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REVIEW

Virtual reality based-rehabilitation for chronic neck pain: an overview of systematic reviews with meta-analysis of randomized clinical trials

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Abstract

Purpose This overview of systematic reviews with meta-analysis aimed to synthesize the quality of the evidence of the short-, and intermediate-effects of virtual reality (VR), alone or combined with other interventions, in individuals with chronic neck pain (NP).

Methods CINAHL, Embase, Epistemonikos, PubMed, Scopus, SPORTDiscus, and the Cochrane Library were searched from inception until April 2025. The methodological quality of systematic reviews was assessed using the AMSTAR 2 checklist. The degree of overlap between reviews was calculated.

Results Nine systematic reviews, with over 2,000 participants, were included. The degree of overlap was very high for all outcomes (40%-100%). The findings of the included systematic reviews were inconsistent about the possible impact of VR on pain intensity, disability, and global perceived effect in the short- and intermediate- terms. Overall, the results show that VR-based rehabilitation was no better than control interventions to manage kinesiophobia, health-related quality of life, and cervical kinematics. Positive effects in favor of VR were only found in the short term for patient satisfaction and cervical range of motion.

Conclusion No consistent findings were found in favor of VR-based rehabilitation to manage chronic pain related symptoms in the short- and intermediate- terms. The clinical applicability of these findings is limited by the heterogeneity between reviews in the delivery mode of VR and control interventions, the poor quality of information provided on how VR was delivered, a very high overlap among meta-analyses, and the low/very low certainty of evidence in most meta-analyses when GRADE system was applied.

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Keywords Disability · Health-related quality of life · Kinesiophobia · Neck pain · Virtual reality

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Introduction

The implementation of virtual reality (VR)-based rehabilitation in the context of chronic pain is a reality [1]. Currently, the term "virtual reality" in the healthcare field remains vague, with numerous definitions, including key terms such as computer, environment, simulation, interactive, and user. However, a recent systematic review analyzed more than 80 articles looking for similarities between definitions and proposed a new updated definition: "VR may be a three-dimensional computer-generated simulated environment, which attempts to replicate real world or imaginary environments and interactions, thereby supporting work, education, recreation, and health" [2].

Immersive, semi-immersive, or non-immersive VR are probably the three most common ways of applying VR in rehabilitation, including tools such as console gaming systems (e.g., Wii gaming technology) or specific devices such as head-mounted displays. Whereas immersive VR leads individuals to directly interact with the virtual environment and needs mainly the use of a headset along with other tools, such as motion tracking systems or hand controllers, non-immersive VR makes possible to experience a less immersive virtual environment using a computer or a console gaming system. VR has been considered cost-effective and useful in rehabilitation [3], and it is often applied alone or in combination with other therapies (e.g., physical exercise programs). The possible effectiveness of VR has been recently studied in numerous chronic pain conditions, such as fibromyalgia [4], osteoarthritis [5], low-back pain [6], migraine [7], shoulder pain [8], or cancer-related pain [9], with positive results in favour of VR to improve pain intensity, depression, acute analgesic use, or quality of life (mental health dimension).

Chronic neck pain is one of the most prevalent and disabling forms of chronic musculoskeletal pain and VR may not only improve pain-related outcomes (e.g., pain intensity) [10], but also may help to increase adherence rates to other interventions such as physical exercise [11]. Currently, the number of randomized clinical trials (RCTs) evaluating the effectiveness of VR in people with chronic neck pain is increasing [12], and some systematic reviews with meta-analysis have been published on this topic [10, 13, 14]. Therefore, we considered to develop a specific overview of systematic reviews with meta-analysis on the possible effectiveness of VR on chronic neck pain. This overview is essential to show if all systematic reviews with meta-analysis in this field show similar results or exist conflict evidence with a determined outcome. In addition, this overview of systematic reviews may help to detect if previous reviews have shown overlap between meta-analyses and if they have rated the certainty of evidence using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system. Hence, the objective of this overview of systematic reviews with meta-analysis has been to summarize the effectiveness of VR applied alone or combined with other interventions to improve the management of chronic neck pain without restrictions in the type of outcome measure.

Methods

The PRIOR statement and the PRISMA 2020 statement for abstracts were followed [15, 16]. The review protocol was prospectively registered at Open Science Framework: https://doi.org/10.17605/OSF.IO/AER7J.

Deviations from the review protocol

The following deviations were made to develop a more robust and homogeneous overview of systematic reviews: (1) only systematic reviews with meta-analysis of RCTs were considered. No other deviations were conducted.

Data sources and search strategies

The following e-databases were searched from inception to April 30, 2025: CINAHL (via EBSCOhost), Embase, Epistemonikos, PubMed, Scopus, SPORTDiscus (via EBSCOhost), and the Cochrane Library. **Supplementary File 1** shows the full search strategy for each e-database. In addition, we conducted manual searches looking for potential articles in those scoping reviews and overviews of systematic reviews related to our topic that were retrieved from the e-databases during search strategies. Search filters by type of document were included when possible (see **Supplementary File 1**).

Eligibility criteria

The PICOS (Population, Intervention, Comparison, Outcome, Study design) framework was used to develop the eligibility criteria [17].

P: Individuals with chronic neck pain (pain lasting more than 3 months) without other restrictions.

I: VR applied alone or combined with other intervention (e.g., physical exercise programs) without restrictions in the type of intervention. All types of VR (immersive, semi-immersive, and non-immersive) were considered.

C: No restrictions imposed.

O: No restrictions imposed.

S: Systematic review with meta-analysis of RCTs published in peer-reviewed journals and written in English or

Spanish language. Any type of RCT was considered (e.g., pilot RCT). The decision to include only systematic reviews that have performed meta-analysis stems from the importance of making the data as accessible as possible to readers. While it is true that very high-quality systematic reviews without meta-analysis may exist, comparing them with systematic reviews that have performed meta-analysis would be methodologically complicated. This complication may primarily be related to those results sections in a systematic review without meta-analysis that are based exclusively on a single study.

We excluded meta-analyses that combined: (1) studies evaluating different types of population (e.g., chronic neck pain and chronic low back pain); (2) studies evaluating VR and other interventions rather than VR (e.g., psychological interventions); (3) studies evaluating different stages of pain (e.g., acute, subacute, and chronic neck pain); (4) and studies where the full text was not available after requesting it via email to the corresponding author.

Study selection

Two co-authors developed independently the study selection process. One co-author (JMC) used Zotero 6.0.36 Citation Management Software to manage those references retrieved from e-databases. This co-author removed duplicates and analysed titles and abstracts. Afterward, two co-authors (JMC and AMHR) evaluated full texts of those abstracts that seemed to be eligible or those studies where abstracts were unavailable. The percentage of agreement between these co-authors was calculated. This percentage was obtained considering the number of items rated with the same score before pooling the results of their independent assessments. The percentage of agreement was 100%. **Supplementary File 2** shows all excluded studies during full text analysis and the reason for their exclusion.

Methodological quality assessment

Two co-authors (JMS and OVA) applied independently the AMSTAR 2 checklist to assess the methodological quality of systematic reviews [18]. AMSTAR 2 is composed of 16 items and each item can be scored as 'Yes', 'Partially yes', or 'No'. No overall score is recommended, but seven items are considered as critical domains (items 2, 4, 7, 9, 11, 13, and 15) [18]. The percentage of agreement between these co-authors was calculated. This percentage was obtained considering the number of items rated with the same score before pooling the results of their independent assessments.

Data extraction

Two co-authors (JMC and AMHR) independently developed the data extraction process. One co-author (JMC) extracted from each review the following information: (1) study and year of publication, (2) population and study design of original research (meta-analyses of interest), (3) intervention group (meta-analyses of interest), (4) control group (meta-analyses of interest), (5) meta-analyses of interest and the certainty of evidence (the GRADE system). Afterward, a second co-author independently compared his results with those extracted by JMC. The percentage of agreement between these co-authors was calculated (91.8% at first round, and 100% in a second round). This percentage was obtained considering the number of items rated with the same score before pooling the results of their independent assessments.

The degree of overlap between reviews

One co-author (JMC) calculated the degree of overlap between meta-analyses of interest. This overlap was only calculated if at least two systematic reviews meta-analyzed the same outcome (e.g., disability). Firstly, JMC developed matrices of evidence for each outcome. Then, JMC calculated the corrected covered area (CCA), that is the covered area after original studies are removed the first time they are counted [19]. The formula is obtained using:

1. N: The total number of original studies (including duplicates) in the meta-analyses of interest (the sum of all checked boxes in the citation matrix).
2. r: The number of original studies without accounting for duplicates.
3. c: The number of systematic reviews included in the matrix of evidence.

The CCA is needed to know the degree of overlap between meta-analyses of interest and permits to classify the degree of overlap as slight (CCA 0–5%); moderate (CCA 6–10%); high (CCA 11–15%); or very high (CCA > 15%) [19]. Finally, one co-author (CGM) developed a bar plot to depict the degree of overlap between meta-analyses of interest.

Data analysis

The main results are shown in Table 1 and reported by type of outcome measure and time effect in the main text (e.g., effects of VR for kinesiophobia at short-term). Considering the values of the meta-analyses, only those that clearly described the period in which outcomes were assessed were included in the main text. The rest of meta-analyses are

Table 1 Characteristics of the included systematic reviews

Study and year of publication	Population and study design original research (meta-analyses of interest)	Intervention group (meta-analyses of interest)	Control group (meta-analyses of interest)	Meta-analyses of interest and the certainty of evidence (GRADE)
Ahern et al. 2020	N: 122 Two randomized clinical trials	Virtual reality applied alone or combined with other interventions (e.g., multimodal exercise programs, strengthening exercises…) VR involved head-mounted displays	Kinematic training via head-mounted laser	Short-term (closest to 4 weeks after randomization) and intermediate term (closest to 6 months after randomization) **Pain intensity (short-term)** (MD -9.08; 95%CI -21.84, 3.67; I^2 48%; k = 2; *N* = 109) **GRADE**: low evidence (limitations design/interpretation and imprecision) **Pain intensity (intermediate term)** (MD -6.90; 95%CI -16.05, 2.25; I^2 0%; k = 2; *N* = 82) **GRADE**: low evidence (limitations design/interpretation and imprecision) **Disability (short-term)** (MD -2.24; 95%CI -6.38, 1.90; I^2 0%; k = 2; *N* = 109) **GRADE**: low evidence (limitations design/interpretation and imprecision) **Disability (intermediate term)** (MD -4.30; 95%CI -10.57, 1.96; I^2 0%; k = 2; *N* = 82) **GRADE**: low evidence (limitations design/interpretation and imprecision) **Kinesiophobia (short-term)** (MD -1.75; 95%CI -6.78, 3.28; I^2 17%; k = 2; *N* = 109) **GRADE**: low evidence (limitations design/interpretation and imprecision) **Kinesiophobia (intermediate term)** (MD -0.84; 95%CI -5.39, 3.70; I^2 0%; k = 2; *N* = 82) **GRADE**: low evidence (limitations design/interpretation and imprecision) **Global perceived effect (short-term)** (MD 4.88; 95%CI 2.51, 7.26; I^2 0%; k = 2; *N* = 109) **GRADE**: low evidence (limitations design/interpretation and imprecision) **Global perceived effect (intermediate term)** (MD 12.27; 95%CI -3.89, 28.43; I^2 92%; k = 2; *N* = 109) **GRADE**: very low evidence (limitations design/interpretation, imprecision, and inconsistency) **Patient satisfaction (short-term)** (MD 6.26; 95%CI 3.90, 8.62; I^2 0%; k = 2; *N* = 109) **GRADE**: low evidence (limitations design/interpretation and imprecision)

Table 1 (continued)

Study and year of publication	Population and study design original research (meta-analyses of interest)	Intervention group (meta-analyses of interest)	Control group (meta-analyses of interest)	Meta-analyses of interest and the certainty of evidence (GRADE)
Brea-Gómez et al. 2024	N: 299 Six randomized clinical trials	Virtual reality applied alone or combined with other interventions (e.g., kinematic training) VR involved head-mounted displays, glasses, specifically designed videos games or software	Multiple types of control were included (Kinematic training, conventional proprioceptive training -motor control-, standard rehabilitation, sensorimotor training, different cervical mobility exercises…)	Short-term (less than 3 months) **GRADE** was not applied in any meta-analysis All meta-analyses were separated by the type of control group. **Virtual reality vs. rehabilitation: Pain intensity (global)** (SMD − 0.46; 95%CI -0.74, -0.19; I^2 12%; k = 6; *N* = 243) **Virtual reality vs. rehabilitation: Pain intensity (short-term)** (MD -6.12; 95%CI -12.74, 0.49; I^2 41%; k = 4; *N* = 204) **Virtual reality vs. rehabilitation: Disability (global)** (MD -2.84; 95%CI -4.23, -1.45; I^2 0%; k = 5; *N* = 209) **Virtual reality vs. rehabilitation: Disability (short-term)** (MD -3.52; 95%CI -5.85, -1.20; I^2 26%; k = 4; *N* = 204) **Virtual reality vs. rehabilitation: Kinesiophobia (global)** (SMD − 0.18; 95%CI -0.52, 0.17; I^2 0%; k = 3; *N* = 130) **Virtual reality vs. rehabilitation: Kinesiophobia (short-term)** (SMD − 0.29; 95%CI -0.73, 0.15; I^2 42%; k = 3; *N* = 162) **Virtual reality vs. rehabilitation: Cervical kinematics – range of motion- (global)** (SMD 0.18; 95%CI -0.03, 0.38; I^2 38%; k = 4; *N* = 155) **Virtual reality vs. rehabilitation: Cervical kinematics – range of motion- (short-term)** (SMD − 0.42; 95%CI -0.65, -0.19; I^2 24%; k = 2; *N* = 112) **Virtual reality vs. rehabilitation: Cervical kinematics – vpeak- (global)** (SMD 0.03; 95%CI -0.18, 0.24; I^2 0%; k = 2; *N* = 88) **Virtual reality vs. rehabilitation: Cervical kinematics – vpeak- (short-term)** (SMD 0.03; 95%CI -0.20, 0.26; I^2 26%; k = 2; *N* = 112) **Virtual reality vs. rehabilitation: Cervical kinematics – vmean- (global)** (SMD 0.03; 95%CI -0.18, 0.24; I^2 0%; k = 2; *N* = 88) **Virtual reality vs. rehabilitation: Cervical kinematics – vmean- (short-term)** (SMD − 0.03; 95%CI -0.30, 0.24; I^2 44%; k = 2; *N* = 112) **Virtual reality vs. rehabilitation: Cervical kinematics – TTP%- (global)** (SMD 0.05; 95%CI -0.31, 0.41; I^2 62%; k = 2; *N* = 88) **Virtual reality vs. rehabilitation: Cervical kinematics – TTP%- (short-term)** (SMD − 0.17; 95%CI -0.51, 0.16; I^2 62%; k = 2; *N* = 112) **Virtual reality vs. rehabilitation: Global perceived effect (global)** (MD 0.49; 95%CI 0.25, 0.72; I^2 0%; k = 2; *N* = 122) **Virtual reality vs. rehabilitation: Global perceived effect (short-term)** (MD 1.22; 95%CI -0.40, 2.83; I^2 93%; k = 2; *N* = 118) **Virtual reality vs. rehabilitation: Patient satisfaction (global)** (MD 0.62; 95%CI 0.38, 0.86; I^2 0%; k = 2; *N* = 122) **Virtual reality vs. waitlist or usual care: Pain intensity (global)** (SMD − 0.38; 95%CI -0.79, 0.02; I^2 0%; k = 2; *N* = 95) **Virtual reality vs. waitlist or usual care: Disability (global)** (MD -1.52; 95%CI -5.49, 2.45; I^2 0%; k = 2; *N* = 95) **Virtual reality vs. waitlist or usual care: Cervical kinematics – range of motion- (global)** (SMD − 0.13; 95%CI -0.38, 0.12; I^2 33%; k = 2; *N* = 95)

Table 1 (continued)

Study and year of publication	Population and study design original research (meta-analyses of interest)	Intervention group (meta-analyses of interest)	Control group (meta-analyses of interest)	Meta-analyses of interest and the certainty of evidence (GRADE)
Grassini 2022	N: 176 Three randomized clinical trials	Virtual reality applied alone	Usual care	The authors did not define the time effect of each meta-analysis. **GRADE** was not applied in any meta-analysis **Pain intensity** (MD -8.08; 95%CI -12.49, -3.67; I^2 0%; k = 3; *N* = 136) **Disability** (MD -2.87; 95%CI -4.36, -1.39; I^2 33%; k = 3; *N* = 136) **Kinesiophobia** (MD -0.28; 95%CI -3.46, 2.90; I^2 0%; k = 2; *N* = 94)
Guo et al. 2023	N: 293 Six randomized clinical trials	Virtual reality was applied alone or combined with other interventions (e.g., kinematic training, motor control, usual rehabilitation)	Multiple types of controls were included: kinematic training, exercise, usual rehabilitation, sensorimotor training + usual rehabilitation, usual propioceptive training, or no intervention	All studies included under the umbrella follow-up were less or equal to 3 months, and thus we considered the meta-analysis of follow-up as short-term. The time effect for the rest of meta-analyses was not clearly defined. **Pain intensity** (SMD − 0.70; 95%CI -1.08, -0.32; I^2 53%; k = 6; *N* = 261) **GRADE**: moderate evidence (serious inconsistency) **Disability** (SMD − 3.23; 95%CI -4.32, -2.14; I^2 46%; k = 5; *N* = 211) **GRADE**: moderate evidence (serious risk of bias) **Disability (short-term)** (SMD − 3.07; 95%CI -6.57, 0.43; I^2 67%; k = 3; *N* = 112) **GRADE**: very low evidence (serious risk of bias, inconsistency and imprecision) **Cervical kinematics – vmean-** (SMD 8.98; 95%CI 2.91, 15.06; I^2 46%; k = 2; *N* = 112) **GRADE**: moderate evidence (serious risk of bias) **Cervical kinematics – vpeak-** (SMD 10.24; 95%CI 1.28, 19.15; I^2 39%; k = 2; *N* = 112) **GRADE**: moderate evidence (serious risk of bias)
Hao et al. 2024	N: 243 Six randomized clinical trials	Virtual reality applied alone or combined with other interventions (e.g., e.g., kinematic training, motor control, sensorimotor training, usual rehabilitation…)	Multiple types of controls were included: Kinematic training, home-based kinematic training, multimodal exercise program, motor control, general sensorimotor or proprioceptive training…	The authors did not clearly define what the term short and long-term implies in this review. **GRADE** was not applied in any meta-analysis **Pain intensity (short-term)** (MD -0.94; 95%CI -1.31, -0.58; I^2 0%; k = 6; *N* = 275) **Pain intensity (long-term)** (MD -0.61; 95%CI -1.27, 0.05; I^2 41.4%; k = 4; *N* = 204) **Disability (short-term)** (MD -2.16; 95%CI -3.50, -0.82; I^2 15.4%; k = 5; *N* = 241) **Disability (long-term)** (MD -2.95; 95%CI -4.93, -0.97; I^2 36.2%; k = 4; *N* = 204) **Kinesiophobia (short-term)** (MD -1.04; 95%CI -3.54, 1.45; I^2 0%; k = 3; *N* = 166) **Kinesiophobia (long-term)** (MD -2.10; 95%CI -5.46, 1.25; I^2 51.5%; k = 3; *N* = 162)

Table 1 (continued)

Study and year of publication	Population and study design original research (meta-analyses of interest)	Intervention group (meta-analyses of interest)	Control group (meta-analyses of interest)	Meta-analyses of interest and the certainty of evidence (GRADE)
Henriquez-Jurado et al. 2024	N: 261 Five randomized clinical trials	Virtual reality was applied alone or combined with other interventions (e.g., kinematic training, multimodal exercise program, usual rehabilitation)	Multimodal exercise program, sensorimotor training, usual rehabilitation, kinematic training, no intervention, neck stabilization exercises	* Primary studies with more than two arms where the number of participants were counted multiple times; therefore, k and N refer to the total number of comparisons rather than unique studies or individuals. We considered both immediate and 1 month meta-analyses as short-term according to our definition of short-term (see data analysis section) **Pain intensity (immediate)** (SMD − 0.45; 95%CI -0.68, -0.21; I^2 0%; k = 7; *N* = 272)* **GRADE**: this is not clear, but the authors reported risk of bias and imprecision **Pain intensity (1 month)** (SMD − 0.18; 95%CI -0.62, 0.25; I^2 0%; k = 2; *N* = 86) **GRADE**: Very low evidence (risk of bias, imprecision, suspected publication bias) **Disability (immediate)** (SMD − 0.26; 95%CI -0.49, -0.03; I^2 5.1%; k = 7; *N* = 417)* **GRADE**: Low evidence (risk of bias, imprecision, publication bias) **Disability (1 month)** (SMD − 0.64; 95%CI -1.1, -0.2; I^2 0%; k = 2; *N* = 86) **GRADE**: Very low evidence (risk of bias, imprecision, suspected publication bias) **Kinesiophobia (immediate)** (SMD − 0.08; 95%CI -0.4, 0.25; I^2 0%; k = 3; *N* = 224)* **GRADE**: Low evidence (risk of bias, imprecision) **Health-related quality of life (immediate)** (SMD 0.06; 95%CI -0.29, 0.4; I^2 11.5%; k = 3; *N* = 221)* **GRADE**: Very low evidence (risk of bias, inconsistency, imprecision)
Lo et al. 2024	N: 305 7 randomized clinical trials	Virtual reality applied alone or combined with other interventions (e.g., multimodal exercise programs, strengthening exercises…)	Multiple types of control were included (e.g., multimodal exercise programs, usual rehabilitation, sensorimotor or proprioceptive training …)	Short-term (12 weeks) and intermediate term (6 months) **Pain intensity (short-term)** (SMD − 0.55; 95%CI -1.02, -0.08; I^2 75%; k = 7; *N* = 316) **GRADE**: Low evidence (risk of bias, indirectness) **Disability (short-term)** (MD -2.59; 95%CI -3.51, -1.67; I^2 0%; k = 6; *N* = 282) **GRADE**: Low evidence (risk of bias, imprecision) **Kinesiophobia (short-term)** (SMD − 0.09; 95%CI -0.40, 0.23; I^2 0%; k = 3; *N* = 153) **GRADE**: Moderate evidence (risk of bias)

Table 1 (continued)

Study and year of publication	Population and study design original research (meta-analyses of interest)	Intervention group (meta-analyses of interest)	Control group (meta-analyses of interest)	Meta-analyses of interest and the certainty of evidence (GRADE)
Opara & Kozinc 2024	N: 352 8 randomized or non-randomized clinical trials *The authors included in their methods that randomized or non-randomized clinical trials could be included	Virtual reality applied alone or combined with other interventions (e.g., kinematic training…)	Multiple types of control were included (e.g., kinematic training, multimodal exercise program, usual propioceptive training, conventional general and neck-specific exercises, motor control, waitlist)	Short-term (immediately post-intervention) and follow-up (Six studies also included follow-up measurements after 4 weeks to 6 months). Follow-up was not considered in the main text considering our definition of short-intermediate, and long term (see data analysis) **Pain intensity (short-term)** (SMD − 0.50; 95%CI -1.10, 0.09; I^2 85%; k = 8; *N* = 324) **GRADE**: Low evidence (the reasons were not reported) **Pain intensity (follow-up)** (SMD − 0.39; 95%CI -0.73, 0.15; I^2 89%; k = 5; *N* = 201) **GRADE**: Low evidence (the reasons were not reported) **Disability (short-term)** (SMD − 0.49; 95%CI -1.05, 0.06; I^2 78%; k = 6; *N* = 252) **GRADE**: Low evidence (the reasons were not reported) **Disability (follow-up)** (SMD − 0.95; 95%CI -1.70, -0.20; I^2 83%; k = 5; *N* = 197) **GRADE**: Low evidence (the reasons were not reported) **Kinesiophobia (short-term)** (SMD − 0.19; 95%CI -0.52, 0.15; I^2 0%; k = 3; *N* = 136) **GRADE**: Moderate evidence (the reasons were not reported) **Kinesiophobia (follow-up)** (SMD − 0.69; 95%CI -1.34, -0.03; I^2 67%; k = 3; *N* = 136) **GRADE**: Low evidence (the reasons were not reported) * No global meta-analysis for range of motion was included, and thus specific analysis in this outcome were not extracted.
Ye et al. 2023	N: 180 4 randomized clinical trials	UR	UR	The authors did not clearly define what short-term implies in this review. **GRADE** was not applied in any meta-analysis **Pain intensity (short-term)** (SMD 0.58; 95%CI 0.25, 0.91; I^2 2%; k = 3 *N* = 155) **Disability (short-term)** (SMD 0.54; 95%CI -0.15, 1.24; I^2 72%; k = 3; *N* = 113) **Cervical range of motion (short-term)** (SMD 0.42; 95%CI -0.15, 0.98; I^2 77%; k = 3; *N* = 113)

Note: 95%CI: confidence interval; GRADE: Grading of Recommendations, Assessment, Development, and Evaluations; MD: mean difference; SMD: standardized mean difference

reported in Table 1 for transparency. In this sense, we categorized the results into short, intermediate, and long term, with short term being those findings from immediately after the intervention up to around 3 months after intervention, and intermediate term up to 6 months to respect the timeline described in some of the included systematic reviews. Those systematic reviews that included meta-analyses considering immediate and short-term (less or equal 3 months) were all included under the term short-term. Specific explanations in each systematic review are provided in Table 1. Long-term, defined as follow-up measurements beyond 6 months were not included in any systematic review (at least considering the meta-analyses of interest). Finally, results are reported in mean difference (MD) or standardized mean difference (SMD) according to the statistic parameter applied in the included systematic reviews.

Results

A total of 126 citations were retrieved from e-databases. After removing duplicates, 64 titles and abstracts were evaluated. Subsequently, 24 full texts were examined in detail to check whether they satisfied our inclusion criteria. Of them, 9 systematic reviews with meta-analysis involving over 2,000 participants were included in this overview [10, 13, 14, 20–25]. Figure 1 shows the study selection process. The main characteristics of systematic reviews are shown in Table 1. Table 2 summarizes the characteristics of the VR interventions evaluated in the primary studies, including delivery mode, software used, duration, and frequency, where such information was reported in the included systematic reviews.

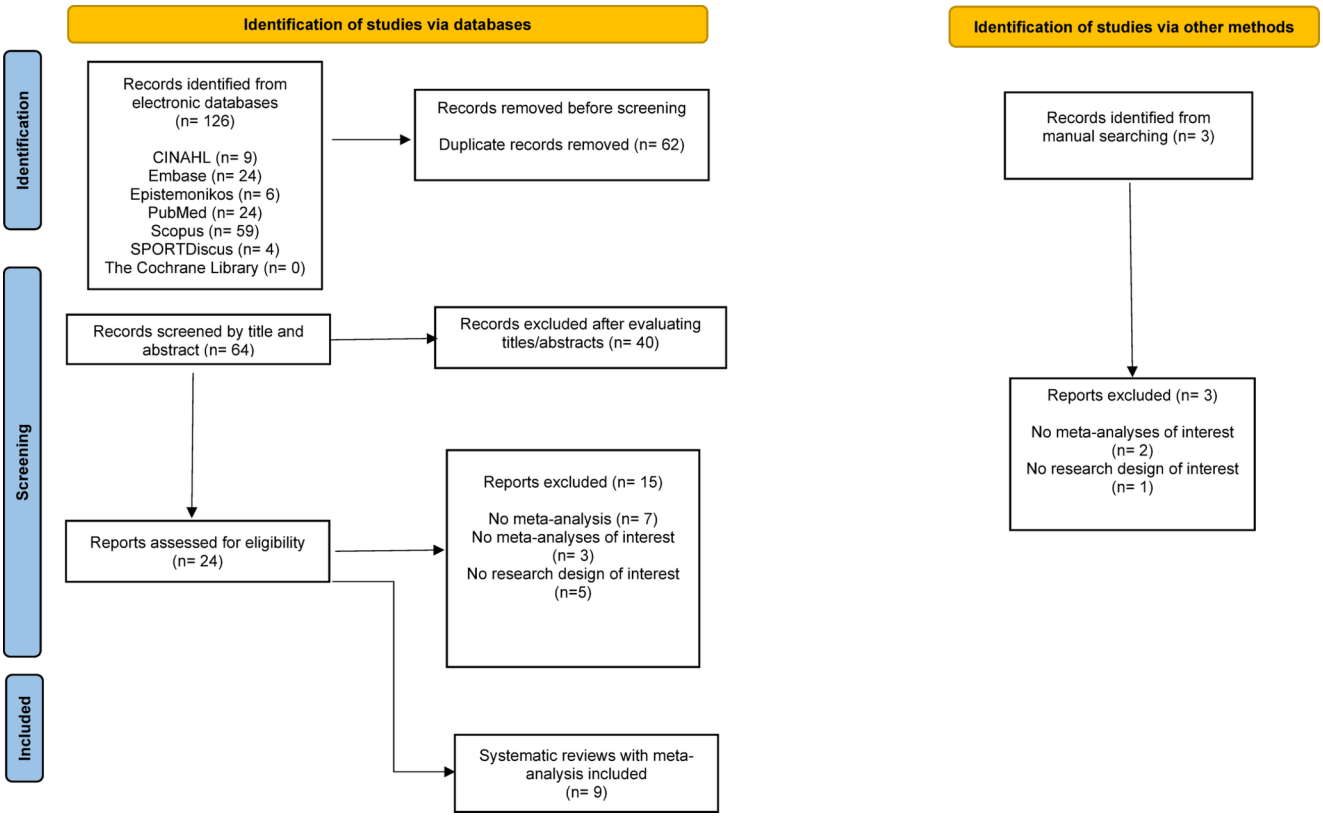

Fig. 1 PRISMA flowchart diagram of the study selection process

Methodological quality assessment

No reviews checked all items from AMSTAR 2 (Table 3). Inter-rater agreement was 95.83%. Mainly, no reviews completely reported a clear rationale for including only RCTs in their reviews (item 3). Only one review reported the sources of funding for the primary studies (item 10). A list of excluded studies and reasons for exclusion was included in only two reviews (item 7). A clear study protocol was reported by only two reviews (item 2). Additionally, the original studies were poorly described in detail (item 8). All reviews included the components of PICOS to build their eligibility criteria and/or research question (item 1), and most of the reviews addressed some items related to the development of meta-analysis (item 11) and declared their conflicts of interest (item 16).

The Degree of Overlap between meta-analyses

The degree of overlap was very high for all outcomes: range of motion (CCA=40%), pain (CCA=46%), disability (CCA=43%), kinesiophobia (CCA=80%), global perceived effect (CCA=100%), patient satisfaction (CCA=100%), cervical kinematic vmean (CCA=100%), and cervical kinematic vpeak (CCA=100%). Matrices of evidence and CCA calculations are shown in **Supplementary Files 3–11**.

Main findings: meta-analyzed outcomes and GRADE assessment

A total of six out of nine included reviews were included [14, 20, 21, 23–25]. Table 4 shows a summary of those meta-analyzed findings where GRADE assessment was applied. All meta-analyses that did not satisfy our definition of time effect in terms of short, intermediate, and long term were only reported in Table 1 for transparency.

Effects of VR on pain intensity (short term)

Most of the meta-analyses showed no differences between VR and control groups to improve pain intensity:

1. Ahern et al. (MD -9.08; 95%CI -21.84, 3.67; I2 48%; k = 2; *N* = 109) (GRADE: low evidence) [20].
2. Brea-Gómez et al. (MD -6.12; 95%CI -12.74, 0.49; I2 41%; k = 4; *N* = 204) (GRADE was not applied) [21].

Table 2 Key characteristics of the Virtual Reality interventions evaluated in each of the included reviews

Systematic review	Primary studies included in the MA	Delivery mode (iVR, niVR, siVR), VR system	Software used	VR use during sessions/ frequency/treatment duration
Ahern et al. 2020	Two RCTs	(study 1): N/R, VR airplane flight via headset (study 2): N/R, VR airplane flight via headset	(study 1): N/R (study 2): N/R	(study 1): Four 5-min sessions/day, 4 times/wk., for 4 wks. (study 2): Four to six 30-min sessions over 5 wks.
Brea-Gómez et al. 2024	Six RCTs	(study 1): iVR, Head-mounted VR display with 3D motion tracker (study 2): iVR, Oculus Rift DK1 (study 3): niVR, Monitor screen and Head Mouse Extreme® (study 4): iVR, Vox Play glasses with HMD and LG Q6 smartphone (study 5): iVR, Modified 3Space Fastrak and helmet with an integrated monitor (Full Dive and Ocean Aquatium) (study 6): iVR, Oculus Go glasses by remote control	(study 1): Unity-pro software 3.5 (study 2): Unity-pro software 3.5 (study 3): N/R (study 4): N/R (study 5): N/R (study 6): N/R	(study 1): One 15–20 min session/wk., for 5 wks. (study 2): Four 20 min (5 min, 4 times/day) sessions/wk., for 4 wks. (study 3): Two 16 min sessions/wk., for 4 wks. (study 4): Two sessions/wk., for 4 wks. Session duration: N/R (study 5): Two 20 min sessions/wk., for 3 wks. (study 6): Three 20 min sessions/wk., for 6 wks.
Grassini 2022	Three RCTs	(study 1): N/R, Cervigame® (study 2): N/R, N/R (study 3): N/R, Vox Play glass with HMD clamping system	(study 1): N/R (study 2): N/R (study 3): N/R	(study 1): N/R (study 2): N/R (study 3): N/R
Guo et al. 2023	Six RCTs	(study 1): iVR, N/R (study 2): iVR, N/R (study 3): iVR, N/R (study 4): iVR, Cervigame® (study 5): iVR, N/R (study 6): iVR, N/R	(study 1): N/R (study 2): N/R (study 3): N/R (study 4): N/R (study 5): N/R (study 6): N/R	(study 1): Four to six 30-min sessions over 5 wks. (study 2): Two sessions/wk., for 4 wks. Session duration: N/R (study 3): Six 20 min sessions/wk. over 4 wks. (study 4): Eight sessions over 4 wks. Session duration: N/R (study 5): Four 20 min (5 min, 4 times/day) session/wk., for 4 wks. (study 6): Eighteen 20 min sessions over 6 wks.
Hao et al. 2024	Six RCTs	(study 1): iVR, HMD with 3D motion tracking (study 2): iVR, Oculus HMD with 3D motion tracking (study 3): iVR, Oculus HMD, Oculus Rift and Gala 360 apps (study 4): iVR, HMD (study 5): niVR, Cervigame® (study 6): iVR, Head-mounted devices	(study 1): N/R (study 2): N/R (study 3): N/R (study 4): N/R (study 5): N/R (study 6): N/R	(study 1): Four to six 30-min sessions over 5 wks. (study 2): Four 20 min sessions/4 days over 4 wks. (study 3): Three 20 min sessions/wk., for 6 wks. (study 4): Six 20 min sessions over 3 wks. (study 5): Two 21 min sessions over 4 wks. (study 6): Two sessions/wk., for 4 wks. Session duration: N/R
Henriquez-Jurado et al. 2024	Five RCTs	(study 1): iVR, Oculus Go VR glasses (study 2): iVR, N/R (study 3): niVR, Cervigame® (study 4): iVR, Oculus Rift (study 5): iVR, Vox Play glass and smartphone	(study 1): N/R (study 2): N/R (study 3): N/R (study 4): N/R (study 5): N/R	(study 1): Three 20 min sessions/wk., for 6 wks. (study 2): Six 20 min sessions. Treatment duration: N/R (study 3): Two 21 min sessions over 4 wks. (study 4): Sessions over 4 wks. Session duration: N/R (study 5): Two sessions/wk., for 4 wks. Session duration: N/R
Lo et al. 2024	Seven RCTs	(study 1): iVR, BOBOVR Z-6 attached to Samsung Galaxy A30s smartphone (study 2): iVR, Oculus Go VR HMD, Ocean Rift and Gala 360 apps (study 3): iVR, Pico G2 4k head-mounted glasses (study 4): iVR, Schutzhelm uvex pheos alpine, with an integrated monitor (VR 5DT HMD 8000-26 2D), 3Space Fastrak (study 5): iVR, HMD with a 3D motion tracker (Wrap 1200VR) (study 6): iVR, Oculus Rift DK1 HMD (study 7): iVR, Vox Play glass with HMD clamping system, Fulldive and Ocean Aquarium 3D	(study 1): HY Games v. 1.0.25 (study 2): N/R (study 3): N/R (study 4): N/R (study 5): Vuzix (study 6): N/R (study 7): N/R	(study 1): Three sessions/wk., for 6 wks. Session duration: N/R (study 2): Three 20 min sessions/wk., for 6 wks. (study 3): Ten 20 min sessions over 4 wks. (study 4): Two 20 min sessions/wk., for 3 wks. (study 5): Three 15–20 min sessions/wk., for 12 wks. (study 6): Four 20 min sessions/wk., for 4 wks. (study 7): Two sessions/wk., for 4 wks. Session duration: N/R

Table 2 (continued)

Systematic review	Primary studies included in the MA	Delivery mode (iVR, niVR, siVR), VR system	Software used	VR use during sessions/ frequency/treatment duration
Opara & Kozinc 2024	Eight RCTs	(study 1): niVR, Cervigame®, v1.01 (study 2): iVR, head device (study 3): niVR, head device (study 4): iVR, head device (study 5): iVR, head device (study 6): iVR, head device (study 7): iVR, N/R (study 8): iVR, 'Ocean Rift' and 'Gala 360' apps.	(study 1): N/R (study 2): N/R (study 3): N/R (study 4): N/R (study 5): N/R (study 6): N/R (study 7): N/R (study 8): N/R	(study 1): Two 21 min sessions/wk. over 4 wks. (study 2): Four to six 30-min sessions over 5 wks. (study 3): Two 3.5 min sessions/wk., for 4 wks. (study 4): Two sessions/wk., for 4 wks. Session duration: N/R (study 5): Six 20 min sessions over 3 wks. (study 6): Four 20 min (5 min, 4 times/day) sessions/wk., for 4 wks. (study 7): Four 5 min sessions/wk., for 4 wks. (study 8): Three 20 min sessions/wk., for 6 wks.
Ye et al. 2023	Four RCTs	(study 1): N/R (study 2): N/R (study 3): N/R (study 4): N/R	(study 1): N/R (study 2): N/R (study 3): N/R (study 4): N/R	(study 1): N/R (study 2): N/R (study 3): N/R (study 4): N/R

Abbreviations: HMD, head-mounted display; RCT, randomized controlled trial; MA, meta-analysis; N/R, not reported; VR, virtual reality; wk., week.Note: The VR type (immersive, iVR; non-immersive, niVR; or semi-immersive, siVR) is described as reported in the included systematic reviews

Table 3 The methodological quality of reviews (AMSTAR 2)

Author(s)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Ahern et al. 2020																
Brea-Gomez et al. 2024																
Grassini, 2022																
Guo et al. 2023																
Hao et al. 2024																
Henriquez-Jurado et al. 2024																
Lo et al. 2024																
Opara & Kozinc, 2024																
Ye et al. 2024																

Note: Answers: redcolor: No, yellow color: Partially yes, green color: Yes. Items: AMSTAR 1: Didthe research questions and inclusion criteria for the review include thecomponents of PICO? AMSTAR 2: Did the report of the review contain an explicitstatement that the review methods were established prior to the conduct of thereview and did the report justify any significant deviations from the protocol?AMSTAR 3: Did the review authors explain their selection of the study designsfor inclusion in the review? AMSTAR 4: Did the review authors use acomprehensive literature search strategy? AMSTAR 5: Did the review authorsperform study selection in duplicate? AMSTAR 6: Did the review authors performdata extraction in duplicate? AMSTAR 7: Did the review authors provide a listof excluded studies and justify the exclusions? AMSTAR 8: Did the reviewauthors describe the included studies in adequate detail? AMSTAR 9: Did thereview authors use a satisfactory technique for assessing the risk of bias inindividual studies that were included in the review? AMSTAR 10: Did the reviewauthors report on the sources of funding for the studies included in thereview? AMSTAR 11: If meta-analysis was performed did the review authors useappropriate methods for statistical combination of results? AMSTAR 12: Ifmeta-analysis was performed, did the review authors assess the potential impactof risk of bias in individual studies on the results of the meta-analysis orother evidence synthesis? AMSTAR 13: Did the review authors account for risk ofbias in individual studies when interpreting/ discussing the results of thereview? AMSTAR 14: Did the review authors provide a satisfactory explanationfor, and discussion of, any heterogeneity observed in the results of thereview? AMSTAR 15: If they performed quantitative synthesis did the reviewauthors carry out an adequate investigation of publication bias (small studybias) and discuss its likely impact on the results of the review? AMSTAR 16:Did the review authors report any potential sources of conflict of interest,including any funding they received for conducting the review?

3. Henríquez-Jurado et al. (SMD − 0.18; 95%CI -0.62, 0.25; I2 0%; k = 2; *N* = 86) (GRADE: very low evidence) [14].
4. Opara & Kozinc (SMD − 0.50; 95%CI -1.10, 0.09; I2 85%; k = 8; *N* = 324) (GRADE: low evidence) [25].

On the other hand, two meta-analyses found positive results in favour of VR in comparison to control groups to improve pain intensity:

Table 4 Summary of meta-analyses in which GRADE assessment was applied

Study	Outcome	Period	Effect size	Direction of effect	GRADE assessment
Ahern et al. 2020	Pain intensity	Short term	(MD -9.08; 95%CI -21.84, 3.67; I^2 48%; k = 2; *N* = 109)	No difference between groups	Low evidence
		Intermediate term	(MD -6.90; 95%CI -16.05, 2.25; I^2 0%; k = 2; *N* = 82)	No difference between groups	Low evidence
Henríquez-Jurado et al. 2024	Pain intensity	Short term	(SMD − 0.18; 95%CI -0.62, 0.25; I^2 0%; k = 2; *N* = 86)	No difference between groups	Very low evidence
Lo et al. 2024	Pain intensity	Short term	(SMD − 0.55; 95%CI -1.02, -0.08; I^2 75%; k = 7; *N* = 316)	Favour VR	Low evidence
Opara & Kozinc 2024	Pain intensity	Short term	(SMD − 0.50; 95%CI -1.10, 0.09; I^2 85%; k = 8; *N* = 324)	No difference between groups	Low evidence
Ahern et al.2020	Disability	Short term	(MD -2.24; 95%CI -6.38, 1.90; I^2 0%; k = 2; *N* = 109)	No difference between groups	Low evidence
	Disability	Intermediate term	(MD -4.30; 95%CI -10.57, 1.96; I^2 0%; k = 2; *N* = 82)	No difference between groups	Low evidence
Guo et al. 2023	Disability	Short term	(SMD − 3.07; 95%CI -6.57, 0.43; I^2 67%; k = 3; *N* = 112)	No difference between groups	Very low evidence
Henriquez-Jurado et al. 2024	Disability	Short term	(SMD − 0.26; 95%CI -0.49, -0.03; I^2 5.1%; k = 7; *N* = 417)	Favour VR	Low evidence
	Disability	Short term	(SMD − 0.64; 95%CI -1.1, -0.2; I^2 0%; k = 2; *N* = 86)	Favour VR	Very low evidence
Lo et al. 2024	Disability	Short term	(MD -2.59; 95%CI -3.51, -1.67; I^2 0%; k = 6; *N* = 282)	Favour VR	Low evidence
Opara & Kozinc 2024	Disability	Short term	(SMD − 0.49; 95%CI -1.05, 0.06; I^2 78%; k = 6; *N* = 252)	No difference between groups	Low evidence
Ahern et al. 2020	Kinesiophobia	Short term	(MD -1.75; 95%CI -6.78, 3.28; I^2 17%; k = 2; *N* = 109)	No difference between groups	Low evidence
	Kinesiophobia	Intermediate term	(MD -0.84; 95%CI -5.39, 3.70; I^2 0%; k = 2; *N* = 82)	No difference between groups	Low evidence
Henríquez-Jurado et al. 2024	Kinesiophobia	Short term	(SMD − 0.08; 95%CI -0.4, 0.25; I^2 0%; k = 3; *N* = 224)	No difference between groups	Low evidence
Lo et al. 2024	Kinesiophobia	Short term	(SMD − 0.09; 95%CI -0.40, 0.23; I^2 0%; k = 3; *N* = 153)	No difference between groups	Moderate evidence
Opara & Kozinc 2024	Kinesiophobia	Short term	(SMD − 0.19; 95%CI -0.52, 0.15; I^2 0%; k = 3; *N* = 136)	No difference between groups	Moderate evidence
Ahern et al. 2020	Global perceived effect	Short term	(MD 4.88; 95%CI 2.51, 7.26; I^2 0%; k = 2; *N* = 109)	Favour VR	Low evidence
	Global perceived effect	Intermediate term	(MD 12.27; 95%CI -3.89, 28.43; I^2 92%; k = 2; *N* = 109)	No difference between groups	Very low evidence
Henríquez-Jurado et al. 2024	Health-related quality of life	Short term	(SMD 0.06; 95%CI -0.29, 0.4; I^2 11.5%; k = 3; *N* = 221)	No difference between groups	Low evidence
Ahern et al. 2020	Patient satisfaction	Short term	(MD 6.26; 95%CI 3.90, 8.62; I^2 0%; k = 2; *N* = 109)	Favour VR	Low evidence

Note: MD: mean difference; SMD: standardized mean difference; VR: virtual reality

1. Henríquez-Jurado et al. (SMD − 0.45; 95%CI -0.68, -0.21; I2 0%; k = 7; *N* = 272) (GRADE rating was unclear) [14].
2. Lo et al. (SMD − 0.55; 95%CI -1.02, -0.08; I2 75%; k = 7; *N* = 316) (GRADE: low evidence) [24].

Effects of VR on pain intensity (intermediate term)

No difference between VR and control groups was found to improve pain intensity (MD -6.90; 95%CI -16.05, 2.25; I2 0%; k = 2; *N* = 82) (GRADE: low evidence) [20].

Effects of VR on disability (short term)

More than half of the meta-analyses found positive results in favour of VR decreasing disability:

1. Brea-Gómez et al. (MD -3.52; 95%CI -5.85, -1.20; I2 26%; k = 4; *N* = 204) (GRADE was not applied) [21].
2. Henrique-Jurado et al. (SMD − 0.26; 95%CI -0.49, -0.03; I2 5.1%; k = 7; *N* = 417) (GRADE: low evidence) [14].
3. Henríquez-Jurado et al. (SMD − 0.64; 95%CI -1.1, -0.2; I2 0%; k = 2; *N* = 86) (GRADE: very low evidence) [14].
4. Lo et al. (MD -2.59; 95%CI -3.51, -1.67; I2 0%; k = 6; *N* = 282) (GRADE: low evidence) [24].

On the other hand, three meta-analyses showed no differences between VR and control groups:

1. Ahern et al. (MD -2.24; 95%CI -6.38, 1.90; I2 0%; k = 2; *N* = 109) (GRADE: low evidence) [20].
2. Guo et al. (SMD − 3.07; 95%CI -6.57, 0.43; I2 67%; k = 3; *N* = 112) (GRADE: very low evidence) [23].
3. Opara & Kozinc (SMD − 0.49; 95%CI -1.05, 0.06; I2 78%; k = 6; *N* = 252) (GRADE: low evidence) [25].

Effects of VR on disability (intermediate term)

No difference between VR and control groups was found to improve disability (MD -4.30; 95%CI -10.57, 1.96; I2 0%; k = 2; *N* = 82) (GRADE: low evidence) [20].

Effects of VR on kinesiophobia (short term)

All the meta-analyses found no differences between VR and control groups to reduce kinesiophobia:

1. Ahern et al. (MD -1.75; 95%CI -6.78, 3.28; I2 17%; k = 2; *N* = 109) (GRADE: low evidence) [20].
2. Brea-Gómez et al. (SMD − 0.29; 95%CI -0.73, 0.15; I2 42%; k = 3; *N* = 162) (GRADE was not applied) [21].
3. Henríquez-Jurado et al. (SMD − 0.08; 95%CI -0.4, 0.25; I2 0%; k = 3; *N* = 224) (GRADE: low evidence) [14].
4. Lo et al. (SMD − 0.09; 95%CI -0.40, 0.23; I2 0%; k = 3; *N* = 153) (GRADE: moderate evidence) [24].
5. Opara & Kozinc (SMD − 0.19; 95%CI -0.52, 0.15; I2 0%; k = 3; *N* = 136) (GRADE: moderate evidence) [25].

Effects of VR on kinesiophobia (intermediate term)

No differences between VR and control groups to decrease kinesiophobia was found (MD -0.84; 95%CI -5.39, 3.70; I2 0%; k = 2; *N* = 82) (GRADE: low evidence) [20].

Effects of VR on global perceived effect (short term)

Inconsistent results between meta-analyses were found considering the effects of VR to improve the global perceived effect:

1. Ahern et al. (MD 4.88; 95%CI 2.51, 7.26; I2 0%; k = 2; *N* = 109) (GRADE: low evidence) [20].
2. Brea-Gómez et al. (MD 1.22; 95%CI -0.40, 2.83; I2 93%; k = 2; *N* = 118) (GRADE was not applied) [21].

Effects of VR on global perceived effect (intermediate term)

No difference between VR and control groups were found to improve the global perceived effect (MD 12.27; 95%CI -3.89, 28.43; I2 92%; k = 2; *N* = 109) (GRADE: very low evidence) [20].

Effects of VR on health-related quality of life (short term)

No differences between VR and control groups were found to improve health-related quality of life (SMD 0.06; 95%CI -0.29, 0.4; I2 11.5%; k = 3; *N* = 221) (GRADE: very low evidence) [14].

Effects of VR on patient satisfaction (short term)

Positive results were found in favour of VR in comparison to control groups to increase patient satisfaction (MD 6.26; 95%CI 3.90, 8.62; I2 0%; k = 2; *N* = 109) (GRADE: low evidence) [20].

Effects of VR on cervical kinematics (short term)

Positive results in favour of VR in comparison to control groups were found to increase cervical range of motion, but no differences between VR and control groups were found considering the rest of cervical kinematics parameters:

1. Cervical range of motion (SMD − 0.42; 95%CI -0.65, -0.19; I2 24%; k = 2; *N* = 112) (GRADE was not applied) [21].
2. vpeak (SMD 0.03; 95%CI -0.20, 0.26; I2 26%; k = 2; *N* = 112) (GRADE was not applied) [21].
3. vmean (SMD − 0.03; 95%CI -0.30, 0.24; I2 44%; k = 2; *N* = 112) (GRADE was not applied) [21].
4. Time to peak velocity percentage (TTP%) (SMD − 0.17; 95%CI -0.51, 0.16; I2 62%; k = 2; *N* = 112) (GRADE was not applied) [21].

Discussion

This overview of systematic reviews has shown whether meta-analyses evaluating the effects of VR applied alone or in combination with other interventions are more effective than control groups in improving important outcome measures, including pain intensity, disability, kinesiophobia, or global perceived effect. Overall, the meta-analyses found that in the short term (from immediate post-intervention up to 3 months), VR based-rehabilitation may not be better than control groups for managing kinesiophobia, health-related quality of life, and some cervical kinematics parameters such as vmean or vpeak. Furthermore, we found inconsistencies between the results of meta-analyses from different systematic reviews regarding the effects of VR on pain intensity, disability, and global perceived effect.

Finally, positive results have been found in favor of VR in terms of patient satisfaction and cervical range of motion. On the other hand, those meta-analyses that evaluated the effects of VR in the intermediate term (from 3 to 6 months) found that VR is not better than controls in improving pain intensity, disability, kinesiophobia, and the global perceived effect. These results may be alarming considering the relevance that VR based-rehabilitation is having in the management of musculoskeletal disorders in recent years. However, we have detected important methodological issues, and they need to be discussed so that the reader is aware of them when interpreting the results of this overview.

A first relevant issue concerns the poor reporting of key characteristics of the VR interventions, including the delivery mode. Although VR can be applied through immersive, semi-immersive, and non-immersive modes, not all included systematic reviews consistently described the delivery mode of the interventions, and most of them included clinical trials primarily evaluating the effects of immersive or non-immersive VR and did not perform subgroup analyses to explore whether outcomes differed according to the type of VR used. In particular, the use of semi-immersive VR in patients with chronic neck pain was scarcely reported and has not been meta-analyzed, leaving a significant gap in our knowledge in this regard. The second point is related to the software used. Under the VR premise, various applications have been tested, including, but not limited to, computer-based games or airplane flight-simulations delivered via headsets. These applications have not been fully described in most systematic reviews, so we do not know the details of whether they involved movements not only of the cervical region but also of the upper limb or the whole body. We also do not know whether the clinical trials reported in detail how the VR sessions were executed, since none of the included systematic reviews used the TIDieR checklist to show whether the interventions reviewed were reported in sufficient detail to allow replicability. As shown in Table 2, important aspects such as the delivery mode, and the specific VR parameters were frequently unreported, while treatment dosage (session frequency and treatment duration) was not even described in two of the included reviews [13, 22]. Taken together, these findings leads us to speculate that perhaps the problem is not VR itself, but rather the possible lack of standardization and the insufficient description of programs specifically tailored and adapted to patients with chronic neck pain.

The third point relates to heterogeneity in pain intensity and disability findings. Regarding control groups, most of the clinical trials included in meta-analyses used active controls, primarily involving different exercise modalities such as proprioceptive training, kinematic training via head-mounted laser, sensorimotor training, or motor control exercises. In this sense, we could speculate that the application of VR alone or in conjunction with any of the exercise modalities (as evaluated in some clinical trials) might not be more effective than the exercise modality alone. However, we believe that it would have been necessary to conduct subgroup analyses to detect whether there is specific exercise modalities or other interventions that produce better results than VR. Furthermore, some systematic reviews have conducted subgroup analyses by the type of control group, but they used global terms such as rehabilitation and control group, which tells nothing to the reader, much less to the clinician, so the reproducibility of these data in the clinical setting is not very high. In addition, other aspects such as characteristics of patient population, the presence of psychosocial factors that could limit adherence (e.g., low self-efficacy beliefs or high kinesiophobia or pain catastrophizing), and poor inclusion of some VR types (e.g.

semi-immersive) may have affected heterogeneity on pain intensity and disability.

The final point is associated with the enormous overlap found in the meta-analyses, as well as the low certainty of the evidence (GRADE system). Considering the overlap between meta-analyses, it is important for the reader to be aware that the clinical trials used by the different systematic reviews are practically the same, so we invite the reader to be thoughtful when comparing the results of the included reviews. Furthermore, it was very positive to observe that many of the systematic reviews used the GRADE system to assess the certainty of the evidence. However, the certainty of the evidence was found to be mainly low or very low for most outcomes, highlighting the presence of aspects such as risk of bias, inconsistency in the results, or imprecision of the findings.

Clinical implications

Despite the lack of consistency observed in this overview for most of the outcome measures (e.g., pain intensity and disability), readers, especially clinicians, should consider the following. First, the very high degree of overlap found among the meta-analyses reviewed suggests that we cannot know with robust certainty whether VR could be an effective intervention for managing these outcomes. Therefore, new, high-quality systematic reviews analyzing all the findings presented in this study are needed. Second, our results have shown that VR could be a promising intervention for improving certain outcomes, such as patient satisfaction and cervical range of motion. These results could encourage clinicians to use VR primarily as a distraction technique and even as a more user-friendly way to engage in physical activity, which could help increase patient satisfaction levels. However, it is also important to note that the degree of overlap among meta-analyses for these outcomes was very high. Third, clinicians who are encouraged to apply VR should consider the possible presence of barriers to applying the intervention such as patient preferences, cost-effectiveness of intervention, and technical skills to use VR.

Future research

We primarily encourage authors of systematic reviews to conduct subgroup analyses considering the delivery modes and content of VR. Subgroup analyses in terms of the control group and whether VR was applied in isolation or in combination with other interventions are also recommended. Furthermore, future randomized clinical trials should use the TIDieR checklist to show a complete description of VR interventions along with the necessity of establishing standardized intervention protocols that could guide clinicians in the use of VR in a real-world clinical context.

Limitations

The main limitation is inherent to this type of design. We acknowledge that the results are based on findings reported by systematic reviews and not by the clinical trials themselves. Therefore, our criticism is associated with the methodological improvement of systematic reviews with meta-analyses in this field, rather than with clinical trials.

Conclusion

The meta-analyses included in this overview have shown that VR does not produce better effects than different control groups in the short term, considering kinesiophobia, health-related quality of life, and cervical kinematic parameters (e.g., vmean). These results were also observed in the intermediate term for kinesiophobia, pain intensity, disability, and global perceived effect. Only positive effects in favor of VR have been found in the short term for patient satisfaction and cervical range of motion. Inconsistency between meta-analyses were found in the short term for pain intensity, disability, and global perceived effect. However, there are some important points that need to be considered before determining whether VR should be incorporated into the rehabilitation of people with chronic neck pain. Particularly, it is important to underline a very high degree of overlap found between meta-analyses analyzed, which invites us to be cautious with the synthetized findings.

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Declarations

Competing interests The authors declare no competing interests.

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Consent to Participate Not applicable (overview of systematic reviews with meta-analyses previously published).

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