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SPINE

# Virtual reality-based therapy for chronic low back and neck pain: a systematic review with meta-analysis

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- *Purpose:* To compile all the scientific evidence available to date to evaluate the effect of virtual reality based therapy (VRBT) on reducing pain intensity, kinesiophobia, and associated disability, and on increasing the hr-QoL in patients with chronic neck pain (CNP) or chronic low back pain (CLBP).
- *Methods:* Studies published in PubMed Medline, SCOPUS, Web of Science, CINAHL Complete, and Physiotherapy Evidence Database (PEDro) up to June 2023 were searched. All searches followed the PICOS Framework. Two authors independently screened the studies found in the searches. Any differences of opinion regarding the selection of studies were settled by a third author.
- *Results:* Twenty-five RCTs, published between 2013 and 2022, providing data from 1261 patients (20 RCTs) with CLBP and 261 patients (five RCTs) with CNP, were included. In reducing pain intensity for patients with CLBP, meta-analyses showed that VRBT is effective in reducing pain just to the end of the intervention, and this effect could be maintained 1 and 6 months after the therapy.
- *Conclusion:* VRBT was found to be better than therapeutic exercise (TE), sham, and no intervention (NI), showing a major effect when VRBT was used as a complementary therapy to conventional physiotherapy (CPT). Further, VRBT showed an immediate effect and immersive VRBT was the most adequate VRBT modality in reducing pain in CNP patients. No differences were found between non-immersive VRBT and immersive VRBT in reducing pain, kinesiophobia, disability, and hr-QoL in patients with CLBP.

Keywords: chronic low back pain; chronic neck pain; virtual reality-based therapy; kinesiophobia; disability; health related-quality of life

## Introduction

According to the International Association for the Study of Pain (IASP), pain is defined as 'an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage' (1). Chronic pain is pain that persists for more than 3 months, even if the injury has healed. Musculoskeletal pain is one of the most prevalent causes of chronic pain worldwide, characterized by discomfort in the muscles, tendons, ligaments, and bones. The back is one of the musculoskeletal areas

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most affected by chronic pain. Chronic neck pain (CNP) and chronic low back pain (CLBP) are considered the leading causes of musculoskeletal disability worldwide (2, 3), and their symptoms tend to be recurrent and persist over time. CLBP is the leading cause of years lived with disability (YLD) (4) worldwide and in Spain (5). About 50–70% of people will suffer back pain during their lifetime (6), 50% of whom will experience CNP (7), and 60–70% will present with CLBP (8). CNP is more prevalent in women (9), whereas in cases of CLBP, no significant differences are observed between men and women (10). Patients with CNP and CLBP feel reduced functional capability to perform basic, ordinary, family, or social daily living activities (DLAs), thus decreasing their health-related quality of life (hr-QoL) and work productivity (11, 12, 13, 14). This results in a high socio-economic cost to health services, such as in the United States where $134.5 billion is spent on CNP and CLBP management (15).

The most prevalent conservative therapeutic approaches used for CNP and CLBP are pharmacotherapy and physiotherapy. In terms of drug therapies, non-steroidal anti-inflammatory drugs and opioids are the most widely used to reduce the intensity of pain in these patients (16, 17), although they have been found to cause alterations in sleep and in the gastrointestinal (18), cardiovascular, and physical functioning of patients (19, 20). Physiotherapy encompasses a set of passive (such as massage, dry needling, or electrotherapy, among others) and active procedures (such as therapeutic exercise) that are used to reduce the disability associated with CNP and CLBP. However, patients who receive any type of physiotherapy frequently report kinesiophobia, the presence of post-therapy musculoskeletal pain, a lack of motivation, or the repetitive nature of their treatment. These can hinder adherence to treatment (21, 22, 23), which is a key factor in achieving training-induced hypoalgesia (24).

Virtual reality-based therapy (VRTV) is a complementary therapeutic tool that could increase motivation and adherence to conventional physiotherapy programs and could be a therapeutic option to add to physiotherapy programs. There has been an increase in the creation and use of virtual reality hardware and software in physical rehabilitation, which has shown to be effective in pathologies such as total knee arthroplasty (25), total hip arthroplasty (26), or fibromyalgia (27). VR headsets enable the recreation and motor interaction with immersive or semi-immersive experiences and objects that subjects consider to be similar to real ones. The two most important characteristics of VR headsets are presence, defined as the perception of being in a virtual location; and immersion, which is the ability to interact with the virtual environment (28). Depending on the headset, VRBT can be immersive, semi-immersive, or non-immersive (29). Immersive VR devices (iVR) use head-mounted displays to visualize 360° virtual environments in which the subject has the possibility to interact with the virtual scenario using controllers or their hands (30). On the other hand, non-immersive VR devices (niVR) reduce the level of presence and immersion, as virtual scenarios are displayed on 2D screens and do not interact directly with the subjects (31). However, although VRBT is well accepted by the general population for therapeutic use, it is not exempt from side effects (32); one of the main ones is cybersickness, caused by a discordance between visual and vestibular information in the real and virtual world, resulting in sensorimotor discordance and feelings of dizziness and nausea (33).

In recent years, several reviews (34, 35, 36, 37, 38) have analyzed the efficacy of VRBT for the treatment of CNP and CLBP, demonstrating promising results in relation to pain and associated disability. However, a new review is needed in light of the growing scientific literature published recently and due to the uncertainty as to whether the effect of VRBT is maintained over time and as to which VRBT modality is the most effective (iVR or niVR) for each chronic condition. Therefore, the objective of our review is to compile all the scientific evidence available to date to evaluate the effect of VRBT on reducing pain intensity, kinesiophobia, and associated disability, and on increasing the hr-QoL in patients with CNP or CLBP. The secondary objectives are: (1) to evaluate whether the effect of VRBT is maintained 1 and 6 months after the end of the intervention; (2) to understand which VRBT modality is most appropriate for each variable; and (3) to specifically analyze the effect of VRBT versus other therapies, such as therapeutic exercise, conventional physiotherapy, a placebo, or no intervention.

# Methods

## Study design

This systematic review with meta-analysis was carried out following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020 version) (39) and the Cochrane Handbook for Systematic Reviews of Interventions (40). The protocol of this review was previously registered in PROSPERO.

## Search strategy

The literature search was carried out by two authors (JMHJ and ICP), who independently searched for studies published in PubMed Medline, SCOPUS, Web of Science (WOS), CINAHL Complete, and Physiotherapy Evidence Database (PEDro) up to June 2023. To complete the search, the reference lists of previously published studies, abstracts, grey literature, and document excerpts were analyzed. All searches followed the PICOS framework (41): population (patients with CNP or CLBP), intervention (VRBT), comparators (other therapies, sham, or no-intervention), outcomes (pain intensity,

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kinesiophobia, associated disability, and hr-QoL), and study design (randomized controlled trials (RCTs) or pilot RCTs). The main keywords used in the search strategy corresponded to Medline Medical Subject Headings (MeSH): 'neck pain', 'low back pain', 'virtual reality', and 'virtual reality-exposure therapy'. Boolean operators 'AND'/'OR' were used to join and create the search strategies for each database (Supplementary Table 1, see section on supplementary materials given at the end of this article). Filters related to language, publication date, and free full-text access were not set in our search strategy.

## Eligibility criteria and study selection

Two authors (JMHJ and ICP) independently screened the studies found in the searches. Any differences of opinion regarding the selection of studies were settled by a third author (EOG).

The included studies met all the following PICOS inclusion criteria: (1) population and study design, RCT or pilot RCT involving patients with CNP or CLBP; (2) intervention group that received VRBT; (3) comparator group that carried out an alternative therapy to VRBT, a sham treatment, or no intervention; (4) outcomes: studies that provided statistical data that could be included in the meta-analysis (mean and standard deviation) on pain intensity, kinesiophobia, associated disability, or hr-QoL. The exclusion criterion was studies in which patients with CNP and CLBP were joined in the same group.

## Data extraction

Two authors (MCOP and MCLR) independently extracted data from the studies that met the inclusion criteria using a standardized Microsoft Excel data collection, and differences settled by consulting a third author (ICP).

The following data were collected from the included studies: (1) general characteristics of each study (authorship, publication date, country, funding received, study design, and blinding). (2) Characteristics of the participants from each group (total sample size, number of participants in each group, age, sex, and time with pain). (3) Characteristics of the VRBT intervention (type of VRBT employed, number of sessions received, number of weeks, times per week, and duration of each session in minutes). (4) Characteristics of the comparison group (type of therapy employed). (5) Data from the outcomes (type of variable assessed, instrument used to assess it, point in time of the assessment, and quantitative data reported). Quantitative data of the outcomes used to perform the meta-analysis were sample size and mean and standard deviation of each outcome in each group. When a study provided the standard error, the range, or interquartile range from non-skewed distributions, it was transformed into a standard deviation value (40, 42).

## Variables

The variables analyzed in this study were pain intensity (subjective perception of discomfort from the neck and lower back area), kinesiophobia (anxiety and fear of movement following an injury), associated disability (impact of CNP and CLBP on functional capability during DLAs), and hr-QoL (subjective evaluation of the influence of health status (43)).

## Risk of bias and quality of evidence

The evaluation of the risk of bias and the quality of the evidence was carried out by two authors (HGL and RLV), and any discrepancies were resolved by a third author (MCLR).

On the one hand, the risk of bias and methodological quality of the studies included were assessed using the PEDro Scale (44). The PEDro scale has shown high reliability and validity in assessing methodological quality in RCTs (45), which, according to PEDro scores, can be high (10–9 points), good (8–6 points), moderate (5–4 points), and poor (>3 points). On the other hand, the quality of the evidence of findings from the meta-analyses was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) tool (46), and Meader's GRADE checklist (47). The quality of evidence is determined by five items: the risk of bias in individual studies, inconsistency, indirect evidence, imprecision, and risk of publication bias. Combining these items allowed for the presentation of findings with four different levels of evidence: high (if findings are robust), moderate (when a future study can change the current findings), low (the level of confidence is low), and very low (findings are uncertain). If one of the items did not meet the level of evidence, it was downgraded by one level.

## Statistical analysis

The meta-analysis was carried out by two expert authors (EOG and ICP) using the 4.0 version of the Comprehensive Meta-Analysis software (48). The effect size was calculated using the standardized mean difference (SMD) and its 95% CI. The random-effects model was used when fixed-effects model heterogeneity was greater than 40%, with the aim of guaranteeing the generalization of our findings (49). According to Kinney *et al.*, effect sizes in rehabilitation research can be categorized as small (0.08–0.15), medium (0.19–0.36), or large (0.41–0.67) (50). The results of each meta-analysis were graphically represented in forest plots (51). The risk of publication bias was assessed through the visualization of the funnel plot (52) and the *P*-value of the Egger test (53). Additionally, we estimated the adjusted effect size taking into account the presence of publication bias using the trim-and-fill method (54, 55), which shows if the publication bias in the original effect can under or overestimate the true pooled effect.

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Variations >10% between the original and the adjusted effect size indicate a possible risk of publication bias, thus downgrading the quality of evidence one level even though the funnel plot was asymmetric (56). To assess the level of heterogeneity, we took into account the *P*-value for the *Q*-test ($P < 0.1$ indicates heterogeneity) and the Higgins' degree of inconsistency ($I^2$): null ($I^2$: 0), low ($I^2$: <25%), moderate ($I^2$: 25–50%), or large heterogeneity ($I^2$: > 50%) (57, 58).

To assess the contribution of each study to the global effect, we performed a sensitivity analysis (leave-one-out method). In addition, we conducted some subgroup analyses. First, when possible, we assessed the effect of VRBT on each variable 1 and 6 months after finishing the intervention, in order to assess if the effect would be maintained over time. Secondly, we assessed the effectiveness of each VRBT modality separately (iVR or niVR). Finally, we analyzed the effect of VRBT based on comparisons made in the included RCTs: VRBT versus therapeutic exercise (TE), VRBT + conventional physiotherapy (CPT) versus CPT, VRBT versus sham, and VRBT versus no intervention (NI).

# Results

## Literature search and screening

The PRISMA flow diagram shows the eligibility process of the included articles (Fig. 1). In total, 2163 records were identified. Nine hundred and forty-four records were excluded for being duplicates, and 799 articles were deleted for not being relevant. Additionally, 395 articles were excluded for not meeting the inclusion criteria (Fig. 1). Finally, 25 RCTs were included in this systematic review with meta-analysis (59, 60, 61, 62, 63, 64, 65, 66, 68, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83).

## Characteristics of eligible studies

All RCTs included in this review were carried out between 2013 and 2022, reporting data on 1522 participants: 1261 patients with CLBP (59, 61, 62, 63, 64, 65, 66, 68, 68, 69, 70, 71, 72, 74, 77, 78, 79, 81, 82, 83) (mean age of 49.1 ± 16.2 years old; 482 men (38.22%) and 779 women; mean symptom duration 4.6 ± 5.6 years) and 261 patients with CNP (60, 73, 75, 76, 80) (mean age of 38.9 ± 9.5 years old; 113 men (39.37%) and 148 women; mean symptom duration 1.9 years). The experimental intervention was applied to 617 people with CLBP and 112 with CNP. For patients with CLBP, seven RCTs used the iVR modality and 13 used niVR; and for CNP, iVR was applied in four studies and niVR in one. In 20 studies, VRBT was used as the sole therapy, while in five studies it was used in combination with TE and CPT. In the control group, participants received TE, CPT, and sham treatment, or did not receive any intervention (being instructed to continue their DLAs). The duration of VRBT ranged from 4 to 8 weeks, and the duration of each session ranged from 4 to 60 min. Twenty-four patients

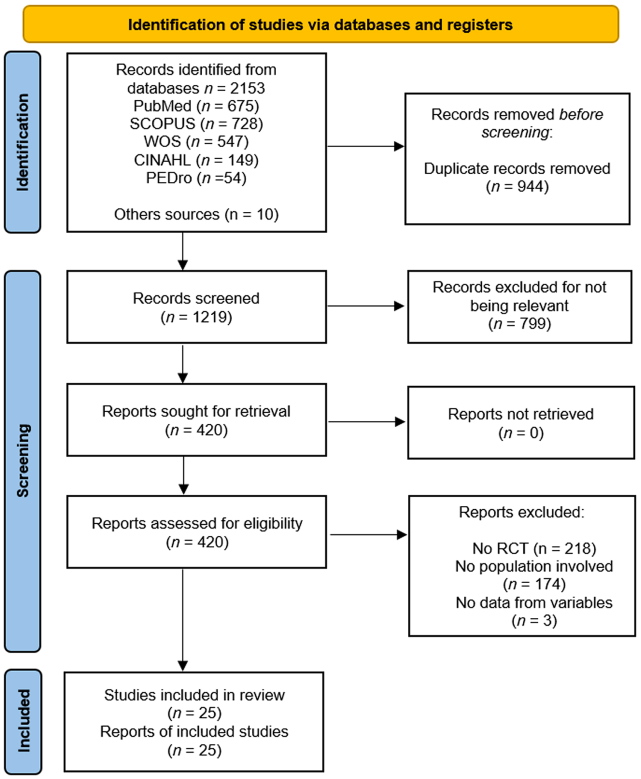


**Figure 1**

PRISMA flow diagram.

reported data of post-immediate assessment (19 for CLBP and five for CNP); specifically, for CLBP, three RCTs provided follow-up data at 1 month and five RCTs at 6 months, and for CNP, two RCTs provided follow-up data at 1 month. Supplementary Table 2 shows the characteristics of the studies included.

## Outcome measures

Pain intensity was assessed with data from the following tests: Visual Analogue Scale for pain, Numeric Rating Scale, and Defense and Veterans Pain Rating Scale. Kinesiophobia was assessed using data using the Tampa Scale for Kinesiophobia. Low back disability was assessed using data from Modified Oswestry Disability Index, Oswestry Disability Index, and Roland Morris Disability Questionnaire), while cervical disability was assessed using Neck Disability Index and ProFitMap-Neck. Finally, hr-QoL was assessed with data using the SF-36, SF-12, European Quality of Life Five-Dimension Scale, RAND-36, Ankylosing spondylitis Quality of Life questionnaire, and Physical Fitness Index.

## Study quality and risk of bias

The average score according to the PEDro scale was 6.16 ± 1.3 points, demonstrating moderate-to-good methodological quality and moderate risk of bias. Two studies presented high methodological quality and very low risk of bias (63, 64), 14 good quality and low

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risk of bias (61, 62, 65, 68, 69, 70, 71, 72, 73, 75, 76, 80, 82, 83), and 9 moderate quality and medium risk of bias (59, 60, 66, 68, 74, 77, 78, 79, 81). The impossibility of blinding the participants and the therapist were the items with the highest risk of bias in the selected studies (affecting performance and detection biases). The hidden allocation item was not met in repeated studies, indicating a risk of selection bias. Table 1 shows the evaluation of the methodological quality of the studies included in this review using the PEDro scale.

## Synthesis of results

Table 2 shows the main findings from the meta-analysis for each variable and the quality of the evidence. Supplementary Table 3 shows the main findings from subgroup analyses.

### Pain intensity

#### Chronic low back pain

With data from 19 RCTs (59, 61, 62, 63, 65, 66, 68, 68, 69, 70, 71, 72, 74, 77, 78, 79, 81, 82, 83, 84) (1415 subjects), our results showed a large immediate effect (SMD = −1.27, 95% CI: −1.45 to −0.8, $P < 0.001$) in favor of VRBT (Fig. 2). Trim-and-fill estimation showed the risk of publication bias, indicating that the original effect could be underestimated (adjusted SMD = −1.6, 25% of variation) (Supplementary Figure 1). Heterogeneity was high ($I^2 = 63.9\%$; $Q = 66.5$; $df = 24$; $P = 0.87$). Sensitivity analysis showed a contribution similar to that of the studies in the overall effect.

In relation to follow-up, the effect of VRBT was maintained both at 1 month (SMD = −1.14; 95% CI: −1.41 to −0.87; $P < 0.001$) and at 6 months after completing the intervention (SMD = −1.44; 95% CI: −1.7 to −1.18; $P < 0.001$). In addition, VRBT was superior to TE (SMD = −1.05; 95% CI: −1.27 to −0.82; $P < 0.001$), sham (SMD = −0.83; 95% CI: −1.03 to −0.62; $P < 0.001$), and NI (SMD = −0.5; 95% CI: −0.76 to −0. 22; $P = 0.003$), and the largest effect of VRBT was found when combined with CPT, instead of CPT alone (SMD = −2; 95% CI: −2.45 to −1.55; $P < 0.001$). Besides, no differences were found between iVR (SMD = −0.78; 95% CI: −0.96 to −0.6; $P = 0.001$) and niVR (SMD = −0.98; 95% CI: −1.15 to −0.81, $P < 0.001$).

#### Chronic neck pain

With data from five RCTs (60, 73, 75, 76, 80) (417 subjects) our meta-analysis showed a large immediate effect (SMD = −0.45, 95% CI: −0.68 to −0.21, $P < 0.001$)

**Table 1** PEDro score for each study included in the review.

| | Items | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Study** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **Total** | **Quality** |
| Afzal *et al*. (59) | No | Yes | No | Yes | No | No | No | Yes | No | Yes | Yes | 5/10 | Moderate |
| Cetin *et al*. (60) | Yes | Yes | Yes | Yes | No | No | No | No | No | Yes | Yes | 5/10 | Moderate |
| Eccleston *et al*. (61) | Yes | Yes | Yes | Yes | Yes | No | No | Yes | Yes | Yes | Yes | 8/10 | Good |
| García *et al*. 2021 (63) | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | 9/10 | High |
| García *et al*. (62) | Yes | Yes | Yes | Yes | No | No | No | Yes | Yes | No | Yes | 7/10 | Good |
| García *et al*. (64) | Yes | Yes | Yes | Yes | Yes | No | Yes | Yes | Yes | Yes | Yes | 9/10 | High |
| Karahan *et al*. (65) | Yes | Yes | Yes | Yes | No | No | No | Yes | Yes | No | Yes | 6/10 | Good |
| Kim *et al*. (66) | No | Yes | No | Yes | No | No | No | No | Yes | Yes | Yes | 5/10 | Moderate |
| Li *et al*. (68) | No | Yes | No | Yes | No | No | Yes | No | No | Yes | Yes | 5/10 | Moderate |
| Matheve *et al*. 2020 (68) | Yes | Yes | Yes | Yes | No | No | No | Yes | No | Yes | Yes | 6/10 | Good |
| Monteiro-Jr *et al*. (69) | Yes | Yes | No | Yes | No | No | Yes | Yes | No | Yes | Yes | 6/10 | Good |
| Nambi *et al*. (70) | Yes | Yes | No | Yes | No | No | No | Yes | Yes | Yes | Yes | 7/10 | Good |
| Nambi *et al*. (72) | Yes | Yes | Yes | Yes | No | No | No | Yes | Yes | Yes | Yes | 6/10 | Good |
| Nambi *et al*. (71) | Yes | Yes | No | Yes | No | No | No | Yes | Yes | Yes | Yes | 6/10 | Good |
| Nusser *et al*. (73) | Yes | Yes | No | Yes | No | No | No | Yes | Yes | Yes | Yes | 6/10 | Good |
| Park *et al*. (74) | Yes | Yes | No | Yes | No | No | No | Yes | No | Yes | Yes | 5/10 | Moderate |
| Rezaei *et al*. (75) | Yes | Yes | No | Yes | No | No | Yes | Yes | No | Yes | Yes | 6/10 | Good |
| Sarig Bahat, *et al*. (76) | No | Yes | Yes | Yes | No | No | Yes | No | Yes | Yes | Yes | 7/10 | Good |
| Sato *et al*. (77) | Yes | Yes | Yes | Yes | No | No | No | No | No | Yes | Yes | 5/10 | Moderate |
| Soysal-Tomruk *et al*. (78) | Yes | Yes | Yes | Yes | No | No | No | No | No | Yes | Yes | 5/10 | Moderate |
| Stamm *et al*. (79) | Yes | Yes | Yes | Yes | No | No | No | No | No | Yes | Yes | 5/10 | Moderate |
| Tejera *et al*. (80) | Yes | Yes | No | Yes | No | No | No | Yes | Yes | Yes | Yes | 6/10 | Good |
| Yalfani *et al*. (81) | Yes | Yes | No | Yes | No | No | No | No | No | Yes | Yes | 4/10 | Moderate |
| Yilmaz-Yelvar *et al*. (82) | Yes | Yes | No | Yes | No | No | Yes | Yes | No | Yes | Yes | 7/10 | Good |
| Zadro *et al*. (83) | Yes | Yes | Yes | Yes | No | No | Yes | Yes | Yes | Yes | Yes | 8/10 | Good |

1, eligibility criteria; 2, random allocation; 3, concealed allocation; 4, baseline comparability; 5, blind subjects; 6, blind therapists; 7, blind assessors; 8, adequate follow-up; 9, intention-to-treat analysis; 10, between-group comparisons; 11, point estimates and variability. The 'eligibility criteria' item does not contribute to the total score.

**Table 2** Main findings in meta-analyses.

| | Summary findings | | | | | | | | | | | Quality of evidence (GRADE) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Effect size | | | | | | Heterogeneity | | Publication bias | | | RoB | IC | ID | IP | PuB | OQ |
| | | | | | | | | | | Trim and fill | | | | | | | |
| Variable/ area/ timepoint | *K* | *n* | PTS | SMD | 95% CI | *P* | *Q* (*df*) | $I^2$ (*P*) | Egger *P* | ASMD | % var | | | | | | |
| Pain intensity | | | | | | | | | | | | | | | | | |
| CLBP | | | | | | | | | | | | | | | | | |
| IM | 25 | 1415 | 56.6 | −1.27 | −1.45–−0.8 | <0.001 | 66.5 (24) | 63.9% (< 0.01) | 0.05 | −1.6 | 25% | Mod | Lar | No | No | Yes | Mod |
| 1 mo | 5 | 398 | 79.6 | −1.14 | −1.41–−0.87 | <0.001 | 7.2 (4) | 44.9% (0.13) | 0.001 | −0.8 | 76% | Mod | Mod | No | Yes | Yes | Low |
| 6 mo | 7 | 509 | 72.7 | −1.44 | −1.7–−1.18 | <0.001 | 10.5 (6) | 42.7% (0.11) | 0.001 | −1 | 44% | Mod | Mod | No | Yes | Yes | Low |
| CNP | | | | | | | | | | | | | | | | | |
| IM | 7 | 272 | 38.8 | −0.45 | −0.68–−0.21 | <0.001 | 4.4 (6) | 0% (0.62) | 0.08 | -0.48 | 9% | Mod | No | No | Yes | No | Med |
| 1 mo | 2 | 86 | 43 | −0.18 | −0.62–0.25 | 0.41 | 1 (1) | 0% (0.31) | NR | NR | NR | Mod | No | No | Yes | Prob. | VL |
| Kinesio-phobia | | | | | | | | | | | | | | | | | |
| CLBP | | | | | | | | | | | | | | | | | |
| IM | 8 | 370 | 46.2 | −0.75 | −1–−0.5 | <0.001 | 12.8 (7) | 45.3% (0.07) | 0.13 | −0.75 | 0% | Mod | Mod | No | Yes | No | Med |
| 6 mo | 2 | 60 | 30 | −1.33 | −1.91–−0.76 | < 0.001 | 1 (1) | 0% (0.31) | NR | NR | NR | Mod | No | No | Yes | Prob. | VL |
| CNP | | | | | | | | | | | | | | | | | |
| IM | 3 | 224 | 74.6 | −0.08 | −0.4–0.25 | 0.65 | 0.1 (2) | 0% (0.95) | 0.66 | −0.08 | 0% | Mod | No | No | Yes | No | Low |
| Disability | | | | | | | | | | | | | | | | | |
| CLBP | | | | | | | | | | | | | | | | | |
| IM | 10 | 469 | 46.9 | −0.66 | −1.26 –−0.1 | 0.031 | 9.2 (9) | 2% (0.42) | 0.07 | −0.96 | 38% | Mod | No | No | Mod | Yes | Low |
| CNP | | | | | | | | | | | | | | | | | |
| IM | 7 | 417 | 59.5 | −0.26 | −0.49–−0.03 | 0.031 | 6.3 (6) | 5.1% (0.39) | 0.09 | −0.4 | 53% | Mod | No | No | Yes | Yes | Low |
| 1 mo | 2 | 86 | 43 | −0.64 | −1.1–−0.2 | 0.005 | 1 (1) | 0% (0.31) | NR | NR | NR | Mod | No | No | Yes | Prob. | VL |
| Hr-QoL | | | | | | | | | | | | | | | | | |
| CLBP | | | | | | | | | | | | | | | | | |
| IM | 10 | 400 | 40 | 0.62 | 0.38 – 0.85 | < 0.001 | 12.6 (9) | 28.5% (0.19) | 0.45 | 0.71 | 14% | Mod | Low | No | Mod | Yes | Med |
| 1 mo | 2 | 120 | 60 | 1.99 | 1.41–2.56 | 0.001 | 1 (1) | 6.6% (0.31) | NR | NR | NR | Mod | No | No | Yes | Prob. | VL |
| 6 mo | 2 | 120 | 60 | 2.23 | 1.64–2.83 | 0.001 | 1 (1) | 0% (0.31) | NR | NR | NR | Mod | No | No | Yes | Prob. | VL |
| CNP | | | | | | | | | | | | | | | | | |
| IM | 3 | 221 | 73.6 | 0.06 | −0.29–0.4 | 0.736 | 2.2 (2) | 11.5% (0.33) | 0.47 | 0.06 | 0% | Mod | Low | No | Yes | No | VL |

ASMD, adjusted standardized mean difference; Adj, adjusted; CLBP, chronic low back pain; CNP, chronic neck pain; *df*, degrees of freedom; Hr-QoL, health related-quality of life; IC, inconsistency; ID, indirectness; IP, imprecision; $I^2$, degree of inconsistency of Higgins; IM, immediate; *K*, number of comparisons; Lar, large; mo, months; Mod, moderate; Med, medium; *n*, total sample size in each meta-analysis; NR, not reported; OQ, overall quality; PTS, patients per comparisons; PuB, publication bias; RoB, risk of bias; *Q*, *Q*-test; VL, very low; % var, percentage of variation.

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in favor of VRBT (Fig. 3) without risk of publication bias or heterogeneity ($I^2 = 0\%$; $Q = 4.4$; $df = 6$; $P = 0.62$). No variations were found between studies according to the sensitivity analysis.

The effect of VRBT 1 month after finishing the intervention was not greater than others (SMD = −0.18; 95% CI: −0.62 to 0.25; $P = 0.41$). VRBT is more effective than TE (SMD = −0.44; 95% CI: −0.75 to −0.14; $P = 0.005$), and iVR is the most appropriate VRBT modality for reducing pain in patients with CNP (SMD = −0.36, 95% CI: −0.61 to −0.11, $P < 0.001$).

### Kinesiophobia

#### Chronic low back pain

With data from six RCTs (61, 72, 77, 79, 82, 83) (370 subjects), the results showed a large immediate effect of VRBT (SMD = −0.75, 95% CI: −1 to −0.5, $P < 0.001$) in reducing kinesiophobia (Fig. 4), without risk of publication bias. Heterogeneity was moderate-high ($I^2 = 45.3\%$; $Q = 12.8$; $df = 7$; $P = 0.07$). The sensitivity analysis showed no variation with respect to the original effect.

In relation to follow-up, the effect of VRBT was maintained 6 months after the end of the therapy (SMD = −1.33; 95% CI: −1.91 to −0.76; $P < 0.001$). VRBT was more effective than TE (SMD = −0.98, 95% CI: −1.45 to −0.52, $P = 0.003$), and NI (SMD = −0.23; 95% CI: −0.6 to −0.13; $P = 0.027$). No differences were found between iVR (SMD = −1.16, 95% CI: −1.55 to −0.77; $P = 0.003$) and niVR (SMD = −0.47, 95% CI: −0.8 to −0.14; $P = 0.005$).

#### Chronic neck pain

With data from two RCTs (76, 80) (224 participants), no effect of VRBT was found (SMD = −0.08; 95% CI: −0.4 to 0.25; $P = 0.65$) (Fig. 4), without risk of publication bias or heterogeneity ($I^2 = 0\%$; $Q = 0.1$; $df = 2$; $P = 0.95$). The sensitivity analysis did not show substantial differences.

### Associated disability

#### Chronic low back pain

With data from eight RCTs (59, 61, 65, 66, 68, 78, 82, 83) (469 patients), a large immediate effect (SMD = −0.66, 95% CI: −1.26 to −0.1, $P = 0.031$) was found in favor of VRBT (Fig. 5) without heterogeneity ($I^2 = 2\%$; $Q = 9.2$; $df = 9$; $P = 0.42$). The trim-and-fill demonstrated that the original was underestimated (adjusted SMD = −0.96, 38% of variation), showing a risk of publication bias (Supplementary Figure 2). There were no variations after the sensitivity analysis.

Subgroup analysis showed that VRBT was more effective than TE (SMD = −0.4; 95% CI: −0.83 to −0.09; $P = 0.003$), and NI (SMD = −0.34; 95% CI: −0.65 to −0.03; $P = 0.031$), and that the combination of VRBT and CPT is more effective than the use of CPT alone (SMD = −1.75; 95% CI: −2.2 to −1.32; $P < 0.001$). No differences were found between iVR (SMD = −0.49; 95% CI: −0.9 to −0.1; $P = 0.016$) and niVR (SMD = −0.77; 95% CI: −1 to −0.53; $P < 0.001$).

#### Chronic neck pain

With data from five RCTs (60, 73, 75, 76, 80) (417 participants), our meta-analysis showed a medium immediate effect (SMD = −0.26, 95% CI: −0.49 to −0.03, $P = 0.031$) in favor of VRBT (Fig. 5) without heterogeneity ($I^2 = 5.1\%$, $Q = 6.3$, $df = 6$, $P = 0.39$). The trim-and-fill showed that the original effect could be underestimated (adjusted SMD = −0.4, 53% of variation), showing a risk of publication bias (Supplementary Figure 3). There were no changes after the sensitivity analysis.

In addition, the effect of VRBT was maintained 1 month after the end of the intervention (SMD = −0.64; 95% CI: −1.1 to −0.2, $P = 0.005$). VRBT is greater than TE in reducing cervical disability (SMD = −0.42, 95% CI: −0.73 to −0.12, $P = 0.007$).

### Health-related quality of life

#### Chronic low back pain

With data from seven RCTs (61, 65, 71, 74, 79, 81, 82) (400 participants), our results showed a large effect (SMD = 0.62; 95% CI: 0.38 to 0.85; $P < 0.001$) in favor of VRBT in increasing hr-QoL (Fig. 6). The trim-and-fill estimation demonstrated that the original effect was underestimated (adjusted SMD = 0.71, 14% of variation), showing a risk of publication bias (Supplementary Figure 4). Heterogeneity was medium ($I^2 = 28.5\%$; $Q = 12.6$; $df = 9$; $P = 0.19$), and there were no variations after the sensitivity analysis.

The effect of VRBT was maintained both at 1 month (SMD = 1.99; 95% CI: 1.41–2.56; $P = 0.001$) and at 6 months after intervention (SMD = 2.23; 95% CI: 1.64–2.83; $P = 0.001$). VRBT was more effective than TE (SMD = 0.72, 95% CI: 0.31–1.13, $P = 0.001$) and NI (SMD = 0.38, 95% CI: 0.38–1.18; $P < 0.001$) in improving hr-QoL. No differences were found between iVR (SMD = 0.45; 95% CI: 0.11–0.79; $P = 0.019$) and niVR (SMD = 0.78; 95% CI: 0.45–1.11; $P < 0.001$).

#### Chronic neck pain

With data from two RCTs (60, 76) (221 patients), our results did not show an effect of VRBT (SMD = 0.06; 95% CI: −0.29 to 0.4; $P = 0.736$) (Fig. 6), nor the risk of bias of publication or heterogeneity ($I^2 = 11.5\%$; $Q = 2.2$; $df = 2$; $P = 0.33$).

## Discussion

The objective of this review was to analyze the effectiveness of VRBT in reducing pain, kinesiophobia,

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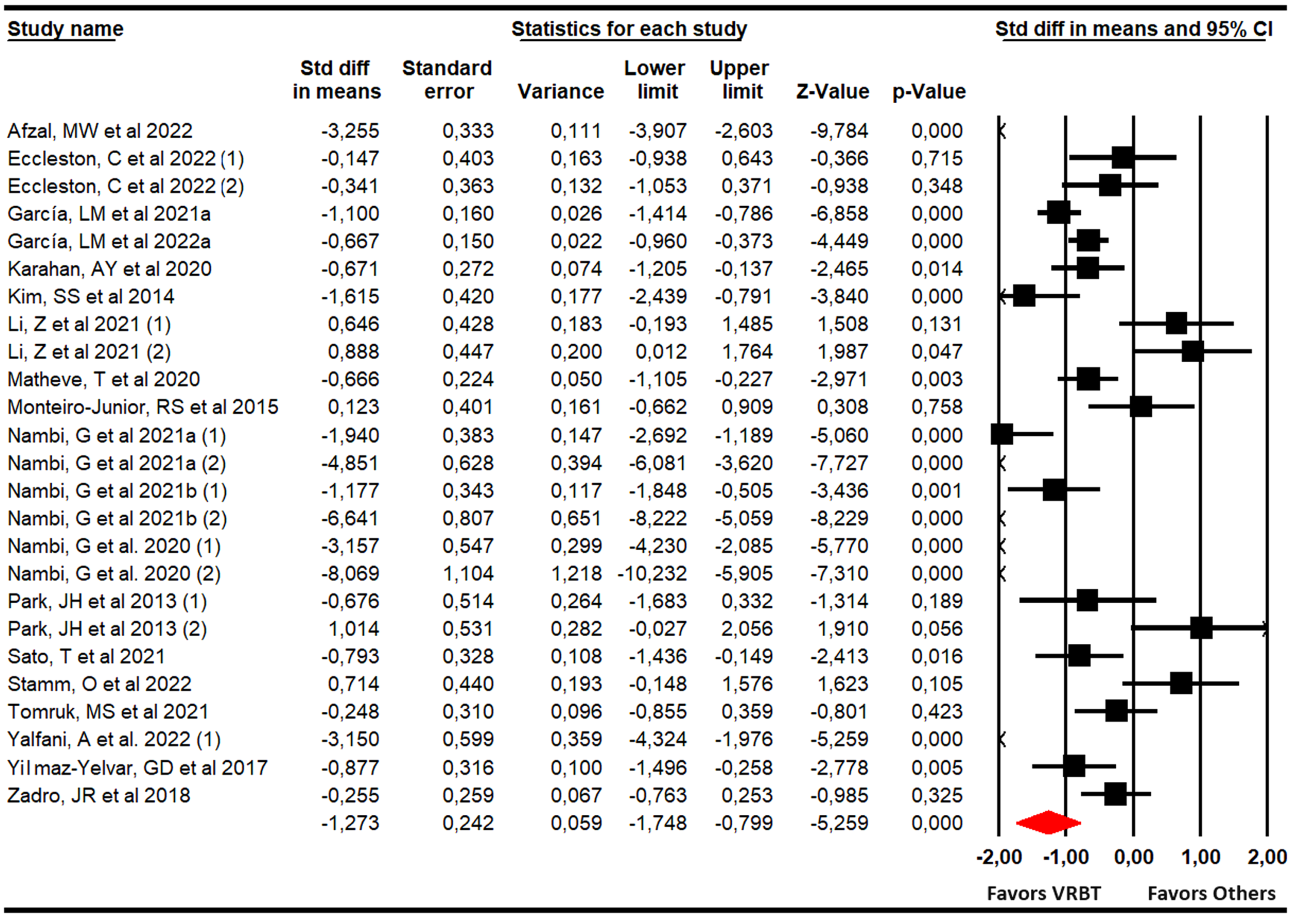


**Figure 2**

Forest plot for pain intensity in CLBP (59, 61, 62, 63, 65, 66, 68, 68, 69, 70, 71, 72, 74, 77, 78, 79, 81, 82, 83, 84).

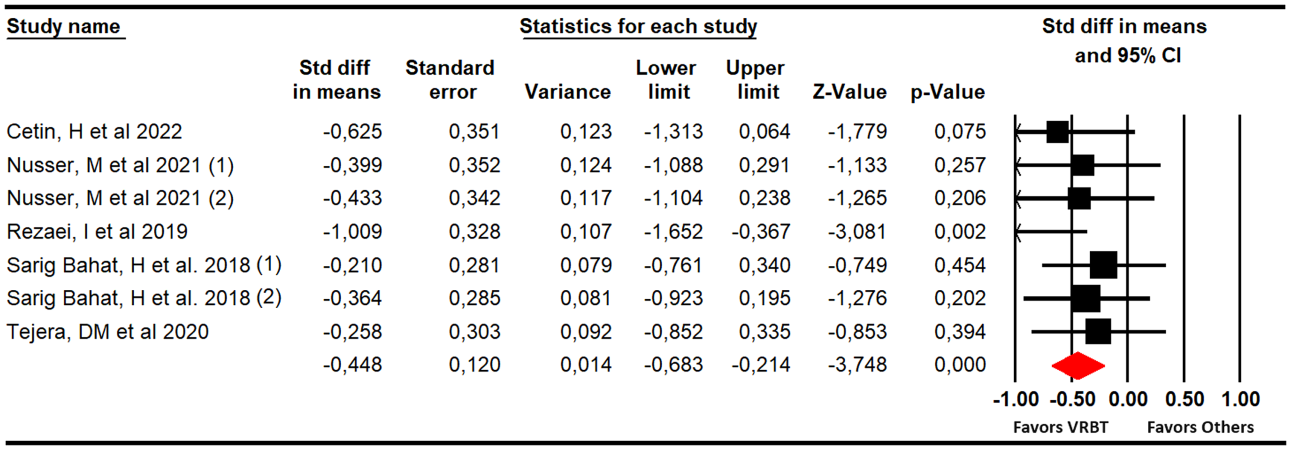


**Figure 3**

Forest plot for pain intensity and CNP (60, 73, 75, 76, 80).

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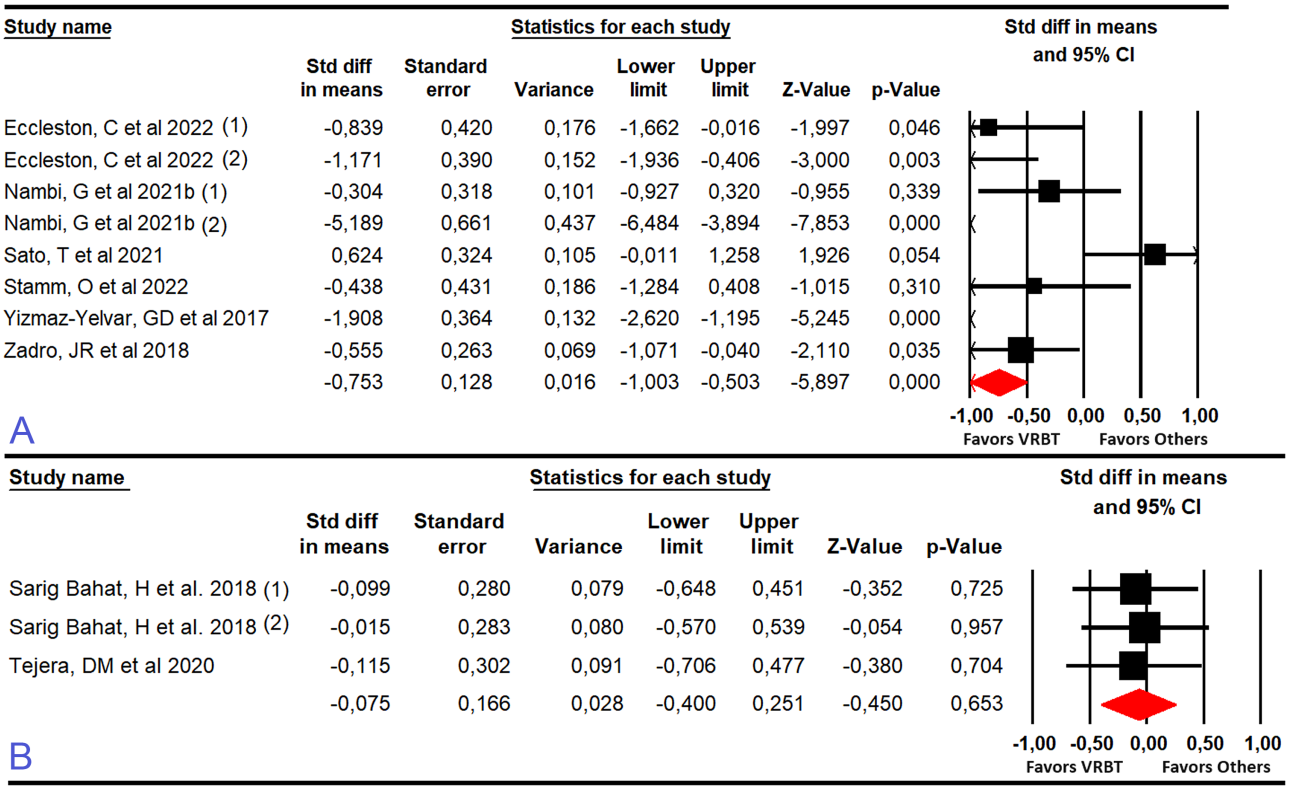


**Figure 4**

Forest plot for kinesiophobia in CLBP (A) (61, 72, 77, 79, 82, 83) and CNP (B) (79, 80).

and disability, and in improving hr-QoL in patients with CLBP and CNP. A secondary objective was to analyze whether the possible beneficial effect of VRBT was maintained over time after the intervention ended and which VRBT modality (iVR or niVR) was more suitable for each variable. To this end, our bibliographical search yielded a total of 25 RCTs that analyzed the effectiveness of VRBT in the treatment of CNP and CLBP. Of the included RCTs, 20 studies reported data of patients with CLBP (59, 61, 62, 63, 64, 65, 66, 68, 68, 69, 70, 71, 72, 74, 77, 78, 79, 81, 82, 83) and five of patients with CNP (60, 73, 75, 76, 80).

First, concerning the reduction of pain intensity in patients with CLBP, our findings showed that VRBT is effective in immediate post-assessment, and its effectiveness is maintained at follow-ups 1 and 6 months after the end of the intervention. In terms of specific therapy comparisons, VRBT was better than TE, sham treatment, or NI, while no differences were found between iVR and niVR VRBT modalities. Furthermore, our findings reported that combining VRBT and CT is more effective in reducing pain in CLBP than the use of CT alone. These findings align with Brea-Gómez *et al.* (35), although our results show greater generalizability and quality of evidence due to the larger number of studies included. Grassini et al. (36) did not show differences between VRBT and TE, yet our findings did report that VRBT is better than TE in reducing pain intensity in CLBP. With regard to CNP, VRBT is better than comparators right after the intervention is completed, but not 1 month later, so its effect is not maintained over time. Subgroup analysis revealed that iVR is the most effective VRBT device for reducing pain intensity in patients with CNP. These results are in line with the reviews of Ahern (34), Grassini (36), Guo (37), and Ye (38) who also found differences in favor of VRBT in short-term pain treatment but not at follow-up.

Secondly, concerning the reduction of kinesiophobia in patients with CLBP, our meta-analysis showed that VRBT is effective at the end of the intervention and at 6 months post intervention, while for CNP patients, no differences were found between VRBT and comparators in decreasing kinesiophobia. For patients with CLBP, VRBT was more effective than TE and NI in reducing kinesiophobia, and no differences were found for the VRBT modality. These results are in line with those of Brea-Gómez (35), who also found greater effectiveness in favor of VRBT both in the short and long term. However, our meta-analysis includes three more RCTs, which gives our results greater statistical precision as the confidence interval range is considerably smaller. Our results also provide new evidence of the effectiveness of VRBT compared to the review of Grassini (36), whose results were not significant in the study of this variable in the short term.

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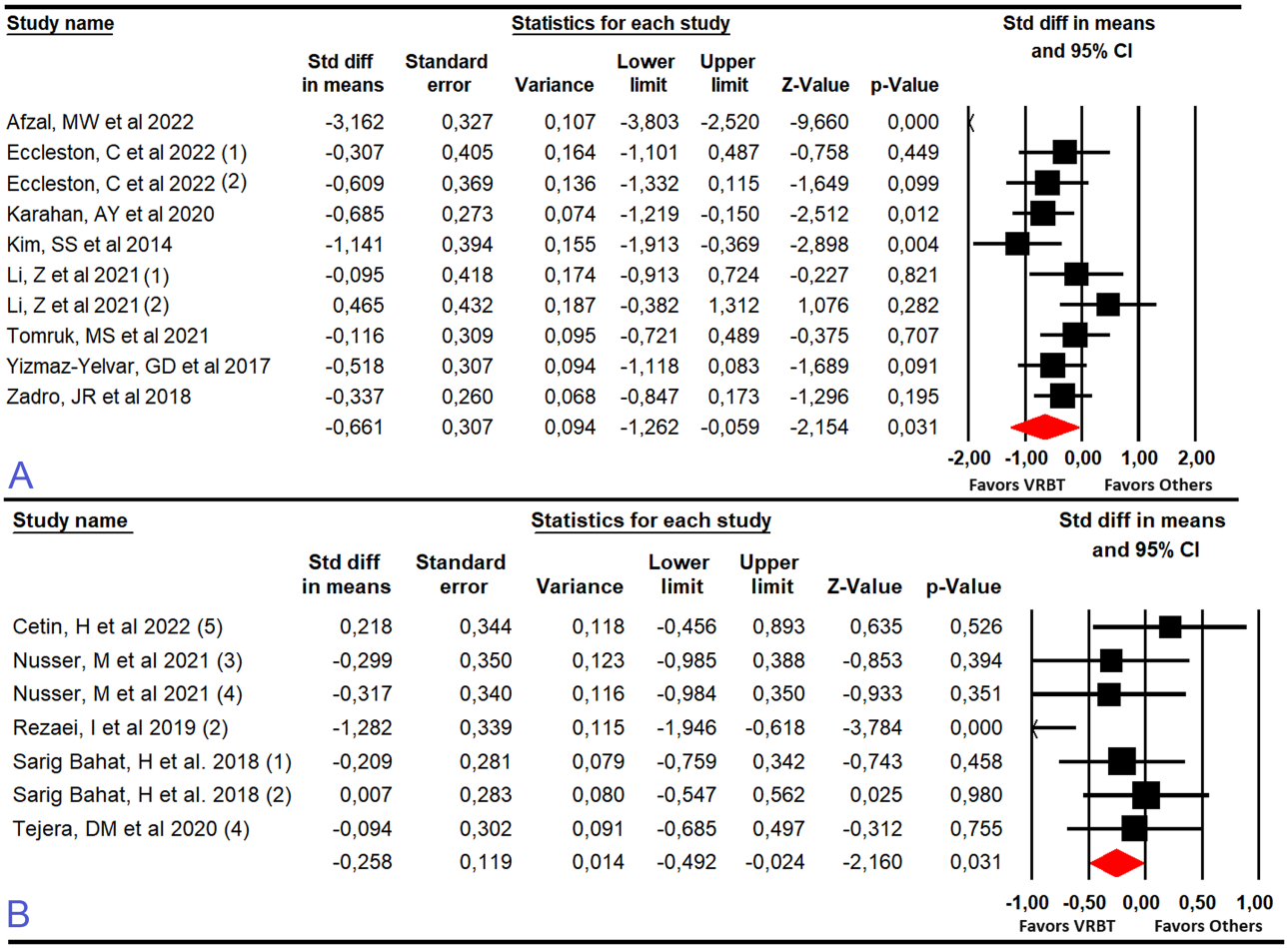


**Figure 5**

Forest plot for disability in CLBP (A) (59, 61, 65, 66, 68, 78, 82, 83) and CNP (B) (60, 73, 75, 76, 80).

For patients with CLBP, VRBT is effective in reducing low back disability, and is better than TE and NI. In terms of VRBT devices, no statistically significant differences were found between iVR and niVR. Moreover, our meta-analysis showed that when VRBT is combined with CT, the reduction of low back disability is more significant than when CT alone is used. Our findings contrast with the reviews of Brea-Gómez (35) and Grassini (36), who did not find differences between VRBT and comparators for low back disability. These differences could be explained by the fact that these authors included hypotherapy simulators, whereas we only included VRBT interventions. For CNP, VRBT was effective at the end of the intervention and at the 1-month follow-up. Minimal statistically significant differences were found in favor of VRBT over TE, and it is not clear whether iVR was the best VRBT device to be employed in reducing low back disability. These results are in line with those of Guo (37) and Grassini (36). Our results provide new evidence of how VRBT is more effective than ET in improving disability in CNP.

Finally, in the assessment of hr-QoL, for patients with CLBP, VRBT proved to be effective at the end of the intervention, and at 1- and 6-month follow-ups. Subgroup analysis revealed that VRBT was better than TE and NI, and no differences between iVR and niVR were found. For CNP, no statistically significant differences were found between VRBT and comparators, most likely due to the low number of studies included. However, no reviews have assessed the effect of VRBT on hr-QoL in patients with CNP, so our findings and the very low quality of evidence are susceptible to change with the publication of new RCTs in the future. Only Ahern (34) concluded in a systematic review without meta-analysis that VRBT was probably better than comparators. Nonetheless, the statistical analysis of our review contradicts the hypothesis of Ahern.

The beneficial effect of VRBT as a therapeutic tool could be due to several phenomena. First, distraction can be highlighted for its effectiveness in pain management (85, 86, 87, 88). VRBT can act on brain structures such as the hippocampus and the cortico-limbic system, which are related to the cognitive-affective dimension of pain, stimulating the descending pain modulation systems that reduce kinesiophobia or catastrophizing (89, 90, 91). In addition, positive emotions related to virtual

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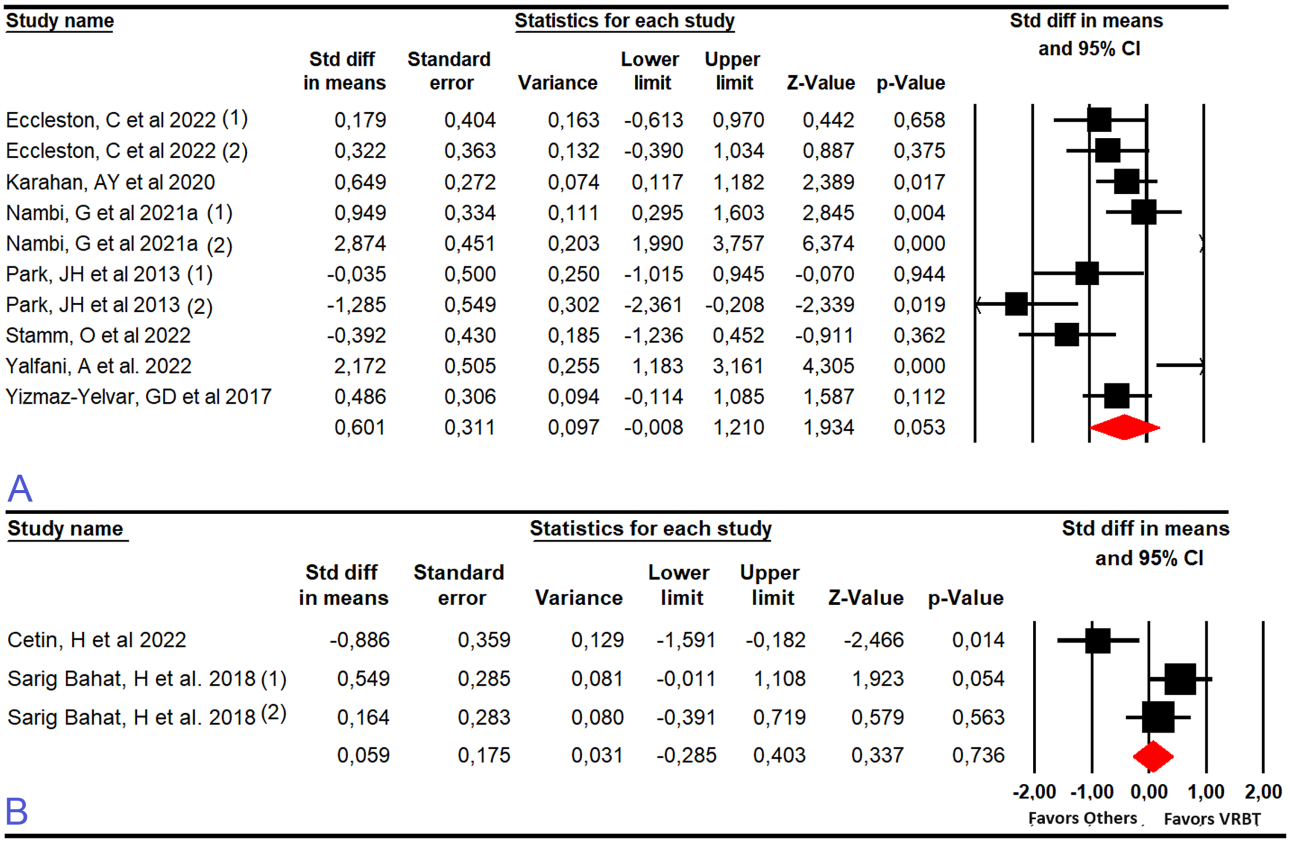


**Figure 6**

Forest plot for health related-quality of life in CLBP (A) (61, 65, 71, 74, 79, 81, 82) and CNP (B) (60, 76).

experiences that simulate reality can help to reduce the pain experience. 'Embodiment therapy' that uses virtual avatars in videogames or exergames can help to produce these changes and reorganize nociceptive input in motor and sensory areas of the brain, thus reducing the experience of pain (92).

The results of this review are useful for the clinical practice of physiotherapists as they provide relevant and high-quality information on the use of VRBT in the management of CLBP and CNP, in relation to different variables. A key finding in our results demonstrated the greater effect of combining VRBT and CT in comparison to using CT alone. Furthermore, VRBT could be a more useful therapeutic option than TE in reducing pain intensity and disability associated with CLBP and CNP. These results can guide clinicians in choosing the most effective therapeutic combination or the most appropriate VRBT modality, according to the characteristics of their patient. This therefore represents a new advance in the treatment of CLPB and CNP.

Although the results have clinical relevance, a number of limitations need to be addressed. First, the moderate risk of bias in the included studies, generally due to the fact that patients, therapists, and evaluators were not blinded, increases the detection and performance biases, potentially decreasing the generalizability of the results. Secondly, the low number of studies included in the meta-analyses of some variables or the CNP could reduce the generalizability of the results, as well as affect the quality of its evidence. Thirdly, the high heterogeneity in pain intensity and kinesiophobia outcomes in CLBP means that we should be cautious when drawing conclusions. Fourthly, the observed publication bias and the percentage of variation in the trim-and-fill method in some of the meta-analyses reduce the generalizability of the results, while showing how the original effect could be underestimated by the presence of publication bias. Finally, another limitation is that our meta-analysis did not report findings about the effect of VRBT on each variable according to VRBT intensity (number of sessions or time in minutes of each session) due to the low level of evidence of these analyses by the low number of studies that would be included in each subgroup. In the future, new studies would be carried out, especially in patients with CNP, with the aim of obtaining results with more evidence and generalization. Additionally, it would be important to assess the effect of VRBT according to its intensity (number of sessions, sessions per week, minutes) with the aim of establishing homogenous protocols of VRBT in these patients.

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## Conclusion

Our results show that, in the short term, VRBT is effective in reducing pain intensity and associated disability, as well as increasing hr-QoL in patients with CLBP and CNP. However, kinesiophobia is only reduced in patients with CLBP. The beneficial effect of VRBT on pain, kinesiophobia, and hr-QoL can be maintained for up to 6 months in patients with CLBP. VRBT appears to be more effective than TE in reducing pain and disability in both populations and better at improving kinesiophobia and hr-QoL in patients with CLBP. Our results demonstrate that the effect of VRBT on pain and associated disability is greater when combined with CT. Finally, both iVR and niVR seem to be equally effective, with no statistically significant differences as to which VRBT modality produces a greater effect.

**Supplementary materials**

This is linked to the online version of the paper at https://doi.org/10.1530/EOR-23-0197.

**Declaration of interest**

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the study reported.

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**Author contribution statement**

JMHJ, MCOP, EOG, and ICP contributed to study design; JMHJ and ICP contributed to the literature; JMHJ, MCOP, MCLR, EOG, and ICP contributed to study selection and data extraction; RLV, MCLR, and HGL contributed to methodological quality assessment; EOG and ICP contributed to data and outcome synthesis. MCOP, HGL, RLV, EOG, and ICP contributed to figures and tables design; JMHJ, MCOP, HGL, MCLR, and EOG contributed to writing – original draft; RLV and ICP contributed to writing-review and editing. All authors read and approved the final version of the manuscript.

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