Supportive Care in Cancer (2024) 32:603
https://doi.org/10.1007/s00520-024-08813-8

REVIEW

Virtual reality-based supportive care interventions for patients with cancer: an umbrella review of systematic reviews and meta-analyses

Jie Hao[1,2] · Zhengting He[3] · Yanfei Li[2] · Biying Huang[2] · Andréas Remis[4] · Zixuan Yao[5] · Dongqi Zhu[6]

Received: 21 March 2024 / Accepted: 14 August 2024 / Published online: 21 August 2024

Abstract

Purpose This umbrella review aimed to identify, critically appraise, and synthesize current evidence from systematic reviews and meta-analyses on the applications of virtual reality-based supportive care interventions in cancer.

Methods Three bibliographic databases were searched from inception to February 1, 2024. Two independent reviewers screened the titles and abstracts of 421 records and retrieved 26 full-text systematic reviews. Assessing the Methodological Quality of Systematic Reviews 2 (AMSTAR-2) was used for quality assessment. Qualitative syntheses were performed to investigate the effects of virtual reality-based supportive care interventions on quality of life and physical, psychological, cognitive, and functional outcomes. Meta-analysis was performed based on data from the distinct primary studies that were extracted from the included reviews.

Results This umbrella review included 20 systematic reviews that were published between 2018 and 2023; nine of them conducted meta-analyses. A total of 86 distinct primary studies were identified. According to the AMSTAR-2 assessment, two reviews were evaluated as moderate quality, nine as low, and nine as critically low. Meta-analyses of primary studies revealed significant effects of virtual reality on anxiety ($p < 0.001$), depression ($p < 0.001$), and pain ($p < 0.001$), but not fatigue ($p = 0.263$). Qualitative syntheses revealed positive effects of virtual reality on physical function, cognitive function, and quality of life. Limited evidence was reported regarding outcomes of balance, gait, mobility, and activities of daily living.

Conclusion Virtual reality has proven to be a safe and feasible approach to deliver supportive care in cancer. Virtual reality can be implemented in various stages and settings of the cancer care continuum to support patients undergoing painful procedures, during or after chemotherapy, and after surgical interventions. Virtual reality can serve as an effective supportive care intervention to manage anxiety, pain, and depression for patients with cancer.

Keywords Virtual reality · Simulation · Oncology · Neoplasm · Pain · Function

✉ Jie Hao
jie.hao.unmc@outlook.com

1 Department of Physical Therapy and Rehabilitation, Southeast Colorado Hospital, Springfield, CO, USA

2 Department of Health & Rehabilitation Sciences, College of Allied Health Professions, University of Nebraska Medical Center, Omaha, NE, USA

3 Department of Epidemiology, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, MD, USA

4 Health Research Association of Keck Medicine, University of Southern California, Los Angeles, CA, USA

5 Department of Rehabilitation Medicine, Beijing Hospital, National Center of Gerontology, Institution of Geriatric Medicine, Chinese Academy of Medical Science, Beijing, P.R. China

6 Department of Rehabilitation Medicine, Shanghai Sixth People's Hospital, Shanghai, P.R. China

Introduction

Cancer is one of the leading causes of death and disability worldwide, creating significant challenges for healthcare and society. According to the latest Global Burden of Disease Study [1], there were 23.6 million new cancer cases and 10.0 million cancer deaths in 2019; an estimated 250 million disability-adjusted life years were related to cancer. From 2010 to 2019, the incidence and mortality of cancer increased by 26.3% and 20.9%, respectively. The global cancer burden may continue to increase in the following decades [2]. With the aging population and the advancement of curative interventions, more people will be living with cancer. In addition, the ongoing COVID-19 pandemic affects the screening, diagnosis, and treatment of cancer and compromises the health of patients with cancer [3].

Cancer induces impairments of body functions and structures, limits activity, and restricts participation, negatively affecting quality of life and life expectancy. Further, cancer treatments (chemotherapy, radiotherapy, immunotherapy, and surgery) have an array of side effects that impose additional burdens on patients. Patients with cancer can suffer from physical deconditioning, pain, psychological distress, cognitive impairments, and functional deficits. Supportive care interventions are essential to reduce symptoms and adverse effects throughout the continuum of cancer management [4]. Medical, nursing, and allied health professionals can deliver supportive care interventions to improve patient tolerance to oncological interventions and promote well-being.

In recent years, virtual reality as an emerging innovative technology has gained increasing attention in complementary and alternative therapies. Virtual reality is a computer-generated simulation technology that immerses users in a novel environment with interactive activities and multidimensional feedback [5]. Virtual reality is a non-pharmacological and non-invasive intervention with promising effects on physical, cognitive, and psychological outcomes among patients with cancer [6]. As virtual reality is rapidly incorporated into supportive care in cancer, there is a need to systematically collect and critically evaluate information from existing systematic reviews to navigate the expanding body of research literature to inform clinical practice and research. An umbrella review is a methodological approach to synthesize the accumulating evidence from systematic reviews and meta-analyses. It provides an overall assessment of evidence available on a specific topic and facilitates readers to keep pace with the increasing volume of reviews [7]. Therefore, this umbrella review aimed to identify, critically appraise, and summarize current systematic reviews on the effects of virtual reality-based supportive care interventions on quality of life and physical, cognitive, psychological, and functional outcomes for cancer survivors.

Methods

This umbrella review was conducted by following the Preferred Reporting Items for Overviews of Reviews (PRIOR) guidelines to guarantee high-quality reporting [8]. This review was registered at the International prospective register of systematic reviews (PROSPERO): CRD42024500175.

Three bibliographic databases were searched, including Embase, PubMed, and Scopus. These databases were searched from inception to February 1, 2024. The search strategies combined medical subject headings and title/abstract keywords on search themes of virtual reality, cancer, and systematic review or meta-analysis. The full search strategies are described in the Appendix. The literature search was limited to human studies reported in English in peer-reviewed journal articles. Records were exported to RefWorks (ProQuest LLC, Ann Arbor, MI) for duplication removal.

Review studies were eligible for this umbrella review if they met all the following criteria: (1) Participants: participants with current or previous diagnosis of cancer, with no restrictions on age, gender, and cancer type; (2) Intervention: virtual reality was used as a supportive care intervention for mitigating adverse symptoms and promoting function and well-being; (3) Comparison: conventional supportive care interventions or usual care; (4) Outcome: physical, psychological, cognitive, and functional outcomes, and quality of life; and (5) Study design: systematic review and/or meta-analysis. Systematic review was defined as "a review that uses explicit, systematic methods to collate and synthesize findings of studies that address a clearly formulated question," according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 statement [9]. Review studies were excluded if they met any of the following criteria: (1) reviews including mixed health conditions and data related to cancer cannot be extracted separately or (2) scoping review, narrative review, protocol of systematic review, clinical practice guideline, abstract-only, or non-peer-reviewed articles.

Two reviewers independently assessed the titles and abstracts for potential eligibility and then retrieved full-text articles for those that appeared relevant. They assessed full-text articles against the inclusion and exclusion criteria for final eligibility. For each included review, data were extracted on the number of included primary studies, type of included primary studies, participant characteristics and sample size, intervention, outcome measures, and quality assessment tool. Throughout this process, we resolved discrepancies through group discussion with an experienced third reviewer until we reached a consensus.

The methodological quality of included systematic reviews was evaluated using the Assessing the Methodological Quality of Systematic Reviews 2 (AMSTAR-2) assessment tool. This instrument was developed by an expert panel to critically appraise systematic reviews of randomized and non-randomized interventional studies [10]. There are 16 items in this instrument, seven of which are set as critical domains. Based on the number of critical flaws and non-critical weaknesses, the overall confidence in the results of the systematic review being examined is classified into one of the four levels: high, moderate, low, and critically low. The same two reviewers independently completed the quality assessment, and any discrepancies were identified and solved with the third experienced reviewer.

We qualitatively evaluated clinical and methodological heterogeneity among the included systematic reviews and risk of bias that could impact interpretation of the evidence. Qualitative synthesis was performed according to types of reported outcome measures to determine the effects of virtual reality-based supportive care interventions on quality of life and physical, psychological, cognitive, and functional outcomes. Meta-meta-analysis based on the secondary data from the included reviews was not conducted due to the overlap of primary studies in the included reviews. To address the study overlap issue, all primary studies were extracted from each included review, and any duplicates were identified and removed. Meta-analysis was performed based on data from distinct primary studies using random-effects models incorporating within- and between-study heterogeneity. Subgroup analysis was performed according to specific types of cancer. We reported the standardized mean difference (SMD) and its 95% confidence interval (CI). Subgroup analysis was performed stratified by types of cancer. Statistical significance was set at a two-sided p-value < 0.05. All analyses were conducted with R (R Foundation for Statistical Computing, Vienna, Austria, version 4.2.0) and the R package "meta" (version 6.0–0).

Results

A total of 421 records were identified from three databases, and 149 duplications were removed. After screening the titles and abstracts of the remaining 272 records, 26 studies were selected for full-text retrieval. Finally, 20 articles met the eligibility criteria and were included in this umbrella review; 11 were systematic reviews only, and nine were systematic reviews with meta-analyses. The study identification process and reasons for excluding papers are illustrated in the PRISMA flow diagram (Fig. 1). A list of excluded studies with reasons was presented in the Supplementary Material. These 20 reviews included a total of 86 primary studies; 49 primary studies were included by multiple reviews, and 37 were included by a single review.

The 20 included reviews were published between 2018 and 2023. The number of included primary studies ranged from six to 17. Two reviews [11, 12] included only randomized controlled trials, and 18 reviews included primary studies with multiple study designs, including quasi-experimental, crossover, single cohort, and case studies. For the patient population, six reviews were for breast cancer [12–17], four for pediatric cancer [18–21], three for cancer patients undergoing chemotherapy [22–24], one for solid tumor [25], and the remaining six reviews [6, 11, 26–29] did not specify the type of cancer or condition. For intervention, 14 reviews covered all types of virtual reality, four reviews focused on virtual reality exergames, and two focused on immersive virtual reality. Nine reviews used the Cochrane risk-of-bias tool for quality assessment, three used the Joanna Brigg's Institute assessment tool, and two used the Physiotherapy Evidence Database scale. Nine systematic reviews conducted one or more meta-analyses. The characteristics of the included reviews in detail are summarized in Table 1. Effects of virtual reality-based supportive care in comparison to usual care on different outcomes were summarized in Fig. 2.

For quality assessment using the AMSTAR-2, two studies were evaluated as moderate quality, nine as low, and nine as critically low (Table 2). Twelve reviews reported the four components of PICO (population, intervention, comparator group, and outcome) in the research question or eligibility criteria, and eight reviews missed reporting the comparator group. Eight reviews did not register their protocols prior to conducting the review. Eleven reviews completed registration at the PROSPERO, and Cheng et al. [18] registered at the INPLASY database. Only two reviews [19, 23] explained the selection of the study designs for inclusion in the review. Most reviews adopted a comprehensive or partially comprehensive literature search strategy. All but four reviews performed study selection and data extraction in duplicate. Only six reviews [20, 21, 23, 24, 26, 27] provided a list of excluded studies and justified the exclusions; other reviews reported the reasons for exclusion in the PRISMA flow diagram but did not provide a list of the excluded studies. All reviews reported the included studies in adequate detail in texts or tables. All but one review used a satisfactory technique for assessing the risk of bias in included studies; Leggiero et al. [25] did not use any tools for risk of bias or methodological evaluation. No studies reported on the sources of funding for included studies. The majority of meta-analysis studies used appropriate statistical methods and considered the potential impact of risk of bias. Most reviews accounted for the risk of bias in the interpretation and discussion of the results and provided adequate discussion regarding heterogeneity. Only two [21, 22] out of ten meta-analysis studies performed analysis to investigate publication bias. All reviews declared no competing interests.

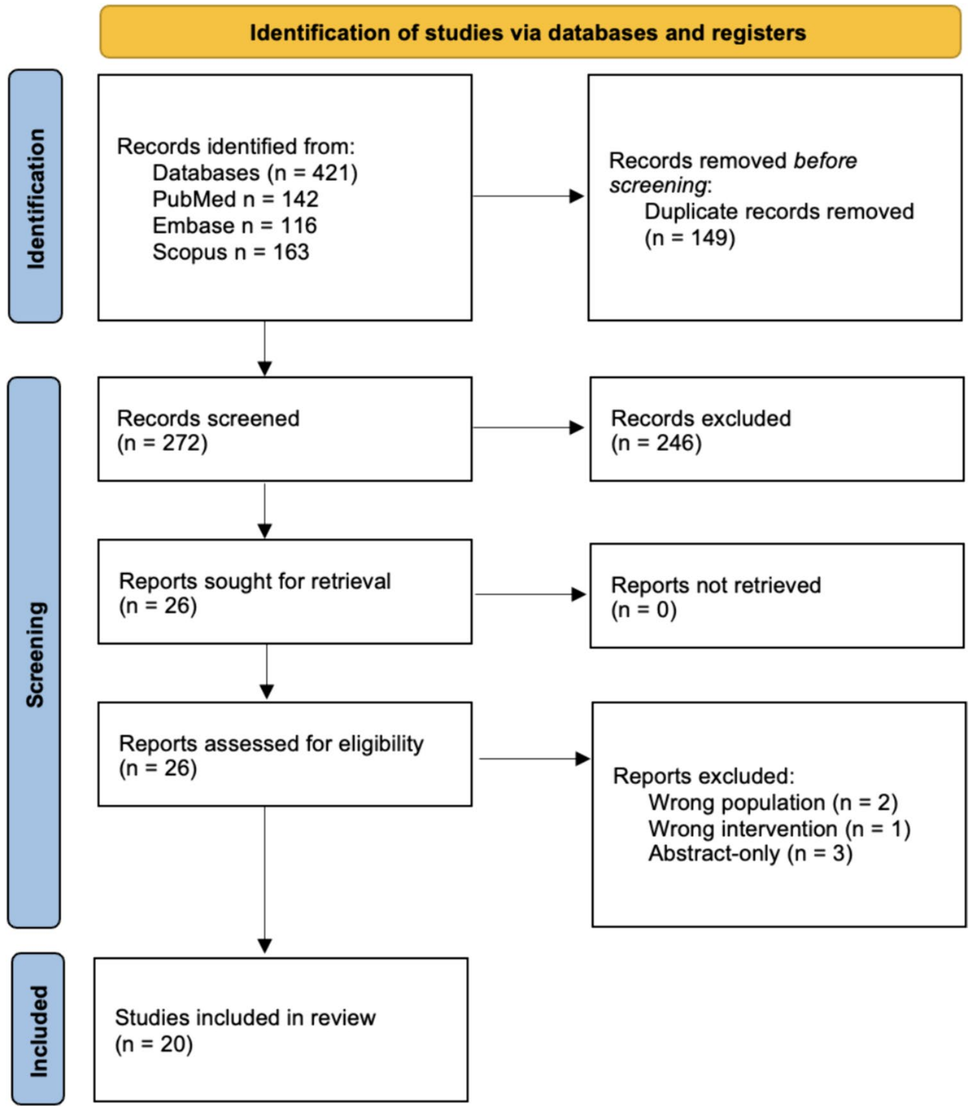

Fig. 1 PRISMA flow diagram

Anxiety

For patients with breast cancer, two systematic reviews [15, 16] suggested the positive role of virtual reality in reducing anxiety, and three meta-analyses [12, 14, 17] reported significant pooled estimates regarding the effects of virtual reality on anxiety. For children and adolescents with cancer, three reviews [18, 20, 21] revealed the effects of virtual reality on anxiety and fear, with two [18, 21] performing meta-analyses. Hao et al. [6] and Wu et al. [11] also demonstrated significant effects of virtual reality on anxiety. We performed a meta-analysis of 15 primary studies of the systematic reviews included; results indicated significantly lower anxiety symptoms in virtual reality group compared to usual care, with an SMD estimate of – 1.01 (95% CI – 1.48, – 0.54, p-value < 0.001, Fig. 3A). Subgroup analysis revealed an SMD estimate of – 1.87 (95% CI – 3.02, – 0.72, p-value < 0.001, Fig. 4A) for breast cancer patients and – 1.45 (95% CI – 2.38, – 0.53, p-value < 0.001, Fig. 4A) for pediatric cancer patients.

Depression

Wu et al. [11] reported significant effects of virtual reality on reducing depression in patients with cancer. For patients with breast cancer, two meta-analyses [12, 14] also demonstrated significant effects of virtual reality on depression. Qualitative syntheses by Fernandes et al. [13], Yazdipour et al. [15], and Zhang et al. [17] supported the positive effects as well. A meta-analysis of five primary studies indicated significant between-group differences in depression in favor of virtual reality, with an SMD estimate of – 1.42 (95% CI – 2.54, – 0.30, p-value = 0.013, Fig. 3B).

Table 1 Characteristics of included systematic reviews and meta-analyses

Article	Included studies	Population	Intervention	Outcomes	Quality assessment tool	Meta-analysis
Ahmad 2020	Randomized controlled trials: 5 Quasi-experimental studies: 8	Patients with cancer $N=522$	Virtual reality	Pain and anxiety	Modified Downs and Black checklist	None
Bu 2022	Randomized controlled trials: 6 Quasi-experimental studies: 2 Controlled trial: 1 Single cohort trial: 3	Patients with breast cancer $N=604$	Virtual reality	Health-related outcomes Shoulder range of motion, grip strength, anxiety, depression, pain, cognition, fatigue, fear of movement, and adverse events	Cochrane risk-of-bias tool Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I)	Shoulder range of motion, grip strength, anxiety, depression, pain, cognition
Burrai 2023	Randomized controlled trials: 4 Crossover studies: 4	Patients with cancer undergoing chemotherapy $N=459$	Immersive virtual reality	Anxiety, pain, and fatigue	Cochrane risk-of-bias tool Grading of Recommendations Assessment, Development and Evaluation methodology (GRADE)	Anxiety, pain, fatigue
Cheng 2022	Randomized controlled trials: 6	Children with cancer $N=379$	Virtual reality	Anxiety, pain, and fear	Cochrane risk-of-bias tool	Anxiety, pain, fear
Chow 2021	Randomized controlled trials: 4 Crossover studies: 5	Patients with cancer undergoing medical procedures or chemotherapy $N=568$	Immersive virtual reality	Pain and anxiety	Jadad quality appraisal	None
Christopherson 2022	Randomized controlled trials: 2 Quasi-experimental study:1 Crossover studies: 2 Single cohort trial: 1	Adolescent and young adult cancer survivors $N=151$	Virtual reality exergames	Physical function, physical activity, fatigue, and quality of life	Cochrane risk-of-bias tool Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I)	None
Comparcini 2023	Randomized controlled trials: 6 Quasi-experimental studies: 5 Crossover studies: 2	Children and adolescents with hematological and solid cancer $N=643$	Virtual reality	Pain and anxiety	Cochrane risk-of-bias tool	None
Czech 2023	Randomized controlled trials: 6 Crossover studies: 3	Children and adolescents with cancer $N=396$	Virtual reality	Physical function, fear, and quality of life	Cochrane risk-of-bias tool	Anxiety, pain, fear
Fernandes 2023	Randomized controlled trials: 5 Quasi-experimental studies: 3	Women with breast cancer after surgery $N=209$	Virtual reality exergames	Range of motion, pain, functionality, depression, and adverse events	Joanna Brigg's Institute assessment tool	None
Hao 2023	Randomized controlled trials: 12 Controlled clinical trials: 5	Patients with cancer $N=799$	Virtual reality	Physical, cognitive, and psychological outcomes; adverse events	Physiotherapy Evidence Database scale	Pain, fatigue, anxiety, upper extremity function, quality of life

Table 1 (continued)

Article	Included studies	Population	Intervention	Outcomes	Quality assessment tool	Meta-analysis
Leggiero 2020	Randomized controlled trials: 3 Quasi-experimental studies: 3 Crossover studies: 3 Single cohort trial: 3	Patients with solid tumor $N = 721$	Virtual reality	Anxiety, pain, distress, depression, mood, and adverse events	None	None
Peyrachon 2023	Randomized controlled trials: 9 Quasi-experimental studies: 2 Single cohort trial: 4 Case series: 1 Qualitative study: 1	Patients with cancer $N = 362$	Virtual reality exergames	Physiological and psychological outcomes	Physiotherapy Evidence Database scale Cochrane risk-of-bias tool	None
Rutkowski 2021	Randomized controlled trials: 3 Crossover studies: 3	Patients with cancer undergoing chemotherapy $N = 453$	Virtual reality	Anxiety and fatigue	Cochrane risk-of-bias tool	Anxiety
Tian 2022	Randomized controlled trials: 8 Quasi-experimental studies: 6	Patients with breast cancer $N = 797$	Virtual reality	Anxiety, depression, pain, cognition, shoulder range of motion, grip strength, and upper extremity function	Joanna Brigg's Institute assessment tool	Anxiety, depression, pain, cognition, shoulder range of motion, grip strength
Tough 2018	Randomized controlled trial: 1 Quasi-experimental study: 1 Single cohort trials: 3 Case study: 1 Qualitative study: 1	Patients with cancer $N = 89$	Virtual reality exergames	Feasibility, acceptability, physical functioning, and symptoms	Cochrane risk-of-bias tool Critical Appraisal Skills Programme (CASP) tool Quality Checklist for Healthcare Intervention Studies	None
Wu 2023	Randomized controlled trials: 12	Patients with cancer $N = 825$	Virtual reality	Physical and psychological symptoms, quality of life; adverse events	Cochrane risk-of-bias tool	Anxiety, pain, depression, fear, distress, quality of life
Yazdipour 2023	Randomized controlled trials: 4 Quasi-experimental studies: 3 Crossover studies: 5 Single cohort trial: 5 Cross-sectional study: 1	Patients with breast cancer $N = 842$	Virtual reality	Physical outcomes, mental outcomes; challenges and limitations of virtual reality	Effective Public Health Practice Project (EPHPP) Tool	None

Table 1 (continued)

Article	Included studies	Population	Intervention	Outcomes	Quality assessment tool	Meta-analysis
Zasadzka 2021	Randomized controlled trials: 2 Quasi-experimental studies: 2 Crossover studies: 4 Single cohort trial: 3	Patients with breast cancer $N = 619$	Virtual reality	Physical function, mental sphere, and pain	Quality Assessment Tool for Quantitative Studies	None
Zeng 2019	Randomized controlled trials: 1 Quasi-experimental studies: 1 Single cohort trial: 4	Patients with cancer $N = 225$	Virtual reality	Cancer-related symptoms	A customized 8-item quality and risk of bias assessment tool	Anxiety, depression, pain, fatigue, cognition
Zhang 2022	Randomized controlled trials: 6 Single cohort trial: 2	Patients with breast cancer $N = 529$	Virtual reality	Pain, fatigue, anxiety, depression, cognition, range of motion of upper extremity	Joanna Brigg's Institute assessment tool	Anxiety, shoulder abduction, fatigue

Pain

Positive effects of virtual reality on pain management were consistently suggested in the six reviews for breast cancer [12–17]. Two meta-analyses [18, 21] suggested significant effects of virtual reality on reducing pain among children and adolescents with cancer. Hao et al. [6] and Wu et al. [11] also demonstrated significant effects of virtual reality on pain. A meta-analysis of 15 primary studies indicated significant between-group differences in pain in favor of virtual reality, with an SMD estimate of −0.83 (95% CI −1.22, −0.44, p-value < 0.001, Fig. 3C). Subgroup analysis revealed an SMD estimate of −1.27 (95% CI −2.04, −0.50, p-value < 0.001, Fig. 4C) for breast cancer patients and −0.94 (95% CI −1.46, −0.42, p-value < 0.001, Fig. 4C) for pediatric cancer patients.

Fatigue

Hao et al. [6] and Zeng et al. [29] demonstrated significant effects of virtual reality on reducing fatigue in patients with cancer, while Zhang et al. [17] did not observe significant effects on fatigue in patients with breast cancer. A meta-analysis of five primary studies found no significant between-group difference (SMD −0.68, 95% CI −1.87, 0.51, p-value = 0.26, Fig. 3D).

Physical function

Three reviews suggested that virtual reality may improve upper extremity range of motion and function via qualitative syntheses among patients with breast cancer [15, 16] and following breast cancer surgery [13]. Two meta-analyses [14, 17] showed that virtual reality significantly improved shoulder range of motion in patients with breast cancer, while Tian et al. [14] found no significant improvements in grip and upper extremity function.

Cognitive function

Two meta-analyses [12, 14] reported that virtual reality had a significant effect on cognitive function in patients with breast cancer. A systematic review by Tough et al. [28] suggested that virtual reality exergames support improvements in cognitive function. In contrast, Hao et al. [6] reported mixed results of virtual reality on cognition.

Quality of life

Two reviews quantitatively examined the effects of virtual reality on quality of life. While Hao et al. [6] revealed

	Anxiety	Depression	Pain	Fatigue	Physical function	Cognitive function	Quality of life
Ahmad 2020	+		+				
Bu 2022	+	+	+		+	+	
Burrai 2023	+	-	-				
Cheng 2022	+		+				
Chow 2021	?		?				
Christopherson 2022				+	?		+
Comparcini 2023	?		?				
Czech 2023					+		+
Fernandes 2023		?	?		?		
Hao 2023	+		+		+	+	
Leggiero 2020	+	?	?				
Peyrachon 2023	-	?		+	?		+
Rutkowski 2021	?			?			
Tian 2022	+	+	+		-	+	
Tough 2018			+		+	+	
Wu 2023	+	+	+				-
Yazdipour 2023	+		+	+	+		
Zasadzka 2021	+	+			+		
Zeng 2019	-		-	+		-	
Zhang 2022	+	+	+	-	+	+	

+ : Potential better

- : No difference

? : Unclear

Fig. 2 Effects of virtual reality-based supportive care interventions in comparison of usual care on different outcomes

significant results, Wu et al. [11] did not. Only three and two primary studies were included in these two meta-analyses, respectively. A systematic review by Christopherson et al. [19] found that few studies reported on the effects of virtual reality exergames on quality of life among adolescents and young adult cancer survivors. Peyrachon et al. [27] also suggested the positive effects of virtual reality exergames on the quality of life for patients with cancer.

Adverse events

Eleven systematic reviews summarized adverse events of virtual reality interventions, and six systematic reviews reported no virtual reality-related adverse events. In five reviews [11, 14, 22, 23, 29], cybersickness and dizziness were reported in included primary studies with low incidence. No other significant adverse events were shown.

Discussion

This umbrella review synthesized the evidence from systematic reviews and meta-analyses on the effects of virtual reality-based supportive care interventions on patients with cancer. This umbrella review identified 20 systematic reviews published between 2018 and 2023, which included 86 primary studies. Overall, virtual reality is a safe and feasible supportive care intervention in cancer. The results

Table 2 Quality assessment of included reviews

Study	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Overall quality
Ahmad 2020	N	N	N	PY	Y	Y	Y	Y	Y	N	-	-	Y	Y	-	Y	Low
Bu 2022	Y	Y	N	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	N	Y	Low
Burrai 2023	Y	Y	N	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	Y	Low
Cheng 2022	Y	Y	N	Y	Y	Y	N	Y	Y	N	Y	N	N	Y	N	Y	Critically low
Chow 2021	Y	Y	Y	N	Y	Y	Y	Y	Y	N	-	-	Y	N	-	Y	Low
Christopherson 2022	Y	Y	Y	Y	Y	Y	N	Y	Y	N	-	-	Y	Y	-	Y	Low
Comparcini 2023	Y	Y	N	Y	Y	N	Y	Y	PY	N	-	-	Y	Y	-	Y	Moderate
Czech 2023	Y	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Moderate
Fernandes 2023	N	N	N	Y	Y	Y	N	Y	Y	N	-	-	Y	N	-	Y	Critically low
Hao 2023	Y	Y	N	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	N	Y	Critically low
Leggiero 2020	N	N	N	PY	Y	Y	N	Y	N	N	-	-	N	Y	-	Y	Critically low
Peyrachon 2023	Y	N	N	PY	N	N	Y	Y	Y	N	-	-	Y	Y	-	Y	Low
Rutkowski 2021	N	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Low
Tian 2022	N	N	N	Y	Y	Y	N	Y	Y	N	Y	Y	N	Y	N	Y	Critically low
Tough 2018	Y	Y	N	Y	Y	N	N	Y	Y	N	-	-	Y	Y	-	Y	Low
Wu 2023	Y	Y	N	PY	Y	Y	N	Y	Y	N	Y	Y	Y	Y	N	Y	Critically low
Yazdipour 2023	N	N	N	Y	Y	Y	N	Y	Y	N	-	-	Y	N	-	Y	Critically low
Zasadzka 2021	N	Y	N	PY	Y	Y	N	Y	Y	N	-	-	Y	N	-	Y	Low
Zeng 2019	N	N	N	PY	N	Y	N	Y	Y	N	Y	N	N	Y	N	Y	Critically low
Zhang 2022	Y	N	N	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	N	Y	Critically low

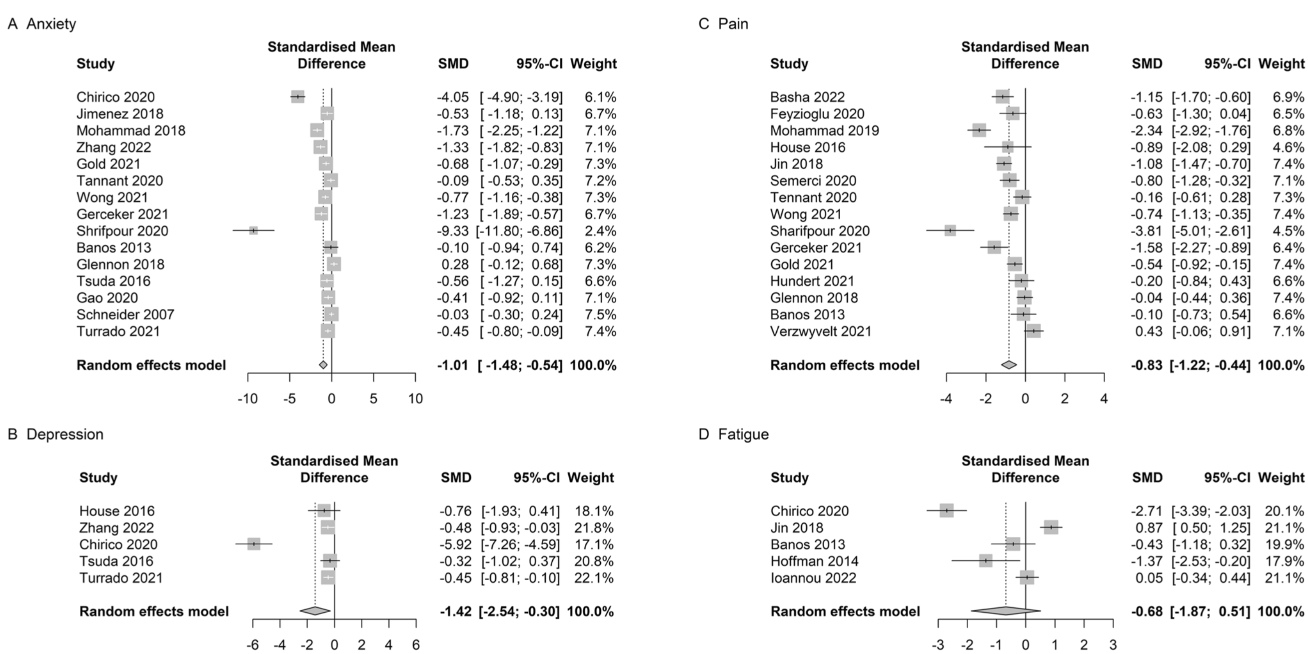

Fig. 3 Forest plots of the effects of virtual reality on anxiety (**A**), depression (**B**), pain (**C**), and fatigue (**D**)

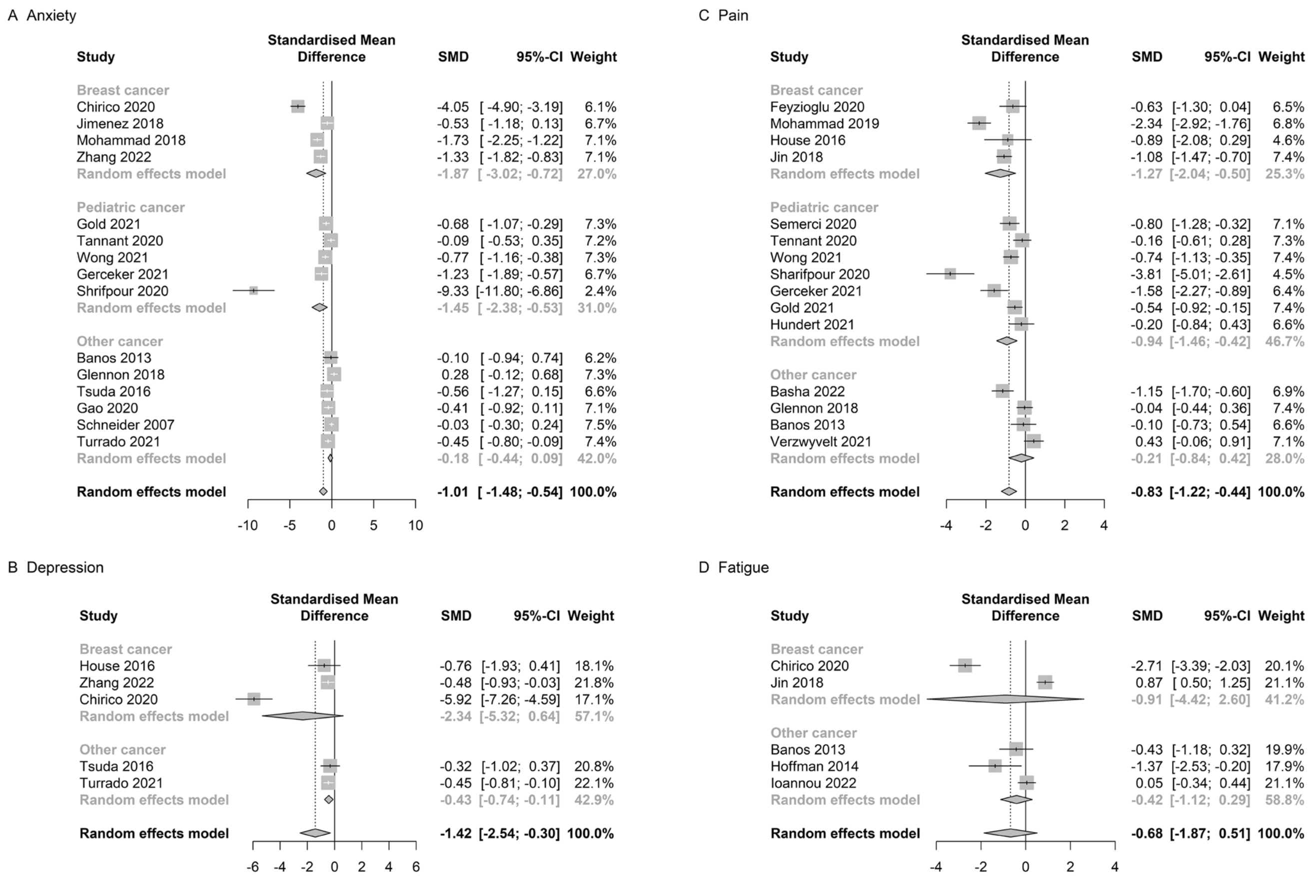

Fig. 4 Forest plots of subgroup analysis on anxiety (**A**), depression (**B**), pain (**C**), and fatigue (**D**)

suggest the significant effects of virtual reality on anxiety, depression, and pain. Although positive effects have been revealed on physical function, cognitive function, and quality of life, more studies are warranted to consolidate the evidence. In addition, it should be considered that 18 of 20 of the included systematic reviews were evaluated as low or critically low quality according to the AMSTAR-2 quality assessment.

Underlying factors contributed to the overall low-quality grading of the systematic reviews. According to the AMSTAR-2 rating instructions [10], the presence of more than one critical flaw indicates critically low quality, and the presence of one critical flaw indicates low quality. Item 15 of the AMSTAR-2 assesses the presence and likely impact of publication bias, and this item only applies to systematic reviews with meta-analyses. Of the ten systematic reviews with meta-analyses, only two received a score for this item, as the remaining eight failed to perform quantitative synthesis or funnel plots to investigate publication bias. However, at least ten studies are needed to examine funnel plot asymmetry [30], and all meta-analyses of the included systematic reviews included fewer than ten primary studies. Due to this single reason, the quality of the reviews that received no score for this item would be low or critically low. Item 7 (justification for excluded studies) is another critical domain of the AMSTAR-2. While most reviews presented reasons for excluding studies in the PRISMA flow diagram, only five of them provided a list of excluded studies in tables or main texts. Another issue is item 10, which assesses whether the reviews report on the funding sources for the studies included in the review. None of the included reviews received a score for this item. Item 10 was generated considering industry-funded studies that may report favorable results for sponsored products. However, it is not a common practice for systematic reviews of non-pharmacological interventions, especially exercise trials, to summarize funding sources [31]. Therefore, these underlying factors contributed to the overall low quality of systematic reviews.

Virtual reality provides a novel environment with positive sensory features, which can divert attention from illness and unpleasant experiences to intriguing scenarios. It can be used as an emotion-focused distraction intervention and decrease the severity of anxiety, depression, and pain [32], which are commonly sustained psychological distresses among patients with cancer. Compared with traditional distraction methods, virtual reality encompasses visual, somatosensory, and auditory processing, which demand more attention and, thus, could be more effective at distraction [33]. In addition, patients can access a natural and relaxing environment through a virtual environment. Stress recovery theory supports the physiological and psychological benefits of viewing scenes of nature for people with elevated stress [34]. The aesthetic experience in virtual reality can facilitate attention to tasks and scenarios and achieve a flow state [35]. These factors could contribute to why this umbrella review supports using virtual reality to mitigate psychological distress in various stages and settings of the cancer care continuum.

The promising effects of virtual reality on pain reduction provide important implications for clinical practice and policy-making. Virtual reality interventions are safe and effective non-pharmacological alternatives that minimize the risk of side effects associated with pain medications. Physicians, nurses, and therapists can adopt virtual reality in various scenarios, such as during painful procedures, post-surgery recovery, or to support pain management during chemotherapy. For example, one session of immersive virtual reality significantly augmented the effects of morphine on pain reduction for patients with breast cancer [36]. Another study found that when combined with virtual reality, tramadol induced similar effects on pain reduction as morphine [37]. Current clinical practice guidelines for cancer pain mainly focus on opioids and non-opioid analgesics [38]. Incorporating virtual reality into comprehensive pain management has the potential to improve outcomes, reduce medication-related side effects, and enhance patient experience.

Given the conflicting reports in systematic reviews [6, 17, 29] and the insignificant result of the quantitative synthesis, the definite effects of virtual reality on fatigue remain unclear. Cancer-related fatigue is a pervasive and debilitating symptom that is not relieved by rest or sleep. It is a complex condition with many potential contributors, including tumor-related factors, comorbidities, malnutrition, pain, impaired physical function, psychological distress, and the lack of sleep [39]. The mechanism of cancer-related fatigue has yet to be fully elucidated, making management challenging. Although this study revealed significant effects of virtual reality on anxiety, depression, and pain, the effect on fatigue was relatively elusive. The multifactorial nature of fatigue might undermine the effect of virtual reality as a standalone intervention. Besides medical interventions and supportive care, exercise is a feasible and effective approach [40]. A systematic review suggested that supervised multimodal exercise interventions significantly improved cancer-related fatigue for those undergoing chemotherapy [41]. Future studies may integrate virtual reality into an exercise program to facilitate fatigue management.

Virtual reality has different types, such as immersive or non-immersive systems, that can be customized to induce different levels of interventional effects to provide supportive care to patients with cancer. Immersion refers to the degree to which virtual reality systems can deliver experiences that are extensive, surrounding, inclusive, vivid, and matching [42]. For non-immersive virtual reality, computer monitors or television screens are typically used to present the 2D virtual environment to the user, and the user experiences a low sense of immersion and interaction in the virtual environment. The platform partially occludes the user's field of view. Immersive virtual reality encompasses the overall sense of the user. The virtual environment displaces the real world, constraining the user's field of view to the 3D virtual environment. The head-mounted display is a common type of immersive virtual reality.

In this umbrella review, most systematic reviews included mixed types of virtual reality; the two systematic reviews, Burrai et al. [22] and Chow et al. [23], focused on the application of immersive virtual reality to patients with cancer undergoing chemotherapy or medical procedures. Both systematic reviews reported that current evidence was insufficient and inconclusive regarding the effects of immersive virtual reality on pain and anxiety. No meta-analysis was conducted by Chow et al. [23], and each meta-analysis by Burrai et al. [22]was only based on two to three primary studies. The strength of the recommendation was overall limited by the small number of studies, low sample sizes of primary studies, low methodological quality, and high heterogeneity of intervention protocols. Immersive virtual reality is portable, user-friendly, and readily usable in different clinical settings. Although the advantages of immersive virtual reality have been highlighted in the rehabilitation management of other patient populations (e.g., patients with stroke [43]), empirical evidence regarding its role in supportive care interventions in cancer is underdeveloped. Therefore, randomized controlled trials with adequate sample size and rigorous methodology are called for in this area.

Virtual reality has clinical potential to support patients with cancer beyond reducing psychological challenges and improving physical health, wellness, and rehabilitation. Late effects of cancer treatments are prevalent among cancer survivors, and morbidity or dysfunction related to cancer treatments can persist after treatment completion [44]. Upper extremity impairments are common in breast cancer survivors, and they are linked with higher incidence of functional deficits and morbidity [45]. The included systematic reviews of this umbrella review have consistently revealed positive effects of virtual reality-based interventions on shoulder range of motion [12–17] and upper extremity function [6, 15, 16] among patients with breast cancer. Compared with conventional exercise therapy, virtual reality can provide task-specific and goal-oriented training in an interactive environment, which may lead to improved and sustained engagement. Reduced fear of movement in virtual reality could promote active movements and enhance tolerance to therapeutic activities [46]. Therefore, virtual reality can be integrated into exercise therapy to improve physiological and functional outcomes. While current research focusing on upper extremity impairments in patients with breast cancer patients has revealed compelling findings, applications to other functional domains and other cancer populations remain to be investigated.

Although promising effects of virtual reality have been shown in the outcomes above, the applications of virtual reality to balance, gait, mobility, and activities of daily living were relatively underrepresented in current cancer literature. One study from Christopherson et al. [19] and three from Tough et al. [28] used the Wii Fit balance board for balance and mobility training. The review by Hao et al. [6] included studies that used an interactive sensor-based virtual reality balance training paradigm and Xbox Kinect for patients with chemotherapy-induced peripheral neuropathy [47] and prostate cancer [48], respectively. Gait and balance impairments are prominent among older adults with cancer [49] and patients with breast cancer [50], contributing to an increased risk of falls and related injuries. Further, accumulating evidence has suggested that chemotherapy negatively affects static balance, dynamic balance, and gait throughout the survivorship continuum [51]. The advantages of virtual reality in restoring balance and gait have been supported by substantial evidence in neurological conditions [52]. These benefits should be assessed further in those with cancer to determine if similar advantages are present. Furthermore, virtual reality is well positioned to deliver simulation training for basic and instrumental activities of daily living [53], which allows practice with progressive task complexity in a safe environment, promoting care transition in different settings and improving independence.

This umbrella review has several limitations. First, the majority of included systematic reviews were graded as low or critically low quality based on the AMSTAR-2 assessment tool. Therefore, the synthesized results should be interpreted with caution. Second, only publications in English were searched and included in this umbrella review, which may have induced language bias. Thirdly, some primary studies can be included by multiple systematic reviews, leading to the overlap issue. However, quantitative syntheses of this umbrella review were based on data from primary studies rather than meta-analyses in these systematic reviews to address the overlap issue. While most systematic reviews were graded as low or critically low, underlying factors associated with the nature of the AMSTAR-2 grading criteria contributed to the ratings. Specifically, eight of ten meta-analyses did not have an adequate number of primary studies to conduct quantitative synthesis or funnel plots to investigate for publication bias. Additionally, none of the reviews reported on funding sources. Both factors reduced the quality rating for included studies. Finally, there was considerable heterogeneity among included systematic reviews, which limited the ability to interpret overall pooled estimates.

Conclusion

This umbrella review synthesized evidence from 20 systematic reviews and clarified the role of virtual reality as a supportive care intervention for patients with cancer. Virtual reality has proven to be a safe and feasible approach to delivering supportive care. Virtual reality can be implemented in various stages and settings of the cancer care continuum to support patients undergoing painful procedures, during or after chemotherapy, and after surgical interventions. Meta-analyses based on primary studies suggested significant effects of virtual reality on anxiety, depression, and pain. Qualitative syntheses revealed positive effects of virtual reality on physical function, cognitive function, and quality of life, and more studies are warranted to consolidate the evidence on these outcomes. The applications of virtual reality to balance, gait, mobility, and activities of daily living were relatively underrepresented in current cancer literature. Most included systematic reviews were evaluated as low or critically low quality based on the AMSTAR-2 quality assessment tool, and considerable heterogeneity exists across the systematic reviews, which affects the strength of evidence summarized in this umbrella review. Therefore, rigorously designed and implemented randomized controlled trials with adequate sample sizes are called for to further investigate the roles played by virtual reality in supporting patients with cancer.

Appendix

PubMed search strategy

("Virtual Reality"[Mesh] OR "Exergaming"[Mesh] OR "Virtual Reality Exposure Therapy"[Mesh] OR "virtual reality" OR "virtual environment" OR "augmented reality" OR "mixed reality" OR "video game*" OR "exergam*") AND ("Neoplasms"[Mesh] OR cancer OR tumor* OR oncolog* OR neoplasm*) AND ("systematic review*" OR meta-analysis OR "meta analys*" OR "meta-analys*" OR "Meta-Analysis as Topic"[Mesh] OR "Meta-Analysis"[Publication Type] OR "Systematic Reviews as Topic"[Mesh] OR "Systematic Review"[Publication Type]).

Scopus search strategy

(TITLE-ABS-KEY (“virtual reality” OR “virtual environment” OR “augmented reality” OR “mixed reality” OR “video game*” OR “exergam*”) AND TITLE-ABS-KEY (cancer OR tumor* OR oncolog* OR neoplasm*) AND TITLE-ABS-KEY (“systematic review*” OR meta-analysis OR “meta analys*” OR “meta-analys*”)) AND (LIMIT-TO (EXACTKEYWORD, “Human”)) AND (LIMIT-TO (SRCTYPE, “j”)) AND (LIMIT-TO (LANGUAGE, “English”)).

Embase search strategy

(‘virtual reality’/exp/mj OR ‘virtual reality head mounted display’/exp/mj OR ‘virtual reality’:ti,ab OR vr:ti,ab OR ‘augmented reality’:ti,ab OR ‘mixed reality’:ti,ab OR ‘virtual environment’:ti,ab OR ‘video game*’:ti,ab OR ‘exergam*’:ti,ab) AND (‘malignant neoplasm’/exp/mj OR ‘cancer’:ti,ab OR ‘tumor*’:ti,ab OR ‘ongolog*’:ti,ab OR ‘neoplasm*’:ti,ab) AND (‘systematic reivew’/exp/mj OR ‘meta analysis’/exp/mj OR ‘systematic review’:ti,ab OR ‘meta-analysis’:ti,ab OR ‘meta analys*’:ti,ab OR ‘meta-analys*’:ti,ab) AND [english]/lim AND [humans]/lim.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00520-024-08813-8.

Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by J.H., Z.H., Y.L., and B.H.. The first draft of the manuscript was written by J.H. and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability No datasets were generated or analyzed during the current study.

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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