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Research Article

Virtual reality as a pain reduction method in burn and wound healing: a systematic review and meta-analysis

Marina Moreno-Martínez[1,2], **Artur Dalfó-Pibernat**[3,*], **Josep Vidal-Alaball**[1,2]

[1]Unitat de Recerca i Innovació, Gerència d'Atenció Primària i a la Comunitat de la Catalunya Central, Institut Català de la Salut, Soler i March, 6, (08242) Manresa, Spain
[2]Intelligence for Primary Care Research Group, Fundació Institut Universitari per a la Recerca a l'Atenció Primària de Salut Jordi Gol i Gurina, Soler i March, 6, (08242) Manresa, Spain
[3]Centre d'Atenció Primària Horta, Gerència Territorial de Barcelona ciutat, Institut Català de la Salut, Lisboa s/n, Horta-Guinardó, (08032) Barcelona, Spain

*Corresponding author. E-mail: adpibernat@gmail.com

Abstract

Background: Burns and wounds cause significant physical and psychological distress, with pain being a major barrier to recovery. Traditional pharmacological methods for pain management carry risks such as side effects and dependency. Virtual reality has emerged as a non-invasive, distraction-based technique that may reduce pain perception during wound care by modulating sensory input.

Methods: This systematic review and meta-analysis, conducted following PRISMA guidelines and registered in PROSPERO (CRD420251005004), assessed the effectiveness of virtual reality in managing pain during wound and burn care. A comprehensive search of PubMed, Web of Science, Scopus, and Cochrane Library was conducted in March 2025. Eligible studies included randomized controlled trials comparing virtual reality interventions to standard care or other distraction techniques in patients with active wounds or burns. Data on pain outcomes, as well as physiological indicators, were extracted. Meta-analysis was performed using a random-effects model and Hedges' g as the effect size estimator. The analysis was performed with SPSS version 29 and the risk of bias was assessed using the RoB 2.0 tool.

Results: Eleven studies (n = 936 participants) were included, with diverse wound types (burns, surgical, limb injuries) and virtual reality setups, predominantly immersive. The overall pooled effect showed a statistically significant reduction in pain using virtual reality ($g = -1.528$; 95% CI: -2.259 to -0.797; $p < 0.001$), indicating a moderate-to-large effect. Subgroup analysis revealed that virtual reality was most effective in children ($g = -2.348$), followed by adolescents ($g = -0.538$), while adults showed a non-significant effect ($g = -1.453$). High heterogeneity ($I^2 = 95.5\%$) was explained by age group differences and sensitivity analysis. No significant publication bias was detected.

Conclusions: Virtual reality appears to be a promising tool for reducing procedural pain, particularly in children with wounds or burns. Its efficacy in adolescents is moderate, while evidence in adults remains inconclusive. Given its non-pharmacological nature and potential to improve patient experience, virtual reality warrants broader implementation and further age-specific research in wound care settings.

Keywords: Virtual reality; Pain; Burns; Wounds; Meta-analysis

Background

Burns and wounds represent a significant global health problem, affecting millions of people each year. These injuries not only cause considerable physical impact but also generate emotional and psychological consequences for patients [1]. Furthermore, both burns and wounds can be extremely painful, with a prolonged recovery process [1,2]. Effective pain management in these patients is a critical challenge in clinical practice, since severe pain not only compromises quality of life [3] but can also interfere with the healing and recovery process [2].

Pain management in patients with burns and wounds is an essential aspect of medical treatment. The presence of acute and chronic pain in these cases requires a comprehensive therapeutic approach that minimizes patient suffering and optimizes recovery [2]. Traditionally, analgesics, local anaesthetics, and opioids have been the primary options for pain control. However, these methods have several limitations, including adverse side effects, risk of tolerance and dependence, and variable efficacy depending on individual patient response [1, 3, 4].

Given the need for complementary and less invasive strategies, virtual reality has emerged as an innovative technology with promising applications in the medical field [5]. Virtual reality is a technology that immerses the user in an interactive 3D digital environment through devices such as screens, helmets, or visualization glasses [6]. In the healthcare field, its application in pain management has attracted increasing interest due to its ability to modulate pain perception through distraction mechanisms and multisensory stimulation [7]. This could be explained by the pain gate model. This theory suggests that the transmission of pain signals to the brain can be modulated by competing sensory stimuli acting on spinal nerve pathways. In this way, by focusing the patient's attention on alternative visual and auditory stimuli, virtual reality limits the amount of painful information reaching the brain, resulting in a lower pain perception [5, 8].

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Several studies evaluate virtual reality as a method for pain reduction in the context of wounds and burns [9–12]. However, existing systematic reviews evaluate virtual reality as a method for pain reduction in general medical procedures, combining vaccination techniques, peripheral catheter placement, blood tests, with wound and burn care, among others [13–15]. A systematic review that only evaluates the effectiveness of virtual reality in relation to wound care is needed, since venepuncture only involves a specific moment of pain, while wound care involves more prolonged pain throughout the procedure. For this reason, the present review aims to conduct a systematic review of the existing evidence on the effectiveness of virtual reality in pain management in patients with burns and wounds.

Methods

Protocol and registration

A systematic review of the literature was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines [16]. The study protocol was registered in the PROSPERO (International Prospective Registrar of Ongoing Systematic Reviews) database with the following code CRD420251005004.

Data sources and searches

The PICO format was used to formulate the research question [17], with P (population) being people with burns or wounds; I (intervention) being virtual reality; C (comparison) being other methods used according to the protocol; O (outcome) being pain reduction. The resulting research question was: According to protocols for pain reduction, how does virtual reality affect individuals with burns or wounds compared to other methods?

The eligibility criteria according to PICO were:

- Population: individuals with any type of wound or burn undergoing the healing process. Studies in which the wound was already healed and rehabilitation or physical therapy was being performed were excluded.
- Intervention: any type of virtual reality device, regardless of whether it was immersive or non-immersive virtual reality.
- Comparison: any other traditional method or distractor consistent with the protocol, regardless of whether the intervention was pharmacological or non-pharmacological.
- Outcome: Changes in pain recorded using validated instruments. Studies that collected objective complementary parameters such as heart rate, blood pressure, oxygen saturation, respiratory rate, among others, were also included.
- Study type: Experimental studies that followed a randomized clinical trial methodology with parallel groups were included, regardless of publication date, location, or language. For this reason, pre-post studies without a control group, quasi-experimental studies, and randomized crossover clinical with a repeated measures or within-subjects design were excluded due to clinical variability between wounds, which prevents replicability. Parallel designs allow for greater stability by always evaluating the same wound in each patient. Randomized clinical trials shared at conferences and congresses were also excluded due to lack of detailed full text.

In March 2025, a systematic search was conducted in the following databases: PubMed, Web of Science, Scopus, and the Cochrane Library. These platforms were selected for their extensive multidisciplinary healthcare content, thus obtaining a broad range of literature on 'virtual reality as a method for reducing pain in people with wounds or burns.' The search strategy included both keywords and Medical Subject Headings, which were combined as appropriate using the Boolean operators AND or OR. The Boolean operator NOT was also used to exclude studies whose titles included the words protocol, review, rehabilitation, or physiotherapy. Search terms for the on-line research were a combination of the following: virtual reality AND pain AND (wound* OR burn* OR dress* OR healing OR injur* OR lesion*) NOT protocol NOT review NOT rehabi*. All searches were filtered by words present in the title, abstract, and keywords, as well as by study design by selecting the randomized clinical trial option.

Identification and selection of studies

All records were exported from their corresponding databases and imported into the Rayyan review management program (AI-Powered Systematic Review Management Platform, Rayyan Systems Inc., Cambridge, MA, USA) using a.ris file. Duplicate detection was performed automatically by the program itself, and the authors then manually evaluated and discarded the duplicate records. The review was conducted by peer reviewers (MM-M, AD-P, and JV-A).

Data extraction and management

A customized data extraction form was used to collect the following information: author, year of publication, study setting, sample size (specified by sex), mean and standard deviation of age, wound type, mean and standard deviation of healing time, comparison of the control group, virtual reality equipment of the intervention group, and reported outcomes. Data extraction was performed by one reviewer (MM-M), while the others (AD-P and JV-A) verified its accuracy.

Information regarding the effect size was also extracted: participants in the control and intervention groups, as well as the mean and standard deviation of pain in the control and intervention groups. For studies with more than one intervention group, e.g. comparing virtual reality and passive distraction with the control group, only the values for the virtual reality intervention were extracted. Studies with missing means and standard deviations were estimated from graphs without numerical data. In graphs representing the mean and standard error, the standard deviation was calculated from the standard error. In studies with mean and 95% confidence interval, the standard deviation was calculated from the confidence intervals using the standard error formula in combination with Student's T test (Supplementary Table S1).

Assessing the risk of bias

The risk of bias of the included studies was assessed using the Cochrane Risk of Bias (RoB 2) tool. This tool evaluates five domains: D1: Bias arising from the randomization process; D2: Bias due to deviations from intended interventions; D3: Bias due to missing outcome data; D4: Bias in measurement of the outcome; and D5: Bias in selection of the reported outcome [18]. The risk of bias assessment was carried out independently by the investigators (MM-M, AD-P, and JV-A).

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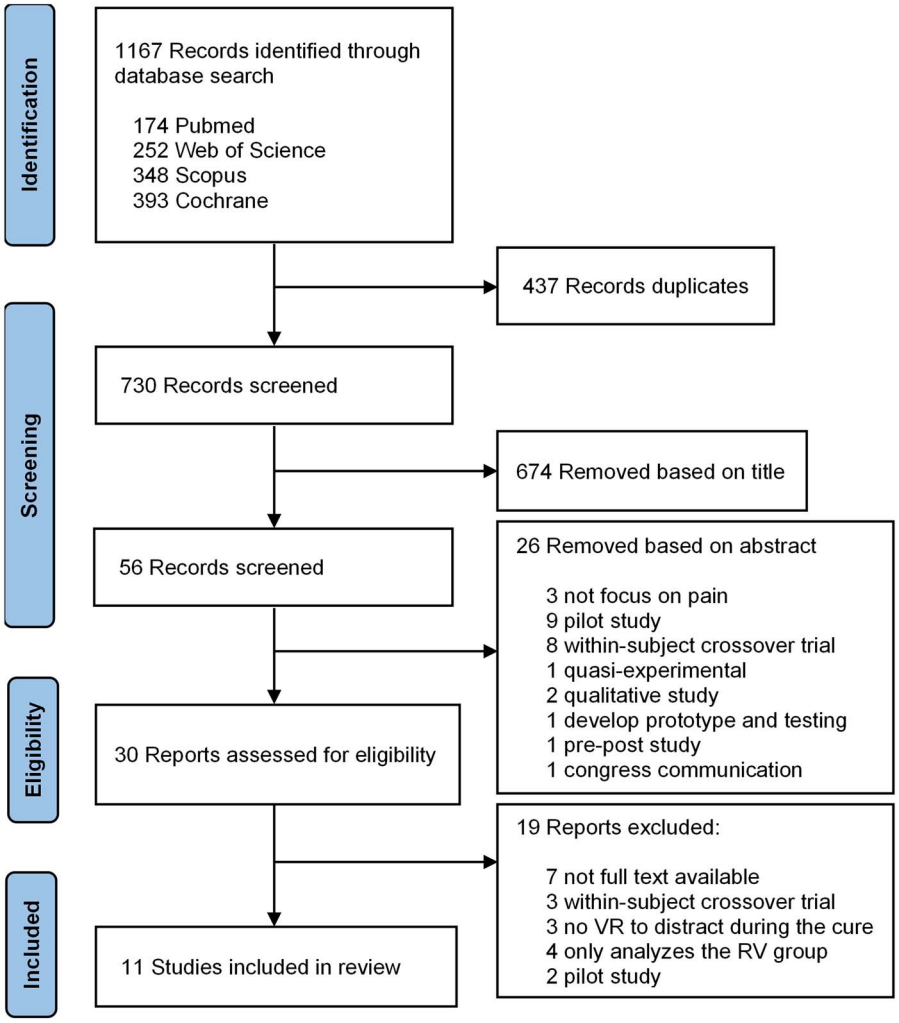


Figure 1. PRISMA flow diagram of study selection process. Template source: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. the PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ 2021;372:n71. Doi: 10.1136/bmj.n71 [16].

Data synthesis and analysis

In the meta-analysis, a forest plot was performed using a random-effects model to calculate the pooled effect size. The effect size was calculated using Hedges' g test. The variance between studies was estimated using the restricted maximum likelihood (REML) method. Weights applied to individual studies were calculated using the adjusted inverse variance method. Statistical heterogeneity between trials was assessed using Cochran's Q test, in addition to the Tau^2, H^2, and I^2 tests. The statistical significance of the overall effect was determined using a Z test. Because the heterogeneity result was high, a funnel plot was performed to rule out publication bias. Visually, asymmetry was observed in the graph, so the Egger test and the trim and fill procedure were applied to obtain an adjusted estimate of the virtual reality effect after accounting for publication bias. Additionally, the influence of age group (child, adolescent, and adult) on the effect size was explored through subgroup analysis, applying random-effects models within each category. The effect size (Hedges' g) and its 95% confidence interval were calculated for each subgroup. Heterogeneity was assessed within each subgroup using the I^2 statistic and Cochran's Q test for homogeneity, while differences between subgroups were assessed using the Q-between test for homogeneity. A sensitivity analysis was then performed, eliminating those records with a high risk of bias. All statistical analyses were performed in SPSS Statistics version 29 for Windows (SPSS Inc., Chicago, IL, USA), using the meta-analysis module for continuous data with raw data.

Results

Study selection

The initial search yielded a total of 1167 records. Once duplicates were excluded (n = 437), a total of 730 articles were obtained. First, a title screening was performed, eliminating n = 674 studies, leaving 56 titles selected. Second, all abstracts were read, eliminating n = 26 records. The remaining 30 articles were potentially eligible, so the entire article was read, eliminating a total of 19 studies (serial studies due to unavailability of the full text; three had a within-subjects crossover design; three used virtual reality before treatment as a method for hypnosis or relaxation, but in no case as a distraction to reduce pain during treatment; four performed only an analysis of the virtual reality group, excluding the control group; and two were pilot studies). Finally, 11 studies were included in the systematic review (Figure 1).

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Study characteristics

A total of 11 studies published between 2008 and 2024 were included. All studies had a randomized, parallel-group clinical trial design [19–29]. The studies were conducted in seven different countries: three (27.3%) in China, two (18.9%) in Australia, two (18.9%) in the USA, one (9.1%) in Canada and China, one (9.1%) in Turkey, one (9.1%) in Poland, and one (9.1%) in Iran. A total of 936 participants were included, of which 567 (60.6%) were men and 369 (39.4%) were women. The sample size of the included studies ranged from n = 40 to n = 182 subjects. The age of the patients varied from 3.5–62.3 years. The types of wounds treated were burns (four studies), surgical (four studies—haemorrhoid, circumcision, appendectomy or other abdominal surgeries and drained perianal abscesses), lower extremities (two studies), and hand injuries (one study). Dressing time ranged from a minimum of 4 minutes between removal and application of the new dressing to a maximum of 120 minutes. However, most studies averaged around 20–30 minutes of dressing time.

All studies used a virtual reality device as a method for pain reduction during wound healing. The most commonly used equipment was virtual reality headsets, specifically the eMagin Z800 3DVISOR head-mounted display, used by three studies, along with Snow World software used in two studies. All control groups followed protocol guidelines, including medication or other traditional distractions such as conversation, parental reassurance, books, or television. The ratio of subjects between the control and intervention groups was 1:1, although some studies ranged from one to two people.

All studies reported pain as the primary outcome. Some also included secondary outcomes such as heart rate and oxygen saturation (five studies), anxiety (three studies), fear (one study), and respiratory rate (one study). The most used scales for measuring pain were the Visual Analogue Scale (seven studies) and the Faces, Legs, Activity, Cry, and Consolability scale (four studies). Pain monitoring ranged from a single assessment of the entire process to consecutive assessments every 5 minutes until the end of treatment. Table 1 shows the characteristics of the included studies.

Risk of bias within studies

Six of the studies had an overall risk of bias score with some concerns, while the rest had a high risk of bias, due to a high risk of bias in one or more domains with some concerns. Regarding bias arising from the randomization process, three studies had a score with some concerns, since, although it was stated that the study was randomized, this process was not explained. All studies had a low risk of bias score for bias due to deviations from the planned interventions and for bias due to missing outcome data. On the other hand, regarding bias in outcome measurement, all studies had a score with some concerns, because the assessors in all studies, both the participant and the healthcare professional, were unaware of whether or not they received the intervention with the virtual reality device. Likewise, it was also difficult to determine whether the outcome was influenced by the knowledge that they were receiving the intervention with the virtual reality device. Regarding bias in the selection of the reported outcome, eight studies had a low risk of bias score, while two studies had a risk of bias with some concern, and one study had a high risk of bias score. This result was due, on the one hand, to some studies collecting the same variable with more than one scale, selecting the one with significant results, and on the other, to some results presented being based on a group of selected participants who met a certain condition. Figure 2 and Table 2 present the risk of bias in the included studies and the summary of the risk of bias for each of them.

Synthesis of results

Eleven studies were included in the meta-analysis, and the overall effect size was calculated using Hedges' g index under a random-effects model with REML estimation. The pooled effect size was statistically significant (g = −1.528; SE = 0.373; 95% CI: −2.259 to −0.797; Z = −4.095; $P < 0.001$), indicating a moderate to large effect size. However, the analysis of heterogeneity revealed substantial variability between studies (Q = 170.89; df = 10; $P < 0.001$), along with the I^2 index being 95.5%, representing extremely high heterogeneity. The variance between studies estimated using REML was $Tau^2 = 1.428$, and the H^2 index = 22.322, confirming the presence of significant heterogeneity and justifying the use of the random effects model (Figure 3).

To explore the possible existence of publication bias, a funnel plot was created, which showed visual asymmetry (Figure 4). To evaluate this statistically, Egger's regression test was applied. The result showed an intercept of 1.360 with a $P = 0.072$, indicating no statistically significant evidence of publication bias in the included studies. To confirm these results, Trim and Fill analysis was also performed, which did not identify missing studies and did not adjust the combined effect (k imputed = 0). The adjusted effect size remained identical to the original (g = −1.528; 95% CI: −2.259 to −0.797), reinforcing the reliability of the results and the absence of distortion attributable to publication bias.

Given the high level of heterogeneity observed, possible sources were explored through subgroup analysis, classifying the studies according to wound type: burns, hand injuries, lower extremities, and surgical. However, heterogeneity remained high within each subgroup ($I^2 > 90\%$), with no statistical significance found between groups (Q-between = 3.189; df = 3; $P = 0.363$). Therefore, wound type does not explain the observed heterogeneity. For this reason, the analysis was performed by subgroup according to the age of the population: children, adolescents, and adults. The variable "age group" was used as a categorical moderator, and effect sizes were estimated within each subgroup. In the child population subgroup (k = 4), a statistically significant effect size of g = −2.348 (SE = 0.294; 95% CI: −2.925 to −1.771; Z = −7.980; $P < 0.001$) was observed, with moderate heterogeneity (Q = 7.479; df = 3; $P = 0.058$; $I^2 = 59.9\%$; $Tau^2 = 0.204$). In the adolescent subgroup (k = 3), the effect size was also significant, although of a smaller magnitude: g = −0.538 (SE = 0.166; 95% CI: −0.863 to −0.212; Z = −3.241; $P = 0.001$). In this group, no heterogeneity was observed (Q = 1.005; df = 2; $P = 0.605$; $I^2 = 0.0\%$; $Tau^2 = 0$). In the adult subgroup (k = 3), the effect did not reach statistical significance (g = −1.453; SE = 0.815; 95% CI: −3.051 to 0.144; Z = −1.783; $P = 0.075$), and heterogeneity was moderate (Q = 5.405; df = 2; $P = 0.067$; $I^2 = 63.0\%$; $Tau^2 = 2.586$) (Figure 5).

Sensitivity analysis

Given the evidence of moderate heterogeneity even in the subgroup analysis, a sensitivity analysis was performed, eliminating five studies, those with the highest risk of bias, as observed in Table 2. This new analysis reduced heterogeneity

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Table 1. Characteristics of the included studies

Author (year) place	Sample (M/F) mean ± SD age	Type of Wound (mean ± SD) dressing change	Comparison intervention (n)	VR equipment (n)	Outcomes reported
Ding et al. (2019) China, Canada [19]	n=182 (72/110) 45.8±12.6 years	Surgical haemorrhoid wound care 22.3 ± 1.2 min	Only received the standard dressing change procedure (n=91)	eMagin Z800 3DVISOR Head Mounted Display, FasTrak Control Box and Dell 650 Precision. Software: Snow World version 2.1 (n=91)	Pain intensity – VAS HR and SaO_2 – pulse oximeter before starting the cure and every 5 minutes until its completion
Guo et al. (2015) China [20]	n=98 (85/13) 31.1±18.5 years	Hand injuries (soft tissue defect, cuts, skin avulsion and nail bed, finger and hand damage) The duration of the wound care is not reported.	Only received the standard dressing change procedure (n=49)	Ultra-high-resolution 3D glasses, headphones, a mouse and a computer. Software: 3D film Afanda (n=49)	Pain level – VAS Anxiety level – STAI and S-AI before and after the cure
Hassannia et al. (2021) Iran [21]	n=40 (40/0) 6.69±1.3 years	Circumcision wound care 20.1 ± 1.3 min	Only received the standard procedure. Included 5.5 ml dose of lidocaine (n=20)	Remax-RT-V03 audio-visual glasses. Software: 360° full HD animation Tom and Jerry (n=20)	Severity of pain – Oucher pain scale Anxiety – OSBD-R 30 min before starting, during the anesthesia injection and at the end of the procedure
Hoffman et al. (2020) USA [22]	n=50 (42/8) 6-17 years	Burn wound care 23.6 ± 7.6 min	Only received the standard dressing change procedure. Included medication (fentanyl, morphine, lorazepam) (n= no reported)	MX90 VR goggles, from NVISinc.com, Bose speakers. Software: Snow World (n= no reported)	Time spent thinking about pain during burn wound care, pain unpleasantness, worst pain and lowest pain – GRS baseline, and Study Days 1–10
Hua et al. (2015) China [23]	n=65 (31/34) 8.72±3.36 years	Chronic wounds on lower limbs 25.1±7.34	Only received the standard dressing change procedure. Included toys, television, books and parental comfort (n=32)	eMagin Z800 3DVISOR head-mount display, BETOP TE BTP-2185 joystick and Lenovo-Y430p. Software: *Ice Age 2: The Meltdown* game (n=33)	Pain intensity – WBFPS, FLACC, VAS HR and SaO_2 – pulse oximeter before, during, and after the changing dressings
Kipping et al. (2012) Australia [24]	n=41 (28/13) 13.08±1.6 years	Burn wound care 2-62 min for dressing removal 2-58 min for dressing application	Only received the standard dressing change procedure. Included television, stories, music, caregivers or no distraction as was their choice and as per standard practice. Also included medication, paracetamol, opioid (n=21)	eMagin, Z800 3DVisor head mounted display, LOGIK PC ATTACK 3 joystick and a personal computer. Software: Chicken Little™ or Need for Speed™ (n=20)	Pain intensity – VAS, FLACC HR and SaO_2 – pulse oximeter before, after removal of the dressing and after application of the new dressing
Mott et al. (2008) Australia [25]	n=42 (29/13) 3.5-14 years (mean 9 years)	Burn wound care Mean 33.95 min	Only received the standard dressing change procedure. Icluded basic multi-dimensional cognitive techniques, such as attention–distraction, positive reinforcement, relaxation and an age appropriate video program. Also included medication, paracetamol/codeine, oxycodone, morphine and midazolam (n=22)	AVR—LCD screen and Intel Pentium Trade Mark 4 computer. Software: Hospital Harry (n=20)	Pain – VAS, FLACC, FPS-R HR and SaO_2 – pulse oximeter RR – breaths per minute before starting the cure and every 10 minutes until its completion

(continued)

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Table 1. Continued.

Author (year) place	Sample (M/F) mean ± SD age	Type of Wound (mean ± SD) dressing change	Comparison intervention (n)	VR equipment (n)	Outcomes reported
Özsoy et al. (2022) Turkey [26]	n=96 (54/42) 8.58±1.13 years	Wound care after appendectomy or other abdominal surgeries 8-10 min	Only received the standard dressing change procedure (n=32)	VR—3D PREO myVRbox VR headset Software: 3D-VR VIDEOS 234 SBS VR Video 2k Google cardboard (n=32) PD—Apple A1823 iPad tablet. Software: Keloğlan: Food Competition cartoon (n=32)	Pain level – WBFPS Fear level – CFS before and after the cure
Spyrka et al. (2024) Poland [27]	n=60 (31/29) 62.28±6.2	Venous leg ulcers The duration of the wound care is not reported.	Only received the standard dressing change procedure (n=30)	Oculus Meta Quest 2 goggles. Software: beach, forest, mountains, desert island, canyon (n=30)	Pain intensity – NRS after the cure, single assessment of the entire procedure
Xiang et al. (2021) USA [28]	n=90 (45/45) 6-17 years (mean 11.3 years)	Burn wound care The duration of the cure is not reported	Only received the standard dressing change procedure. Included iPads, music, books or talking and medication use within 6h prior to the dressing change (n=29)	AcVR—Apple iPhone paired with Google Cardboard. Software: Virtual River Cruise (n=31) PVR—Apple iPhone paired with Google Cardboard. Software: Virtual River Cruise, without interaction (n=30)	Self-reported Overall Pain – VAS Self-reported Worst Pain – VAS Observed Pain – FLACC-R Anxiety-prone traits – STAI-CH after the cure, single assessment of the entire procedure
Zheng et al. (2023) China [29]	n=172 (110/62) 45.6 ± 8.6 years	Wound care of perianal abscess that has been drained surgically 22.5 ± 4.3 min	Only received the standard dressing change procedure (n=86)	Pico G2 4K head-mounted display and a hand-held controller. Software: immersive 360° Cine-VR scene of movies (n=86)	Pain intensity – VAS HR and SaO_2 – pulse oximeter before starting the cure and every 5 minutes until its completion

M male, *F* female, *AVR* augmented virtual reality, *PD* passive distraction, *AcVR* Active virtual reality, *PVR* passive virtual reality, *VAS* visual analogue scale, *HR* heart rates, SaO_2 oxygen saturation, *FLACC-R* faces, legs, activity, cry, and consolability–revised, *S-AI* State Anxiety Scale, *STAI* State Trait Anxiety Inventory, *STAI-CH* State Trait Anxiety Inventory for Children, *OSBD-R* Observational Scale of Behavioral Distress-Revised, *GRS* Graphic Rating Scales, *WBFPS* Wong-Baker faces pain rating scale, *CFS*Children's Fear Scale, *NRS* Numerical Rating Scale, *RR* respiratory rates, *FPS-R* faces pain scale – revised

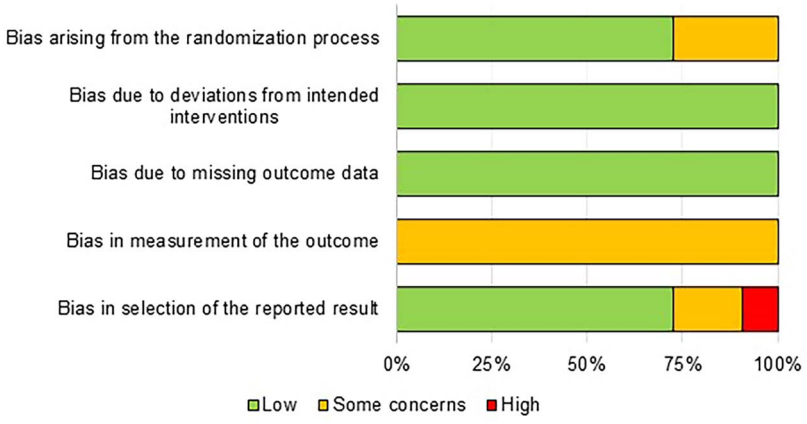


Figure 2. Risk of bias in included studies

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Table 2. Risk of bias specified by study

Study	D1	D2	D3	D4	D5	Overall
Ding, 2019	+	+	+	!	+	!
Guo, 2015	!	+	+	!	!	−
Hassannia, 2021	+	+	+	!	+	!
Hoffmann, 2020	+	+	+	!	+	!
Hua, 2015	+	+	+	!	+	!
Kipping, 2012	+	+	+	!	+	!
Mott, 2008	+	+	+	!	!	−
Özsoy, 2022	!	+	+	!	+	−
Spyrka, 2024	!	+	+	!	+	−
Xiang, 2021	+	+	+	!	−	−
Zheng, 2023	+	+	+	!	+	!

Domains:

- D1: Bias arising from the randomization process
- D2: Bias due to deviations from intended interventions
- D3: Bias due to missing outcome data
- D4: Bias in measurement of the outcome
- D5: Bias in selection of the reported result

+ Low
! Some concerns
− High

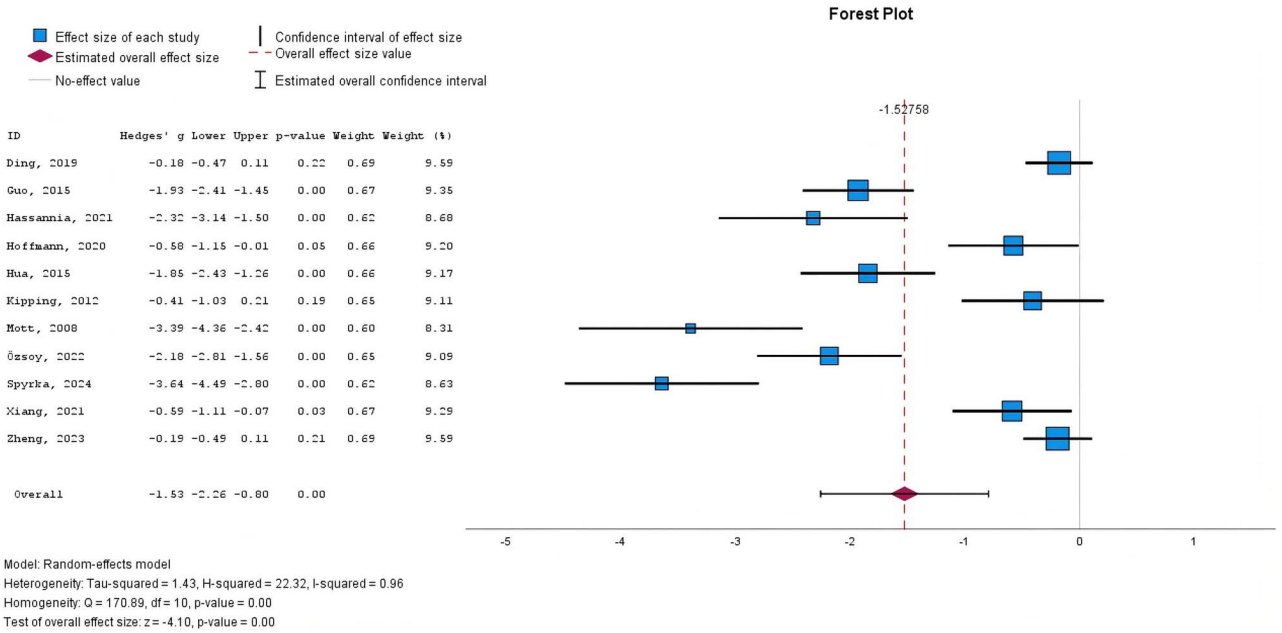


Figure 3. Forest plot of the effectiveness of virtual reality therapy as a method for pain reduction.

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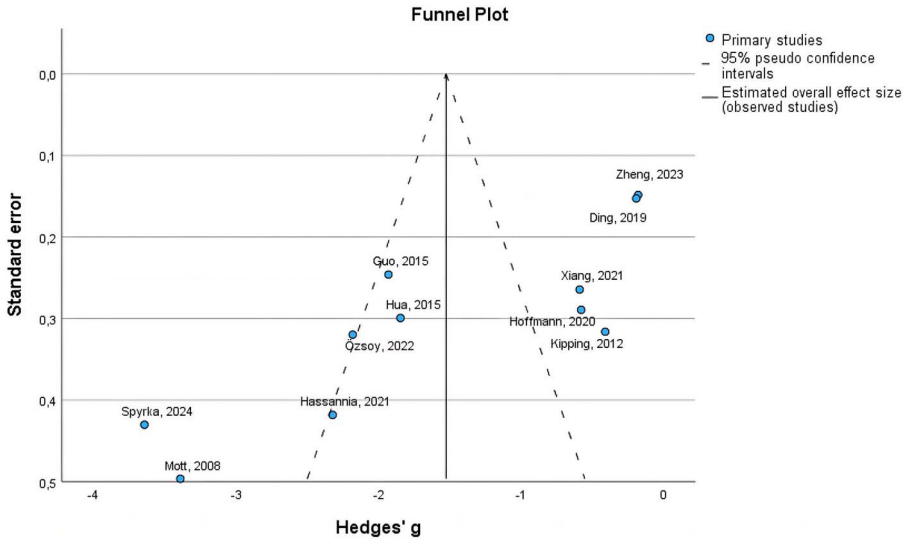
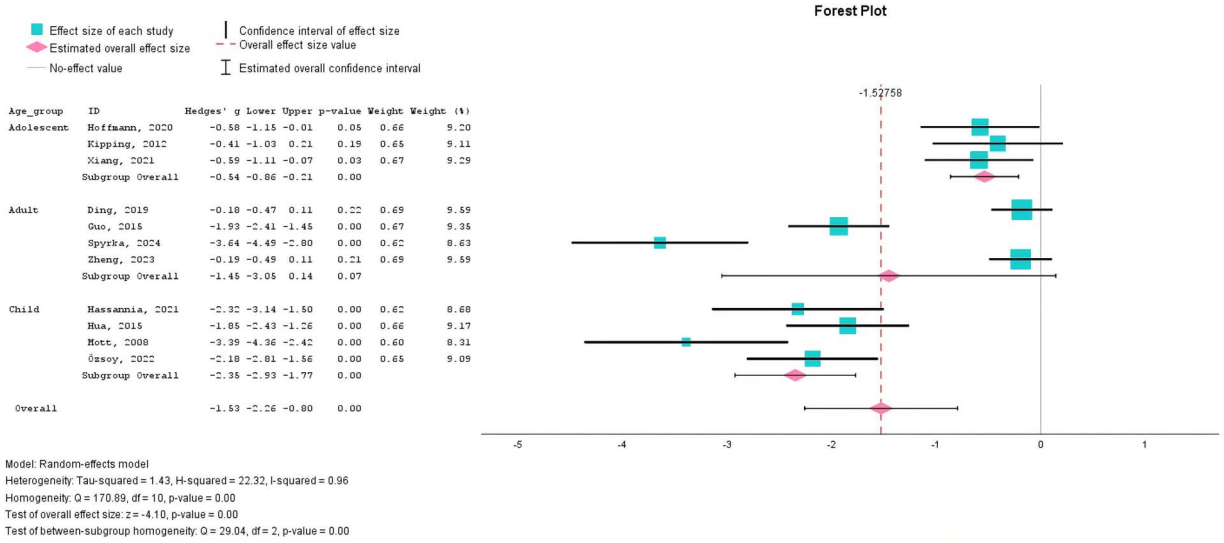


Figure 4. Funnel plot of Hedges' g versus its standard error for virtual reality therapy to reduce pain intensity



Age_group	ID	Hedges' g	Lower	Upper	p-value	Weight	Weight (%)
Adolescent	Hoffmann, 2020	-0.58	-1.15	-0.01	0.05	0.66	9.20
	Kipping, 2012	-0.41	-1.03	0.21	0.19	0.65	9.11
	Xiang, 2021	-0.59	-1.11	-0.07	0.03	0.67	9.29
	Subgroup Overall	-0.54	-0.86	-0.21	0.00		
Adult	Ding, 2019	-0.18	-0.47	0.11	0.22	0.69	9.59
	Guo, 2015	-1.93	-2.41	-1.45	0.00	0.67	9.35
	Spyrka, 2024	-3.64	-4.49	-2.80	0.00	0.62	8.63
	Zheng, 2023	-0.19	-0.49	0.11	0.21	0.69	9.59
	Subgroup Overall	-1.45	-3.05	0.14	0.07		
Child	Hassannia, 2021	-2.32	-3.14	-1.50	0.00	0.62	8.68
	Hua, 2015	-1.85	-2.43	-1.26	0.00	0.66	9.17
	Mott, 2008	-3.39	-4.36	-2.42	0.00	0.60	8.31
	Özsoy, 2022	-2.18	-2.81	-1.56	0.00	0.65	9.09
	Subgroup Overall	-2.35	-2.93	-1.77	0.00		
Overall		-1.53	-2.26	-0.80	0.00		

Model: Random-effects model
Heterogeneity: Tau-squared = 1.43, H-squared = 22.32, I-squared = 0.96
Homogeneity: Q = 170.89, df = 10, p-value = 0.00
Test of overall effect size: z = -4.10, p-value = 0.00
Test of between-subgroup homogeneity: Q = 29.04, df = 2, p-value = 0.00

Figure 5. Forest plot of the effectiveness of virtual reality as a method for pain reduction, analysis by age subgroups

for all age subgroups to $I^2 = 0.0\%$, $Tau^2 = 0$. The overall effect size remained significant ($g = -0.879$; $SE = 0.364$; 95% CI: -1.594 to -0.165; $Z = -2.413$; $P = 0.016$). In the subgroups, the effect size also remained statistically significant for the child and adolescent population, while it remained no significant for adults (Figure 6).

The test for homogeneity between subgroups showed statistically significant differences (Q-between = 47.06; df = 2; $P < 0.001$), indicating that the variable "age group" significantly explains the heterogeneity observed in the overall analysis. Residual heterogeneity within subgroups was completely reduced, supporting the explanatory value of subgroup analysis. Overall, these results indicate that the observed effect size varies according to the age of the population, being larger in studies with children and smaller in adolescents. The absence of publication bias and the reduction in heterogeneity within subgroups reinforce the robustness of the findings.

Discussion

This study conducts a systematic review of the existing evidence on the effectiveness of virtual reality in pain management in patients with burns and wounds. A total of 11 parallel-group randomized controlled trials with 936 participants were included. The results of this systematic review and meta-analysis showed a significant overall effect size. This demonstrates that the use of virtual reality is effective in reducing pain during wound and burn treatment, compared to control treatment (traditional distractors or medication). This fact could be explained by the gating theory, which suggests that, since the brain's capacity to process incoming stimuli is limited, directing a person's cognitive attention away from the noxious stimulus helps inhibit pain [30]. However, it is worth mentioning the existence of previous systematic reviews that obtained inconclusive results [31] or with low and very low certainty regarding the effectiveness of virtual reality distraction [32].

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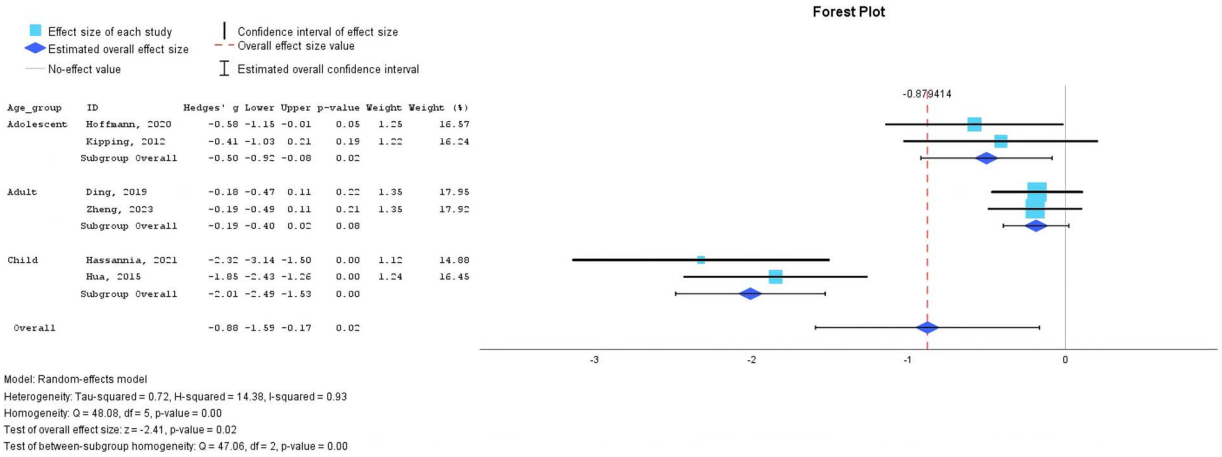


Figure 6. Forest plot of the effectiveness of virtual reality as a method for pain reduction, sensitivity analysis and by age subgroups

Several authors point out that when patients experience pain, brain areas related to pain perception (such as the insula, anterior cingulate cortex, thalamus, and primary and secondary somatosensory cortices) show increased activity. However, when virtual reality is applied during these painful episodes, a reduction of more than 50% in the activity of these brain areas is observed, which coincides with a decrease in the pain scores reported by patients [33, 34]. These results reinforce the clinical and statistical utility of virtual reality as a complementary tool in the field of acute pain during wound care procedures. However, it should be noted that high heterogeneity was noted among the studies, which led to the exploration of possible factors that could explain this. This finding has also been repeated in other meta-analyses, where heterogeneity was also extremely high, ranging from $I^2 = 81.7\%–99\%$ [34–37].

One of the most notable observations from the subgroup analysis was the difference in virtual reality efficacy according to the age of the participants. In studies that included paediatric populations [20, 22, 24, 25], a very pronounced effect was observed, with significantly greater pain reduction compared to adolescents [22, 24, 28] and adults [19, 20, 27, 29]. In this sense, age appears to explain the heterogeneity observed in the analysis. The results indicated that virtual reality therapy had a better effect on pain intensity relief in the child population, whereas, in adolescents, although the effect of virtual reality on pain was also statistically significant, it was of a smaller magnitude. In contrast, in the adult group, the effect of virtual reality on pain did not reach statistical significance. This pattern was also found in the systematic review and meta-analysis by Norouzkhani et al [36], where virtual reality had a statistically significant effect in the paediatric population, while it was ineffective in adults. Thus, it appears that virtual reality would be most effective in paediatric populations, gradually losing its effect with increasing age. However, these findings do not fully coincide with those of other authors, where virtual reality has also been found to be effective in the adult population [3, 37, 38]. Although virtual reality is effective for pain management in the context of medical procedures for both youth and adults, evidence highlights that virtual reality has greater effect for youth compared to adults [3, 38]. However, conversely, children have also had greater difficulty tolerating virtual reality compared to adolescents [39].

This difference in the effectiveness of virtual reality depending on the patient's age can be explained by the central role that distraction plays in pain processing at an early age. Children have a greater capacity to engage in playful activities, as well as greater receptivity to visual and auditory stimuli, in addition to their natural tendency to be absorbed by playful or fantasy environments. Virtual reality, by offering an immersive, multisensory environment, acts as a powerful distraction tool in this age group, reducing their perception of pain during painful procedures. The more moderate, albeit significant, effect in adolescents could be due to a lower level of immersion, changes in motivation, or greater awareness of the medical procedure, which could interfere with virtual reality's ability to fully capture their attention. On the other hand, a possible explanation for the non-significant effect in adults could be skepticism toward technology, a lower propensity to be distracted by virtual environments, or even a greater ability to anticipate and rationalize pain, which could decrease the effectiveness of distraction strategies [3, 13, 39].

Therefore, unlike analgesics, which act by blocking the transmission of pain signals, virtual reality influences pain perception through attention, concentration, and emotions, reducing the experience of pain by changing the way the brain processes signals [3, 35]. For this reason, when implementing these technologies, it is essential to consider adapting the content and the form of presentation according to the stage of development of the patient, in order to maximize their therapeutic impact [31].

One of the main strengths of this study is its specific focus on patients with burns and wounds, allowing for more concrete and applicable evidence for these types of clinical procedures, characterized by high levels of acute pain. Moreover, the exclusive inclusion of randomized clinical trials provides a high level of evidence, which increases the internal validity of the results. However, the study has some limitations. Overall heterogeneity was high, indicating significant variability between studies, although this was explained by subgroup analyses by age group. Furthermore, all studies presented a risk of bias in one or more domains evaluated. Other limitations included the variability in the types of virtual reality devices used, the duration of the interventions, as well as their content, in addition to the pain assessment scales employed, all of which may have influenced the consistency of the observed

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effects. Additionally, it was not possible to include secondary variables in the analysis due to the lack of comparable data or their absence in the reported results, as they were often omitted because of non-significant statistical findings. This lack of standardisation hinders direct comparison between studies and may have affected the overall effect size.

The results obtained suggest that virtual reality can be an effective tool for pain management in the context of wounds and burns, particularly in the paediatric population. This reinforces the possibility of integrating this technology into standard clinical protocols, especially in paediatrics, as a complement or alternative to traditional pharmacological strategies. Furthermore, its use could be especially valuable in settings seeking to reduce the use of analgesics, either due to medical contraindications or to avoid side effects associated with prolonged opioid use. In adults, the lower effectiveness observed suggests that more personalized interventions or more immersive experiences, tailored to their cognitive characteristics and individual preferences, may be required.

Despite the findings presented in this meta-analysis, several gaps in the literature remain that should be addressed in future research. One of the main recommendations is to conduct longitudinal studies evaluating the long-term effects of virtual reality, especially in settings where the patient requires multiple follow-up treatments. Analysing the cumulative impact of repeated use of this technology would allow for an assessment of its sustained effectiveness. Likewise, it would be useful to more systematically explore the differences between types of technology, such as immersive versus non-immersive virtual reality, and their differential impact by age group. Furthermore, it would be beneficial to advance the standardization of both virtual reality application methods and the instruments used to assess pain, which would facilitate comparisons across studies and strengthen the available evidence base.

Conclusions

The results of this systematic review and meta-analysis support the effectiveness of virtual reality as a complementary tool for pain management in burn and wound-related procedures, especially in the paediatric population. The magnitude of the observed analgesic effect was significant and clinically relevant, particularly in children, where virtual reality proved to be a highly effective strategy, likely due to its ability to generate distraction through immersive and multisensory environments. However, efficacy decreased in adolescents and was not significant in adults, suggesting that age could act as a key moderator in response to these types of interventions. These findings reinforce the importance of tailoring the design and content of virtual reality experiences according to patient characteristics, considering aspects such as attention level, motivation, and receptivity to digital stimuli. Overall, virtual reality emerges as a promising, safe, and non-invasive tool with high potential to improve the patient experience during painful procedures.

Author contributions

Marina Moreno-Martínez (Conceptualization [equal], Data curation [equal], Formal Analysis [equal], Investigation [equal], Methodology [equal], Visualization [equal], Writing—original draft [equal], Writing—review & editing [equal]), Josep Vidal-Alaball (Conceptualization [equal], Investigation [equal], Methodology [equal], Supervision [equal], Visualization [equal], Writing—review & editing [equal]), Artur Dalfó Pibernat (Conceptualization [equal], Investigation [equal], Methodology [equal], Writing—original draft [equal], Writing—review & editing [equal]).

Supplementary data

Supplementary data are available at *Burns & Trauma* online.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Conflict of interest

The authors declare no conflicts of interest.

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Data availability

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