The effects of virtual reality technology on reducing pain in wound care: A meta-analysis and systematic review

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Abstract
Virtual reality (VR) technology has been widely used in clinical nursing care in recent years. We aimed to systematically evaluate the effect and safety of VR technology on pain control in wound care, to provide evidence and support for clinical wound care. We searched PubMed, EMBASE, Cochrane Library, Web of Science, CINAHL, China Biomedical Literature Database, China National Knowledge Infrastructure (CNKI), Wanfang Data Knowledge Service Platform, and Chinese Science and Technology Journal databases for randomised controlled trials (RCTs) on the application of VR technology in wound care up to December 20, 2021. Two researchers independently assessed the quality of the included RCTs and extracted associated data. RevMan5.3 statistical software was used for data analysis. 13 RCTs involving 1258 adult patients were included, of whom 588 patients underwent VR intervention. VR technology intervention could reduce the VAS score (MD = -1.13, 95% CI: -2.01 to -0.26, P < .001), pain cognition score (MD = -3.94, 95% CI: -4.59 to -3.30, P < .001), pain emotion score (MD = -5.21, 95% CI: -10.46 to -0.04, P < .001), pain sensation score (MD = -4.94, 95% CI: -9.46 to -0.42, P = .03) and blood pressure (MD = -4.66, 95% CI: -8.63 to -0.69, P = .02) during wound care. There were no significant differences on the heart rate (MD = -1.85, 95% CI: -5.71 to 2.01, P = .45) and VR interestingness (MD = 28.96, 95% CI: -22.10 to 80.02, P = .27) of the VR group and control group. No publication biases among the synthesised outcomes were found (all P > .001). VR technology can effectively reduce the pain degree and sensation of patients during wound care, which may be an effective auxiliary non-drug method used for pain relief during wound care.

Keywords
meta-analysis, nursing, pain, review, virtual reality, wound care

List of Abbreviations: CI, confidence interval; CNKI, China National Knowledge Infrastructure; MD, mean difference; RCTs, randomised controlled trials; RR, relative risk; VAS, Visual Analog Scale; VR, virtual reality.

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1 | BACKGROUND

Pain is one of the most common clinical symptoms, with is an unpleasant subjective sensory and emotional experience associated with tissue damage or potential tissue injury.1 Wound-related pain is the harmful symptoms or unpleasant experiences directly related to open wounds, which are likely to have adverse effects on wound healing and the patient’s anxiety or quality of life.2,3 In clinical nursing, patients feel more pain when removing or changing dressings, cleaning wounds, removing necrotic tissue compared to other nursing care practice. Analgesics are the first-line recommendations for the treatment of pain, but the effects and safety vary from person to person, and analgesics use often lead to side effects such as gastrointestinal reactions, respiratory depression, physical and mental dependence, etc.4,5 Therefore, there is an urgent need in clinical practice using additional non-pharmacological interventions for better pain management in wound care.

Virtual reality (VR) can immerse participants in three-dimensional dynamic scenes and virtual reality of physical behaviour interaction through head-mounted displays, headsets, motion tracking systems with different devices that interact with the virtual environment, such as mice, trackballs, keyboards, etc.6,7 It has been widely used in acute and chronic pain management, phobia and anxiety treatment, cognitive and physical rehabilitation exercises, et al.8,9 In recent years, VR technology has also attracted increasing attention in the field of non-drug-assisted analgesia in wound care. With the further improvement of its popularisation and acceptance, more and more researchers have conducted randomised controlled trials (RCTs) to explore the effects and safety of VR application in wound pain care, but the findings remain inconsistent. Therefore, we aimed to conduct a meta-analysis and systematic review to evaluate the effects and safety of VR technology in clinical wound care, to provide reference and support for clinical wound nursing care.

2 | METHODS

We performed and reported this meta-analysis and systematic review according to the Preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement.10

2.1 | Literature search strategy

The two researchers searched PubMed, EMBASE, Cochrane Library, Web of Science, CINAHL, China Biomedical Literature Database, China National Knowledge Infrastructure (CNKI), Wanfang Data Knowledge Service Platform and Chinese Science and Technology Journal Database for RCTs on the effects of VR technology in clinical wound care. The retrieval time limit was from the establishment of the database to December 20, 2021. We used a combination of subject headings and free words for literature retrieval. The search terms used were as following: (“VR” OR “virtual reality” OR “virtual simulation” OR “virtual”) AND (“wound” OR “wound care” OR “wound nursing” OR “dressing”) AND (“pain” OR “pain management” OR “pain care”). We conducted a separate search for important relevant reviews and references of the included literature to avoid missing relevant research reports.

2.2 | Literature inclusion and exclusion criteria

Inclusion criteria for this meta-analysis were as following: (a) The type of study was an RCT design. (b) The study population were adult patients who have accepted wound care, and there was no limit on the types of wound. (c) Intervention measures: VR technology was used to intervene to assist analgesia during wound care in the VR group. The hardware equipment included modelling equipment (such as 3D scanners), 3D visual
display equipment sources (such as 3D display systems, projection systems, head-mounted devices) Stereo display, etc.; sound devices (such as stereo or 3D sound systems) and interactive devices (such as position trackers, data gloves, 3D mice, motion capture devices, eye trackers, force feedback devices, etc.); software devices including virtual reality systems, developed graphics and image three-dimensional processing software, etc. The control group did not have VR intervention and adopted traditional wound care. (d) related outcome indicators such as Pain Visual Analog Scale (VAS) score, heart rate, blood pressure, VR interestingness (defined as the VR expression method was full of interesting and human qualities that attracted the audience) were reported. We excluded quasi experimental studies, reviews, case and empirical reports, purely descriptive studies, uncontrolled clinical trials, duplicate publications, no valid data, or literature for which the full text was not available by various methods.

2.3 | Literature screening and data extraction

Two researchers independently searched the literature, performed preliminary screening by reading the titles and abstracts of the literature, and then double-checked by reading the full text to eliminate the literature that did not meet the inclusion criteria. In case of disagreement, a third investigator arbitrated the final decision.

2.4 | Literature quality evaluation

We assessed the quality of the included RCTs according to the evaluation criteria recommended by Cochrane library.11 Two researchers independently assessed the quality of the included literature. Items evaluated in this present meta-analysis included: random sequence generation, allocation concealment, blinding of performers and participants, blinding of outcome measurers, completeness of outcome data, selective reporting of outcomes, and other sources of bias. For dissention of evaluation results, the third researcher shall arbitrate or decide by the research team through discussion.

2.5 | Statistical methods

We used RevMan5.3 statistical software to perform meta-analysis on the data of the included studies. Measurement data were expressed by mean difference (MD) and 95% confidence interval(CI), and enumeration data were expressed by relative risk(RR) and 95% CI. The chi-square test was used to determine whether there was heterogeneity among the studies. If $P > .1$, $I^2 < 50\%$ indicated that there was no heterogeneity among the studies, and a fixed effect model was selected for analysis; if $P \leq .1$, $I^2 \geq 50\%$ indicated that there was no heterogeneity among the studies. There was heterogeneity, and a random-effects model was selected for analysis. Sensitivity analysis was performed on the test results to evaluate the stability and reliability of the meta-analysis results. Publication bias were assessed by funnel plots and Egger regression test. $P < .05$ was considered as being significantly different in this present meta-analysis.

3 | RESULTS

3.1 | Literature search results

We obtained a total of 222 literatures through the initial database search, and 202 literatures remained after the duplicate literatures were eliminated by Endnote. After reading the title and abstract, 164 papers that did not meet the inclusion criteria were excluded, and 38 papers remained. After searching the full text and reading the whole article, 25 articles were further excluded, and 13 RCTs12-24 were finally included (Figure 1).

3.2 | The characteristics and quality of included RCTs

Of the included 13 RCTs,12-24 a total of 1258 patients were involved, 588 patients underwent VR intervention, and 670 patients accepted traditional wound care. The characteristics of included RCTs were presented in Table 1. There was no statistically significant difference between the VR group and the control group in gender, age, wound size and severity, and baseline pain score, and the baseline data of the patients were comparable.

3.3 | The quality of included RCTs

The quality of included RCTs were indicated in Figures 2 and 3. The quality of the included 13 RCTs12-24 was high. Most of the studies did not use allocation concealment and had insufficient blinding, which may be related to the difficulty in implementing blinding of virtual reality intervention technology. No other significant biases were found.
3.4 | Meta-analysis

VAS score 7 RCTs\textsuperscript{12,13,17,19,20,22,24} reported the effect of VR technology on the VAS score. There was heterogeneity among the studies ($I^2 = 97\%, P < .001$), and the random effects model was used for analysis. The results of meta-analysis showed that the VAS score of the VR group was lower than that of the control group, and the difference was statistically significant ($MD = -1.13$, 95% CI: $-2.01 \sim -0.26$, $P < 0.001$, Figure 4A).

Pain cognition score 3 RCTs\textsuperscript{16,18,21} reported the effect of VR technology on the pain cognition score. There was no heterogeneity among the studies ($I^2 = 26\%, P = .26$), and the fixed effects model was used for analysis. The results of meta-analysis showed that the pain cognition score of the VR group was lower than that of the control group, and the difference was statistically significant ($MD = -3.94$, 95% CI: $-4.59 \sim -3.30$, $P < .001$, Figure 4B).

Pain emotion score 4 RCTs\textsuperscript{16,18,21,23} reported the effect of VR technology on the pain emotion score. There was heterogeneity among the studies ($I^2 = 99\%, P < 0.001$), and the random effects model was used for analysis. The results of meta-analysis showed that the pain emotion score of the VR group was lower than that of the control group, and the difference was statistically significant ($MD = -5.21$, 95% CI: $-10.46 \sim -0.04$, $P < .001$, Figure 4C).

Pain sensation score 4 RCTs\textsuperscript{16,18,21,23} reported the effect of VR technology on the pain sensation score. There was heterogeneity among the studies ($I^2 = 99\%, P < .001$), and the random effects model was used for analysis. The results of meta-analysis showed that the pain sensation score of the VR group was lower than that
of the control group, and the difference was statistically significant \( \text{MD} = -4.94, 95\% \text{CI:} -9.46 \sim -0.42, P = .03, \) Figure 4D).

| RCT ID     | Country | Population                              | Sample size | VR group | Control group | VR technology                           |
|------------|---------|-----------------------------------------|-------------|----------|---------------|-----------------------------------------|
| Brown 2014 | Australia | Patients undergoing dressing change with burn wound | 35          | 40       | Ditto TM      |                                         |
| Chen 2019  | China    | Patients undergoing dressing change with burn wound | 57          | 55       | Sony VR Play-station |                                    |
| Chong 2019 | China    | Male patients with dressing change after circumcision | 100         | 100      | 3D glasses, headphones |                                     |
| Deng 2015  | China    | Patients undergoing dressing change with hand wound | 49          | 49       | 3D glasses, headphones, computer software |                                 |
| Ding 2019  | China    | Patients undergoing dressing change after hemorrhoid surgery | 91          | 91       | eMagin Z800 3DVisor |                                     |
| Ebrahim 2018 | USA     | Patients undergoing dressing change with burn wound | 20          | 40       | VR headphones |                                         |
| Guo 2014   | China    | Patients with lower extremity vascular ulcer | 45          | 45       | 3D glasses, headphones, computer software |                                 |
| Hoffman 2008 | USA   | Patients undergoing dressing change with burn wound | 11          | 11       | Dell530 · GeForce 6800 video card · LP70 |                                     |
| Kipping 2012 | Australia | Patients undergoing dressing change with burn wound | 20          | 21       | eMagin Z800 3DVisor |                                 |
| Maani 2011 | USA      | Soldier undergoing dressing change with war blast wound | 6           | 6        | NVIDIA GForce Go 7900 GTX |                                     |
| McSherry 2017 | USA    | Patients undergoing dressing change with burn wound | 15          | 15       | VR goggles, headset, computer software |                                 |
| Sharar 2007 | USA      | Patients undergoing dressing change with burn wound | 88          | 146      | 2GB of RAM · GeForce 6800 |                                     |
| Wang 2021  | China    | Patients undergoing dressing change after hepatobiliary and pancreatic surgery | 51          | 51       | 3D glasses, headphones, computer software |                                 |

**Table 1** The characteristics of included RCTs

*Heart rate* 4 RCTs\(^1\text{3,18,20,24}\) reported the effect of VR technology on the heart rate. There was heterogeneity among the studies \( (I^2 = 88\%, P < .001) \), and the random
effects model was used for analysis. The results of meta-analysis showed that there was no significant difference on the heart rate of the VR group and control group (MD = -1.85, 95%CI: -5.71 to 2.01, P = .45, Figure 5A).

Blood pressure 4 RCTs reported the effect of VR technology on the blood pressure. There was heterogeneity among the studies (I² = 97%, P < .001), and the random effects model was used for analysis. The results of meta-analysis showed that the blood pressure of the VR group was lower than that of the control group (MD = -4.66, 95%CI: -8.63 to -0.69, P = .02, Figure 5B).

VR interestingness 3 RCTs reported the effect of VR technology on the VR interestingness. There was heterogeneity among the studies (I² = 100%, P < .001), and the random effects model was used for analysis. The results of meta-analysis showed that there were no significant differences on the VR interestingness of the VR group and control group (MD = 28.96, 95%CI: -22.10 to 80.02, P = .27, Figure 5C).

3.5  |  Sensitivity and publication bias analysis

Sensitivity analyses, which evaluate the influence of single study on the overall risk estimate by removing each study in each turn, suggested that the overall risk estimates were not substantially changed by any single RCT.

As presented in Figure 6, the dots in the funnel plots were evenly distributed, and the results of Egger regression test indicated that there were no publication biases among the synthesised outcomes (all P > .001).

4  |  DISCUSSIONS

Many reactions such as limb disturbance, abnormal perception, and emotional changes caused by pain are one of the most common and direct causes that affect people’s normal physiological functions and lead to loss of work ability. Although clinical medical staff pay more and more attention to patients’ pain, the ability of pain management is still insufficient. At present, China’s pain management measures are dominated by drug interventions, with less non-drug interventions. In recent years, VR technology has been applied more and more in the field of pain management, and it has a good development prospect. The application advantages of VR technology in the medical field are increasingly prominent, and good results have been achieved in nursing education, skills training, and clinical nursing.

As a distraction therapy, VR technology can distract individuals from harmful stimuli and increase their attention to pleasant stimuli, thereby reducing pain signalling and reducing pain perception. The results of this present study have found that as a non-drug-assisted analgesia intervention, VR technology can reduce the pain level, pain sensation of patients during wound care, which may be worthy of promotion and application in clinical wound care.

Previous studies have reported a decrease in the patient’s need for analgesics when the technique is
repeated for intervention. It has been reported that VR technology intervention significantly reduced the activity of five pain-related brain regions in the insula, thalamus, and anterior cingulate cortex sensory cortex. Meanwhile, studies have reported that VR distraction shortens the time of wound re-epithelialization and reduces the incidence of post-traumatic pre-excitation syndrome. However, high pain intensity wounds or characteristics of extreme pain sensitivity limit the efficacy of pain transfer. Previous research has pointed out that VR technology can improve patients' treatment compliance and cooperation. However, researchers have found that once patients are familiar with the virtual environment, they are less interested when they use the same topic again, and their auxiliary analgesia effect is worse than that of the initial intervention. In addition, the efficacy of virtual reality-assisted analgesia is highly related to the level of equipment, and the clinical application of VR technology should fully measure the economic benefits and staffing resources.

When a patient is immersed in a VR environment, the patient is unable to look directly at their wound and is visually and acoustically isolated from the medical environment, thereby cognitively escaping the “painful real world.” Besides, technology can help patients focus on pleasant or interesting stimuli, reduce negative emotions, such as stress and anxiety. Previous studies have found that VR technology changes the way patients receive pain signals, thereby reducing the amount of pain-related brain activity. It has been reported

FIGURE 4 The forest plots for synthesised outcomes
that patients' subjective pain scores were significantly reduced, and objective neurological measurements showed that in the anterior cingulate gyrus, cortex, insula, thalamus, and primary and secondary somatosensory cortex, pain-related brain activity was reduced by 50% or more after the VR intervention.\(^{46}\) It is worth noting that VR intervention is difficult to achieve blinded intervention in clinical practice, and the included RCTs do not mention whether and how to use blinding. Therefore, further, high-quality studies are still needed to validate those findings.

When using VR intervention, different senses can be involved at the same time. The special audio-visual equipment meets the visual requirements of the patients and enriches the imagination of the patients.\(^{47}\) Besides, the virtual sound output is used to imitate the auditory method of the real environment, so that the patient's attention can be completely concentrated, and the patient can be fully focused, thereby effectively improving concentration and transferring pain sensation.\(^{48-50}\) The participation of attention resources in immersive and interactive VR can further adjust the patient's concentration, so that the patient does not feel the pain of dressing change, so as to achieve a stronger pain control effect.\(^{51,52}\) However, there is not yet a complete consensus on the underlying mechanisms by which virtual reality alleviates pain responses, and the precise nature of the hardware and software used in VR interventions varies, issues such as the lasting impact of VR and potential effect mechanisms are necessary to be further investigated in the future.

There are certain limitations of this meta-analysis worth considering. First of all, this study only has searched published Chinese and English literatures, we have excluded grey literature and related studies in other languages, and there may be publication bias. Second, because the intervention cannot be blinded, the nurses performing wound care may provide more careful care to the patients in the trial group if they know the grouping in advance. The double-blind design, although challenging, is still an ideal design for future research; Third, the hardware level requirements for virtual devices vary greatly among the included RCTs. Furthermore, the results for different types of wounds such as burn wounds or post-surgical wounds in children and adults may be different. The provision of the most suitable applications for the therapeutic effect are still areas for further researches. Finally, the sample size of included RCTs varies greatly, it may be underpower to detect the group differences, future studies with larger sample size and rigorous design are needed.
CONCLUSIONS

In conclusion, this present meta-analysis has analysed the effect of VR therapy as an auxiliary analgesic intervention on the pain level in wound care from an evidence-based perspective. Meta-analysis results show that VR intervention can effectively reduce the patient’s pain cognition, pain emotion, pain sensation, and blood
pressure in during wound care. Future researches with scientific and rigorous design, large sample size are needed in the future to evaluate the effects and safety of VR interventions in clinical practice of wound care.

**CONFLICT OF INTEREST**
The authors declare that they have no competing interests.

**AUTHOR CONTRIBUTIONS**
Zhen-Hua He, Hong-Mei Yang designed research; Zhen-Hua He, Hong-Mei Yang, Minerva B. De Ala conducted research; Zhen-Hua He, Hong-Mei Yang analysed data; Zhen-Hua He, Ronnell D. Dela Rosa, Minerva B. De Ala wrote the first draft of manuscript; Hong-Mei Yang, Minerva B. De Ala had primary responsibility for final content. All authors read and approved the final manuscript.

**ETHICS STATEMENT**
In this study, all methods were performed in accordance with the relevant guidelines and regulations. Ethics approval and consent to participate is not necessary since our study was a meta-analysis.

**DATA AVAILABILITY STATEMENT**
All data generated or analyzed during this study are included in this published article.

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**REFERENCES**
1. Dieu A, Huynen P, Lavand’homme P, et al. Pain management after open liver resection: Procedure-Specific Postoperative Pain Management (PROSPECT) recommendations. *Reg Anesth Pain Med*. 2021;46(5):433-445. doi:10.1136/rapm-2020-101933
2. Hughes JA, Chiu J, Brown NJ, Hills A, Allwood B, Chu K. The documentation of pain intensity and its influences on care in the emergency department. *Int Emerg Nurs*. 2021;57:101015. doi:10.1016/j.ienj.2021.101015
3. Olsen BF, Valeberg BT, Jacobsen M, Smastuen MC, Puntilllo K, Rustoen T. Pain in intensive care unit patients—a longitudinal study. *Nurs Open*. 2021;8(1):224-231. doi:10.1002/nop2.621
4. Gethin G, Probst S, Stryja J, Christiansen N, Price P. Evidence for person-centred care in chronic wound care: a systematic review and recommendations for practice. *J Wound Care*. 2020;29(SupplementB):S1-S22. doi:10.12968/jowc.2020.29.Sup9B1
5. Toma E, Veneziano ML, Filomeno L, Villa A, Rosato E, la Torre G. Nursing assessment of wound-related pain: an Italian learning survey. *Adv Skin Wound Care*. 2020;33(10):540-548. doi:10.1097/01.ASW.0000695772.37897.ab
6. Chuan A, Zhou JJ, Hou RM, Stevens CJ, Bogdanovych A. Virtual reality for acute and chronic pain management in adult patients: a narrative review. *Anaesthesia*. 2021;76(5):695-704. doi:10.1111/anae.15202
7. Tack C. Virtual reality and chronic low back pain. *Disabil Rehabil Assist Technol*. 2021;16(6):637-645. doi:10.1080/17483107.2019.1688399
8. Ang SP, Montuori M, Trimbach Y, Maldari N, Patel D, Chen QC. Recent applications of virtual reality for the management of pain in burn and pediatric patients. *Curr Pain Headache Rep*. 2021;25(1):4. doi:10.1007/s11916-020-00917-0
9. Gerceker GO, Bektas M, Aydinok Y, Oren H, Ellidokuz H, Olgun N. The effect of virtual reality on pain, fear, and anxiety during access of a port with huber needle in pediatric hematology-oncology patients: randomized controlled trial. *Eur J Oncol Nurs*. 2021;50:101886. doi:10.1016/j.ejon.2021.101886
10. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ*. 2009;339:b2535. doi:10.1136/bmj.b2535
11. Cumpston M, Li T, Page MJ, 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;10:ED000142. doi:10.1002/14651858.ED000142
12. Brown NJ, Kimble RM, Rodger S, Ware RS, Cuttle L. Play and heal: randomized controlled trial of ditto intervention efficacy on improving re-epithelialization in pediatric burns. *BURNS*. 2014;40(2):204-213. doi:10.1016/j.burns.2013.11.024
13. Chunlan G, Hongyan X. Observation on the effect of virtual reality distraction in patients with reducing the pain of dressing change in lower extremity vascular ulcer. *J Nurs*. 2014;21(1):40-42.
14. Ding J, He Y, Chen L, et al. Virtual reality distraction decreases pain during daily dressing changes following haemorrhoid surgery. *J Int Med Res*. 2019;47(9):4380-4388. doi:10.1177/0300060519875862
15. Ebrahimli H, Namdar H, Ghaforianpour MJ, Ghaforifard M. Effect of virtual reality method and multimedia system on burn patients’ pain during dressing. *J Clin Med*. 2017;8(5):485-489.
16. Hoffman HG, Patterson DR, Seibel E, Jewett-Leahy L, Sharar SR. Virtual reality pain control during burn wound debridement in the hydrotank. *Clin J Pain*. 2008;24(4):299-304. doi:10.1097/AJP.0b013e318164d2cc
17. Hongyan D, Chunlan G. The effect of distraction on the pain of changing dressings for hand wounds. *J Nurs*. 2015;30(22):50-52.
18. Jingjing C, Qiaomei F. The effect of virtual reality technology on reducing the pain caused by dressing change in adult burn patients. *Nurs Res*. 2019;33(12):2120-2122.
19. Kipping B, Rodger S, Miller K, Kimble RM. Virtual reality for acute pain reduction in adolescents undergoing burn wound care: a prospective randomized controlled trial. *BURNS*. 2012;38(5):650-657. doi:10.1016/j.burns.2011.11.010
20. Li W, Ningning Z. The application effect of virtual reality technology in pain control of patients after hepatobiliary and pancreatic surgery. *Nurs Rehab*. 2021;20(2):5-9.
21. Maani CV, Hoffman HG, Morrow M, et al. Virtual reality pain control during burn wound debridement of combat-related burn injuries using robot-like arm mounted VR goggles. *J Trauma*. 2011;71(1 Suppl):S125-S130. doi:10.1097/TAJ.0b013e31822192e2
22. McSherry T, Atterbury M, Gartner S, Helmold E, Searles DM, Schulman C. Randomized, crossover study of immersive virtual
23. Sharar SR, Carrouther GI, Nakamura D, Hoffman HG, Blough DK, Patterson DR. Factors influencing the efficacy of virtual reality distraction analgesia during postburn physical therapy: preliminary results from 3 ongoing studies. Arch Phys Med Rehabil. 2007;88(12 Suppl 2):S43-S49. doi:10.1016/j.apmr.2007.09.004

24. Wu C, Fengying X, Xiaoyan C. A clinical study on the effect of virtual reality technology on postoperative dressing change pain in male foreskin patients. Chinese J Androl. 2019;25(10):942-944.

25. Trost Z, France C, Anam M, Shum C. Virtual reality approaches to pain: toward a state of the science. Pain. 2021;162(2):325-331. doi:10.1016/j.pain.2020.02.060

26. Wong MS, Spiegel BMR, Gregory KD. Virtual reality reduces Pain in laboring women: a randomized controlled trial. Am J Perinatol. 2021b;38(8):e167-e172. doi:10.1055/s-0040-1708851

27. Garcia-Bravo S, Cuesta-Gomez A, Campuzano-Ruiz R, et al. Virtual reality and video games in cardiac rehabilitation programs. A systematic review. Disabil Rehabil. 2021;43(4):448-457. doi:10.1080/09638288.2019.1631892

28. Small C, Laycock H. Are we near to making virtual reality the new reality in pain medicine? Anaesthesia. 2021;76(5):590-593. doi:10.1111/anae.15252

29. Wong CL, Li CK, Chan CWH, et al. Virtual reality intervention targeting pain and anxiety among pediatric cancer patients undergoing peripheral intravenous cannulation: a randomized controlled trial. Cancer Nurs. 2021a;44(6):435-442. doi:10.1097/NCC.0000000000000844

30. Bordeleau M, Stamenkovic A, Tardif PA, Thomas J. The use of virtual reality in back pain rehabilitation: a systematic review and meta-analysis. J Pain. 2021;23:175-195. doi:10.1016/j.jpain.2021.08.001

31. Le May S, Tsimicalis A, Noel M, et al. Immersive virtual reality vs. non-immersive distraction for pain management of children during bone pins and sutures removal: a randomized clinical trial protocol. J Adv Nurs. 2021;77(1):439-447. doi:10.1111/jan.14607

32. Liu J, Qiongong Q, Wentian W, Dongmei W. Effects of virtual reality technology on pain and anxiety in patients undergoing colonoscopy. J Nurs. 2020;25(21):4-9.

33. Peixia W, Zhendong L. Application and effect observation of virtual reality technology in patients with phantom limb pain after amputation. J Nurs Train. 2020;35(8):4-9.

34. Linlin L, Min D, Zhenling L. Application progress of virtual reality technology in critically ill patients in ICU. Chin J Nurs. 2021;56(8):6-9.

35. Xiaoan B, Yongyi C, Di W. Application progress of virtual reality technology in rehabilitation nursing of children with spastic cerebral palsy. PL A Nurs J. 2021;38(9):4-6.

36. Hoffman HG, Patterson DR, Rodriguez RA, Pena R, Beck W, Meyer WJ. Virtual reality analgesia for children with large severe burn wounds during burn wound debridement. Front Virtual Real. 2020;1:11-16. doi:10.3839/frvr.2020.60299

37. Hoffman HG, Richards TL, Coda B, et al. Modulation of thermal pain-related brain activity with virtual reality: evidence from fMRI. Neuroreport. 2004;15(8):1245-1248. doi:10.1097/01.wnr.0000127826.73576.91

38. Lamert V, Boylan P, Boran L, et al. Virtual reality distraction for acute pain in children. Cochrane Database Syst Rev. 2020;10:CD010686. doi:10.1002/14651858.CD010686.pub2

39. Hoffman HG, Rodriguez RA, Atzori B, et al. Immersive virtual reality with interactive eye tracking during brief thermal Pain stimuli: a randomized controlled trial (crossover design). Front Hum Neurosci. 2019;13:467. doi:10.3389/fnhum.2019.00467

40. Hoffman HG. Interacting with virtual objects via embodied avatar hands reduces pain intensity and diverts attention. Sci Rep. 2021;11(1):10672. doi:10.1038/s41598-021-89526-4

41. Ledford CK, VanWagner MJ, Sherman CE, Torp KD. Immersive virtual reality used as adjunct anesthesia for conversion total hip arthroplasty in a 100-year-old patient. Arthroplast Today. 2021;10:149-153. doi:10.1016/j.artd.2021.07.001

42. Chan E, Foster S, Sambell R, Leong P. Clinical efficacy of virtual reality for acute procedural pain management: a systematic review and meta-analysis. PLoS One. 2018;13(7):e0200987. doi:10.1371/journal.pone.0200987

43. Hoffman HG, Rodriguez RA, Gonzalez M, et al. Immersive virtual reality as an adjuctive non-opioid analgesic for pre-dominantly Latin American children with large severe burn wounds during burn wound cleaning in the intensive care unit: a pilot study. Front Hum Neurosci. 2019;13:262. doi:10.3389/fnhum.2019.00262

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