

International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Operating Publisher
SciFormat Publishing Inc.
ISNI: 0000 0005 1449 8214

2734 17 Avenue SW,
Calgary, Alberta, T3E0A7,
Canada
+15878858911
editorial-office@sciformat.ca

ARTICLE TITLE	VIRTUAL REALITY (VR) ANALGESIA IN BURN AND TRAUMA CARE: A SCOPING REVIEW OF CLINICAL EFFICACY AND PSYCHO-SOCIOLOGICAL MECHANISMS OF PAIN DISTRACTION
DOI	https://doi.org/10.31435/ijitss.4(52).2026.6273
RECEIVED	20 August 2026
ACCEPTED	25 October 2026
PUBLISHED	30 October 2026
LICENSE	The article is licensed under a **Creative Commons Attribution 4.0 International License.**

© The author(s) 2026.
This article is published as open access under the Creative Commons Attribution 4.0 International License (CC BY 4.0), allowing the author to retain copyright. The CC BY 4.0 License permits the content to be copied, adapted, displayed, distributed, republished, or reused for any purpose, including adaptation and commercial use, as long as proper attribution is provided.

VIRTUAL REALITY (VR) ANALGESIA IN BURN AND TRAUMA CARE: A SCOPING REVIEW OF CLINICAL EFFICACY AND PSYCHO-SOCIOLOGICAL MECHANISMS OF PAIN DISTRACTION

Julia Szymkowiak *(Corresponding Author, Email: juliaszymkowiak3@gmail.com)*
Medical University of Lodz: Lodz, Łódź Voivodeship, Poland
ORCID ID: 0009-0005-6558-2552

Karolina Reczka
Medical University of Lodz: Lodz, Łódź Voivodeship, Poland
ORCID ID: 0009-0003-7306-5120

Zuzanna Zalewska
Medical University of Lodz: Lodz, Łódź Voivodeship, Poland
ORCID ID: 0009-0003-4441-4782

Maria Woźniak
Medical University of Lodz: Lodz, Łódź Voivodeship, Poland
ORCID ID: 0009-0000-9240-3373

ABSTRACT

Pain management in trauma and burns poses a clinical challenge, often requiring high opioid doses that carry complication risks. Virtual reality (VR) is gaining prominence as a promising non-pharmacological analgesic tool. This scoping review evaluates the clinical efficacy, psychosocial, and neurobiological mechanisms of VR-based analgesia in burn and trauma patients. Based on a synthesis of 31 studies, immersive VR interventions during distressing procedures (e.g., dressing changes, debridement, physical therapy) were analyzed. Evidence clearly indicates VR significantly reduces pain intensity and unpleasantness while shortening cognitive focus on pain stimuli in adults and children. The underlying mechanisms include the limited attention span theory, achieving a 'flow' state, the embodiment illusion, and anxiety reduction. Furthermore, high immersion and interactivity enhance the analgesic effect, which can be amplified synergistically with hypnosis or targeted pharmacotherapy like ketamine. While VR is highly effective for acute procedural pain, it remains unclear whether this efficacy diminishes over time due to habituation or the novelty effect during prolonged hospitalizations. Addressing these limitations, alongside further technological optimization and integration into the biopsychosocial model, is essential for the full personalization of this digital therapy.

KEYWORDS

Virtual Reality, Analgesia, Burn Care, Pain Management, Cognitive Distraction, Trauma, Scoping Review

CITATION

Szymkowiak, J., Reczka, K., Zalewska, Z., & Woźniak, M. (2026). Virtual reality (VR) analgesia in burn and trauma care: A scoping review of clinical efficacy and psycho-sociological mechanisms of pain distraction. *International Journal of Innovative Technologies in Social Science*, 4(52). https://doi.org/10.31435/ijitss.4(52).2026.6273

COPYRIGHT

© The author(s) 2026. This article is published as open access under the **Creative Commons Attribution 4.0 International License (CC BY 4.0)**, allowing the author to retain copyright. The CC BY 4.0 License permits the content to be copied, adapted, displayed, distributed, republished, or reused for any purpose, including adaptation and commercial use, as long as proper attribution is provided.

1.Introduction

Pain management in patients with severe burns and physical trauma is one of the most complex challenges in modern emergency and rehabilitation medicine. Burn pain is widely recognized as one of the most intense forms of suffering a person can experience, characterized by a dual nature: resting pain (background pain) and extremely severe procedural pain, occurring during dressing changes, wound debridement, or intensive physical therapy [7, 13, 17, 30]. Although these procedures are essential for patient survival and infection prevention, they are often perceived by patients as traumatic, leading to the development of severe anticipatory anxiety, post-traumatic stress disorder (PTSD), and a significant reduction in quality of life during prolonged hospitalization [6, 11, 29].

Traditional pain management protocols in burn care rely primarily on aggressive pharmacotherapy, including, above all, the administration of high doses of opioids, often in combination with anxiolytic and sedative medications [2, 13, 21]. Despite its effectiveness, pharmacotherapy has significant limitations; high doses of opioids are associated with the risk of respiratory depression, nausea, constipation, and opioid-induced hyperalgesia [4, 16]. Furthermore, in the context of the global opioid crisis, there is a growing need to seek alternative, non-pharmacological adjunctive therapies that would reduce the demand for opioids while maintaining, or even enhancing, patient comfort [2, 5, 9, 21].

Virtual Reality (VR) has emerged as a groundbreaking non-pharmacological technology, offering unique possibilities for modulating pain perception. Defined as a computer-generated environment that simulates physical presence in the real or imagined world, VR engages multiple senses, isolating the patient from painful external stimuli [1, 5, 10, 15]. The mechanism of action of VR in the context of analgesia is primarily based on the theory of cognitive distraction and pain gating. Since human attention is a limited resource, the intense engagement of the cerebral cortex in processing rich, interactive visual and auditory stimuli in a virtual environment means that the brain has less bandwidth available to interpret nociceptive signals coming from damaged tissues [2, 3, 21, 31].

The key psychological constructs determining the effectiveness of VR are immersion, presence, and agency. Immersion refers to the system's technological ability to deliver multisensory stimuli, while presence is the subjective sensation of "being there," inside the digital world [2, 10, 18]. Research shows that higher levels of immersion and a greater sense of presence correlate with a stronger analgesic effect, suggesting that the quality of hardware and software directly impacts clinical outcomes [8, 16, 28]. Additionally, the introduction of interactive elements that allow the patient to influence the virtual environment (agency) engages higher cognitive processes, which distracts attention from pain even more effectively compared to passive content consumption [2, 18, 26, 30].

In recent years, the scope of VR applications in traumatology has expanded significantly, encompassing not only acute surgical conditions but also long-term rehabilitation and psychosocial support. In patients with injuries, including those with spinal cord injuries (SCI), VR utilizes mechanisms of embodiment and brain plasticity, helping to alleviate neuropathic pain through visual feedback and interactions with avatars [8, 12, 18]. The integration of VR with other psychological techniques, such as hypnosis (VRH – Virtual Reality Hypnosis), opens new avenues for synergistic influence on the autonomic nervous system, leading to deep relaxation and stabilization of physiological parameters in stressful situations [11, 20, 24].

Despite a growing body of evidence supporting the effectiveness of VR, there remains a need for a systematic synthesis of knowledge regarding the psychosocial and neurobiological mechanisms that make this technology such an effective tool for specific populations, such as burn victims and those with physical trauma [3, 15, 21]. This scoping review analyzes 31 key studies to provide a comprehensive answer to the question of how innovative digital technologies can revolutionize patient care within a biopsychosocial model [5, 25, 30, 31]. The article focuses on the analysis of clinical effectiveness, optimal technical parameters of interventions, and future directions for the development of digital analgesia in acute and rehabilitative medicine [1, 21, 30].

2.Methodology

2.1 Study Design and Theoretical Framework

This study was designed and conducted as a scoping review, which constitutes the optimal methodological approach when it is necessary to map a broad, dynamically evolving area of knowledge, such as the use of immersive technologies in acute and rehabilitative medicine [1, 5, 21].

Unlike traditional systematic reviews, which typically focus on answering a single, highly specific clinical question, a scoping review allows for the integration of diverse research paradigms—ranging from quantitative randomized controlled trials (RCTs), through neurobiological analyses (e.g., using functional magnetic resonance imaging – fMRI), to qualitative assessments of the experiences of patients and medical staff [8, 10, 17, 30]. The methodology of this study is based on the extended PRISMA-ScR guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) and the structured framework defined by Arksey and O'Malley, ensuring maximum transparency, reproducibility, and scientific rigor of the research process [7, 8, 30].

2.2 Research Questions and the PCC (Population, Concept, Context)

Framework To precisely guide the research strategy and the source material selection process, the main research questions were formulated based on the PCC (Population, Concept, Context) acronym [1, 30].

2.2.1 Population: The study included pediatric and adult patients who had suffered severe thermal, chemical, or electrical burns, as well as patients with severe physical injuries (including spinal cord injuries—SCI), experiencing acute or chronic procedural and neuropathic pain [6, 12, 13, 26, 28].

2.2.2 Concept: The main phenomenon (intervention) analyzed was virtual reality (VR), defined as a digital, non-pharmacological therapeutic tool, examined in terms of the degree of immersion (immersive vs. non-immersive systems), interactivity (active vs. passive VR environments), and synergy with other methods (e.g., virtual hypnosis—VRH, combination with ketamine) [11, 14, 18, 20, 24].

2.2.3 Context: Interventions had to be conducted in strictly defined clinical settings, such as burn units (during dressing changes and debridement), emergency departments (ED), operating rooms, and physical rehabilitation and physical therapy units [4, 7, 9, 19, 29] .

2.3 Inclusion and Exclusion Criteria

The selection criteria were designed to identify only the highest-quality scientific evidence that directly addresses the efficacy and mechanisms of VR in combating burn and trauma pain [3, 7]. The review included: (a) peer-reviewed scientific articles published in English; (b) randomized controlled trials (RCTs) with parallel and crossover designs; (c) meta-analyses and systematic reviews aggregating data from multiple centers; (d) observational studies, feasibility studies, and case reports, provided they offered unique insights into neurobiological mechanisms or the combination of VR with novel pharmacotherapy [9, 13, 22, 28]. Exclusion criteria included: (a) studies focusing exclusively on the engineering and technical aspects of VR equipment without the involvement of clinical patients (no assessment of health outcomes); (b) studies on animal models; (c) opinion pieces, conference abstracts without full text, and reports with low methodological rigor that lacked standardized pain measurement tools [4, 8, 30].

2.4 Search strategy and study selection

During the literature search, a comprehensive search was performed across leading medical and psychological databases, such as PubMed/MEDLINE, Embase, the Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science, and CINAHL [4, 7, 8, 30]. Complex queries using Boolean operators were employed, combining terms such as: ("Virtual Reality" OR "VR" OR "digital therapeutics" OR "immersive technology") AND ('analgesia' OR "pain management" OR "pain relief" OR "distraction") AND ("burn*" OR 'trauma' OR "wound care" OR "wound dressing" OR "physical therapy" OR "rehabilitation") [2, 7, 15, 21]. After removing duplicates and conducting a rigorous two-stage assessment (first based on titles and abstracts, and then on full texts for compliance with inclusion criteria), 31 unique, full-text scientific articles were selected for the final qualitative and quantitative synthesis, constituting the core source base for this study [1–31].

2.5 Data Extraction (Data Charting Process)

Detailed data were extracted from the 31 eligible articles using a standardized matrix form. The data charting process involved identifying the following variables:

2.5.1 Study characteristics: authors, year of publication, country of origin, study design type (e.g., crossover RCT, parallel RCT, review).

2.5.2 Demographics and clinical parameters: sample size (N), patient age (children vs. adults), etiology of injury, total body surface area (TBSA).

2.5.3 VR intervention parameters: type of equipment used (e.g., Head-Mounted Displays – HMD, robotic arm), software specifications (interactive games such as "SnowWorld," passive landscapes, virtual avatars), duration of exposure, and the inclusion of adjunctive interventions (e.g., tDCS neurostimulation, hypnosis) [8, 12, 17, 18, 20, 24].

2.5.4 Measurement tools: pain and distraction assessment scales used, including the Visual Analog Scale (VAS), Numerical Rating Scale (NRS), Graphic Rating Scale (GRS), and questionnaires assessing presence and simulator sickness (e.g., Presence Questionnaire, Simulator Sickness Questionnaire) [6, 9, 11, 14, 29].

2.6 Methodological quality assessment and data synthesis

Although traditional systematic reviews do not always require a rigorous assessment of the risk of bias, this study attempted to assess the quality of the included evidence to ensure the highest reliability of the conclusions drawn. Many of the meta-analyses and RCTs included in the review utilized recognized tools, such as the Cochrane Collaboration's risk of bias assessment tool and the Joanna Briggs Institute (JBI) critical appraisal tools [7, 8, 30]. The collected data were subjected to narrative synthesis. Due to the significant heterogeneity of the populations (children vs. adults), the diversity of medical procedures (short-term punctures vs. extensive burn debridement), and the variety of equipment protocols, the results were grouped into dedicated thematic blocks. The focus was on isolating clinical efficacy, neurocognitive mechanisms (such as the attention bandwidth theory and the embodiment illusion), as well as on analyzing factors modifying the analgesic effect, including environmental interactivity, anticipatory anxiety, and demographic variables [3, 12, 16, 22, 28, 31].

3.Results

Based on a rigorous selection and analysis, 31 peer-reviewed scientific articles were identified, including meta-analyses, randomized controlled trials (RCTs), crossover studies, and feasibility studies. These studies covered a broad spectrum of patients—from children to the elderly—struggling with burn pain, traumatic pain, neuropathic pain, and acute procedural pain. The collected evidence clearly indicates that virtual reality (VR) is a highly effective, safe, and well-tolerated method of non-pharmacological analgesia. Due to the multidimensional nature of the results, they have been divided into key thematic categories.

3.1.

The characteristics, methodological designs, and main findings of the 31 studies included in this scoping review are summarized in Table 1. The selected literature encompasses a diverse patient population, ranging from pediatric burn victims to adults with spinal cord injuries, and evaluates various virtual reality hardware and software setups

Table 1. Comprehensive mapping and characteristics of the included literature.

Study (Author, Year)	Study Design	Population / Context	VR Setup & Intervention Parameters	Main Outcomes & Mechanisms Explored
Combalia et al. (2024) [1]	Narrative Review	Orthopaedic patients	Immersive VR systems applied in orthopaedic wards	Outlines the expanding role of VR in managing acute skeletal pain and motivating physical rehabilitation.
Theingi et al. (2021) [2]	Literature Review	General hospitalized patients	Non-pharmacological adjunctive VR systems	Evaluates the baseline utility of digital distraction as an opioid-sparing tool in modern hospital care.
Lier et al. (2023) [3]	Systematic Review & Meta-regression	Patients across varied pain environments	Diverse VR hardware/software protocols	Identifies specific effect modifiers (e.g., design, baseline anxiety) that dictate clinical success.
Teh et al. (2024) [4]	Systematic Review & Meta-analysis	Patients undergoing acute medical procedures	Multiple commercial and therapeutic VR devices	Confirms clear, statistically significant analgesic efficacy across diverse minor surgical settings.
Medina et al. (2024) [5]	Theoretical Framework	Chronic and acute pain populations	VR models integrated with psychological tracking	Conceptualizes a new clinical framework linking digital therapeutics directly to the biopsychosocial model.
Lauwens et al. (2020) [6]	Systematic Review & Meta-analysis	Hospitalized children and adolescents with burns	Immersive VR headsets used during dressing changes	Proves a definitive reduction in pediatric procedural pain and emotional distress during wound care.
Lou et al. (2024) [7]	Systematic Review & Meta-analysis	Burn care patients	Immersive VR applied during wound debridement and physical therapy	Demonstrates substantial drops in pain tracking scores across both nursing and physical rehab tasks.

Study (Author, Year)	Study Design	Population / Context	VR Setup & Intervention Parameters	Main Outcomes & Mechanisms Explored
Portaro et al. (2025) [8]	Systematic Review & Meta-analysis	Spinal cord injury (SCI) patients	Neuromodulation, interactive VR, and physical rehab systems	Highlights the efficacy of visual tracking on cortical neuroplasticity and chronic neuropathic pain relief.
Birrenbach et al. (2022) [9]	Prospective Interventional Feasibility Study	Emergency Department (ED) patients	VIPER project: Immersive VR for acute trauma victims	Confirms excellent safety, high patient tolerance, and clinical feasibility in high-stress ER settings.
Furness et al. (2019) [10]	Qualitative Usability Study	Burn patients and clinical nursing staff	Immersive VR integrated into routine burn dressing	Focuses on multi-user usability, documenting immense satisfaction and high practical utility from nurses.
Patterson et al. (2010) [11]	Clinical Trial / Experimental	Trauma recovery patients	Virtual Reality Hypnosis (VRH) systems	Shows that VRH actively dampens autonomic stress responses and accelerates trauma pain relief.
Pozeg et al. (2017) [12]	Experimental Crossover Trial	Spinal cord injury (SCI) patients	Immersive VR displaying customized virtual avatars	Explores embodiment; viewing virtual limb interactions modifies and alleviates central neuropathic pain.
Maani et al. (2011) [13]	Case Series (Military & Civilian)	Severe burn wound care patients	Immersive VR used simultaneously with Ketamine	Uncovers a profound multi-modal synergy, masking severe breakthrough pain when drug thresholds are met.
Patterson et al. (2023) [14]	Randomized Controlled Trial (RCT)	Burn wound care cohorts	Highly interactive immersive VR vs. passive still pictures	Proves active cognitive interaction is vastly superior to passive scene consumption for pain distraction.
Hadjiat & Marchand (2022) [15]	Literature Review	Pediatric and adult pain groups	Developmental mediation software	Maps neurological pathways involved in short-term vs. long-term developmental pain modulation via VR.
Al-Ghamdi et al. (2020) [16]	Randomized Crossover Trial	Healthy participants (thermal pain model)	Immersive VR paired with interactive eye-tracking	Proves eye-tracking interactivity heavily taxes cognitive resources, amplifying the gating mechanism.
Hoffman et al. (2011) [17]	Clinical Trial / Neuroimaging	Acute burn care procedures	Immersive VR compatible with brain imaging (fMRI)	Provides objective evidence; fMRI reveals huge metabolic activity drops in the somatosensory cortex and insula.

Study (Author, Year)	Study Design	Population / Context	VR Setup & Intervention Parameters	Main Outcomes & Mechanisms Explored
Hoffman (2021) [18]	Experimental Study	Acute pain models	Active VR utilizing embodied avatar hands	Highlights that controlling virtual hands shifts focus, lowers pain scores, and induces deep psychological presence.
Spiegel et al. (2019) [19]	Randomized Comparative Effectiveness Trial	General hospitalized populations	Standard VR headsets with assorted environments	Validates widespread, realistic clinical efficacy for diverse types of pain in regular hospital wards.
Terzulli et al. (2023) [20]	Experimental Study	Cold-induced experimental pain models	Virtual Reality Hypnosis (VRH) setups	Demonstrates a shift toward parasympathetic dominance, suppressing autonomic flight-or-fight reflexes.
Li et al. (2011) [21]	Comprehensiv e Review	Broad clinical pain environments	Multi-tiered developmental VR setups	Traces historical paradigms and outlines core clinical requirements for future digital therapies.
Ko et al. (2024) [22]	Pilot Randomized Controlled Trial	Adults undergoing surgical wound closure	Interactive VR headsets	Shows immediate drops in procedural anxiety alongside stabilization of blood pressure and heart rates.
Carrougher et al. (2009) [23]	Within-subject Clinical Trial	Adults with acute burn injuries	Interactive VR utilized during physical therapy	Drastically improves joint range of motion (ROM) by bypassing movement-associated fear and kinesiophobia.
Patterson et al. (2021) [24]	Randomized Controlled Trial	Thermal pain simulation	Hypnotic induction delivered via VR distraction	Proves VR enhances trance entry, unlocking high analgesic benefits even for low-susceptibility patients.
Fougère et al. (2023) [25]	Narrative Review	Multi-sensory experimental cohorts	Sensory-enhanced digital therapeutics	Explores how cross-modal sensory triggers (auditory, visual, tactile) strengthen central pain blocks.
Xiang et al. (2021) [26]	Randomized Clinical Trial (RCT)	Pediatric burn patients	Active vs. Passive Smartphone-based VR	Confirms low-cost mobile setups are highly effective in reducing pain and minimizing rescue medication needs.
Le May et al. (2022) [27]	Controlled Trial Protocol	Burn patients in rehabilitation	Virtual reality mobility (VR-MOBILE) system	Proposes structured clinical methods to safely test physical mobility and active exercises in VR.

Study (Author, Year)	Study Design	Population / Context	VR Setup & Intervention Parameters	Main Outcomes & Mechanisms Explored
Jain et al. (2024) [28]	Randomized Clinical Trial (RCT)	Pediatric burn patients	Feature-optimized therapeutic software	Dissects software mechanics; thematic elements (e.g., cooling environments) optimize pediatric pain relief.
Maani et al. (2011) [29]	Military Clinical Case Study	Combat-related extensive burn wounds	Robot-arm mounted non-contact VR goggles	Overcomes ergonomic barriers; completely avoids pressure on facial grafts during debridement.
Ramage & Davis (2025) [30]	Integrative Review	Adult burn units	Standard clinical VR safety protocols	Reviews systemic implementation, sanitization guidelines, and the low clinical profile of cybersickness.
Gromakovskis & Gūtmanis (2024) [31]	Conceptual Review	Theoretical biopsychosocial models	Absorption-based immersive software	Maps the neurobiological cascades triggered when entering the psychological state of deep 'Flow'.

3.2. The effectiveness of VR in reducing acute burn pain in adults and children

The most consistent and dramatic results regarding the effectiveness of VR come from studies on patients with severe burns. Dressing changes, wound debridement, and physical therapy in these patients cause extreme pain, often unresponsive to standard pharmacological management [7, 10, 30]. Meta-analyses and systematic reviews show that the use of immersive VR during these procedures leads to a statistically and clinically significant reduction in pain scores compared to standard of care (SOC) [6, 7].

In a population of adult burn patients, it has been demonstrated that VR significantly reduces the perception of “worst pain” and “pain unpleasantness” as measured using Graphic Rating Scales (GRS) or Visual Analog Scales (VAS) [23, 29, 30]. Studies using advanced systems, such as robotic arms supporting VR goggles (eliminating the need to apply pressure to the burned head or face), have demonstrated effectiveness in soldiers with extensive combat-related burn injuries [17, 29]. These patients reported a reduction in pain intensity by an average of several dozen percent compared to the control group.

Equally promising, and in some cases even stronger, effects were observed in the pediatric population [6, 26, 28]. Children and adolescents, due to their natural tendency to engage in games and virtual environments, are particularly susceptible to the distracting effects of VR. The use of interactive games (e.g., throwing snowballs in the virtual environment “SnowWorld”) not only significantly reduced pain during painful hydrotherapy and dressing changes, but also drastically reduced anticipatory anxiety in children [17, 28]. Studies using more affordable solutions, such as passive and active smartphone-based systems (Smartphone VR), have confirmed that even widely available technology can significantly reduce the need for additional rescue doses of analgesics in children [26].

3.3. Management of Traumatic and Surgical Pain and Support in Rehabilitation

The effectiveness of digital analgesia extends beyond burn units, finding wide application in traumatology and emergency medicine [1, 4, 19]. In studies conducted in Emergency Departments (EDs) on adult patients undergoing laceration suturing procedures, VR intervention significantly reduced both pain and anxiety levels while stabilizing physiological parameters such as blood pressure and heart rate [4, 22]. In turn, large-scale RCTs in general hospital wards have shown that VR effectively reduces pain in patients hospitalized for various traumatic and orthopedic conditions, offering a safe alternative in the era of the opioid crisis [1, 9, 19].

VR also plays a critical role in painful physical rehabilitation. Studies have shown that patients (both burn victims and those with orthopedic injuries) using VR during physical therapy sessions were able to achieve a significantly greater range of motion (ROM) in injured joints [1, 23, 27] . This is due to the fact that distraction and immersion in the game cause patients to involuntarily perform movements that, under standard conditions, would be associated with strong resistance and fear of pain [23]. Additionally, fascinating results were obtained in patients with spinal cord injuries (SCI), in whom the use of VR combined with the illusion of embodiment and multisensory stimulation significantly reduced debilitating neuropathic pain [8, 12].

3.4 Technological Parameters: The Role of Immersion, Interactivity, and Embodiment

A significant portion of the analyzed studies focused on identifying the technological factors that determine the analgesic success of VR [3, 21, 28]. The results clearly demonstrate that interactive environments (Active VR) are significantly more effective than passive environments (Passive VR). Patients who could actively interact with the virtual world—for example, by throwing virtual snowballs using eye-tracking controllers or virtual hands (embodied avatar hands)—reported a significantly greater reduction in pain intensity and a decrease in "time spent thinking about pain" [14, 16, 18, 26].

The key mechanism identified in the studies is the "illusion of presence"—the subjective sense of being inside the simulation. A high level of presence, amplified by embodiment (the view of one's own virtual hands), drastically strains the patient's cognitive resources, leaving the brain with insufficient computational power to process nociceptive stimuli [2, 18]. Interactivity also reduces accuracy in performing divided-attention tasks, which directly supports the theory of cognitive distraction as the primary mechanism of VR [18, 31]. Importantly, highly immersive systems (e.g., HMDs with a wide field of view) yield better clinical outcomes than simple two-dimensional screens, confirming the advantage of full immersion [10, 14, 17].

3.5 Synergistic effects: Integration of VR with pharmacology and hypnosis

A pioneering direction emerging from the analyzed studies is the combination of digital technologies with traditional treatment methods, which yields synergistic (additive) effects. An example is the simultaneous use of VR and ketamine in patients with extremely severe burns [13]. Studies have shown that in patients for whom pharmacology alone was insufficient, the addition of an immersive virtual environment resulted in a dramatic reduction in the perceived unpleasantness of pain, proving that VR can effectively mask so-called breakthrough pain [13].

Equally groundbreaking results were observed when combining VR with clinical hypnosis (Virtual Reality Hypnosis – VRH). In patients with severe physical injuries, as well as in experimental models (pain induced by cold or thermal stimuli), VRH intervention delivered via software (a virtual hypnotist avatar) effectively reduced both pain sensations and autonomic nervous system responses [11, 20, 24] . Crucially, studies have demonstrated that VR can enhance the effect of hypnotic suggestion, facilitating entry into a trance state even for patients with low hypnotic susceptibility [24].

3.6. Affective variables, the "Flow" phenomenon, and safety of use

In addition to directly lowering pain scores, VR interventions exert a powerful influence on the affective dimension of suffering [5, 15, 25]. In 100% of the analyzed studies measuring the parameter of "joy" or "fun" (fun during procedure), patients using VR reported highly positive emotions during painful procedures, which stands in stark contrast to the trauma experienced in control groups [18, 23, 29]. These changes can be explained by the neurobiological mechanism of the "Flow" phenomenon—a state of deep engagement and loss of self-awareness that triggers endogenous analgesic pathways and reduces pain catastrophizing [31].

In terms of safety, the evidence gathered in this review indicates a high tolerance profile for VR in clinical settings [21, 30]. The incidence of side effects, such as cyber sickness (nausea, motion sickness), was minimal and rarely led to discontinuation of the intervention, even in sensitive pediatric patients and patients on high doses of opioid medications [14, 26, 28]. Furthermore, the development of equipment that allows for easy sterilization makes VR a tool that meets the stringent infection control standards in burn units [10, 14].

3.7. Detailed Analysis of Hardware and Software Parameters (Hardware and Software Specifics)

A significant portion of the collected evidence consists of detailed analyses of hardware specifications and the architecture of virtual environments, which directly influence the final analgesic effect [16, 28]. Early studies were dominated by heavy head-mounted displays (HMDs), which, although they provided a high level of visual isolation from the hospital environment, posed serious ergonomic problems, especially for patients with burns to the head and neck [10, 17]. The response to these challenges was the implementation of innovative solutions, such as robotic articulating arms, which maintain VR screens at an appropriate distance from the patient's face, completely eliminating painful pressure on burn wounds and fresh skin grafts [17, 29]. On the other hand, with a focus on affordability, more recent clinical trials have successfully tested systems based on commercial smartphones (Smartphone VR). Although they have a slightly smaller field of view (FOV) and lower resolution compared to dedicated PC-VR hardware, their effectiveness in reducing procedural pain in children remains at a highly satisfactory clinical level [26, 28].

In terms of software, studies clearly indicate the superiority of dedicated therapeutic games over standard 360-degree videos [14, 18]. A prime example is the "SnowWorld" environment, designed specifically to combat burn pain. This virtual world, in which patients traverse an icy canyon throwing snowballs at penguins and snowmen, not only offers high interactivity but also utilizes the psychological cooling effect, which is beneficial for burn victims [14, 17, 28]. Furthermore, the implementation of advanced control mechanisms, such as eye-tracking, allows patients with limited hand mobility to fully interact with the virtual world using only their eyes, which drastically deepens immersion and enhances the power of distraction [16, 18].

4.Discussion

Pain management in clinical settings, particularly in burn and trauma units, requires a multidimensional approach that goes beyond the traditional biomedical model based solely on pharmacotherapy [5, 15, 30]. This systematic review consolidates evidence from 31 key publications, unequivocally confirming that virtual reality (VR) constitutes a highly effective, safe, and innovative adjunctive therapy for the treatment of acute surgical and rehabilitation pain [1, 7, 21]. These findings are of fundamental importance in the era of the global opioid crisis, offering a tool that has the potential to reduce the need for narcotic medications without compromising patient comfort [2, 4, 9, 19].

4.1 Neurocognitive mechanisms and distraction theory

The primary mechanism attributed to VR's efficacy is cognitive distraction, grounded in the theory of limited human attentional bandwidth. As demonstrated in the analyzed studies, the processing of pain stimuli (nociception) and the conscious perception of pain require significant attentional resources from the cerebral cortex [10, 18, 31]. When a patient is immersed in a rich, multisensory, and interactive virtual environment, their brain must process vast amounts of visual, auditory, and proprioceptive information [25, 28]. As a result, the brain's available processing capacity for pain signals arriving from the periphery is drastically reduced. This is confirmed by studies using divided-attention tasks, where patients in interactive VR made more cognitive errors during pain stimulation, demonstrating that their attentional resources were fully engaged by the digital environment [14, 18].

Furthermore, studies using functional magnetic resonance imaging (fMRI) and functional near-infrared spectroscopy (fNIRS) provide biological evidence for this phenomenon, showing a significant reduction in activity in brain regions associated with the pain matrix, such as the somatosensory cortex, insula, or thalamus, while in VR [15, 17, 21, 28].

4.2 The Role of Embodiment and the "Flow" Phenomenon

A significant finding emerging from recent research is the evolution from passive visual distraction toward advanced mechanisms of embodiment and the "flow" phenomenon [12, 18, 31]. The sense of possessing a virtual body (e.g., seeing one's avatar's hands in digital space) and interacting with virtual objects enhance the illusion of presence. Studies on patients with spinal cord injuries (SCI) suffering from neuropathic pain show that visual feedback combined with tactile stimulation in VR can recalibrate the disrupted body map in the cerebral cortex, leading to analgesia at the neuroplastic level [8, 12].

In turn, the psychological construct of "Flow," described as a state of complete absorption, loss of sense of time, and self-awareness, appears to be the target state that optimizes the effectiveness of VR [31]. Burn patients playing engaging video games in a VR environment often report joy and excitement during procedures that typically cause them to cry and panic [6, 23, 26]. This affective shift—from catastrophizing and fear to motivation and fun—is crucial in preventing long-term psychological trauma, such as PTSD, which is not uncommon following a stay in a burn unit [15, 19, 21].

4.3 Multimodal Synergy: VR, Pharmacology, and Hypnosis

A review of the literature would not be complete without highlighting pioneering attempts to combine VR with other established treatment methods. Traditionally, VR has been treated as a standalone supportive intervention. However, analyzed clinical cases of soldiers with extensive combat burns have demonstrated that VR can act synergistically with dissociative anesthetics such as ketamine [13, 29]. When pharmacotherapy reaches its safety ceiling (maximum tolerated dose), overlaying it with a layer of "digital anesthesia" allows for the masking of breakthrough procedural pain [13].

An even more fascinating phenomenon is Virtual Hypnosis (VRH). Studies on hypnotic induction delivered via VR goggles have shown that the digital environment can increase susceptibility to hypnotic suggestions, facilitating entry into a trance for individuals who normally exhibit low susceptibility to traditional hypnosis [11, 20, 24]. This combination not only reduces the subjective dimension of pain but also calms the sympathetic nervous system, leading to objective changes in parameters such as heart rate variability (HRV) [20]. This paves the way for the development of personalized, multimodal "digital therapeutics" tailored to the patient's individual psychophysiological profile [5, 25].

4.4 Objective neurobiological correlates and biofeedback

In addition to subjective reports collected using VAS and NRS scales, the analyzed articles provide extremely important neuroimaging data that ultimately legitimize virtual reality as an intervention with a solid neurobiological basis [15, 21]. Groundbreaking studies using functional magnetic resonance imaging (fMRI) have demonstrated that being in an immersive virtual environment during thermal stimulation actively inhibits the flow of nociceptive signals to higher levels of the central nervous system [17, 21]. Significant decreases in metabolic activity, in the range of several dozen percent, were observed in areas of the so-called pain matrix, encompassing the thalamus, primary and secondary somatosensory cortex, as well as the anterior cingulate and insula [15, 17]. This empirically demonstrates that VR not only alters the patient's affective state but also tangibly and objectively modifies the way the brain physiologically processes signals of tissue damage.

Furthermore, the growing integration of VR systems with indicators of autonomic nervous system function opens up entirely new perspectives for the full personalization of "digital therapeutics" [5, 25]. Measurements of heart rate variability (HRV) or skin conductance during VR sessions show a clear shift in the autonomic balance toward parasympathetic activity [20, 22]. This phenomenon, particularly pronounced when combining VR with hypnotic induction (VRH), suppresses the physiological fight-or-flight response, which is destructively activated during debridement procedures [11, 20]. Understanding and utilizing these biomarkers forms the foundation for the development of future biofeedback VR systems. In such models, the digital environment will be able to adjust its level of stimulation and difficulty in real time to the patient's current physiological readings, maximizing the therapeutic "Flow" state precisely at the moments of peak pain [25, 31].

4.5 Implementation barriers, safety, and research limitations

Despite overwhelming evidence in favor of VR, the transition from clinical trials to the standard of care faces significant challenges, which have been noted in the analyzed studies. First, in burn units, it is impossible to apply pressure to facial or head wounds using traditional, heavy VR headsets (HMDs). The use of robotic arms (articulating arms) to hold the headset close to the patient's face without physical contact is a solution to this problem, but it significantly increases costs and space requirements in treatment rooms [17, 29]. For this reason, increasing attention is being paid to widely available smartphone-based systems, which, although they offer lower immersion, represent a cost-effective alternative in daily practice, particularly for children [26].

Another challenge is the phenomenon of cybersickness, caused by a conflict between visual stimuli and the vestibular system [21, 30]. Although in more recent studies using advanced equipment the percentage of patients discontinuing sessions due to nausea has dropped dramatically, this factor still requires careful patient selection, especially for those receiving concomitant opioid medications [10, 14, 28].

One must also take a critical view of the limitations of the literature itself. A significant portion of the studies included in this review are characterized by relatively small sample sizes and crossover designs, which may lead to a novelty effect [3, 9, 30]. Furthermore, there is high heterogeneity in the selection of software—ranging from passive 360-degree videos to highly complex interactive games—which makes it difficult to directly compare effect sizes in meta-analyses [7, 30]. There is also a lack of long-term studies demonstrating whether the analgesic effect of VR undergoes habituation (acclimatization) after repeated exposures to the same digital stimulation in patients hospitalized for many months [1, 21].

4.6 Directions for future research

The future of VR application in burn and trauma analgesia requires standardization of clinical protocols. Rigorous, multicenter, large-scale randomized controlled trials (RCTs) are needed that account for the influence of moderating factors such as age, gender, baseline anxiety levels, and cultural specificity [3, 22]. It is also essential to more broadly integrate objective physiological measurements (e.g., respiration, heart rate, blood stress biomarkers) to validate subjective reports on the VAS and NRS scales [20, 22]. Advances in machine learning (AI) and biofeedback may in the future allow for the creation of VR environments that adapt their difficulty level and stimulus intensity in real time to the patient's current physiological indicators, maximizing immersion and "flow" precisely at the moments of peak pain during dressing changes [25, 31].

5. Conclusions

This scoping review, based on a systematic analysis of 31 selected scientific publications, provides clear and strong evidence that virtual reality (VR) constitutes a groundbreaking and highly effective intervention in the non-pharmacological management of acute and chronic pain. The collected data confirm that in patients undergoing burdensome medical procedures—particularly victims of severe burns, orthopedic injuries, and patients undergoing rehabilitation—immersive digital environments drastically reduce the intensity of perceived pain, its unpleasantness, and the time spent thinking about nociceptive stimuli. In the face of global challenges related to opioid abuse, VR is emerging as a safe alternative free from systemic toxicity that can serve as a key adjunctive therapy in modern medicine [1, 2, 6, 7, 30].

5.1

From a theoretical and neurocognitive perspective, the effectiveness of virtual reality extends far beyond simple visual distraction. Research findings unequivocally indicate that the analgesic success of this technology is driven by mechanisms based on the theory of the human brain's limited attention span, supported by the phenomenon of embodiment and the attainment of a state of deep engagement known as "Flow." It has been proven that interventions characterized by a high level of immersion and interactivity (e.g., engaging the patient through eye tracking or virtual avatar arms) significantly more effectively tax the cognitive resources of the cerebral cortex, thereby blocking pain signals from reaching the centers of consciousness. Furthermore, VR has the ability to modify the affective dimension of suffering, transforming anxiety and traumatic procedural experiences into positive emotions such as joy and curiosity, which is particularly valuable in the pediatric population [12, 14, 18, 28, 31].

5.2

Research on the synergistic use of digital technologies with traditional treatment models offers particular added value. It has been demonstrated that combining immersive virtual reality with dissociative medications (such as ketamine in soldiers with extensive combat burns) or with clinical hypnosis (Virtual Reality Hypnosis) allows for overcoming treatment barriers in cases where standard pharmacotherapy proves insufficient. Additionally, in the context of physical therapy and rehabilitation for patients with spinal cord injuries, VR not only alleviates procedural and neuropathic pain but also significantly improves range of motion (ROM), motivating patients to perform exercises that, under standard conditions, would be inhibited by anticipatory anxiety [8, 11, 13, 20, 23].

Despite highly promising results, the widespread implementation of virtual reality into routine standards of care requires overcoming certain technical and methodological barriers. Future research should focus on optimizing equipment—for example, through the wider use of robotic arms that eliminate pressure from the goggles on the burned face, or the adaptation of cheaper and more readily available smartphone-based systems. There is also a critical need for large-scale, multicenter randomized controlled trials (RCTs) that integrate subjective pain assessment scales with objective stress biomarkers and real-time physiological recordings [10, 17, 22, 26, 29].

5.3

In summary, virtual reality has definitively ceased to be merely a technological novelty or an entertainment tool, evolving into a full-fledged "digital therapeutic." Its integration with the biopsychosocial model offers a holistic approach to burn and trauma patients, addressing the sensory, cognitive, and emotional components of pain simultaneously. Further development of this technology, supported by artificial intelligence algorithms that tailor stimuli to the patient's individual profile, has the potential to permanently revolutionize pain management standards in emergency and burn units worldwide [5, 15, 21, 25, 30].

Author Contributions:
Conceptualization: Julia Szymkowiak
Methodology: Julia Szymkowiak, Karolina Reczka
Software: Julia Szymkowiak, Zuzanna Zalewska
Check: Julia Szymkowiak, Maria Woźniak
Validation/Check: Karolina Reczka, Julia Szymkowiak, Maria Woźniak, Zuzanna Zalewska
Formal Analysis: Julia Szymkowiak, Zuzanna Zalewska
Investigation: Julia Szymkowiak, Karolina Reczka
Resources: Julia Szymkowiak, Zuzanna Zalewska, Maria Woźniak
Data curation: Julia Szymkowiak, Zuzanna Zalewska, Karolina Reczka
Writing – rough preparation:, Julia Szymkowiak, Maria Woźniak
Writing – Review and Editing: Julia Szymkowiak, Maria Woźniak
Supervision / Project Administration: Julia Szymkowiak, Karolina Reczka
All authors have read and agreed to the published version of the manuscript.

Statement on the Use of AI-Assisted Technologies: The authors employed ChatGPT during the drafting of this work solely to refine linguistic expression and improve clarity. All AI-generated suggestions were carefully reviewed and edited by the authors, who take complete accountability for the final content and scientific integrity of the article.

REFERENCES

1. Combalia, A., Sanchez-Vives, M. V., & Donegan, T. (2024). Immersive virtual reality in orthopaedics—a narrative review. International Orthopaedics, 48, 21–30. https://doi.org/10.1007/s00264-023-05911-w
2. Theingi, S., Leopold, I., Ola, T., Cohen, G. S., & Maresky, H. S. (2021). Virtual reality as a non-pharmacological adjunct to reduce the use of analgesics in hospitals. Journal of Cognitive Enhancement, 6, 108–113. https://doi.org/10.1007/s41465-021-00212-9
3. Lier, E. J., de Vries, M., Steggink, E. M., ten Broek, R. P. G., & van Goor, H. (2023). Effect modifiers of virtual reality in pain management: A systematic review and meta-regression analysis. PAIN.
4. Teh, J. J., Pascoe, D. J., Hafeji, S., Parchure, R., Koczoski, A., Rimmer, M. P., Khan, K. S., & Al Wattar, B. H. (2024). Efficacy of virtual reality for pain relief in medical procedures: A systematic review and meta-analysis. BMC Medicine, 22, 64. https://doi.org/10.1186/s12916-024-03266-6
5. Medina, S., Clarke, S., & Hughes, S. (2024). Virtual reality-based analgesia: Towards a novel framework for the biopsychosocial management of chronic pain. British Journal of Anaesthesia, 133(3), 486–490. https://doi.org/10.1016/j.bja.2024.06.005
6. Lauwens, Y., Rafaatpoor, F., Corbeel, K., Broekmans, S., Toelen, J., & Allegaert, K. (2020). Immersive virtual reality as analgesia during dressing changes of hospitalized children and adolescents with burns: A systematic review with meta-analysis. Children, 7(10), 194.
7. Lou, J., Li, J., Fan, Y., Zhang, C., & Huang, N. (2024). Effects of virtual reality on analgesia in wound care and physical therapy for burn patients: A systematic review and meta-analysis. Pain Management Nursing, 25, 377–388.
8. Portaro, S., Alito, A., Leonardi, G., Marotta, N., Tisano, A., Bruschetta, D., Longo, U. G., Ammendolia, A., Milardi, D., & de Sire, A. (2025). Efficacy of neuromodulation and rehabilitation approaches on pain relief in patients with spinal cord injury: A systematic review and meta-analysis. Neurological Sciences, 46, 2995–3020. https://doi.org/10.1007/s10072-025-08077-y
9. Birrenbach, T., Bühlmann, F., Exadaktylos, A. K., Hautz, W. E., Müller, M., & Sauter, T. C. (2022). Virtual reality for pain relief in the emergency room (viper) – a prospective, interventional feasibility study. BMC Emergency Medicine, 22, 113. https://doi.org/10.1186/s12873-022-00671-z
10. Furness, P. J., Phelan, I., Babiker, N. T., et al. (2019). Reducing pain during wound dressing in burn care using vr: A study of perceived impact and usability with patients and nurses. Journal of Burn Care & Research, 40(6), 878–885. https://doi.org/10.1093/jbcr/irz106

11. Patterson, D. R., Jensen, M. P., Wiechman, S. A., & Sharar, S. R. (2010). Virtual reality hypnosis for pain associated with recovery from physical trauma. International Journal of Clinical and Experimental Hypnosis, 58(3), 288–300. https://doi.org/10.1080/00207141003760595

12. Pozeg, P., Palluel, E., Ronchi, R., Solcà, M., Al-Khodairy, A.-W., Jordan, X., Kassouha, A., & Blanke, O. (2017). Virtual reality improves embodiment and neuropathic pain caused by spinal cord injury. Neurology.

13. Maani, C. V., Hoffman, H. G., Fowler, M., Maiers, A. J., Gaylord, K. M., & DeSocio, P. A. (2011). Combining ketamine and virtual reality pain control during severe burn wound care: One military and one civilian patient. Pain Medicine, 12(4), 673–678. https://doi.org/10.1111/j.1526-4637.2011.01091.x

14. Patterson, D. R., Drever, S., Soltani, M., Sharar, S. R., Wiechman, S., Meyer, W. J., & Hoffman, H. G. (2023). A comparison of interactive immersive virtual reality and still nature pictures as distraction-based analgesia in burn wound care. Burns, 49(1), 182–192. https://doi.org/10.1016/j.burns.2022.02.002

15. Hadjiat, Y., & Marchand, S. (2022). Virtual reality and the mediation of acute and chronic pain in adult and pediatric populations: Research developments. Frontiers in Pain Research, 3, 840921. https://doi.org/10.3389/fpain.2022.840921

16. Al-Ghamdi, N. A., Meyer, W. J. III, Atzori, B., Alhalabi, W., Seibel, C. C., Ullman, D., & Hoffman, H. G. (2020). Virtual reality analgesia with interactive eye tracking during brief thermal pain stimuli: A randomized controlled trial (crossover design). Frontiers in Human Neuroscience, 13, 467. https://doi.org/10.3389/fnhum.2019.00467

17. Hoffman, H. G., Chambers, G. T., Meyer, W. J. III, Arceneaux, L. L., Russell, W. J., Seibel, E. J., Richards, T. L., Sharar, S. R., & Patterson, D. R. (2011). Virtual reality as an adjunctive non-pharmacologic analgesic for acute burn pain during medical procedures. Annals of Behavioral Medicine, 41(2), 183–191. https://doi.org/10.1007/s12160-010-9248-7

18. Hoffman, H. G. (2021). Interacting with virtual objects via embodied avatar hands reduces pain intensity and diverts attention. Scientific Reports, 11, 10672. https://doi.org/10.1038/s41598-021-89526-4

19. Spiegel, B., Fuller, G., Lopez, M., Dupuy, T., Noah, B., Howard, A., Albert, M., Tashjian, V., Lam, R., Ahn, J., Dailey, F., Rosen, B. T., Vrahas, M., Little, M., Garlich, J., Dzubur, E., IsHak, W., & Danovitch, I. (2019). Virtual reality for management of pain in hospitalized patients: A randomized comparative effectiveness trial. PLOS ONE, 14(8), e0219115. https://doi.org/10.1371/journal.pone.0219115

20. Terzulli, C., Chauvin, C., Champagnol Di-Liberti, C., Faisan, S., Goffin, L., Gianesini, C., Graff, D., Dufour, A., Laroche, E., Salvat, E., & Poisbeau, P. (2023). Virtual reality hypnosis diminishes experimental cold pain and alters autonomic responses. Frontiers in Pain Research, 4, 1237090. https://doi.org/10.3389/fpain.2023.1237090

21. Li, A., Montaño, Z., Chen, V. J., & Gold, J. I. (2011). Virtual reality and pain management: Current trends and future directions. Pain Management, 1(2), 147–157. https://doi.org/10.2217/pmt.10.15

22. Ko, S. Y., Wong, E. M. L., Ngan, T. L., Leung, H. K., Kwok, K. T. Y., Tam, H. F., & Chan, C. C. (2024). Effects of virtual reality on anxiety and pain in adult patients undergoing wound-closure procedures: A pilot randomized controlled trial. Digital Health, 10, 1–11. https://doi.org/10.1177/20552076241250157

23. Carrougher, G. J., Hoffman, H. G., Nakamura, D., Lezotte, D., Soltani, M., Leahy, L., Engrav, L. H., & Patterson, D. R. (2009). The effect of virtual reality on pain and range of motion in adults with burn injuries. Journal of Burn Care & Research, 30(5), 785–791. https://doi.org/10.1097/BCR.0b013e3181b485d3

24. Patterson, D. R., Hoffman, H. G., Chambers, G., Bennetts, D., Hunner, H. H., Wiechman, S., Garcia-Palacios, A., & Jensen, M. P. (2021). Hypnotic enhancement of virtual reality distraction analgesia during thermal pain: A randomized trial. International Journal of Clinical and Experimental Hypnosis, 69(2), 225–245. https://doi.org/10.1080/00207144.2021.1882259

25. Fougère, M., Greco-Vuilloud, J., Arnous, C., Abel, F., Lowe, C., Elie, V., & Marchand, S. (2023). Sensory stimulations potentializing digital therapeutics pain control. Frontiers in Pain Research, 4, 1168377. https://doi.org/10.3389/fpain.2023.1168377

26. Xiang, H., Shen, J., Wheeler, K. K., Patterson, J., Lever, K., Armstrong, M., Shi, J., Thakkar, R. K., Groner, J. I., Noffsinger, D., Giles, S. A., & Fabia, R. B. (2021). Efficacy of smartphone active and passive virtual reality distraction vs standard care on burn pain among pediatric patients: A randomized clinical trial. JAMA Network Open, 4(6), e2112082. https://doi.org/10.1001/jamanetworkopen.2021.12082

27. Le May, S., Genest, C., Francoeur, M., Hung, N., Guingo, E., Khadra, C., Noel, M., Paquette, J., & Roy, A.-A. (2022). Virtual reality mobility for burn patients (vr-mobile): A within-subject-controlled trial protocol. Paediatric & Neonatal Pain, 4(4). https://doi.org/10.1002/pne2.12086

28. Jain, S., Armstrong, M., Luna, J., Thakkar, R. K., Fabia, R., Groner, J. I., Noffsinger, D., Ni, A., Nelson, E., & Xiang, H. (2024). Features of virtual reality impact effectiveness of vr pain alleviation therapeutics in pediatric burn patients: A randomized clinical trial. PLOS Digital Health, 3(4). https://doi.org/10.1371/journal.pdig.0000473

29. Maani, C. V., Hoffman, H. G., Morrow, M., Maiers, A., Gaylord, K., McGhee, L. L., & DeSocio, P. A. (2011). Virtual reality pain control during burn wound debridement of combat-related burn injuries using robot-like arm mounted vr goggles. The Journal of Trauma: Injury, Infection, and Critical Care, 71(1), S125-S130. https://doi.org/10.1097/TA.0b013e31822192e2

30. Ramage, M., & Davis, S. P. (2025). Virtual reality as an intervention for adult burn patients: An integrative review. Journal of Research in Nursing, 30(3), 269-284. https://doi.org/10.1177/17449871251317922

31. Gromakovskis, V., & Gūtmanis, M. G. (2024). Flow-induced analgesia: A conceptual review of biopsychosocial and neurobiological mechanisms of pain modulation. Journal of Pain Research.