

Review

Virtual Reality Intervention for Patients With Neck Pain: Systematic Review and Meta-analysis of Randomized Controlled Trials

Qifan Guo^{1*}, MD; LIMing Zhang^{1*}, BSc; Chenfan Gui¹, MD, DPT; Guanghui Chen², MD; Yi Chen¹, MD; Huixin Tan¹, MD; Wei Su¹, MD; Ruishi Zhang¹, MD; Qiang Gao¹, MD, PhD

¹Department of Rehabilitation Medicine, West China Hospital, Sichuan University, Chengdu, China

²Department of Traumatology and Orthopedics of Traditional Chinese Medicine, The First Affiliated Hospital of Guangxi University of Chinese Medicine, Nanning, China

*these authors contributed equally

Corresponding Author:

Qiang Gao, MD, PhD

Department of Rehabilitation Medicine

West China Hospital

Sichuan University

No. 37 Guoxuexiang

Sichuan Province

Chengdu, 610041

China

Phone: 86 18980605992

Email: gaoqiang_hxkf@163.com

Abstract

Background: Neck pain is a prevalent condition that causes an enormous health care burden due to the lack of efficient therapies. As a promising technology, virtual reality (VR) has shown advantages in orthopedic rehabilitation. However, there is no meta-analysis evaluating the effectiveness of VR in neck pain management.

Objective: This study aims to review original randomized controlled trials (RCTs) evaluating the effectiveness of VR for neck pain and to provide evidence for the clinical application of a new alternative approach for pain management.

Methods: A total of 9 electronic databases were systematically searched for relevant articles published from inception to October 2022. RCTs in English or Chinese that investigated VR therapy for participants with neck pain were included. The methodological quality and the evidence level were assessed using the Cochrane Back and Neck Risk of Bias tool and the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) guideline, respectively.

Results: A total of 8 studies with 382 participants were included for the final analysis. For the pain intensity, the overall pooled effect size was 0.51, with a standardized mean difference (SMD) of -0.51 (95% CI -0.91 to -0.11 ; GRADE: moderate), favoring VR therapy compared with controls. Subgroups analyses revealed that significant differences in pain intensity were found in the multimodal intervention (VR in combination with other therapies) than in other interventions (SMD -0.45 , 95% CI -0.78 to -0.13 ; GRADE: moderate), and better analgesic effects were also observed in patients with chronic neck pain receiving VR intervention (SMD -0.70 , 95% CI -1.08 to -0.32 ; GRADE: moderate) and patients treated in the clinic or research unit (SMD -0.52 , 95% CI -0.99 to -0.05 ; GRADE: moderate) than controls. Regarding other health outcomes, the VR experienced less disability, lower kinesiophobia, and greater kinematic function (cervical range of motion, mean and peak velocity). Nevertheless, the follow-up effects of VR therapy on pain intensity and disability were not found.

Conclusions: Existing moderate evidence support VR as a beneficial nonpharmacological approach to improve pain intensity in patients with neck pain, with advantages to multimodal intervention, people with chronic neck pain, and clinic or research unit-based VR therapy. However, the limited quantity and high heterogeneity of the articles limit our findings.

Trial Registration: PROSPERO CRD42020188635; <https://tinyurl.com/2839jh8w>

(*J Med Internet Res* 2023;25:e38256) doi: [10.2196/38256](https://doi.org/10.2196/38256)

KEYWORDS

meta-analysis; virtual reality; neck pain; disability; systematic review

Introduction

Neck pain is a worldwide condition, with nearly 60% to 80% of individuals developing neck pain during their lifetime [1,2]. Most patients with neck pain experience various physical impairments, such as reduced cervical range of motion (CROM) and moving speed [3,4]. In addition, neck pain can lead to various psychological issues (eg, fear of movement and depression) [5,6]. These issues may impair patients' work performance and quality of life, leading to large economic losses [7]. Current treatments for this health condition are mainly medications, surgeries, and conservative therapies (eg, physiotherapy or acupuncture), which can be time-consuming, expensive, and unsustainable [8]. Therefore, there is an urgent need to explore effective treatments for patients with neck pain.

Exercise is recommended by current clinical guidelines as an effective treatment for patients with neck pain [9,10]. Virtual reality (VR) is a unique form of exercise established by Morton Heiling in 1962 and has been evolving over the past 60 years [11,12]. VR technology is defined as a system that allows users to interact with images and sounds in a virtual environment, which can stimulate response and provide real-time feedback concerning their performance. This technology can be combined with computer or mobile device screens and head-mounted displays to better interact with users [13,14].

Over the past decade, VR has gradually become a valuable tool for assessment and intervention in clinical rehabilitation due to the continuous research and cost reduction in the field of virtual technology [15]. A typical example of the application of VR in the medical field is neurological rehabilitation, especially after a stroke [16,17]. Numerous studies [18-20] have shown that VR therapy can greatly improve upper limb motor function and cognitive abilities in people who have had a stroke with an acceptable safety profile. Other benefits of VR therapy could be realized, on the other hand, in the management of patients with mental health disorders, such as anxiety, depression, drug addiction, and eating disorders [21,22]. The potential therapeutic mechanisms of VR include task-oriented repetition, positive feedback, and embodied simulation [23]. In addition, VR can also assist researchers and clinicians in data collection and monitoring of therapeutic processes via related evaluation tools, which can facilitate medical decision-making and enhance safety in clinical practice [24,25].

As a noninvasive analgesic approach, VR therapy has attracted plenty of studies on pain management. Previous studies [26-28] demonstrated the potential efficacy of VR-based rehabilitation on pain and disability in individuals with orthopedic diseases, including rheumatoid arthritis, shoulder impingement syndrome, low back pain, and chronic neck pain. In addition, a systematic review [29] concluded that VR could improve pain intensity and disability compared to other interventions in patients with neck or lower back pain. However, to our knowledge, no meta-analysis has been carried out to critically evaluate the intervention effects of VR on neck pain. Therefore, we aimed to conduct a meta-analysis of randomized controlled trials (RCTs) through multiple literature searches to investigate the

potential efficacy of VR in reducing pain intensity in patients with neck pain.

Methods

Study Protocol and Registration

This study protocol was registered on PROSPERO (CRD42020188635). This study was reported according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) guidelines to ensure the transparency of the research [30]. The Cochrane Handbook for Systematic Reviews of Interventions (version 5.1.0) was followed [31].

Data Sources and Searches

Databases utilized to search the eligible trials include 7 English literature databases, namely, Medline (via PubMed), Embase, Web of Science Core Collection, CENTRAL, Scopus, Physiotherapy Evidence Database (PEDro), and ClinicalTrials, as well as 2 Chinese literature databases, namely, China National Knowledge Infrastructure Library and Wan Fang database. The databases were searched from their inception until October 2022. Relevant journals were manually searched to identify eligible studies. The last search was conducted on October 30, 2022.

The search was performed using a combination of relevant Medical Subject Headings (MeSH) terms and free text words: (neck pain **or** neck ache **or** cervical spondylosis) **AND** (virtual reality **or** virtual reality exposure therapy **or** VR **or** virtual reality simulator **or** virtual reality system **or** virtual reality head-mounted display **or** telerehabilitation **or** remote rehabilitation). Search strategies for each database are presented in [Multimedia Appendix 1](#). After the selection stage, a further search was carried out by tracking the citations of the included trial (snowballing). The inclusion and exclusion criteria of studies were designed based on the PICO (Participants, Interventions, Control, and Outcomes) principle [32].

Study Selection

Studies were included for RCTs reported in English or Chinese and published in a peer-reviewed journal. The selection criteria were established according to the prespecified PICO strategy: (1) Participants: patients with neck pain, irrespective of age and the stage of pain; (2) Interventions: unimodal intervention (VR therapy alone) or multimodal intervention (VR therapy in combination with other interventions), including various VR delivery device and levels of immersion. We define VR therapy as a technology that enables patients to interact with a virtual environment by motion sensors or other devices and receive real-time feedback to improve their performance; (3) Control: comparison with other interventions (eg, interventions without VR, standard treatment, no intervention); (4) Outcomes: pain intensity and other health outcomes related to neck pain.

Studies were excluded if they were nonrandomized controlled trials or quasi-RCTs, where quasi-randomized was considered as allocating patients based on a pseudorandom sequence (eg, admission number, date of birth, or alternate assignment). In addition, clinical observations, case reports, letters, abstracts, review articles, studies published in languages other than English

and Chinese, and those with insufficient data after contacting the author were excluded from the final synthesis.

Outcome Measures

Pain intensity measured by a numeric rating scale (NRS) or a visual analog scale (VAS) was the primary outcome, and disability, kinesiophobia, CROM, and motion velocity (mean and peak) were descriptively presented as the secondary outcomes.

Identification of Studies

Duplicates were removed by EndNote X9 (Clarivate Analytics), and then 2 reviewers (authors QFG and LZ) independently screened the titles, abstracts, and full texts within the included databases to identify the relevant studies. Any discrepancies were resolved by discussion or by consulting a third reviewer (author QG).

Data Extraction and Management

The extracted data included basic information about the study (ie, author name, year published, and country); risk of bias based on the Cochrane Back and Neck (CBN) Risk of Bias tool [33]; patients' demographic information (ie, sample size, age, sex ratio, and symptoms duration); type of intervention (ie, brief details of VR therapy, duration, and the number of sessions); type of control; outcomes (ie, time of outcome assessment, and outcome measures); and adverse events. In addition, follow-up data were also collected to present the lasting effect of VR therapy. Where available, mean and SD values were extracted from the text and tables.

Two reviewers (authors QFG and LZ) conducted data extraction independently based on the predecided data extraction form. Any dispute was solved by consulting the third reviewer (author QG). If the relevant data were not enough, we contacted the original author for more information via email.

Quality Assessment

The 2 reviewers (authors QFG and LZ) independently evaluated the methodological quality and the evidence levels of the included trials using the updated 2015 CBN Risk of Bias tool [33] and the Grading of Recommendations Assessment, Development, and Evaluation guideline (GRADE) [34], respectively. Unresolved disagreements were reviewed by the third reviewer (author QG).

The Risk of Bias tool is recommended by the CBN group for quality assessments of studies on neck or back pain and has demonstrated great interrater reliability [35]. It consists of 13 items in the following domains: randomization, concealed allocation, blinding (participants, personnel, and assessor),

intention-to-treat, dropouts, reporting bias, baseline differences, cointerventions, compliance, timing, and other bias. Data were imported into RevMan (version 5.3; Cochrane Collaboration) software to create the risk-of-bias plots.

The GRADE guidelines were used to assess the certainty of the evidence for each primary and secondary outcome measure in the meta-analysis [36]. This grading criterion classified the evidence into 4 levels (ie, high, moderate, low, and very low) depending on the bias factors, including the risk of bias, inconsistency, indirectness, imprecision, and other considerations.

Statistical Analysis

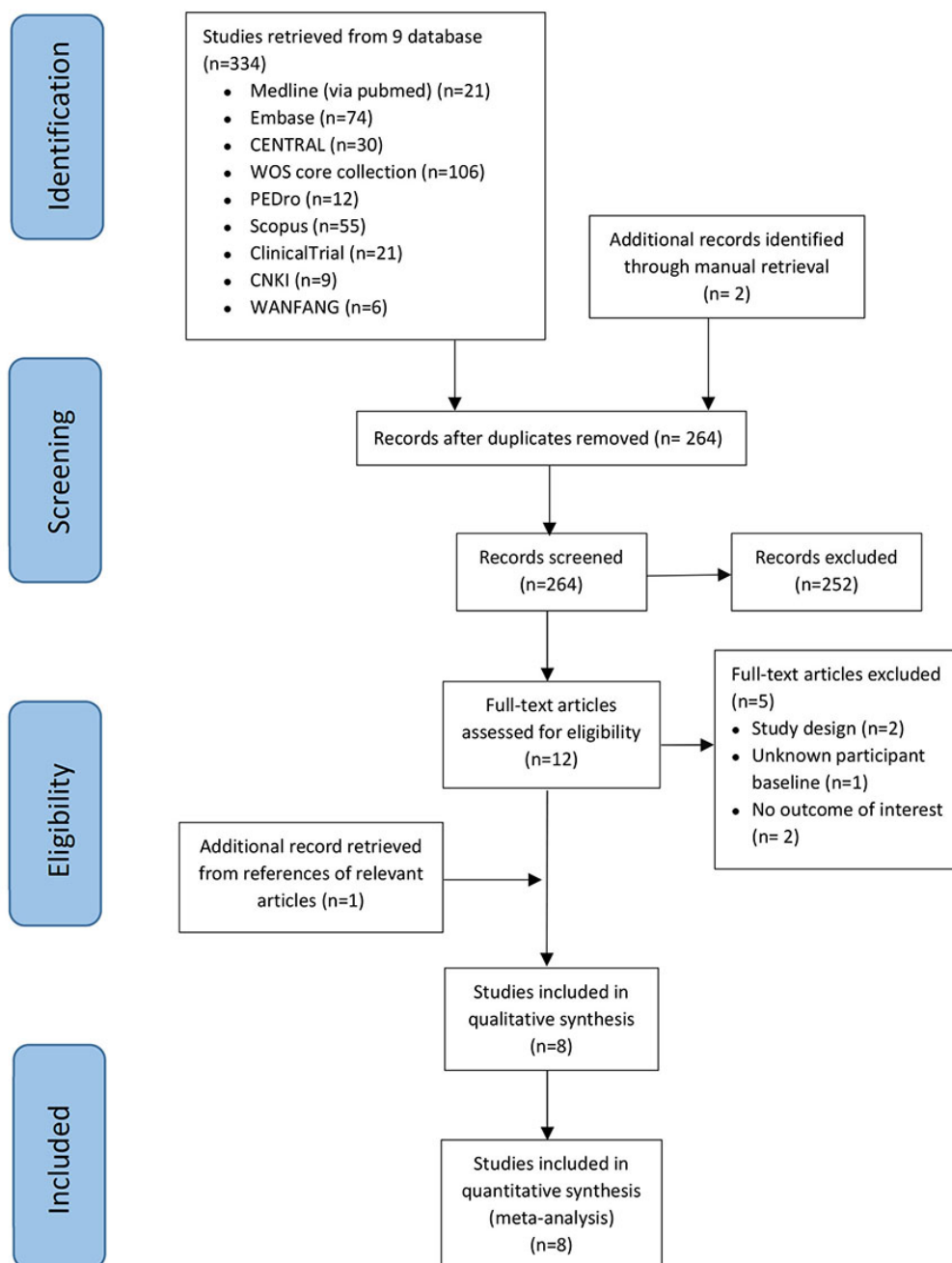
The aforementioned RevMan software was used to perform the statistical analysis and create forest plots to display the results. Related statistical indicators (mean, SD, and sample size) were extracted and imported into RevMan. Continuous outcomes were presented using mean difference for outcomes measured using the same instrument, standardized mean difference (SMD) for outcomes measured by different methods, and 95% CIs. A fixed effects model was used to calculate the size of the pooled effect. When significant heterogeneity ($I^2 > 50\%$) was observed, the random effects model was used, and subgroup analysis was conducted to explore the possible causes of heterogeneity among the studies. Subgroups analyses were performed according to the comparisons of intervention (unimodal vs multimodal intervention), the stage of neck pain (chronic neck pain vs various stages including acute, subacute, and chronic neck pain), the clinical operational model of VR therapy (clinic or research unit-based therapy vs home-based therapy), and the type of scale used (VAS vs NRS).

Regarding the follow-up results, only follow-up effects on pain intensity and disability were explored due to the lack of current studies.

Results

Search and Selection

A total of 334 records were selected from 7 English and 2 Chinese electronic databases. Two studies were obtained through manual retrieval. After removing duplicates, 264 studies remained, among which 12 studies were identified for full-text retrieval based on the aforementioned criteria. An additional article [37] was retrieved through the references of relevant articles, yielding a sum of 8 studies [37-44]. All 8 studies were included in the final quantitative synthesis. Figure 1 presents the selection process and reasons for study exclusion.

Figure 1. Flow chart of the review process.

Study and Patient Characteristics

Study Characteristics

All 8 (100%) RCTs [37-44] included in the meta-analysis were written in English. They were conducted in Oceania (Australia

[38,42]), Europe (Spain [39], Germany [40], and Turkey [44]), and Asia (Iran [41], India [37], and Israel [43]). The studies were published between 2015 and 2022, and a total of 382 participants (intervention: 167; control: 215) were enrolled. The sample sizes of these studies ranged from 32 to 90. Detailed characteristics of the eligible studies are shown in Table 1.

Table 1. Summary of the included studies.

Author, year	Patient characteristics		Stage of pain	Intervention		Dosage	Outcomes	Time points
	Participants, n (F ^a /M ^b)	Age (years), mean (SD)		Experiment	Control			
Sarig Bahat et al [38], 2015	32 (21/11)	IG ^c (n=16): 40.63 (14.18); CG ^d (n=16): 41.13 (12.59)	Chronic neck pain	IG: kinematic training + VR ^e therapy	CG: kinematic training	4-6 sessions for 30 min each week over 5 weeks	VAS ^f , NDI ^g , TSK ^h , CROM ⁱ , and velocity (mean and peak)	Preintervention, postintervention (5 weeks), and follow-up (3 months)
Tejera et al [39], 2020	44 (23/21)	IG (n=22): 32.72 (11.63); CG (n=22): 26.68 (9.21)	Chronic neck pain	IG: VR therapy	CG: exercise	8 treatment sessions for 4 weeks	VAS, NDI, TSK	Preintervention, postintervention (4 weeks), follow-up (1 month), and follow-up (3 months)
Nusser et al [40], 2021	51 (32/19)	IG (n=17): 51.2 (8.8); CG1 (n=16): 53.1 (5.7); CG2 (n=18): 49.8 (8.1)	Chronic neck pain	IG: VR therapy + standard rehabilitation	CG1: Sensorimotor training + standard rehabilitation CG2: standard rehabilitation	6 20-min sessions over 3 weeks	NRS ^j , NDI, CROM	Preintervention and postintervention (3 weeks)
Rezaei et al [41], 2015	42 (20/22)	IG (n=21): 36.19 (9.80); CG (n=21): 31.23 (9.49)	Chronic neck pain	IG: VR therapy	CG: conventional proprioceptive training	8 training sessions over 4 weeks	VAS, NDI	Preintervention, postintervention (4 weeks), and follow-up (5 weeks)
Sarig Bahat et al [42], 2017	90 (63/27)	IG (n=30): 48 (NR ^k); CG1 (n=30): 48 (NR); CG2 (n=30): 48 (NR)	Chronic neck pain	IG: VR therapy	CG1: laser exercise CG2: no intervention	20 min a day, 4 times a week, for 4 weeks	VAS, NDI, TSK, CROM, velocity (mean and peak)	Preintervention, postintervention (4 weeks), and follow-up (3 months)
Mukherjee et al [37], 2021	44 (21/23)	IG (n=22): 55.81 (15); CG (n=22): 54.81 (13)	Subacute or chronic neck pain	IG: VR therapy + conventional physiotherapy	CG: conventional physiotherapy	10 min each day for 3 consecutive days for 1 week	NRS, TSK, CROM	Preintervention and postintervention (3 days)
Sarig Bahat et al [43], 2020	45 (4/41)	IG (n=22): 30 (5.8); CG (n=23): 28 (5.1)	Acute, subacute, or chronic neck pain	IG: VR therapy	CG: conventional physical therapy	20 min for each week over 4 weeks	VAS, NDI, ROM, velocity (mean and peak)	Preintervention, postintervention (4 weeks), and follow-up (6 months)
Cetin et al [44], 2022	34 (23/11)	IG (n=17): 40 (11.88); CG (n=17): 41.94 (10.76)	Chronic neck pain	IG: VR therapy + Motor control	CG: Motor control	40 min each session for 18 sessions over 6 weeks	VAS, CROM	Preintervention and postintervention (6 weeks)

^aF: female.

^bM: male.

^cIG: intervention group.

^dCG: control group.

^eVR: virtual reality.

^fVAS: visual analog scale.

^gNDI: Neck Disability Index.

^hTSK: Tampa Scale of Kinesiophobia.

ⁱCROM: cervical range of motion.

^jNRS: numeric rating scale.

^kNR: not reported.

Participant Characteristics

The 8 studies [37-44] included participants with chronic neck pain, among which 1 (13%) study [37] also included patients in the subacute phase, and another study (n=1, 13%) [43] recruited patients in the acute or subacute stages. All studies included both male and female participants, and 5 (63%) [38,39,42-44] included more females than males. The mean age of patients ranged between 26.68 (SD 9.21) years and 55.81 (SD 15) years. Only 2 (25%) studies [38,41] reported the duration of symptoms, which ranged from 22.04 (SD 16.79) months to 98.06 (SD 96.81) months. The characteristics of the participants are presented in Table 1.

Intervention

The 8 studies [37-44] compared VR with other interventions (eg, kinematic exercise [38,39], general sensorimotor training [40], conventional rehabilitation [37,40,43], proprioceptive training [41], laser training [42], motor control [44], and no intervention [42]). All interventions used the immersive VR device, with the intervention duration varying from 1 to 6 weeks and intervention frequency ranging from once per week to once per day. As a traditional face-to-face care model, participants in 7 (88%) studies [37-41,43,44] received VR therapy in a clinic [37,40,44] or research unit [38,39,41,43]. However, 1 (13%) study [42] adopted a new approach to telemedicine and home-based rehabilitation.

Various VR programs were developed in the included studies. To reduce disability, Sarig Bahat et al [38] from Australia developed a VR system with 3 modules containing CROM, velocity, and accuracy therapy, which were tailored to each participant and progressed according to their performance. Participants were guided to complete between 4 and 6 supervised intervention sessions over 5 weeks. Similarly, Tejera et al [39] from Spain used a VR program that allowed participants to perform cervical flexion, extension, rotation, and lateral flexion movements when immersed in a simulated living room or ocean. The photos of animals in the simulated environment offered enough feedback to motivate the participants' neck motions. The participants were recommended to perform 3 series comprising 10 repetitions of VR exercise with 30 seconds of rest between exercises. Nusser and colleagues [40] from Germany provided VR-based "neck-specific sensorimotor training" for participants with nontraumatic chronic neck pain. During treatment, participants were asked to gradually follow a virtual globe by increasing the CROM to train their cervical kinematic function. The training was divided into six 20-minute sessions, during which the study staff provided assistance. In Iran, Rezaei and colleagues [41] studied the effectiveness of VR (Cervigame) for adults with neck pain. The novel video game comprised 50 stages that were further divided into unidirectional and 2-directional stages ranging from easy to hard. Participants were required to complete 8 training sessions over 1 month. In Australia, Sarig Bahat and colleagues [42] had participants with chronic neck pain receive VR training at home

4 times each week for 1 month. Each participant was provided with a training plan directed toward (1) increasing CROM, (2) increasing motion velocity, and (3) increasing motion accuracy in smooth head pursuit, which was also applied in another study conducted in Israel [43]. Mukherjee et al [37] from India conducted a VR therapy using an immersive VR headset. Participants were requested to sit on a chair with back support and move their necks to hit each virtual goal by increasing their CROM for 3 consecutive days a week. In addition, the VR equipment applied by Cetin et al [44] from Turkey enabled the participants to sit in a chair that allowed 360° movement and required them to rotate their necks in all directions during VR sessions to achieve therapeutic effects. Patients in the intervention group were expected to receive 20 minutes of VR treatment each session and attend a total of 18 treatments over 6 weeks. The characteristics and details of each intervention are listed in Table 1.

Outcome Measures

Various instruments were used to measure the intervention effects. For the primary outcomes, pain intensity was measured using a VAS [38,39,41-44] and an NRS [37,40]. These 2 tools graded the pain intensity from 0 (no pain) to 10 cm or 100 mm (worst pain imaginable) [45-47]. For the secondary outcomes, disability was evaluated by the Neck Disability Index (NDI) in 5 (63%) studies [38-42]. Kinesiophobia was assessed using the Tampa Scale of Kinesiophobia (TSK) in 4 (50%) studies [37-39,42]. Additionally, 5 (63%) studies evaluated CROM using VR devices [38,40,42], a cervical measuring gauge [44], and a standard goniometer [37], respectively. Two (25%) studies [38,42] measured the mean and peak velocity of cervical motion by VR devices. These tools (NDI, TSK, VR devices, and standard goniometer) have proven to have high validity and reliability in measuring these health indicators [48-51]. The outcome measures are shown in Table 1.

Quality and Certainty of Evidence Assessment

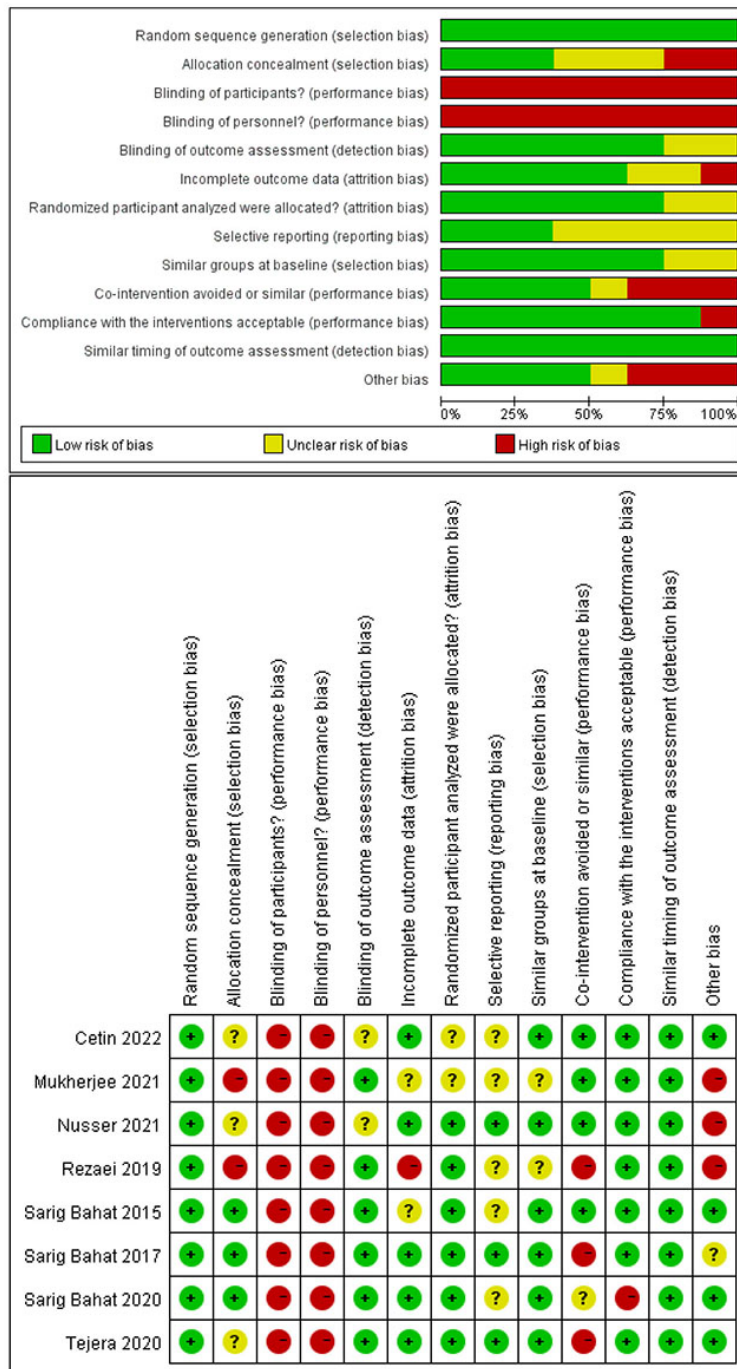
The overall risk of bias assessment results is shown in Figure 2. All (8/8, 100%) included studies did not obtain a high risk of bias in random sequence generation, blinding of outcome assessment, allocated analysis, selective reporting, baseline comparison, and measuring time point. In addition, 3 (38%) studies [38,42,43] reported allocation concealment, while 4 (50%) [39,40,42,43] addressed whether to collect follow-up data. A similar cointervention was satisfied in 4 (50%) studies [37,38,40,44], and 7 (88%) studies [37-42,44] revealed great compliance with the intervention. However, none of the included studies met the criteria of therapist or participant masking due to the nature of the VR intervention.

Based on the GRADE approach, we found moderate or high levels of evidence regarding pain intensity (overall, NRS, multimodal intervention, and chronic neck pain), disability, kinesiophobia, CROM, mean velocity, and peak velocity. These results suggested that the actual effect was likely close to the estimation. Moreover, the quality of evidence for the follow-up

effect on pain intensity and disability was classified as very low, indicating that the actual effect may differ substantially from the estimates. The assessment details by the GRADE

criteria are presented in [Multimedia Appendix 2](#). Agreement between the authors was 100% at each stage.

Figure 2. Summary of the quality evaluation and risk of bias in the included studies.



Effects of VR Therapy in Reducing Pain Intensity

The effect of VR therapy on reducing pain was evaluated by comparing the changes in pain intensity of the VR group and the control. As shown in [Figure 3](#), the randomized effect model revealed a statistically significant decrease in pain intensity favored VR intervention compared to controls (SMD -0.51, 95% CI -0.91 to -0.11). Given the significant heterogeneity observed ($I^2=69%$), we performed subgroup analyses to investigate the source of heterogeneity based on the different

interventions, stages of neck pain, clinical operational model, and measuring tools.

In [Figure 4](#), the results show significant differences (SMD -0.45, 95% CI -0.78 to -0.13) in pain intensity in favor of the multimodal intervention (VR therapy in combination with any other interventions) compared to other interventions, and no heterogeneity was found ($I^2=0%$). When unimodal intervention (VR therapy alone) was compared with other therapies, the subgroup analysis showed no significant differences (SMD

-0.58, 95% CI -1.40 to 0.25; $I^2=86%$). These results show that the heterogeneity was mainly derived from the studies using unimodal intervention, indicating that multimodal intervention had a better impact on reducing pain intensity than unimodal intervention.

In terms of the stages of neck pain, the significant decrease in pain intensity in the VR group was 0.70 lower than that in the control group (SMD -0.70, 95% CI -1.08 to -0.32; $I^2=53%$) for patients with chronic neck pain. However, for patients with various stages of neck pain, no significant changes were found (SMD 0.08, 95% CI -0.78 to 0.93; $I^2=74%$) (Figure 5). Regarding the measuring tools, the results show significant changes in pain intensity in studies investigating neck pain with

an NRS (SMD -0.47, 95% CI -0.89 to -0.04) with no heterogeneity ($I^2=0%$). However, no significant differences were observed in studies using VAS (SMD -0.52, 95% CI -1.08 to 0.03; $I^2=78%$) (Figure 3). Meanwhile, significant improvements were revealed in the clinic or research unit-based therapy (SMD -0.52, 95% CI -0.99 to -0.04; $I^2=74%$) but not found in the home-based therapy (SMD -0.46, 95% CI -0.98 to 0.05) subgroup (Figure 6).

In addition, we found no statistical difference in pain intensity at follow-up between the VR group and the control group (SMD -3.53, 95% CI -17.34 to 10.28; $I^2=84%$). Due to the limitations of eligible literature, no subgroup analysis could be carried out (Figure 7).

Figure 3. Forest plot of the effectiveness of virtual reality (VR) therapy in reducing pain intensity. NRS: numeric rating scale; VAS: visual analog scale.

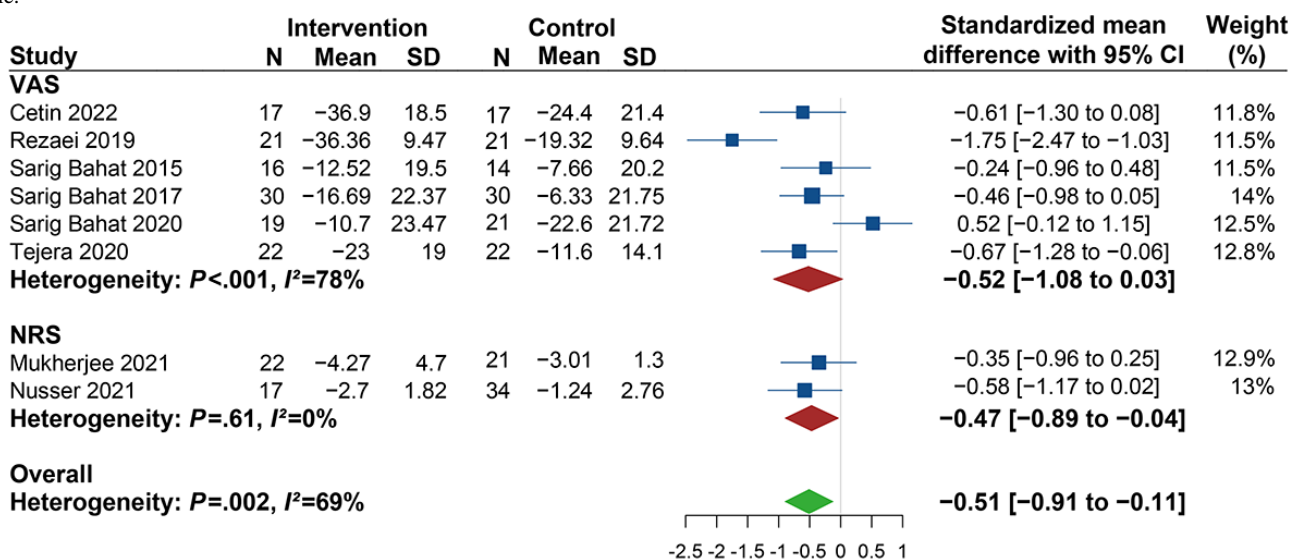


Figure 4. Forest plot of the effectiveness of different virtual reality (VR) interventions in reducing pain intensity.

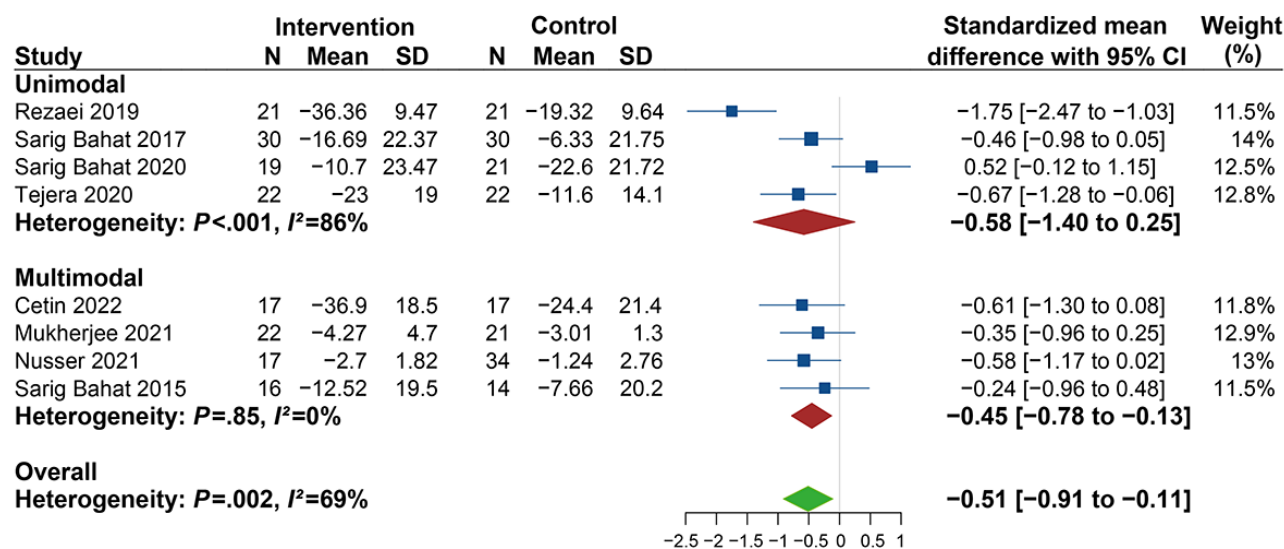


Figure 5. Forest plot of the effectiveness of virtual reality (VR) therapy for different stages of pain.

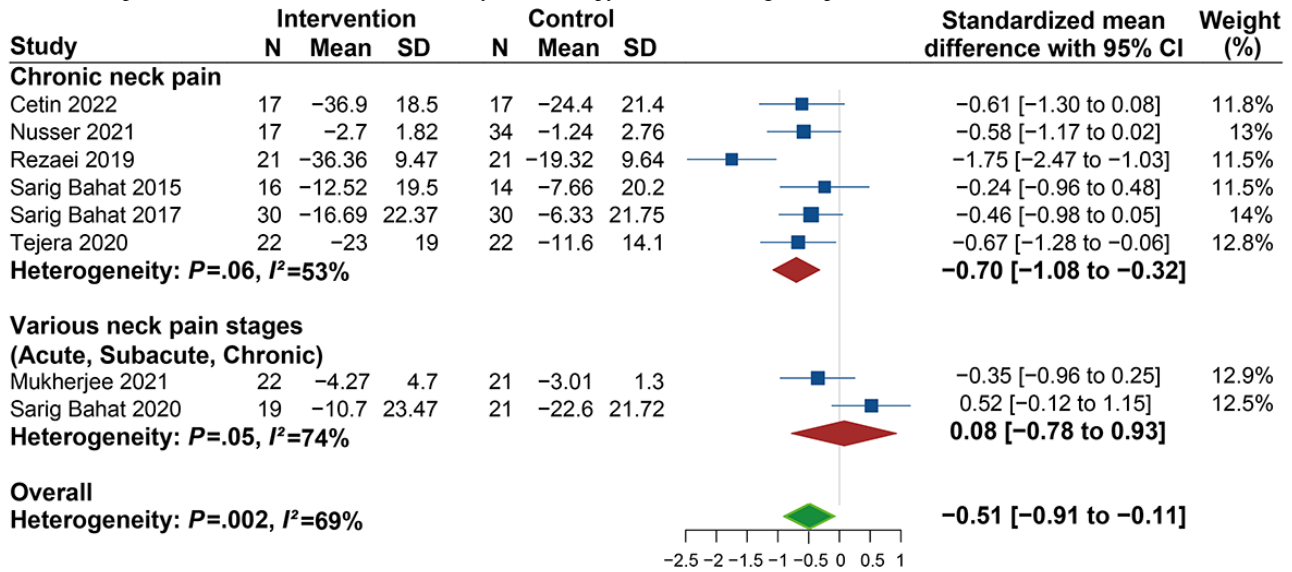


Figure 6. Forest plot of the effectiveness of virtual reality (VR) therapy in different clinical operational models.

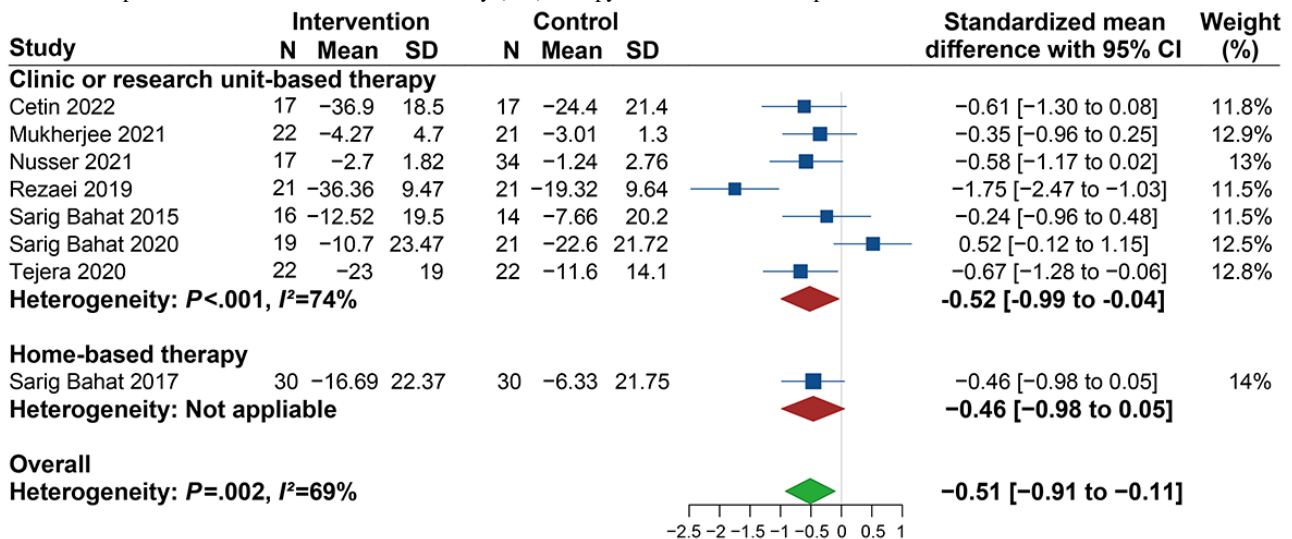
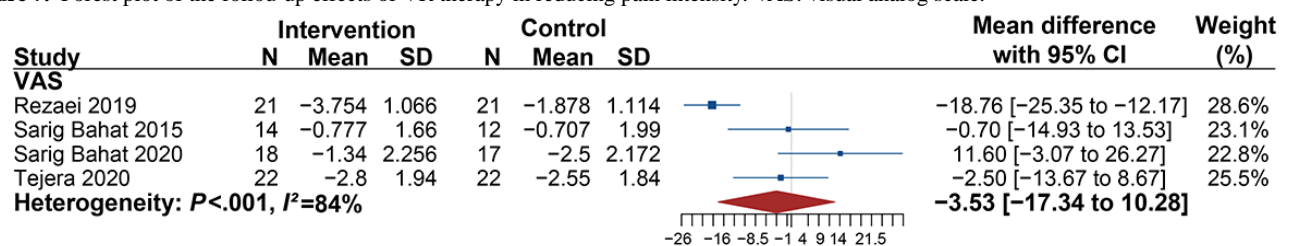


Figure 7. Forest plot of the follow-up effects of VR therapy in reducing pain intensity. VAS: visual analog scale.



Effects of VR Therapy on Other Related Health Outcomes

As shown in Table 2, patients in the VR group had less disability (SMD -3.23, 95% CI -4.32 to -2.14; $I^2=46%$) [38-42], lower kinesiophobia (SMD -0.30, 95% CI -0.59 to -0; $I^2=0%$) [37-39,42], greater CROM (SMD 0.21, 95% CI 0.08-0.33; $I^2=35%$) [37,38,40,42,44], greater cervical mean velocity (SMD

8.98, 95% CI 2.91-15.06; $I^2=46%$) [38,42], and peak velocity (SMD 10.24, 95% CI 1.28-19.15; $I^2=39%$) [38,42] compared to the control group. As for the follow-up effect on disability, we found no significant difference between the VR group and the control group (SMD -3.07, 95% CI -6.57 to 0.43; $I^2=67%$) [38,39,41]. Considering the high heterogeneity across studies, no subgroup analysis was performed.

Table 2. Evaluation of virtual reality (VR) therapy for other health outcomes.

Variables	Studies, n	Patients, n	Effect size	95% CI	P value	I ²
NDI ^a	5	211	-3.23	-4.32 to -2.14	<.001	46%
NDI (follow-up)	3	112	-3.07	-6.57 to 0.43	.09	67%
TSK ^b	4	177	-0.30	-0.59 to -0.00	.05	0%
CROM ^c	5	1018	0.21	0.08 to 0.33	.05	35%
Mean velocity	2	352	8.98	2.91 to 15.06	.004	46%
Peak velocity	2	352	10.24	1.28 to 19.15	.03	39%

^aNDI: Neck Disability Index.

^bTSK: Tampa Scale of Kinesiophobia.

^cCROM: cervical range of motion.

Safety

Adverse events were reported in 2 (25%) studies [38,42]. In an RCT performed by Sarig Bahat et al [38], 10% (4/140) of participants experienced motion sickness during VR assessment, but no pain exacerbation was reported. In another study [42] conducted by the same authors, 6% (5/90) of the participants quit due to simulator sickness and headache during training, which may be attributed to the need for a high immersion level of VR devices. The remaining studies reported no evidence of adverse events.

Discussion

Overview

This systematic review investigated the effectiveness of VR therapy in treating patients with neck pain. The results, with a moderate level of evidence, indicated that VR was a beneficial nonpharmacological approach to pain management. The results of subgroup analyses showed that multimodal intervention had a better therapeutic effect on reducing pain intensity, whereas unimodal intervention did not have obvious effects. For different stages of pain, subgroup analyses indicated that VR could effectively relieve chronic neck pain. Based on the clinical operational model, patients treated in the clinic or research unit reported better outcomes than home-based rehabilitation. Regarding the other health indicators, VR therapy significantly alleviated disability, reduced kinesiophobia, and improved CROM and mean and peak velocity. Nevertheless, the follow-up effects of VR therapy on reducing pain intensity and disability were not found.

Methodological Considerations

Among the risk factors of the CBN tool, various items of the selection, detection, and attrition bias in this systematic review were well controlled, as presented in Figure 2. The low level of bias in these 3 aspects indicates that the included RCTs may have effectively collected, evaluated, and analyzed the data, improving the generalizability and reliability of their findings.

However, a potential primary source of bias in the included studies was that none of the eligible studies achieved the blinding of participants or personnel due to the nature of the proposed VR therapy. The results might be inevitably influenced

by these performance biases. There are currently no studies setting standard control groups to eliminate the placebo effect, which requires more attention from future researchers. Moreover, only 38% (3/8) of the studies reported outcomes in a prespecified manner. This unclear reporting bias may produce misleading results due to the selective outcomes reporting, so we recommend that readers treat our results more cautiously.

Discussions of Results

In terms of pain management, studies using unimodal programs better represented the individual effects of VR therapy, whereas the multimodal approach may be consistent with the clinical scenario. The results of subgroup analyses revealed that the multimodal approach had a better analgesic effect than the control, while no significant difference was found in the unimodal intervention. Our conclusions are consistent with those of earlier studies [33,52]. These results might be explained by the effectiveness of VR in distracting attention and improving neuromuscular control [53,54]. However, the add-on effect of the multimodal intervention may exaggerate the actual therapeutic effect of VR therapy. Therefore, the individual analgesic effect of VR is still unclear.

Besides intervention, subgroup analysis indicated the beneficial effect of VR on patients with chronic neck pain, which was in line with the findings of previous studies [41,42]. Alterations of sensorimotor control were identified in many patients with chronic neck pain and were considered to play an important role in neck disability and limited motor function [55,56]. However, Rezaei et al [41] reported that VR effectively improved pain due to improved coordination between the deep and superficial cervical muscles. Enhanced coordination could better support the cervical segments and unload the stress on cervical structures to relax the neck and relieve pain, which was also confirmed by the therapeutic effects of VR therapy on cervical kinematic indicators (eg, CROM, mean and peak velocity) in this review. However, as a type of pain that lasts longer than 3 months, the lasting analgesic effect on chronic neck pain was a common problem in related research. In this review, no statistical difference at follow-up between the VR group and the control was found, limiting the subsequent clinical application of VR therapy.

As for the measuring tool, the results demonstrated that studies using an NRS showed a significant improvement in pain intensity, but no significant difference was observed in studies using a VAS. This conclusion is different from that of 2 earlier studies [33,57]. We speculated that this might be due to the different measuring sensitivities of the 2 scales on pain measurement. Regarding the clinical operational model, our findings supported the benefits of clinic or research unit–based therapy. As compared to home-based therapy, clinical or research unit–based therapy allowed for real-time supervision of patients by therapists to ensure the completeness and accuracy of the VR treatment, which probably contributed to a better recovery response. However, the actual therapeutic effect of VR therapy across different operational models remains elusive because of the relatively scarce literature and high heterogeneity across studies.

Apart from pain intensity, VR therapy was shown to be effective in improving other health-related indicators (disability, kinesiophobia, CROM, and mean and peak velocity). For the NDI score representing neck disability, our data suggested a beneficial effect of VR compared with other therapeutic methods, which is consistent with previous research [38,41]. We propose that this might be due to the pain relief, which allowed patients to perform more activities of daily living (ADL) involving cervical movement, resulting in an increase in CROM and velocity. Meanwhile, VR treatment significantly relieved kinesiophobia in patients due to the effectiveness of VR therapy in distracting attention, thus reducing disability and removing limitations on cervical movement.

However, the lasting therapeutic effects of VR on neck pain and disability were not found. This might be because the intervention period was short, and treatment effects could not be shown. Among the included studies, participants in 4 (50%) studies [37,38,40,43] received an overall VR intervention duration lower than 180 minutes, while 3 (38%) studies [39,42,44] allowed participants a total VR treatment time ranging between 180 minutes and 360 minutes. Such low treatment dosages might lead to unsustainable therapeutic effects of VR intervention. Therefore, more high-quality studies with long-term VR intervention on neck pain are required to investigate its sustained efficacy.

Study Limitations and Implications

This study has a few limitations to consider. First, only 8 studies comprising a total of 382 patients were eligible for the meta-analysis. The heterogeneity between the included literature inevitably yields methodological errors and potential bias given the limited amount and different research designs of the included studies. Second, the conclusion of this systematic review should be treated with caution due to blinding limitations, although it

was deemed very difficult to conduct blinding on therapists or participants due to the nature of the VR intervention. Third, psychological (eg, anxiety, depression, or stress) and health-related outcome (eg, ADL or quality of life) were lacking in this review. These outcomes were not found in most of the included studies but should be evaluated in future studies. (4) Only 4 (50%) studies [38,39,42,43] investigated the follow-up data over 3 months or more, indicating a lack of assessments on the lasting therapeutic effect of VR in patients with neck pain.

Currently, the COVID-19 pandemic can be an impetus for driving the adoption of VR in telemedicine to meet new requirements from public health measures to mitigate COVID-19 transmission [58,59]. However, due to the operational complexity and high expenditure of current VR therapy, the shuffling card or lighthouse model may be more appropriate for subsequent clinical applications [60,61]. Patients with neck pain can receive individual assessment and treatment in the community and provide real-time feedback to specialists for plan adjustment. These approaches help improve the efficiency of health care workers, reducing the risk of outbreaks, and enabling patients to access suitable therapies with efficacy monitoring, which are likely to be the future application scenario [62]. The findings of this study may provide some guidance and inspire researchers to perform more studies and clinical applications in this field.

Nonetheless, there is still insufficient evidence investigating the benefits of VR therapy on neck pain. The efficacy of VR intervention with different levels of immersion, desired intervention parameters, and common adverse events is uncertain. These issues have been illustrated in previous studies [15,63] and need to be refined in more well-designed trials, with a focus on larger sample sizes and longer interventions to facilitate the development of clinical guidelines. Further, researchers should classify the inclusion criterion for eligible trials and conduct a suitable experimental design for blinding therapists and participants to reduce bias. In addition, more comprehensive evaluation indicators (eg, psychological function or health-related quality of life) should be explored to reflect the effectiveness of VR therapy in all dimensions of health.

Conclusion

There is moderate-quality evidence that VR therapy is a beneficial nonpharmacological approach to improve pain intensity in patients with neck pain, with advantages to multimodal intervention, patients with chronic neck pain, and clinic or research unit–based VR therapy. However, due to the high heterogeneity across the included RCTs, more robust future RCTs are required to yield firmer conclusions.

Authors' Contributions

Q Guo and LZ were responsible for the study design. CG, GC, and YC were responsible for the search strategy, study selection, and data extraction. Q Guo, LZ, HT, WS, and RZ carried out the literature assessment. LZ and Q Gao prepared and revised the manuscript. All authors discussed the results, commented on the manuscript, and approved the final manuscript.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Search strategy.

[\[DOCX File , 13 KB-Multimedia Appendix 1\]](#)

Multimedia Appendix 2

Grading of Recommendations Assessment, Development, and Evaluation (GRADE) results.

[\[DOCX File , 20 KB-Multimedia Appendix 2\]](#)

References

1. Cohen SP, Hooten WM. Advances in the diagnosis and management of neck pain. *BMJ* 2017 Aug 14;358:j3221. [doi: [10.1136/bmj.j3221](https://doi.org/10.1136/bmj.j3221)] [Medline: [28807894](https://pubmed.ncbi.nlm.nih.gov/28807894/)]
2. Safiri S, Kolahi A, Hoy D, Buchbinder R, Mansournia MA, Bettampadi D, et al. Global, regional, and national burden of neck pain in the general population, 1990-2017: systematic analysis of the Global Burden of Disease Study 2017. *BMJ* 2020 Mar 26;368:m791 [FREE Full text] [doi: [10.1136/bmj.m791](https://doi.org/10.1136/bmj.m791)] [Medline: [32217608](https://pubmed.ncbi.nlm.nih.gov/32217608/)]
3. Cohen SP. Epidemiology, diagnosis, and treatment of neck pain. *Mayo Clin Proc* 2015 Feb;90(2):284-299. [doi: [10.1016/j.mayocp.2014.09.008](https://doi.org/10.1016/j.mayocp.2014.09.008)] [Medline: [25659245](https://pubmed.ncbi.nlm.nih.gov/25659245/)]
4. Stanton TR, Leake HB, Chalmers KJ, Moseley GL. Evidence of impaired proprioception in chronic, idiopathic neck pain: systematic review and meta-analysis. *Phys Ther* 2016 Jun;96(6):876-887 [FREE Full text] [doi: [10.2522/ptj.20150241](https://doi.org/10.2522/ptj.20150241)] [Medline: [26472296](https://pubmed.ncbi.nlm.nih.gov/26472296/)]
5. Sarig Bahat H, Chen X, Reznik D, Kodesh E, Treleaven J. Interactive cervical motion kinematics: sensitivity, specificity and clinically significant values for identifying kinematic impairments in patients with chronic neck pain. *Man Ther* 2015 Apr;20(2):295-302. [doi: [10.1016/j.math.2014.10.002](https://doi.org/10.1016/j.math.2014.10.002)] [Medline: [25456272](https://pubmed.ncbi.nlm.nih.gov/25456272/)]
6. Røijezon U, Björklund M, Bergenheim M, Djupsjöbacka M. A novel method for neck coordination exercise--a pilot study on persons with chronic non-specific neck pain. *J Neuroeng Rehabil* 2008 Dec 23;5:36 [FREE Full text] [doi: [10.1186/1743-0003-5-36](https://doi.org/10.1186/1743-0003-5-36)] [Medline: [19105826](https://pubmed.ncbi.nlm.nih.gov/19105826/)]
7. Takasaki H, Treleaven J, Johnston V, Jull G. Contributions of physical and cognitive impairments to self-reported driving difficulty in chronic whiplash-associated disorders. *Spine (Phila Pa 1976)* 2013 Aug 15;38(18):1554-1560. [doi: [10.1097/BRS.0b013e31829adb54](https://doi.org/10.1097/BRS.0b013e31829adb54)] [Medline: [23698571](https://pubmed.ncbi.nlm.nih.gov/23698571/)]
8. Li Y, Li S, Jiang J, Yuan S. Effects of yoga on patients with chronic nonspecific neck pain: A PRISMA systematic review and meta-analysis. *Medicine* 2019 Feb;98(8):e14649 [FREE Full text] [doi: [10.1097/MD.00000000000014649](https://doi.org/10.1097/MD.00000000000014649)] [Medline: [30813206](https://pubmed.ncbi.nlm.nih.gov/30813206/)]
9. Blanpied PR, Gross AR, Elliott JM, Devaney LL, Clewley D, Walton DM, et al. Neck pain: revision 2017. *J Orthop Sports Phys Ther* 2017 Jul;47(7):A1-A83. [doi: [10.2519/jospt.2017.0302](https://doi.org/10.2519/jospt.2017.0302)] [Medline: [28666405](https://pubmed.ncbi.nlm.nih.gov/28666405/)]
10. Wang XQ, Wang YL, Zhang ZJ. Exercise therapy for neck pain: Chinese expert consensus. *J Shanghai Univ Sport* 2020 Jan 15;44(01):59-69. [doi: [10.16099/j.sus.2020.01.007](https://doi.org/10.16099/j.sus.2020.01.007)]
11. Sarig Bahat H, Weiss PL, Laufer Y. The effect of neck pain on cervical kinematics, as assessed in a virtual environment. *Arch Phys Med Rehabil* 2010 Dec;91(12):1884-1890. [doi: [10.1016/j.apmr.2010.09.007](https://doi.org/10.1016/j.apmr.2010.09.007)] [Medline: [21112430](https://pubmed.ncbi.nlm.nih.gov/21112430/)]
12. Iskander M, Ogunsola T, Ramachandran R, McGowan R, Al-Aswad LA. Virtual reality and augmented reality in ophthalmology: a contemporary prospective. *Asia Pac J Ophthalmol (Phila)* 2021;10(3):244-252. [doi: [10.1097/APO.0000000000000409](https://doi.org/10.1097/APO.0000000000000409)] [Medline: [34383716](https://pubmed.ncbi.nlm.nih.gov/34383716/)]
13. Lopez-de-Uralde-Villanueva I, Beltran-Alacreu H, Fernandez-Carnero J, Kindelan-Calvo P, La Touche R. Widespread pressure pain hyperalgesia in chronic nonspecific neck pain with neuropathic features: a descriptive cross-sectional study. *Pain Physician* 2016 Feb;19(2):77-88 [FREE Full text] [Medline: [26815252](https://pubmed.ncbi.nlm.nih.gov/26815252/)]
14. Muñoz-García D, López-de-Uralde-Villanueva I, Beltrán-Alacreu H, La Touche R, Fernández-Carnero J. Patients with concomitant chronic neck pain and myofascial pain in masticatory muscles have more widespread pain and distal hyperalgesia than patients with only chronic neck pain. *Pain Med* 2017 Mar 01;18(3):526-537. [doi: [10.1093/pm/pnw274](https://doi.org/10.1093/pm/pnw274)] [Medline: [28034980](https://pubmed.ncbi.nlm.nih.gov/28034980/)]
15. Pawassar CM, Tiberius V. Virtual reality in health care: bibliometric analysis. *JMIR Serious Games* 2021 Dec 01;9(4):e32721 [FREE Full text] [doi: [10.2196/32721](https://doi.org/10.2196/32721)] [Medline: [34855606](https://pubmed.ncbi.nlm.nih.gov/34855606/)]
16. Wu J, Zeng A, Chen Z, Wei Y, Huang K, Chen J, et al. Effects of virtual reality training on upper limb function and balance in stroke patients: systematic review and meta-meta-analysis. *J Med Internet Res* 2021 Oct 12;23(10):e31051 [FREE Full text] [doi: [10.2196/31051](https://doi.org/10.2196/31051)] [Medline: [34636735](https://pubmed.ncbi.nlm.nih.gov/34636735/)]

17. Chen Y, Gao Q, He C, Bian R. Effect of virtual reality on balance in individuals with Parkinson disease: a systematic review and meta-analysis of randomized controlled trials. *Phys Ther* 2020 Jun 23;100(6):933-945. [doi: [10.1093/ptj/pzaa042](https://doi.org/10.1093/ptj/pzaa042)] [Medline: [32157307](https://pubmed.ncbi.nlm.nih.gov/32157307/)]
18. Laver KE, Lange B, George S, Deutsch JE, Saposnik G, Crotty M. Virtual reality for stroke rehabilitation. *Cochrane Database Syst Rev* 2017 Dec 20;11:CD008349 [FREE Full text] [doi: [10.1002/14651858.CD008349.pub4](https://doi.org/10.1002/14651858.CD008349.pub4)] [Medline: [29156493](https://pubmed.ncbi.nlm.nih.gov/29156493/)]
19. Brunner I, Skouen JS, Hofstad H, Aßmus J, Becker F, Sanders A, et al. Virtual reality training for upper extremity in subacute stroke (VIRTUES). *Neurology* 2017 Nov 15;89(24):2413-2421. [doi: [10.1212/wnl.0000000000004744](https://doi.org/10.1212/wnl.0000000000004744)]
20. Zhang Q, Fu Y, Lu Y, Zhang Y, Huang Q, Yang Y, et al. Impact of virtual reality-based therapies on cognition and mental health of stroke patients: systematic review and meta-analysis. *J Med Internet Res* 2021 Nov 17;23(11):e31007 [FREE Full text] [doi: [10.2196/31007](https://doi.org/10.2196/31007)] [Medline: [34787571](https://pubmed.ncbi.nlm.nih.gov/34787571/)]
21. Yeung AWK, Tosevska A, Klager E, Eibensteiner F, Laxar D, Stoyanov J, et al. Virtual and augmented reality applications in medicine: analysis of the scientific literature. *J Med Internet Res* 2021 Feb 10;23(2):e25499 [FREE Full text] [doi: [10.2196/25499](https://doi.org/10.2196/25499)] [Medline: [33565986](https://pubmed.ncbi.nlm.nih.gov/33565986/)]
22. Kyaw BM, Saxena N, Posadzki P, Vseteckova J, Nikolaou CK, George PP, et al. Virtual reality for health professions education: systematic review and meta-analysis by the digital health education collaboration. *J Med Internet Res* 2019 Jan 22;21(1):e12959 [FREE Full text] [doi: [10.2196/12959](https://doi.org/10.2196/12959)] [Medline: [30668519](https://pubmed.ncbi.nlm.nih.gov/30668519/)]
23. Gray ML, Goldrich DY, McKee S, Schaberg M, Del Signore A, Govindaraj S, et al. Virtual reality as distraction analgesia for office-based procedures: a randomized crossover-controlled trial. *Otolaryngol Head Neck Surg* 2021 Mar;164(3):580-588. [doi: [10.1177/0194599820942215](https://doi.org/10.1177/0194599820942215)] [Medline: [32746734](https://pubmed.ncbi.nlm.nih.gov/32746734/)]
24. Liu Z, Ren L, Xiao C, Zhang K, Demian P. Virtual reality aided therapy towards health 4.0: a two-decade bibliometric analysis. *Int J Environ Res Public Health* 2022 Jan 28;19(3):1525 [FREE Full text] [doi: [10.3390/ijerph19031525](https://doi.org/10.3390/ijerph19031525)] [Medline: [35162546](https://pubmed.ncbi.nlm.nih.gov/35162546/)]
25. Sarig-Bahat H, Weiss PL, Laufer Y. Cervical motion assessment using virtual reality. *Spine (Phila Pa 1976)* 2009 May 01;34(10):1018-1024. [doi: [10.1097/BRS.0b013e31819b3254](https://doi.org/10.1097/BRS.0b013e31819b3254)] [Medline: [19404177](https://pubmed.ncbi.nlm.nih.gov/19404177/)]
26. Lin D, Lin Y, Chai H, Han Y, Jan M. Comparison of proprioceptive functions between computerized proprioception facilitation exercise and closed kinetic chain exercise in patients with knee osteoarthritis. *Clin Rheumatol* 2007 Apr 20;26(4):520-528. [doi: [10.1007/s10067-006-0324-0](https://doi.org/10.1007/s10067-006-0324-0)] [Medline: [16786252](https://pubmed.ncbi.nlm.nih.gov/16786252/)]
27. Pekyavas NO, Ergun N. Comparison of virtual reality exergaming and home exercise programs in patients with subacromial impingement syndrome and scapular dyskinesis: short term effect. *Acta Orthop Traumatol Turc* 2017 May;51(3):238-242 [FREE Full text] [doi: [10.1016/j.aott.2017.03.008](https://doi.org/10.1016/j.aott.2017.03.008)] [Medline: [28446376](https://pubmed.ncbi.nlm.nih.gov/28446376/)]
28. Matheve T, Bogaerts K, Timmermans A. Virtual reality distraction induces hypoalgesia in patients with chronic low back pain: a randomized controlled trial. *J Neuroeng Rehabil* 2020 Apr 22;17(1):55 [FREE Full text] [doi: [10.1186/s12984-020-00688-0](https://doi.org/10.1186/s12984-020-00688-0)] [Medline: [32321516](https://pubmed.ncbi.nlm.nih.gov/32321516/)]
29. Gumaa M, Rehan Youssef A. Is virtual reality effective in orthopedic rehabilitation? A systematic review and meta-analysis. *Phys Ther* 2019 Oct 28;99(10):1304-1325. [doi: [10.1093/ptj/pzz093](https://doi.org/10.1093/ptj/pzz093)] [Medline: [31343702](https://pubmed.ncbi.nlm.nih.gov/31343702/)]
30. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ* 2009 Jul 21;339:b2535 [FREE Full text] [doi: [10.1136/bmj.b2535](https://doi.org/10.1136/bmj.b2535)] [Medline: [19622551](https://pubmed.ncbi.nlm.nih.gov/19622551/)]
31. Cumpston M, Li T, Page MJ, Chandler J, Welch VA, Higgins JP, et al. Updated guidance for trusted systematic reviews: a new edition of the Cochrane Handbook for Systematic Reviews of Interventions. *Cochrane Database Syst Rev* 2019 Oct 03;10:ED000142. [doi: [10.1002/14651858.ED000142](https://doi.org/10.1002/14651858.ED000142)] [Medline: [31643080](https://pubmed.ncbi.nlm.nih.gov/31643080/)]
32. Booth A, Clarke M, Dooley G, Ghersi D, Moher D, Petticrew M, et al. The nuts and bolts of PROSPERO: an international prospective register of systematic reviews. *Syst Rev* 2012 Feb 09;1:2 [FREE Full text] [doi: [10.1186/2046-4053-1-2](https://doi.org/10.1186/2046-4053-1-2)] [Medline: [22587842](https://pubmed.ncbi.nlm.nih.gov/22587842/)]
33. Chaibi A, Stavem K, Russell MB. Spinal manipulative therapy for acute neck pain: a systematic review and meta-analysis of randomised controlled trials. *J Clin Med* 2021 Oct 28;10(21) [FREE Full text] [doi: [10.3390/jcm10215011](https://doi.org/10.3390/jcm10215011)] [Medline: [34768531](https://pubmed.ncbi.nlm.nih.gov/34768531/)]
34. Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ* 2008 Apr 26;336(7650):924-926 [FREE Full text] [doi: [10.1136/bmj.39489.470347.AD](https://doi.org/10.1136/bmj.39489.470347.AD)] [Medline: [18436948](https://pubmed.ncbi.nlm.nih.gov/18436948/)]
35. Yamato TP, Maher C, Koes B, Moseley A. The PEDro scale had acceptably high convergent validity, construct validity, and interrater reliability in evaluating methodological quality of pharmaceutical trials. *J Clin Epidemiol* 2017 Jun;86:176-181. [doi: [10.1016/j.jclinepi.2017.03.002](https://doi.org/10.1016/j.jclinepi.2017.03.002)] [Medline: [28288916](https://pubmed.ncbi.nlm.nih.gov/28288916/)]
36. Goldet G, Howick J. Understanding GRADE: an introduction. *J Evid Based Med* 2013 Feb;6(1):50-54. [doi: [10.1111/jebm.12018](https://doi.org/10.1111/jebm.12018)] [Medline: [23557528](https://pubmed.ncbi.nlm.nih.gov/23557528/)]
37. Mukherjee M, Bedekar N, Sancheti P, Shyam A. Immediate and short-term effect of virtual reality training on pain, range of motion, and kinesiophobia in patients with cervical spondylosis. *Indian J Phys Ther Res* 2020;2(1):55. [doi: [10.4103/ijptr.ijptr_73_19](https://doi.org/10.4103/ijptr.ijptr_73_19)]

38. Sarig BH, Takasaki H, Chen X, Bet-Or Y, Treleaven J. Cervical kinematic training with and without interactive VR training for chronic neck pain - a randomized clinical trial. *Man Ther* 2015 Feb;20(1):68-78. [doi: [10.1016/j.math.2014.06.008](https://doi.org/10.1016/j.math.2014.06.008)] [Medline: [25066503](https://pubmed.ncbi.nlm.nih.gov/25066503/)]
39. Tejera DM, Beltran-Alacreu H, Cano-de-la-Cuerda R, Leon Hernández JV, Martín-Pintado-Zugasti A, Calvo-Lobo C, et al. Effects of virtual reality versus exercise on pain, functional, somatosensory and psychosocial outcomes in patients with non-specific chronic neck pain: a randomized clinical trial. *Int J Environ Res Public Health* 2020 Aug 16;17(16) [FREE Full text] [doi: [10.3390/ijerph17165950](https://doi.org/10.3390/ijerph17165950)] [Medline: [32824394](https://pubmed.ncbi.nlm.nih.gov/32824394/)]
40. Nusser M, Knapp S, Kramer M, Krischak G. Effects of virtual reality-based neck-specific sensorimotor training in patients with chronic neck pain: A randomized controlled pilot trial. *J Rehabil Med* 2021 Feb 10;53(2):jrm00151 [FREE Full text] [doi: [10.2340/16501977-2786](https://doi.org/10.2340/16501977-2786)] [Medline: [33369684](https://pubmed.ncbi.nlm.nih.gov/33369684/)]
41. Rezaei I, Razeghi M, Ebrahimi S, Kayedi S, Rezaeian Zadeh A. A novel virtual reality technique (Cervigame®) compared to conventional proprioceptive training to treat neck pain: a randomized controlled trial. *J Biomed Phys Eng* 2019 Jun;9(3):355-366 [FREE Full text] [doi: [10.31661/jbpe.v0i0.556](https://doi.org/10.31661/jbpe.v0i0.556)] [Medline: [31341881](https://pubmed.ncbi.nlm.nih.gov/31341881/)]
42. Sarig Bahat H, Croft K, Carter C, Hoddinott A, Sprecher E, Treleaven J. Remote kinematic training for patients with chronic neck pain: a randomised controlled trial. *Eur Spine J* 2018 Jun;27(6):1309-1323. [doi: [10.1007/s00586-017-5323-0](https://doi.org/10.1007/s00586-017-5323-0)] [Medline: [29018956](https://pubmed.ncbi.nlm.nih.gov/29018956/)]
43. Bahat HS, German D, Palomo G, Gold H, Nir YF. Self-kinematic training for flight-associated neck pain: a randomized controlled trial. *Aerosp Med Hum Perform* 2020 Oct 01;91(10):790-797. [doi: [10.3357/AMHP.5546.2020](https://doi.org/10.3357/AMHP.5546.2020)] [Medline: [33187565](https://pubmed.ncbi.nlm.nih.gov/33187565/)]
44. Cetin H, Kose N, Oge HK. Virtual reality and motor control exercises to treat chronic neck pain: A randomized controlled trial. *Musculoskelet Sci Pract* 2022 Aug 05;62:102636. [doi: [10.1016/j.msksp.2022.102636](https://doi.org/10.1016/j.msksp.2022.102636)] [Medline: [35952621](https://pubmed.ncbi.nlm.nih.gov/35952621/)]
45. Rosas S, Paço M, Lemos C, Pinho T. Comparison between the visual analog scale and the numerical rating scale in the perception of esthetics and pain. *Int Orthod* 2017 Dec;15(4):543-560. [doi: [10.1016/j.ortho.2017.09.027](https://doi.org/10.1016/j.ortho.2017.09.027)] [Medline: [29146313](https://pubmed.ncbi.nlm.nih.gov/29146313/)]
46. Ibrahim AA, Akindede MO, Bello B, Kaka B. Translation, cross-cultural adaptation, and psychometric properties of the Hausa versions of the numerical pain rating scale and global rating of change scale in a low-literate population with chronic low back pain. *Spine (Phila Pa 1976)* 2020 Apr 15;45(8):E439-E447. [doi: [10.1097/BRS.0000000000003306](https://doi.org/10.1097/BRS.0000000000003306)] [Medline: [31658233](https://pubmed.ncbi.nlm.nih.gov/31658233/)]
47. MacDowall A, Skeppholm M, Robinson Y, Olerud C. Validation of the visual analog scale in the cervical spine. *J Neurosurg Spine* 2018 Mar;28(3):227-235. [doi: [10.3171/2017.5.SPINE1732](https://doi.org/10.3171/2017.5.SPINE1732)] [Medline: [29243996](https://pubmed.ncbi.nlm.nih.gov/29243996/)]
48. Young IA, Dunning J, Butts R, Mourad F, Cleland JA. Reliability, construct validity, and responsiveness of the neck disability index and numeric pain rating scale in patients with mechanical neck pain without upper extremity symptoms. *Physiother Theory Pract* 2019 Dec;35(12):1328-1335. [doi: [10.1080/09593985.2018.1471763](https://doi.org/10.1080/09593985.2018.1471763)] [Medline: [29856244](https://pubmed.ncbi.nlm.nih.gov/29856244/)]
49. Buitenhuis J, Jaspers JPC, Fidler V. Can kinesiophobia predict the duration of neck symptoms in acute whiplash? *Clin J Pain* 2006;22(3):272-277. [doi: [10.1097/01.ajp.0000173180.54261.0a](https://doi.org/10.1097/01.ajp.0000173180.54261.0a)] [Medline: [16514328](https://pubmed.ncbi.nlm.nih.gov/16514328/)]
50. Bell KM, Frazier EC, Shively CM, Hartman RA, Ulibarri JC, Lee JY, et al. Assessing range of motion to evaluate the adverse effects of ill-fitting cervical orthoses. *Spine J* 2009 Mar;9(3):225-231. [doi: [10.1016/j.spinee.2008.03.010](https://doi.org/10.1016/j.spinee.2008.03.010)] [Medline: [18504164](https://pubmed.ncbi.nlm.nih.gov/18504164/)]
51. Malloy KM, Milling LS. The effectiveness of virtual reality distraction for pain reduction: a systematic review. *Clin Psychol Rev* 2010 Dec;30(8):1011-1018. [doi: [10.1016/j.cpr.2010.07.001](https://doi.org/10.1016/j.cpr.2010.07.001)] [Medline: [20691523](https://pubmed.ncbi.nlm.nih.gov/20691523/)]
52. Brea-Gómez B, Torres-Sánchez I, Ortiz-Rubio A, Calvache-Mateo A, Cabrera-Martos I, López-López L, et al. Virtual reality in the treatment of adults with chronic low back pain: a systematic review and meta-analysis of randomized clinical trials. *Int J Environ Res Public Health* 2021 Nov 11;18(22) [FREE Full text] [doi: [10.3390/ijerph182211806](https://doi.org/10.3390/ijerph182211806)] [Medline: [34831562](https://pubmed.ncbi.nlm.nih.gov/34831562/)]
53. Yılmaz YGD, Çırak Y, Dalkılıç M, Parlak DY, Guner Z, Boydak A. Is physiotherapy integrated virtual walking effective on pain, function, and kinesiophobia in patients with non-specific low-back pain? Randomised controlled trial. *Eur Spine J* 2017 Dec;26(2):538-545. [doi: [10.1007/s00586-016-4892-7](https://doi.org/10.1007/s00586-016-4892-7)] [Medline: [27981455](https://pubmed.ncbi.nlm.nih.gov/27981455/)]
54. Rudolfsson T, Djupsjöbacka M, Häger C, Björklund M. Effects of neck coordination exercise on sensorimotor function in chronic neck pain: a randomized controlled trial. *J Rehabil Med* 2014 Oct;46(9):908-914 [FREE Full text] [doi: [10.2340/16501977-1869](https://doi.org/10.2340/16501977-1869)] [Medline: [25182501](https://pubmed.ncbi.nlm.nih.gov/25182501/)]
55. Jull G, Falla D, Treleaven J, Hodges P, Vicenzino B. Retraining cervical joint position sense: the effect of two exercise regimes. *J Orthop Res* 2007 Mar;25(3):404-412 [FREE Full text] [doi: [10.1002/jor.20220](https://doi.org/10.1002/jor.20220)] [Medline: [17143898](https://pubmed.ncbi.nlm.nih.gov/17143898/)]
56. Treleaven J. Sensorimotor disturbances in neck disorders affecting postural stability, head and eye movement control. *Man Ther* 2008 Feb;13(1):2-11. [doi: [10.1016/j.math.2007.06.003](https://doi.org/10.1016/j.math.2007.06.003)] [Medline: [17702636](https://pubmed.ncbi.nlm.nih.gov/17702636/)]
57. Bordeleau M, Stamenkovic A, Tardif P, Thomas J. The use of virtual reality in back pain rehabilitation: a systematic review and meta-analysis. *J Pain* 2021 Aug 21. [doi: [10.1016/j.jpain.2021.08.001](https://doi.org/10.1016/j.jpain.2021.08.001)] [Medline: [34425250](https://pubmed.ncbi.nlm.nih.gov/34425250/)]
58. Gunasekeran DV, Tham Y, Ting DSW, Tan GSW, Wong TY. Digital health during COVID-19: lessons from operationalising new models of care in ophthalmology. *Lancet Digit Health* 2021 Feb;3(2):e124-e134 [FREE Full text] [doi: [10.1016/S2589-7500\(20\)30287-9](https://doi.org/10.1016/S2589-7500(20)30287-9)] [Medline: [33509383](https://pubmed.ncbi.nlm.nih.gov/33509383/)]

59. Hollander JE, Carr BG. Virtually Perfect? Telemedicine for Covid-19. *N Engl J Med* 2020 Mar 11. [doi: [10.1056/NEJMp2003539](https://doi.org/10.1056/NEJMp2003539)] [Medline: [32160451](https://pubmed.ncbi.nlm.nih.gov/32160451/)]
60. Adams M, Ho CYD, Baglin E, Sharangan P, Wu Z, Lawson DJ, et al. Home monitoring of retinal sensitivity on a tablet device in intermediate age-related macular degeneration. *Transl Vis Sci Technol* 2018 Sep;7(5):32 [FREE Full text] [doi: [10.1167/tvst.7.5.32](https://doi.org/10.1167/tvst.7.5.32)] [Medline: [30386684](https://pubmed.ncbi.nlm.nih.gov/30386684/)]
61. AREDS2-HOME Study Research Group, Chew EY, Clemons TE, Bressler SB, Elman MJ, Danis RP, et al. Randomized trial of a home monitoring system for early detection of choroidal neovascularization home monitoring of the Eye (HOME) study. *Ophthalmology* 2014 Feb;121(2):535-544 [FREE Full text] [doi: [10.1016/j.ophtha.2013.10.027](https://doi.org/10.1016/j.ophtha.2013.10.027)] [Medline: [24211172](https://pubmed.ncbi.nlm.nih.gov/24211172/)]
62. Whitelaw S, Mamas MA, Topol E, Van Spall HGC. Applications of digital technology in COVID-19 pandemic planning and response. *Lancet Digit Health* 2020 Aug;2(8):e435-e440 [FREE Full text] [doi: [10.1016/S2589-7500\(20\)30142-4](https://doi.org/10.1016/S2589-7500(20)30142-4)] [Medline: [32835201](https://pubmed.ncbi.nlm.nih.gov/32835201/)]
63. Huang Q, Lin J, Han R, Peng C, Huang A. Using virtual reality exposure therapy in pain management: a systematic review and meta-analysis of randomized controlled trials. *Value Health* 2022 Feb;25(2):288-301. [doi: [10.1016/j.jval.2021.04.1285](https://doi.org/10.1016/j.jval.2021.04.1285)] [Medline: [35094802](https://pubmed.ncbi.nlm.nih.gov/35094802/)]

Abbreviations

ADL: activities of daily living

CBN: Cochrane Back and Neck

CROM: cervical range of motion

GRADE: Grading of Recommendations Assessment, Development, and Evaluation

MeSH: Medical Subject Headings

NDI: Neck Disability Index

NRS: numeric rating scale

PICO: Participants, Interventions, Control, and Outcomes

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-analyses

RCT: randomized controlled trial

SMD: standardized mean difference

VAS: visual analog scale

VR: virtual reality

Edited by R Kukafka, A Mavragani; submitted 25.03.22; peer-reviewed by A Rehan Youssef, D Gunasekeran, S Wei; comments to author 05.05.22; revised version received 31.05.22; accepted 27.02.23; published 03.04.23

Please cite as:

Guo Q, Zhang L, Gui C, Chen G, Chen Y, Tan H, Su W, Zhang R, Gao Q

Virtual Reality Intervention for Patients With Neck Pain: Systematic Review and Meta-analysis of Randomized Controlled Trials
J Med Internet Res 2023;25:e38256

URL: <https://www.jmir.org/2023/1/e38256>

doi: [10.2196/38256](https://doi.org/10.2196/38256)

PMID: [37010891](https://pubmed.ncbi.nlm.nih.gov/37010891/)

©Qifan Guo, LIMing Zhang, Chenfan Gui, Guanghui Chen, Yi Chen, Huixin Tan, Wei Su, Ruishi Zhang, Qiang Gao. Originally published in the Journal of Medical Internet Research (<https://www.jmir.org>), 03.04.2023. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in the Journal of Medical Internet Research, is properly cited. The complete bibliographic information, a link to the original publication on <https://www.jmir.org/>, as well as this copyright and license information must be included.