the studentized residuals revealed that none of the studies had a value larger than ±3.11, which means that there was no evidence of outliers in this model. According to Cook's distances, none of the studies could be overly influential.

3.7 | Publication bias

3.7.1 | Funnel plot

Neither the rank correlation nor the regression test indicated asymmetry of any of the funnel plots for the individual pain domains (Figure 7a–d; pain intensity, $p = 0.2496$ and $p = 0.4513$; pain catastrophizing, $p = 0.3333$ and $p = 0.0581$; pain disability: $p = 0.3587$ and $p = 0.6237$; combined outcomes: $p = 0.2132$ and $p = 0.0593$). However, visual inspection of the funnel plots and trim-and-fill analyses for the combined outcomes (Figure 7d) might suggest small-study effects, as small studies were present for positive effects, yet not for negative effects, which were imputed with the trim-and-fill method.

3.7.2 | PET-PEESE

For the combined outcomes, the PET model of PET-PEESE yielded an adjusted effect size estimate of Hedges' $g = 0.02$, 95% CI [−0.30, 0.34].

3.7.3 | Selection model

The step-function selection model with cut points at $p = 0.05$ yielded a non-significant publication bias test $\chi^2(1) = 0.28$, $p = 0.600$, with a corrected Hedges' $g = 0.32$, 95% CI [0.21; 0.43].

3.7.4 | Robust Bayesian meta-analysis

Robust Bayesian meta-analysis found moderate evidence in favour of the publication bias, $BF_{pb} = 3.75$.

3.8 | Subgroup analyses

All planned subgroup analyses did not reach sufficient power and are therefore reported in the Supporting Information only (Tables S1–S6). Due to the insufficient power of the subgroup analyses, unfortunately, we were not able to answer the third review question: 'What characteristics define effective interventions?'

3.9 | Deviations from the protocol

In the protocol, we did use the term 'pain interference' when we were referring to outcomes that reflect the impact of pain on one's functioning in different areas. However, during the literature search, we recognized that most papers used 'pain disability' outcomes, which is a highly similar construct or which can even be regarded as the same construct (Wilson, 2014). Therefore, we chose to combine pain disability and pain interference outcomes for the purposes of this analysis. In addition to the analysis described in the protocol, we also conducted a combined analysis including all three outcomes, which may reflect a better estimate of an 'overall' effect of an intervention on the well-being of patients. Because there was not enough follow-up data available, we did not perform a meta-analysis for this time point. In addition, we did not include subgroup analyses in the paper, due to the lack of statistical significance.

4 | DISCUSSION

We included 12 studies that investigated the efficacy of various digital self-management interventions in 1545 adults with CLBP. The meta-analyses were based on 27 effect sizes for the outcomes pain intensity, pain catastrophizing and pain disability. We found small-to-medium summary effect sizes for reducing pain intensity and pain catastrophizing, as well as improving pain disability, indicating preliminary evidence for the efficacy of digital self-management interventions in adults with CLBP.

When we analysed all effect sizes ($k = 27$) for all pain domains simultaneously (i.e., pain intensity, pain disability and pain catastrophizing), we found a small-to-medium summary effect size, which was robust to outliers, influential studies and different analytical strategies. These findings indicate that patients with CLBP can benefit from self-management interventions in terms of several clinically relevant outcomes. However, if we included only low RoB studies, the summary effect size decreased and was not statistically significant anymore. This finding is probably a result of the limited number of available studies, and it suggests that more high-quality (i.e., low RoB) studies are needed to obtain a more robust conclusion on the efficacy of digital interventions in CLBP.

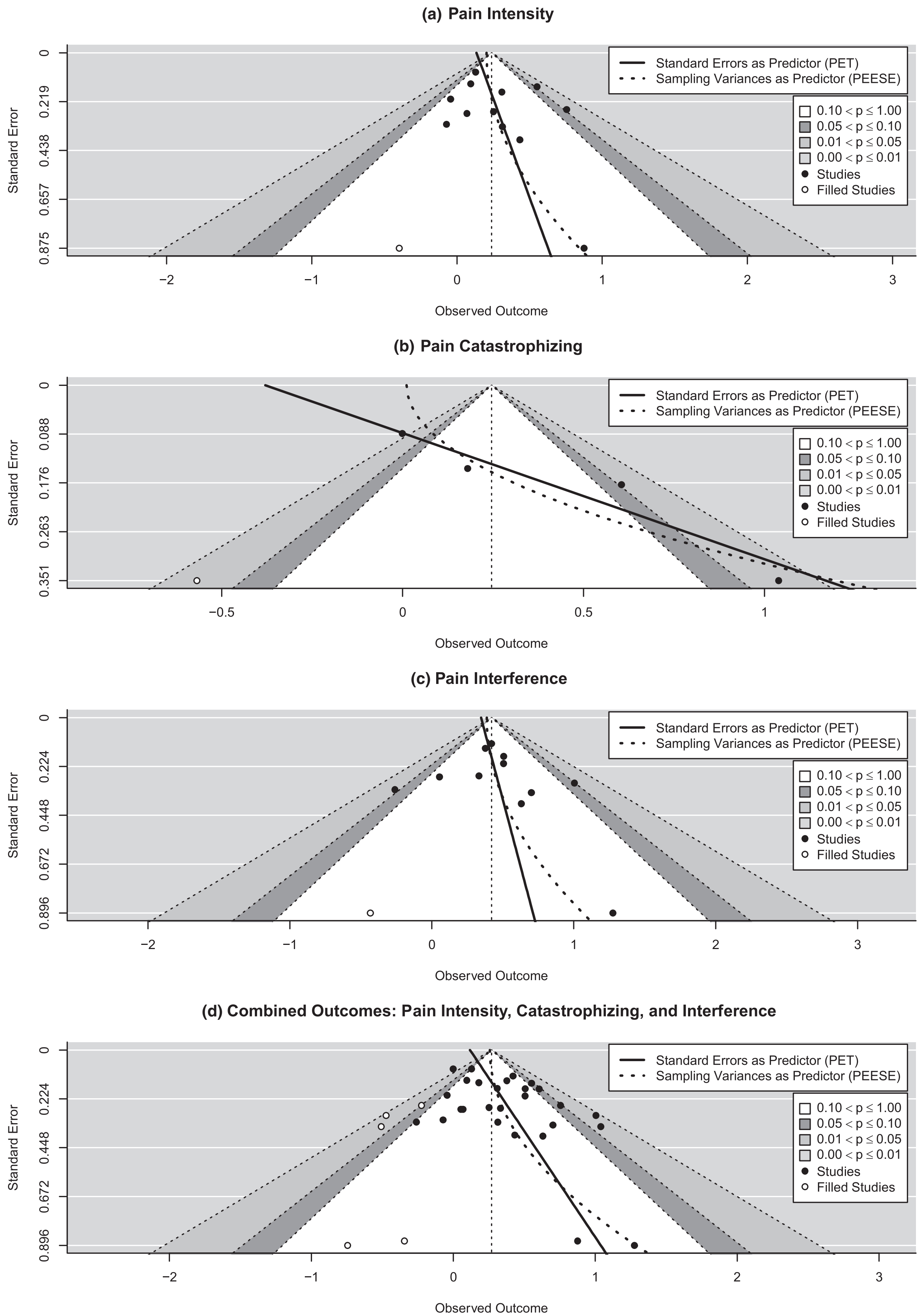

FIGURE 7 (a–d) Funnel plots for pain intensity, pain catastrophizing, pain interference and combined outcomes.

For pain intensity, we found the smallest effect size of all investigated pain domains, which was somewhat surprising given that this was the primary outcome in most of the studies. This small effect size might have been additionally inflated by one study with a disproportionate influence (Garcia et al., 2021; Baujat Plot visualizing the influence can be found in Figure S1). However, after removing the study in the influence analysis the summary effect size did slightly decrease, but was still statistically distinct from zero, showing that the overall finding did not depend solely on this study.

The analysis for the outcome pain disability resulted in larger effect sizes than for pain intensity. We think this is an important finding and may be of clinical relevance. Digitally mediated self-management interventions for CLBP may help patients to cope with their pain. Chronic pain is known to be particularly difficult to treat and reduce in severity (Nilges & Nagel, 2007). Self-management interventions might convey ways to make life easier despite the pain, which may be reflected in the more pronounced improvement in pain-related functioning (i.e., pain disability) compared with pain intensity. With methods like CBT, coaching, motivation and relaxation 'psychosocial factors' of pain such as the influence of higher pain severity on the emotional state, or the dysfunctional cycle between increased catastrophizing and greater pain severity might be treated specifically, which play an important role in the development and maintenance of chronic pain (Nilges & Nagel, 2007).

Furthermore, the effect for pain catastrophizing was not as large as we expected, even though the absolute point estimate for the effect was also larger than for pain intensity. Digital self-management interventions are expected to reduce pain-related thoughts in patients and manage feelings of helplessness if they are in pain (Fritz & Kongsted, 2023). Also, recent evidence suggests that pain catastrophizing is a key outcome in patients with back pain and that it is worth investigating treatment programs that are specifically tailored to reduce catastrophizing (Darnall et al., 2020). However, because only a minority of the included studies assessed pain catastrophizing as an outcome, meta-analytic evidence is yet too small to support the expectation that self-management reduces catastrophizing. Due to recent evidence, pain catastrophizing will likely attract further attention in the field, which will lead to additional evidence on whether self-management interventions are effective for reducing pain catastrophizing (Petrini & Arendt-Nielsen, 2020).

4.1 | Comparison with previous research

Previous meta-analytical research on self-management methods for low back pain has provided similar results like in this study. In summary, regardless of whether self-management programs were provided through digital devices or not, and regardless of whether back pain in participants had already become chronic, summary effect sizes were in the lower to medium range (Du et al., 2011, 2017, 2020; Oliveira et al., 2012). For example, one more recent study investigated the efficacy of e-health in the self-management of CLBP and found similar results for pain intensity and pain disability immediately after the intervention as well as at follow-up time points (Du et al., 2020). In the present paper, however, the amount of follow-up data was insufficient for analysis. The results from the recent meta-analysis (Du et al., 2020) were well suited for a plausibility check of our search results. We found an overlapping amount of five papers that were included in both analyses. Two papers Du et al. included were not included in this paper due to our 10-year search limitation. Another study was not included in this paper because some patients included did not suffer from pain for over 3 months.

Our preliminary findings did not detect major differences between types of interventions. According to a recent meta-analytical review (Schütze et al., 2018), for example, the combination of CBT and exercise works best to improve pain catastrophizing in patients with chronic noncancer pain. The authors conclude, however, that treatment should be individualized to the patient. As it is too soon to tell which patients benefit most from which interventions, this identified gap in evidence should be considered a crucial next step in developing effective treatment options. Digital interventions offer a promising opportunity to tailor treatments to individual patients, for example, through Just-In-Time Adaptive Interventions (JITAIs; Nahum-Shani et al., 2018). JITAIs aim to provide suitable micro-interventions at the best time point and can take other factors into account such as the current location, social context or current symptom severity. The decision on whether a micro-intervention is provided or not can, for example, be based on continuously measured data (e.g., tracking data from a mobile phone) or based on self-reported information that may be collected randomly or at predefined times. Recent evidence points at the effectiveness of JITAIs for a broad range of conditions (Wang & Miller, 2020). We are not aware, however, of such an intervention for patients with pain conditions.

The most recent, but small scoping review on m-health interventions for low back pain patients (Rintala et al., 2022), supports the need for more targeted interventions. However, due to the limited evidence in this field, far more research is needed to investigate whether self-management interventions may be better in some subgroups of patients than in others, especially if they are provided at the right time and dose and in the right situation.

4.2 | Implications for clinical care

As part of the management of patients with low back pain, self-management has great potential. Due to the very large number of patients affected by (chronic) back pain all over the world, it is challenging—or in some parts of the world even not possible—to provide regular face-to-face visits with a healthcare specialist. Thus, easily accessible services are warranted. Digital self-management programs are well suited for this purpose as these programs are usually designed to be used in many places, as long as patients have access to their smartphone or other mobile device. In fact, most (7 of 12 studies) of the self-management programs that we investigated in this study were based on smartphone apps that allow patients to access the self-management information regardless of where they are. Thus, due to favourable properties including accessibility and cost-effectiveness, digital self-management programs are expected to reduce the burden on the healthcare system (Kheirinejad et al., 2023; Stec et al., 2019). Furthermore, digital self-management programs open up opportunities to monitor progress and share data with physicians, contributing to more effective patient care (Didyk et al., 2022).

Given that CLBP is a chronic disease and many patients are affected for life, it is essential to learn how to actively manage their disease (Barlow et al., 2002). Self-management approaches can help patients acquire skills to improve the ability to better manage their disease. A common model suggests that these skills include problem-solving, decision-making, resource utilization, forming of a patient/healthcare provider partnership and taking action (Du et al., 2017; Lorig & Holman, 2003). These and other skills can enhance patients' self-efficacy, a key mechanism that is believed to make self-management effective (Lorig & Holman, 2003). This hypothesis is supported by a large body of evidence suggesting that self-efficacy and changes in self-efficacy are associated with changes in health behaviour and health status (Bandura, 1997).

4.3 | Strengths and limitations

Strengths of this study are that we used a comprehensive search strategy, combining both large databases (MEDLINE, EMBASE and Cochrane), one database for unpublished studies (ICTRP) and subject-specific databases (PsychInfo and CINAHL). We arrived at 12 included studies through our well-defined and strict eligibility criteria. We restricted our search to the last 10 years, as we were mainly interested in interventions developed during a time when internet-based and smartphone-based interventions were emerging due to the digital transformation in health care. Interventions that were previously developed (such as email-based interventions or bibliotherapy) were not in the focus of our investigation. The trend towards digital technology was evident to us as both the interest in and publication of digital interventions for CLBP increased substantially within the last decade.

A limitation of this study may be that 10 of 22 studies that were eligible for full-text screening were obtained through citation tracking. This unexpected ratio could have been resulted from an insufficient search strategy. However, as described above, our complex search strategy has been well considered which is reflected, for example, by using MeSH terms, a wide variety of search terms and the Cochrane Filter for Randomised Controlled Trials. Furthermore, a recent study suggested that the scientific community should reconsider introducing citation tracking as a stand-alone search strategy, as it improves the quality of the search (Hirt et al., 2023).

We applied several methods to control for publication bias to critically assess the validity of our findings. Some methods (funnel plot symmetry, selection model, trim-and-fill method, rank correlation and Egger's regression test) did not detect publication bias while other methods (PET-PEESE and robust Bayesian model) detected publication bias to some extent. Fortunately, in most instances where we adjusted the effect sizes for the presence of small-study effects or publication bias, the adjusted effect sizes remained statistically significant. This overall picture of publication bias assessment does not clearly suggest the inflation of our reported meta-analytical findings—but still is cause for some concern. However, as we included trial registries (such as the Registry Database ICTRP) in our search, it can be assumed we found a substantial portion of existing research—mitigating the risks of publication bias as much as possible.

Overall, the quality of included primary studies was suboptimal. Only three of the 12 studies examined in our RoB2 analysis had a low RoB. However, bias was not found in the most critical domains (randomization process and measurement). When we included only low RoB studies in our meta-analyses, the summary effect sizes were at times substantially decreased, indicating an inflation of effect size estimates due to low-quality studies. This inflation was especially pronounced for pain intensity and pain catastrophizing. Therefore, all results should be carefully considered as preliminary but not as conclusive evidence. This interpretation still holds even when considering the GRADE rating for the quality assessment. While GRADE may suggest a higher quality of evidence than RoB2 based on the percentage of participants from low-risk studies, it may overestimate quality as the majority of included studies in our meta-analysis had a suboptimal RoB rating.

Lastly, the included studies were very heterogeneous and differed greatly in context, digital delivery mode, duration, guidance and settings. This makes it more challenging to draw consistent conclusions for clinical practice. Unfortunately, as the number of available studies was expected to be limited, we did not restrict our search criteria to acquire a more homogeneous sample.

4.4 | Conclusion

Our results point towards a small but relatively robust pooled effect of digital self-management interventions for patients with CLBP. The findings provide preliminary evidence for the efficacy of self-management interventions in improving several key CLBP outcomes, including pain intensity, disability and catastrophizing. The quality of evidence was moderate or high. However, the total number of included studies was limited. Further high-quality studies are needed to replicate and expand our preliminary results, ensure the generalizability in other populations and investigate which patients benefit most from which interventions.

AUTHOR CONTRIBUTIONS

A. Obbarius, M. Rose, P. Vajkoczy and F. Prasser contributed to the study conception and design. C. Scholz, P. Schmigalle, C. Y. Plessen and A. Obbarius contributed to data collection and charting. C. Scholz, P. Schmigalle, C. Y. Plessen and G. Liegl performed the analysis. C. Scholz and P. Schmigalle wrote the first draft of the manuscript. All authors discussed the results and commented on the manuscript and read and approved the final manuscript.

ACKNOWLEDGEMENTS

Dr. Obbarius is a participant in the BIH Charité Digital Clinician Scientist Program funded by Charité—Universitätsmedizin Berlin and the Berlin Institute of Health at Charité (BIH).

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

REGISTRATION

The study was registered on the PROSPERO platform on 22 April 2022, available from: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42022319992.

ORCID

C. Scholz https://orcid.org/0009-0009-1975-7613
P. Schmigalle https://orcid.org/0009-0005-4787-9635
C. Y. Plessen https://orcid.org/0000-0002-4907-3505
G. Liegl https://orcid.org/0000-0001-9073-817X
P. Vajkoczy https://orcid.org/0000-0003-4350-392X
F. Prasser https://orcid.org/0000-0003-3172-3095
M. Rose https://orcid.org/0000-0002-7842-8256
A. Obbarius https://orcid.org/0000-0003-2348-1348

ENDNOTE

[1] Note that pain interference and pain disability outcomes were combined into one outcome because of the highly overlapping constructs (Wilson, 2014). Thus, throughout the article, we refer to pain disability instead of mentioning both.

REFERENCES

Amorim, A. B., Pappas, E., Simic, M., Ferreira, M. L., Jennings, M., Tiedemann, A., Carvalho, E. S. A. P., Caputo, E., Kongsted, A., & Ferreira, P. H. (2019). Integrating mobile-health, health coaching, and physical activity to reduce the burden of chronic low back pain trial (IMPACT): A pilot randomised controlled trial. *BMC Musculoskeletal Disorders*, *20*(1), 71. https://doi.org/10.1186/s12891-019-2454-y

Assink, M., & Wibbelink, C. J. M. (2016). Fitting three-level meta-analytic models in R: A step-by-step tutorial. *The Quantitative Methods for Psychology*, *12*(3), 154–174. https://doi.org/10.20982/tqmp.12.3.p154

Balduzzi, S., Rücker, G., & Schwarzer, G. (2019). How to perform a meta-analysis with R: A practical tutorial. *Evidence-Based Mental Health*, *22*(4), 153–160. https://doi.org/10.1136/ebmental-2019-300117

Bandura, A. (1997). *Self-efficacy: The exercise of control*. W.H. Freeman.

Barlow, J., Wright, C., Sheasby, J., Turner, A., & Hainsworth, J. (2002). Self-management approaches for people with chronic conditions: A review. *Patient Education and Counseling*, *48*(2), 177–187. https://doi.org/10.1016/s0738-3991(02)00032-0

Barone Gibbs, B., Hergenroeder, A. L., Perdomo, S. J., Kowalsky, R. J., Delitto, A., & Jakicic, J. M. (2018). Reducing sedentary behaviour to decrease chronic low back pain: The stand back randomised trial. *Occupational and Environmental Medicine*, *75*(5), 321–327. https://doi.org/10.1136/oemed-2017-104732

Bartoš, F., Maier, M., Quintana, D. S., & Wagenmakers, E.-J. (2022). Adjusting for publication bias in JASP and R: Selection models, PET-PEESE, and robust Bayesian meta-analysis. *Advances in Methods and Practices in Psychological Science*, *5*(3), 9259. https://doi.org/10.1177/25152459221109259

Baumeister, H., Paganini, S., Sander, L. B., Lin, J., Schlicker, S., Terhorst, Y., Moshagen, M., Bengel, J., Lehr, D., & Ebert, D. D. (2021). Effectiveness of a guided internet- and mobile-based intervention for patients with chronic back pain and depression (WARD-BP): A multicenter, pragmatic randomized controlled trial. *Psychotherapy and Psychosomatics*, *90*(4), 255–268. https://doi.org/10.1159/000511881

Begg, C. B., & Mazumdar, M. (1994). Operating characteristics of a rank correlation test for publication bias. *Biometrics*, *50*(4), 1088–1101.

Bianchi, A. B., Meneguetti, L. N., Baladeli, S. M., & Facci, L. M. (2014). Benefits of back school in functional capacity and pain intensity of patients with chronic low back pain. *Manual Therapy, Posturology & Rehabilitation Journal*, *12*, 1–7.

Borrelli, B., & Ritterband, L. M. (2015). Special issue on eHealth and mHealth: Challenges and future directions for assessment, treatment, and dissemination. *Health Psychology*, *34s*, 1205–1208. https://doi.org/10.1037/hea0000323

Breivik, H., Eisenberg, E., & O'Brien, T. (2013). The individual and societal burden of chronic pain in Europe: The case for strategic prioritisation and action to improve knowledge and availability of appropriate care. *BMC Public Health*, *13*, 1229. https://doi.org/10.1186/1471-2458-13-1229

Carpenter, K. M., Stoner, S. A., Mundt, J. M., & Stoelb, B. (2012). An online self-help CBT intervention for chronic lower back pain. *The Clinical Journal of Pain*, *28*(1), 14–22. https://doi.org/10.1097/AJP.0b013e31822363db

Chen, S., Chen, M., Wu, X., Lin, S., Tao, C., Cao, H., Shao, Z., & Xiao, G. (2022). Global, regional and national burden of low back pain 1990–2019: A systematic analysis of the Global Burden of Disease Study 2019. *Journal of Orthopaedic Translation*, *32*, 49–58. https://doi.org/10.1016/j.jot.2021.07.005

Chhabra, H. S., Sharma, S., & Verma, S. (2018). Smartphone app in self-management of chronic low back pain: A randomized controlled trial. *European Spine Journal*, *27*(11), 2862–2874. https://doi.org/10.1007/s00586-018-5788-5

Cochran, W. G. (1954). The combination of estimates from different experiments. *Biometrics*, *10*(1), 101–129. https://doi.org/10.2307/3001666

Cumpston, M., Li, T., Page, M. J., Chandler, J., Welch, V. A., Higgins, J. P., & Thomas, J. (2019). Updated guidance for trusted systematic reviews: A new edition of the Cochrane handbook for systematic reviews of interventions. *Cochrane Database of Systematic Reviews*, *10*, Ed000142. https://doi.org/10.1002/14651858.Ed000142

Darnall, B. D., Krishnamurthy, P., Tsuei, J., & Minor, J. D. (2020). Self-administered skills-based virtual reality intervention for chronic pain: Randomized controlled pilot study. *JMIR Formative Research*, *4*(7), e17293. https://doi.org/10.2196/17293

del Pozo-Cruz, B., Parraca, J. A., del Pozo-Cruz, J., Adsuar, J. C., Hill, J., & Gusi, N. (2012). An occupational, internet-based intervention to prevent chronicity in subacute lower back pain: A randomised controlled trial. *Journal of Rehabilitation Medicine*, *44*(7), 581–587. https://doi.org/10.2340/16501977-0988

Didyk, C., Lewis, L. K., & Lange, B. (2022). Effectiveness of smartphone apps for the self-management of low back pain in adults: A systematic review. *Disability and Rehabilitation*, *44*(25), 7781–7790. https://doi.org/10.1080/09638288.2021.2005161

Du, S., Hu, L., Dong, J., Xu, G., Chen, X., Jin, S., Zhang, H., & Yin, H. (2017). Self-management program for chronic low back pain: A systematic review and meta-analysis. *Patient Education and Counseling*, *100*(1), 37–49. https://doi.org/10.1016/j.pec.2016.07.029

Du, S., Liu, W., Cai, S., Hu, Y., & Dong, J. (2020). The efficacy of e-health in the self-management of chronic low back pain: A meta analysis. *International Journal of Nursing Studies*, *106*, 103507. https://doi.org/10.1016/j.ijnurstu.2019.103507

Du, S., Yuan, C., Xiao, X., Chu, J., Qiu, Y., & Qian, H. (2011). Self-management programs for chronic musculoskeletal pain conditions: A systematic review and meta-analysis. *Patient Education and Counseling*, *85*(3), e299–e310. https://doi.org/10.1016/j.pec.2011.02.021

Foster, N. E., Anema, J. R., Cherkin, D., Chou, R., Cohen, S. P., Gross, D. P., Ferreira, P. H., Fritz, J. M., Koes, B. W., Peul, W., Turner, J. A., & Maher, C. G. (2018). Prevention and treatment of low back pain: Evidence, challenges, and promising directions. *Lancet*, *391*(10137), 2368–2383. https://doi.org/10.1016/s0140-6736(18)30489-6

Fritz, J. M., & Kongsted, A. (2023). A new paradigm for musculoskeletal pain care: Moving beyond structural impairments. Conclusion of a chiropractic and manual therapies thematic series. *Chiropractic & Manual Therapies*, *31*(1), 15. https://doi.org/10.1186/s12998-023-00484-2

Garcia, L. M., Birckhead, B. J., Krishnamurthy, P., Sackman, J., Mackey, I. G., Louis, R. G., Salmasi, V., Maddox, T., & Darnall, B. D. (2021). An 8-week self-administered at-home behavioral skills-based virtual reality program for chronic low back pain: Double-blind, randomized, placebo-controlled trial conducted during COVID-19. *Journal of Medical Internet Research*, *23*(2), e26292. https://doi.org/10.2196/26292

Gliddon, E., Barnes, S. J., Murray, G., & Michalak, E. E. (2017). Online and mobile technologies for self-management in bipolar disorder: A systematic review. *Psychiatric Rehabilitation Journal*, *40*(3), 309–319. https://doi.org/10.1037/prj0000270

Hansson, E. K., & Hansson, T. H. (2005). The costs for persons sick-listed more than one month because of low back or neck problems. A two-year prospective study of Swedish patients. *European Spine Journal*, *14*(4), 337–345. https://doi.org/10.1007/s00586-004-0731-3

Harrer, M., Kuper, P., Sprenger, A., & Cuijpers, P. (2022). *metapsyTools: Several R helper functions for the "Metapsy" database*. https://doi.org/10.5281/zenodo.6566632

Hartvigsen, J., Hancock, M. J., Kongsted, A., Louw, Q., Ferreira, M. L., Genevay, S., Hoy, D., Karppinen, J., Pransky, G., Sieper, J., Smeets, R. J., & Underwood, M. (2018). What low back pain is and why we need to pay attention. *Lancet*, *391*(10137), 2356–2367. https://doi.org/10.1016/s0140-6736(18)30480-x

Heapy, A. A., Higgins, D. M., Goulet, J. L., LaChappelle, K. M., Driscoll, M. A., Czlapinski, R. A., Buta, E., Piette, J. D., Krein, S. L., & Kerns, R. D. (2017). Interactive voice response-based self-management for chronic back pain: The COPES noninferiority randomized trial. *JAMA Internal Medicine*, *177*(6), 765–773. https://doi.org/10.1001/jamainternmed.2017.0223

Hedges, L. V., Tipton, E., & Johnson, M. C. (2010). Robust variance estimation in meta-regression with dependent effect size estimates. *Research Synthesis Methods*, *1*(1), 39–65. https://doi.org/10.1002/jrsm.5

Higgins, J. P. T., & Thompson, S. G. (2002). Quantifying heterogeneity in a meta-analysis. *Statistics in Medicine*, *21*(11), 1539–1558. https://doi.org/10.1002/sim.1186

Hirt, J., Nordhausen, T., Appenzeller-Herzog, C., & Ewald, H. (2023). Citation tracking for systematic literature searching: A scoping review. *Research Synthesis Methods*, *14*(3), 563–579. https://doi.org/10.1002/jrsm.1635

Irvine, A. B., Russell, H., Manocchia, M., Mino, D. E., Cox Glassen, T., Morgan, R., Gau, J. M., Birney, A. J., & Ary, D. V. (2015). Mobile-web app to self-manage low back pain: Randomized controlled trial. *Journal of Medical Internet Research*, *17*(1), e1. https://doi.org/10.2196/jmir.3130

Kheirinejad, S., Visuri, A., Suryanarayana, S. A., & Hosio, S. (2023). Exploring mHealth applications for self-management of chronic low back pain: A survey of features and benefits.

Heliyon, *9*(6), e16586. https://doi.org/10.1016/j.heliyon.2023.e16586

Knapp, G., & Hartung, J. (2003). Improved tests for a random effects meta-regression with a single covariate. *Statistics in Medicine*, *22*(17), 2693–2710. https://doi.org/10.1002/sim.1482

Koppenaal, T., Pisters, M. F., Kloek, C. J., Arensman, R. M., Ostelo, R. W., & Veenhof, C. (2022). The 3-month effectiveness of a stratified blended physiotherapy intervention in patients with nonspecific low back pain: Cluster randomized controlled trial. *Journal of Medical Internet Research*, *24*(2), e31675. https://doi.org/10.2196/31675

Krein, S. L., Kadri, R., Hughes, M., Kerr, E. A., Piette, J. D., Holleman, R., Kim, H. M., & Richardson, C. R. (2013). Pedometer-based internet-mediated intervention for adults with chronic low back pain: Randomized controlled trial. *Journal of Medical Internet Research*, *15*(8), e181. https://doi.org/10.2196/jmir.2605

Lorig, K. R., & Holman, H. (2003). Self-management education: History, definition, outcomes, and mechanisms. *Annals of Behavioral Medicine*, *26*(1), 1–7. https://doi.org/10.1207/s15324796abm2601_01

Malfliet, A., Kregel, J., Meeus, M., Roussel, N., Danneels, L., Cagnie, B., Dolphens, M., & Nijs, J. (2018). Blended-learning pain neuroscience education for people with chronic spinal pain: Randomized controlled multicenter trial. *Physical Therapy*, *98*(5), 357–368. https://doi.org/10.1093/ptj/pzx092

Nahum-Shani, I., Smith, S. N., Spring, B. J., Collins, L. M., Witkiewitz, K., Tewari, A., & Murphy, S. A. (2018). Just-in-time adaptive interventions (JITAIs) in mobile health: Key components and design principles for ongoing health behavior support. *Annals of Behavioral Medicine*, *52*(6), 446–462. https://doi.org/10.1007/s12160-016-9830-8

Nilges, P., & Nagel, B. (2007). Was ist chronischer Schmerz? *DMW-Deutsche Medizinische Wochenschrift*, *132*(41), 2133–2138.

Oliveira, V. C., Ferreira, P. H., Maher, C. G., Pinto, R. Z., Refshauge, K. M., & Ferreira, M. L. (2012). Effectiveness of self-management of low back pain: Systematic review with meta-analysis. *Arthritis Care Res (Hoboken)*, *64*(11), 1739–1748. https://doi.org/10.1002/acr.21737

Özden, F., Sarı, Z., Karaman, Ö. N., & Aydoğmuş, H. (2022). The effect of video exercise-based telerehabilitation on clinical outcomes, expectation, satisfaction, and motivation in patients with chronic low back pain. *Irish Journal of Medical Science*, *191*(3), 1229–1239. https://doi.org/10.1007/s11845-021-02727-8

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ (Clinical Research Ed)*, *372*, n71. https://doi.org/10.1136/bmj.n71

Petrini, L., & Arendt-Nielsen, L. (2020). Understanding pain catastrophizing: Putting pieces together. *Frontiers in Psychology*, *11*, 603420. https://doi.org/10.3389/fpsyg.2020.603420

Qaseem, A., Wilt, T. J., McLean, R. M., Forciea, M. A., Denberg, T. D., Barry, M. J., Boyd, C., Chow, R. D., Fitterman, N., Harris, R. P., Humphrey, L. L., & Vijan, S. (2017). Noninvasive treatments for acute, subacute, and chronic low back pain: A clinical practice guideline from the American College of Physicians. *Annals of Internal Medicine*, *166*(7), 514–530. https://doi.org/10.7326/m16-2367

R Core Team. (2020). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. http://www.r-project.org/

Riley, R. D., Higgins, J. P., & Deeks, J. J. (2011). Interpretation of random effects meta-analyses. *BMJ (Clinical Research Ed)*, *342*, d549. https://doi.org/10.1136/bmj.d549

Rintala, A., Rantalainen, R., Kaksonen, A., Luomajoki, H., & Kauranen, K. (2022). mHealth apps for low Back pain self-management: Scoping review. *JMIR mHealth and uHealth*, *10*(8), e39682. https://doi.org/10.2196/39682

Riva, S., Camerini, A. L., Allam, A., & Schulz, P. J. (2014). Interactive sections of an internet-based intervention increase empowerment of chronic back pain patients: Randomized controlled trial. *Journal of Medical Internet Research*, *16*(8), e180. https://doi.org/10.2196/jmir.3474

Sandal, L. F., Bach, K., Øverås, C. K., Svendsen, M. J., Dalager, T., Stejnicher Drongstrup Jensen, J., Kongsvold, A., Nordstoga, A. L., Bardal, E. M., Ashikhmin, I., Wood, K., Rasmussen, C. D. N., Stochkendahl, M. J., Nicholl, B. I., Wiratunga, N., Cooper, K., Hartvigsen, J., Kjær, P., Sjøgaard, G., & Mork, P. J. (2021). Effectiveness of app-delivered, tailored self-management support for adults with lower Back pain-related disability: A self back randomized clinical trial. *JAMA Internal Medicine*, *181*(10), 1288–1296. https://doi.org/10.1001/jamainternmed.2021.4097

Sander, L. B., Paganini, S., Terhorst, Y., Schlicker, S., Lin, J., Spanhel, K., Buntrock, C., Ebert, D. D., & Baumeister, H. (2020). Effectiveness of a guided web-based self-help intervention to prevent depression in patients with persistent Back pain: The PROD-BP randomized clinical trial. *JAMA Psychiatry*, *77*(10), 1001–1011. https://doi.org/10.1001/jamapsychiatry.2020.1021

Schünemann, H., Broek, J., Guyatt, G., & Oxman, A. (Eds.). (2013). *GRADE handbook for grading quality of evidence and strength of recommendations*. Grade Working Group.

Schütze, R., Rees, C., Smith, A., Slater, H., Campbell, J. M., & O'Sullivan, P. (2018). How can we best reduce pain catastrophizing in adults with chronic noncancer pain? A systematic review and meta-analysis. *The Journal of Pain*, *19*(3), 233–256. https://doi.org/10.1016/j.jpain.2017.09.010

Selter, A., Tsangouri, C., Ali, S. B., Freed, D., Vatchinsky, A., Kizer, J., Sahuguet, A., Vojta, D., Vad, V., Pollak, J. P., & Estrin, D. (2018). An mHealth app for self-management of chronic lower back pain (Limbr): Pilot study. *JMIR mHealth and uHealth*, *6*(9), e179. https://doi.org/10.2196/mhealth.8256

Shebib, R., Bailey, J. F., Smittenaar, P., Perez, D. A., Mecklenburg, G., & Hunter, S. (2019). Randomized controlled trial of a 12-week digital care program in improving low back pain. *npj Digital Medicine*, *2*, 1. https://doi.org/10.1038/s41746-018-0076-7

Stec, M. A., Arbour, M. W., & Hines, H. F. (2019). Client-centered Mobile health care applications: Using the mobile application rating scale instrument for evidence-based evaluation. *Journal of Midwifery & Women's Health*, *64*(3), 324–329. https://doi.org/10.1111/jmwh.12941

Sterne, J. A. C., & Egger, M. (2005). Regression methods to detect publication and other bias in meta-analysis. In H. R. Rothstein, A. J. Sutton, & M. Borenstein (Eds.), *Publication bias in meta-analysis* (pp. 99–110). John Wiley & Sons. https://doi.org/10.1002/0470870168.ch6

Sterne, J. A. C., Savović, J., Page, M. J., Elbers, R. G., Blencowe, N. S., Boutron, I., Cates, C. J., Cheng, H. Y., Corbett, M. S., Eldridge, S. M., Emberson, J. R., Hernán, M. A., Hopewell, S., Hróbjartsson, A., Junqueira, D. R., Jüni, P., Kirkham, J. J., Lasserson, T., Li, T., & Higgins, J. P. T. (2019). RoB 2: A revised tool for assessing risk of bias in randomised trials. *BMJ (Clinical Research Ed)*, *366*, l4898. https://doi.org/10.1136/bmj.l4898

Toelle, T. R., Utpadel-Fischler, D. A., Haas, K.-K., & Priebe, J. A. (2019). App-based multidisciplinary back pain treatment versus combined physiotherapy plus online education: A randomized controlled trial. *npj Digital Medicine*, *2*(1), 34. https://doi.org/10.1038/s41746-019-0109-x

Valenzuela-Pascual, F., Molina, F., Corbi, F., Blanco-Blanco, J., Gil, R. M., & Soler-Gonzalez, J. (2015). The influence of a biopsychosocial educational internet-based intervention on pain, dysfunction, quality of life, and pain cognition in chronic low back pain patients in primary care: A mixed methods approach. *BMC Medical Informatics and Decision Making*, *15*, 97. https://doi.org/10.1186/s12911-015-0220-0

Viechtbauer, W. (2005). Bias and efficiency of meta-analytic variance estimators in the random-effects model. *Journal of Educational and Behavioral Statistics*, *30*(3), 261–293. https://doi.org/10.3102/10769986030003261

Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. *Journal of Statistical Software*, *36*(3), 1–48. https://doi.org/10.18637/jss.v036.i03

Viechtbauer, W., & Cheung, M. W. (2010). Outlier and influence diagnostics for meta-analysis. *Research Synthesis Methods*, *1*(2), 112–125. https://doi.org/10.1002/jrsm.11

Wang, L., & Miller, L. C. (2020). Just-in-the-moment adaptive interventions (JITAI): A meta-analytical review. *Health Communication*, *35*(12), 1531–1544. https://doi.org/10.1080/10410236.2019.1652388

Wenig, C. M., Schmidt, C. O., Kohlmann, T., & Schweikert, B. (2009). Costs of back pain in Germany. *European Journal of Pain*, *13*(3), 280–286. https://doi.org/10.1016/j.ejpain.2008.04.005

Weymann, N., Dirmaier, J., von Wolff, A., Kriston, L., & Härter, M. (2015). Effectiveness of a web-based tailored interactive health communication application for patients with type 2 diabetes or chronic low back pain: Randomized controlled trial. *Journal of Medical Internet Research*, *17*(3), e53. https://doi.org/10.2196/jmir.3904

Wilson, M. (2014). Integrating the concept of pain interference into pain management. *Pain Management Nursing*, *15*(2), 499–505. https://doi.org/10.1016/j.pmn.2011.06.004

Wu, A., March, L., Zheng, X., Huang, J., Wang, X., Zhao, J., Blyth, F. M., Smith, E., Buchbinder, R., & Hoy, D. (2020). Global low back pain prevalence and years lived with disability from 1990 to 2017: Estimates from the Global Burden of Disease Study 2017. *Annals of Translational Medicine*, *8*(6), 299. https://doi.org/10.21037/atm.2020.02.175

Yang, J., Wei, Q., Ge, Y., Meng, L., & Zhao, M. (2019). Smartphone-based remote self-management of chronic low back pain: A preliminary study. *Journal of Healthcare Engineering*, *2019*, 4632946. https://doi.org/10.1155/2019/4632946

Zadro, J. R., Shirley, D., Simic, M., Mousavi, S. J., Ceprnja, D., Maka, K., Sung, J., & Ferreira, P. (2019). Video-game-based exercises for older people with chronic low back pain: A randomized controlled table trial (GAMEBACK). *Physical Therapy*, *99*(1), 14–27. https://doi.org/10.1093/ptj/pzy112

Zheng, F., Liu, S., Zhang, S., Yu, Q., Lo, W. L. A., Li, T., & Wang, C. H. (2022). Does m-health-based exercise (guidance plus education) improve efficacy in patients with chronic low-back pain? A preliminary report on the intervention's significance. *Trials*, *23*(1), 190. https://doi.org/10.1186/s13063-022-06116-z

Zheng, F., Zheng, Y., Liu, S., Yang, J., Xiao, W., Xiao, W., Chen, L., Yang, W., Zhang, S., Yu, Q., Hao, Z., Wang, Y., & Wang, C. (2022). The effect of M-health-based core stability exercise combined with self-compassion training for patients with non-specific chronic low back pain: A randomized controlled pilot study. *Pain and Therapy*, *11*(2), 511–528. https://doi.org/10.1007/s40122-022-00358-0

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Scholz, C., Schmigalle, P., Plessen, C. Y., Liegl, G., Vajkoczy, P., Prasser, F., Rose, M., & Obbarius, A. (2023). The effect of self-management techniques on relevant outcomes in chronic low back pain: A systematic review and meta-analysis. *European Journal of Pain*, *00*, 1–19. https://doi.org/10.1002/ejp.2221