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Review Articles

Virtual Reality in Pediatric Burns rehabilitation: A Systematic Review of randomized clinical trials

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Abstract

Background: Pediatric burns can have long-term physical, psychological, economic, and social implications for patients and their families. Burn rehabilitation is an essential part of treatment of Pediatric burn **Purpose:** To systematically review and summarize the evidence on the effectiveness of virtual reality (VR) in pediatric burns rehabilitation. **Material and Methods:** An electronic search on databases of PubMed, PEDro, Cochrane library and science direct databases, was performed to find the published RCTs on the effect of different types of VR on pediatric burns, from 2000 to 2024. Data was extracted from the included studies and methodological quality was assessed using PEDro scale. Meta-analysis was not applicable, and data was qualitatively analyzed. **Results:** seven studies met the inclusion criteria with a mean PEDro score of 7. Strong evidence was found to support the effectiveness of VR for improving pain, ROM, grip strength and hand function, while moderate evidence for quality of life.

Conclusion: The present evidence supports that VR could be an effective intervention in improving pain, ROM, grip strength, hand function and quality of life for children post-burn. More high-quality research with larger samples sizes is still needed to confirm and update the current evidence.

Keywords: : **Burn; Pediatric rehabilitation; Virtual Reality; Systematic Review.**

Introduction:

Children under 4 years old are particularly vulnerable to burns, often due to their impulsiveness, natural curiosity, and reliance on caregivers, which increases their risk of injury **(1).** Burn rehabilitation is a continuous and essential process that begins upon admission, addressing both physical and emotional recovery **(2).** Non-pharmacological approaches, such as VR and gamification can play a vital role in

reducing the perception of pain, stress, and providing distraction for children during rehabilitation by offering interactive simulations that create engaging, real-world-like environments and improve movement by motivating patients to perform repetitive exercises **(3,4).**

Virtual reality therapy has shown promising results in pediatric rehabilitation in general, and some applications gradually entering mainstream clinical practice **(5).** It can reduce procedural pain, anxiety, and fear in pediatric patients, ultimately preventing healthcare avoidance later in life. Using VR either alone or alongside pharmacological analgesia, the need for medications and their associated costs and side effects can be minimized **(6).** Although VR provides an interactive rehabilitation environment, its evidence for pediatric burn rehabilitation is still unclear. Therefore, this systematic review aimed to systematically review and summarize the RCTs on the effectiveness of VR in rehabilitation of pediatric burns.

Materials and Methods:

Design: systematic review of RCTs

The protocol of this review was registered on PROSPERO register (CRD42023408830), and its conduct and reporting followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines **(7).**

Search strategy:

PubMed, Physiotherapy evidence database (PEDro), Cochrane and science direct were searched and lastly updated in December 2024. Searching was done according to the following keywords: (“virtual reality” OR Xbox OR “Kinect based virtual reality” OR “Wii based games” OR “mobile games” OR exergame OR “computer games”) AND (burn OR “burn wound” OR “burn injury”) AND (pediatric OR pediatrics OR child OR children) AND (rehabilitation OR management OR treatment). Boolean operators were used to make many combinations of the keywords describing the criteria to be used. In addition to the electronic search, a manual search of relevant published studies and reviews was done.

Two independent reviewers reviewed the collected records, first by title, then by abstract, and finally by full text, using these eligibility criteria: **Inclusion criteria:** RCTs were included when they fulfilled the following criteria of the PICO model: **Population**: pediatrics (age 6 months-19years) from both genders with any burn types; **Intervention**: any VR technology; **Comparator**: traditional/no treatment; **Outcomes**: pain, range of motion (ROM), grip strength, hand function, and quality of life. **Exclusion criteria:** Study designs rather than RCTs as surveys, case reports and also articles published in non- English languages.

Data Extraction

Eligible studies were read in detail, and the following data was extracted: patient characteristics, interventions, outcomes, measures, and summary of results.

Quality Assessment

Two independent reviewers assessed the quality of included studies using PEDro scale which has 11 items, and score differences were discussed with the third reviewer until consensus was achieved. PEDro score determine the quality: 0-3 (poor), 4-5 (fair), 6-8 (good), and 9-10 (excellent) **(8).**

Data analysis

Modified Sackett's scale was used to determine the level of evidence for each outcome (9). Studies was summarized then analyzed according to gathered information regarding to PICO by descriptive analysis, and due to heterogeneity of studies that differ in interventions protocols and outcomes measures, meta-analysis was not applicable.

Results:

The search strategy revealed a total number of 575 records of published RCTs from 2000 to 2024. Fifteen of them were duplicated, 560 records were screened, 511 of them were excluded after screening titles and abstracts and 42 article were excluded after reading the full text articles. The included articles were 7 RCTs (10-16). The main reasons for exclusion were different study design, not being published in English or not assessing the targeted outcomes. The search results were displayed according to PRISMA flowchart **in Figure (1) (7).**

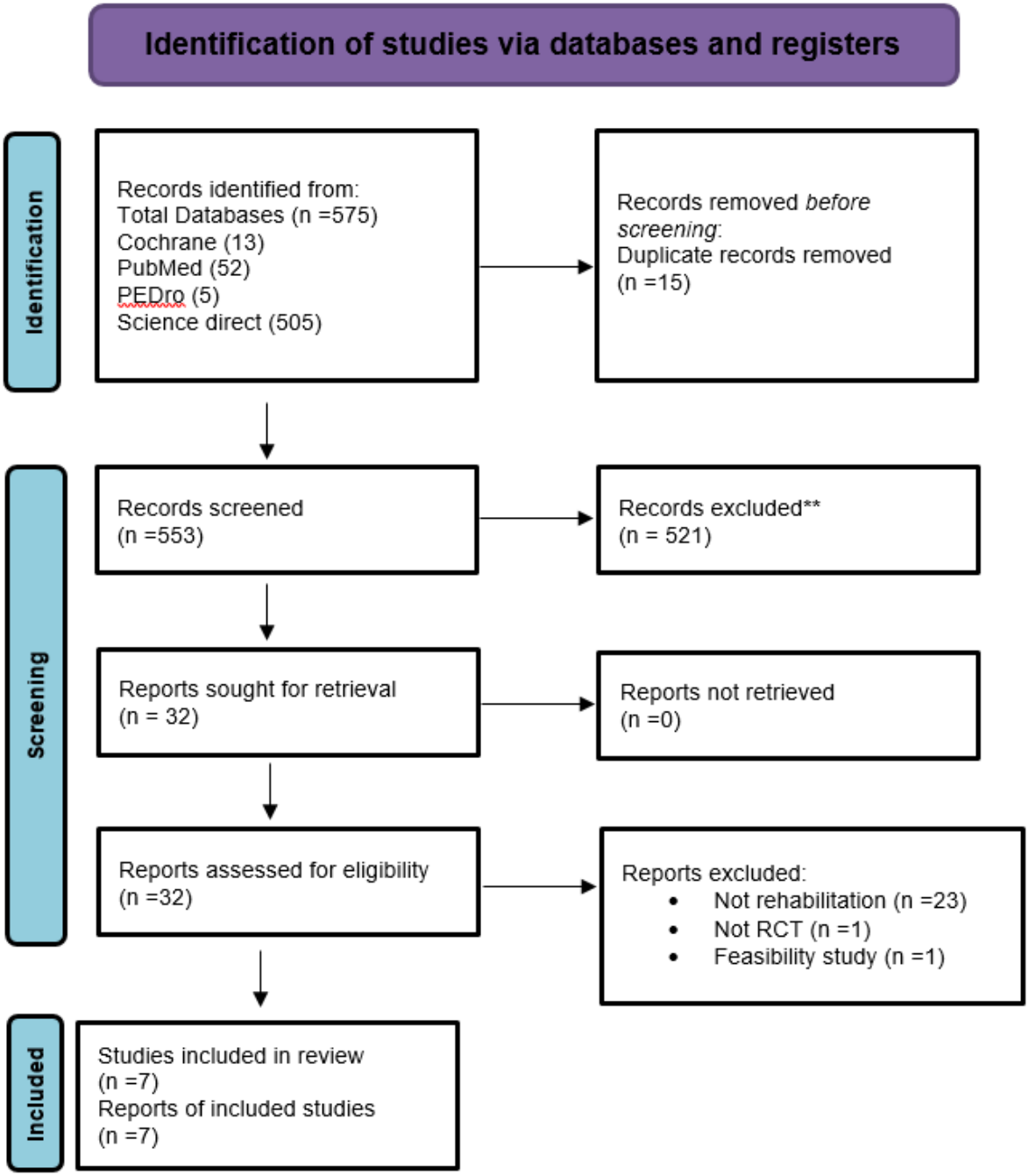

Figure (1): The PRISMA flow chart of the included studies.

Quality of Included Studies

The quality of the studies (Table 1) ranged from good (11,12,13,14&16) to fair (10,15), with a mean PEDro score of 7 out of 10 (range: 5–8). All studies clearly specified eligibility criteria that ensured baseline similarity between intervention and control groups and maintained at least 85% follow-up for at least one key outcome. Additionally, they conducted between-group statistical comparisons and reported point estimates with variability, which are crucial for evaluating the effectiveness of VR interventions.

* This criterion is not counted for the total PEDro score

Criteria of PEDro Scale: 1=eligibility specified; 2=random allocation; 3=concealed allocation; 4=prognostic similarity at baseline; 5=subject blinding; 6=therapist blinding; 7=assessor blinding; 8=85% follow-up of at least 1 key outcome; 9= treatment and control subjects received treatment as allocated; 10=between group statistical comparison for at least 1 key outcome; and 11=point estimates and measures of variability provided for at least 1 key outcome. Scoring: N= no (absent/unclear) = 0, Y=yes (present) =1. **(7).**

Table (1): PEDro scores

Study/ Criteria	1*	2	3	4	5	6	7	8	9	10	11	Total (0-10)	Quality
Schmitt et al.2011(10)	Y	N	N	Y	N	N	Y	Y	N	Y	Y	5	fair
Burns-Nader et al.2017 (11)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	7	good
Khadra et al.2020 (12)	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8	good
Samhan et al. 2020 (13)	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8	good
Kamel& Basha. 2021(14)	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8	good
Radwan et al.2021(15)	Y	Y	N	Y	N	N	N	Y	N	Y	Y	5	fair
Basha et al.2022 (16)	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	8	good

Data Analysis

This systematic review was limited to RCTs; seven studies met its inclusion criteria. The total number of subjects who participated in the included RCTs was 295 children with ages ranged from 6 months to 19 years. The sample size ranged from 30 to 54, description of patients' characteristics in addition to intervention and outcome measurement and results were displayed in Table **(2).**

Table (2) Summary of included studies

Authors (Year)	Participants	Interventions		Outcomes (measures)	Summary of Results
		Study	Control		
Schmitt et al. (2011) (10)	N=54 Age=6-19 yrs Any burn required post-burn active ROM	Immersive VR (SnowWorld) + standard analgesia (1-5 days)	Standard Medications	**-Pain** (GRS scale) **-ROM** (goniometer)	44% reduction in pain, 3x increase in fun
Burns-Nader et al. (2017) (11)	N=30 Age=4-12 yrs Any burn undergoing a hydrotherapy	Interactive tablet games during hydrotherapy	Child life specialist	**-Pain** (FACES) **-Anxiety** (CEMS)	Significant anxiety reduction &improved coping
Khadra et al. (2020) (12)	N=38 Age=6m-7 yrs Any burn undergoing a hydrotherapy	Projector-based VR dome during hydrotherapy	Standard Medications	**-Pain** (FLACC) **- Comfort** (OCCEB-BECCO Scale)	Significant pain reduction and improved comfort
Samhan et al. (2020) (13)	N=33 Age=6-12 yrs full-thickness burn of the wrist and hand,	Robotic-assisted VR (Amadeo1, Tyromotion) (30 min, 3/week, 8 weeks)	Traditional PT for hand (paraffin, massage, ROM)	**-Active ROM** (goniometer) **- Grip strength** (JAMAR PLUS+ digital hand dynamometer) **- Hand function** (JHFT)	Significant ROM and strength improvements, maintained at 3-month follow-up
Kamel & Basha (2021) (14)	N=50 Age=7-14 yrs with deep partial-thickness or full thickness hand burns	Xbox hands-free gaming (50 min, 3/week, 8 weeks)	Traditional PT (paraffin, stretching, ROM, strength training)	**-ROM** (goniometer) **-Grip & pinch strength** (Jamar hydraulic) **-Hand function** (JTHFT, DHI, COPM)	Significant improvement in hand function and strength
Radwan et al. (2021) (15)	N=50 Age=7-12 yrs partial thickness burns on	30 min Nintendo Wii training + 30 min PT	Traditional PT	**-Upper limb spatiotemporal parameters** (Vicon3-D motion analysis system)	Significant improvements in movement speed, hand function

	dominant upper limb	(3/week, 6 weeks)		**-Hand function** (JHFT)	
Basha et al. (2022) (16)	N=40 Age=10-16 yrs burns on 40% to 60% of (TBSA)	Xbox Kinect games (40 min) + 60 min standard PT (3/week, 12 weeks)	Standard PT (ROM, stretching, ADL training)	**-Quality of life** (PedsQL)	Significant increase in VOpeak, strength &PedsQL

The clinical heterogeneity in the methods of the included studies made meta-analysis not applicable; therefore, data from the studies were descriptively summarized and analyzed.

Participants

A total number of 295 pediatric patients was included in the reviewed studies; their ages ranged from 6 months to 19 years. The sample size ranged from 30 to 54 patients.

Interventions & Comparators

Reviewed studies utilized various forms of VR and interactive gaming to enhance burn rehabilitation; Xbox Kinect and Nintendo Wii games were used to promote movement **(14,15&16),** robotic-assisted VR provided targeted hand rehabilitation **(13),** Immersive VR and projector-based VR were used for pain management **(10,12)** and interactive tablet games served as a distraction tool during hydrotherapy sessions **(11).** These interventions aimed to make therapy more engaging and effective.

Control groups in the reviewed studies followed conventional treatments, including standard physiotherapy techniques such as ROM, stretching and strength exercises, paraffin, and mobilizing techniques **(13,14,15&16).** Pain management studies **(10,12)** relied on standard pharmacological therapy, while one study **(11)** provided only child life specialist support without interactive distractions. These traditional approaches focused on standard rehabilitation practices without the added engagement of VR.

Outcomes

I. Pain:

Schmitt et al. (2011) (10) examined the effects of immersive VR (Snow World) on 54 hospitalized pediatric burn patients aged 6-19 years who required post-burn painful physical therapy at least once during their stay in the hospital. There was a significant reduction in various pain types, with cognitive pain decreasing by 44% ($p<0.05$), affective pain by 32% ($p<0.05$), and sensory pain by 27% ($p<0.05$). They suggested that immersive VR was a powerful adjunct for enhancing pain control during rehabilitation therapy in pediatric burn patients.

Burns-Nader et al. (2017) (11) evaluated the effectiveness of tablet distraction to minimize pain and anxiety in thirty pediatric burn patients with ages ranging from 4 to 12 years who underwent hydrotherapy. Participants were allowed to choose an application of their choice. The used tablet applications included interactive games (car racing, bubble popping, cupcake making, etc.) with sessions ranging from 5 to 17min. Nurses reported significantly less pain for the tablet distraction group when compared to the control group ($p=0.03$). There was no significant difference between groups on self-reported pain ($p=0.29$). The tablet distraction group displayed significantly less anxiety during the procedure when compared to the control group ($p=0.001$). It was found that children who received tablet distraction displayed less observed pain and anxiety compared to a control group.

Khadra et al. (2020) (12) examined the effect of a water-friendly projector-based hybrid VR on pain during hydrotherapy. Thirty-eight children aged from 6 months to 7 years old with burn injuries underwent hydrotherapy sessions. The intervention was operated by a computer linked to a projector to display the VR game (Bubbles1) on the screen that transported the child into the virtual game without the need to wear any special VR equipment. The results revealed that there was significant pain reduction in the "Hybrid VR first" group ($p = 0.002$) according to the FLACC Pain Scale, a significant difference in the "Hybrid VR first" group ($p = 0.031$) in NRS-obs, significant comfort difference in "Hybrid VR first" group ($p = 0.001$) in Comfort (OCCEB-BECCO Scale and there was no significant difference in sedation levels ($p = 0.366$), or use of additional medication ($p = 1.000$) and No side effects reported. Projector-Based Hybrid VR helped in reducing the pain related to hydrotherapy.

II- ROM, Grip Strength and Hand Function

Schmitt et al. (2011) (10) used the immersive VR (Snow World) for 54 hospitalized pediatric burn patients aged 6-19 years to control pain during the active-assisted ROM physical therapy during their stay in the hospital. There was a remarkable three-fold increase in the perception of fun during VR conditions ($p<0.001$). Although VR experience did not lead to a statistically significant increase in maximal joint ROM compared to the control group ($p=0.21$), there was a significant increase in maximal ROM, averaging 6.8 degrees ($p=0.03$), during the VR therapy.

Samhan et al. (2020) (13) used robotic-assisted exercise with virtual gaming to improve digit ROM and hand function in 33 children with deep partial-thickness or full-thickness wrist and hand burns caused by thermal injury aged 6-12 years. They had a 30-minute interactive program after a 60-minute TR session, 3 times/week for 8 weeks. There was a statistically significant improvement in all measured outcomes compared to the control group after treatment ($P<.05$, $P=.04$, & $P=.005$).

Kamel & Basha (2021) (14) investigated the effect of Xbox interactive video games using motion-sensing, hands-free gaming devices on digits ROM, grip and pinch strengths, hand function, activity performance, and satisfaction in 50 children aged 7-14 years with deep partial-thickness or full-thickness hand burns. They had 50-minute sessions, 3 days/week for 8 weeks. There was a significant improvement in all measurements compared to the control group post-intervention ($P<.05$).

Radwan et al. (2021) (15) compared the Nintendo Wii sports intervention with traditional treatment on the upper limb spatiotemporal parameters and function. Fifty children with the dominant side upper limb burn aged 7-12 years, received 60-minute session daily, 3 times/week for 6 weeks. There was significant improvement in the spatiotemporal parameters, and consequently, it enhanced upper limb functions.

III. Quality of Life:

Basha et al. (2022) (16) determined the impact of Xbox Kinect (Rally Ball, Reflex Ridge, River Rush, and 20000 Leaks) on muscle strength, quality of life, lean mass, cardiopulmonary fitness, and enjoyment in severely burned children after hospital discharge. Forty children aged 10-16 years received 40-minute sessions (10 minutes each game) in addition to the 60-minute standard physical therapy program (splinting, walking every day, joint ROM exercises, muscle stretching, scar management, and ADL training), 3 days/week for 12 weeks. There was a 35% improvement in the PedsQL self-report and 31% improvement in the PedsQL-parent report ($p<0.001$), statistically significant increases in peak torque, cardiopulmonary function, lean body mass, lean trunk mass, and lean leg mass ($p<0.001$), and significantly higher enjoyment compared to the control group ($p<0.001$).

Level of Evidence:

Modified Sackett's scale was used to determine the overall evidence and presented in **table (3)**.

Table (3) Level of Evidence

Outcome	Included study	PEDro score (Quality)	Level of Evidence
Pain	Schmitt et al. 2011 (10)	5 (fair)	1a (strong)
	Burns-Nader et al.2017 (11)	7 (good)	
	Khadra et al. 2020 (12)	8 (good)	
ROM, grip strength & hand function	Schmitt et al. 2011 (10)	5 (fair)	1a (strong)
	Samhan et al. 2020 (13)	8 (good)	
	Kamel & Basha. 2021(14)	8 (good)	
	Radwan et al.2021(15)	5 (fair)	
Quality of life	Basha et al. 2022 (16)	8 (good)	1b (moderate)

Discussion:

This systematic review aimed to find and summarize the evidence on the effect of VR in the rehabilitation of pediatric burns. Systematic methods were applied to search for and evaluate the available relevant studies. Strong evidence was found to support the effectiveness of VR on ROM, Hand function, grip strength, and pain in post-burn children rehabilitation. Moderate evidence was found regarding the quality of life.

The current review used systematic methods to identify and critically appraise relevant research to collect and analyze data from the included studies. It was conducted according to the PRISMA 2020 guidelines, which provide updated and comprehensive reporting standards for systematic reviews. PRISMA 2020 reflected recent advances in the methodologies used to identify, select, appraise, and synthesize studies. By adhering to these updated guidelines, the review ensured greater transparency, rigor, and consistency in its approach, allowing readers to assess the appraise and synthesize studies. By adhering to these updated guidelines, the review ensured greater transparency, rigor, and consistency in its approach, allowing readers to assess the trustworthiness and applicability of the findings. Guidelines also helped standardize reporting practices, facilitating replication and updating of the review **(17).** Electronic databases were used including, Cochrane Library (CENTRAL) which, contains high-quality and independent evidence to inform healthcare decision-making, PEDro database which, is designed to support the practice of evidence-based physiotherapy, in addition to the PubMed (MEDLINE) database, and Science Direct databases. The main reasons for the exclusion of studies during the literature search were that they did not meet the inclusion criteria of this systematic review as a survey, case report, Feasibility study, and non-English articles. The search of the current SR revealed 7 RCTs **(10-16)** that investigated the effect of VR in the rehabilitation of pediatric burn, with a total of 295 pediatric patients with ages ranging from 6 months to 19 years.

The internal validity of the included studies was assessed by PEDro scale criteria of adequate randomization, allocation concealment, baseline similarity, blinding, outcome data, and use of intention to treat analysis **(18).** The quality of studies ranged from good **(11,12,13,14&16)** to fair **(10,15)** and a mean PEDro score of 7 out of 10 (range 5–8).

In all included studies in this review, participants were allocated randomly, enhancing internal validity by reducing selection bias however, the concealed allocation was absent in two studies **(13,15)**. All trials reported the results of between-group statistical comparisons and provided measures of variability for at least one outcome, specified the eligibility criteria, and had groups of similar baselines. All included studies had blind assessors except two studies **(11,15)**, which reduced potential bias in outcome evaluations. None of the studies had blind therapists due to the interactive nature of VR interventions, making it difficult to mask participants and therapists. All included studies obtained at least one outcome from more than 85% of the initially allocated participants and carried out an intention-to-treat analysis except two studies **(10,15).**

The included studies in this review were clinically heterogeneous regarding the interventions used and the outcomes measured; therefore, descriptive analysis was used to present its data **(19)**, and the overall level of evidence for each intervention was specified according to the modified Sackett's scale **(20).**

The three included studies reviewed pain **(10,11&12)** revealed strong evidence of the effectiveness of VR in improving pain during the rehabilitation of pediatric burns.

In conclusion, the use of immersive virtual reality, tablet distraction, and Projector-Based Hybrid VR **(10,11&12)** suggested that various types of virtual reality are efficient and powerful adjuncts for enhancing pain control during rehabilitation therapy in the pediatric burn population, and they are effective methods for improving pain and anxiety in children undergoing hydrotherapy treatment for burns.

A recent review by Norouzkhani (2022) studied the effects of various VR methods on pain during wound care, and they showed that immersive VR intervention significantly decreased pain intensity in the intervention group **(21)**

Interactive VR, projector-based VR, and multi-modal distractions have been examined in the context of pediatric burn injuries and procedural pain. Overall, there was a significant analgesic effect of VR during burn wound care for pediatric patients compared to standard distractions (e.g., TV, videos, books, and toys, as well as standard medication care). Moreover, different types of VR interventions did not seem to influence the magnitude of the analgesic effects as it revealed by the included studies **(22).**

Moreover, VR reduced the anxiety level as well as the experience of aversive stimuli in children. Research on VR interventions for pain and anxiety levels held considerable promise in the medical field. A collaboration between researchers, clinicians, and programmers was crucial for including VR technology in more clinical procedures, which would consequently enhance the patient's quality of life **(23).**

The four included studies **(10,13,14&15)** that measured ROM, grip strength, and hand function revealed strong evidence of the effectiveness of VR in improving these outcomes. The studies utilizing immersive virtual reality, Xbox interactive gaming, Wii-habilitation, and virtual gaming **(10,13,14&15)** demonstrated significant improvements in range of motion (ROM) of the digits, grip and pinch strength, hand function, activity performance, and patient satisfaction in pediatric hand burn rehabilitation. Additionally, these interventions enhanced spatiotemporal parameters of the upper limb in children with post-burn injuries, leading to better overall upper limb function. Furthermore, total active ROM of the fingers, hand grip strength (HGS), and overall hand function showed marked improvement compared to traditional rehabilitation approaches.

Virtual reality allows a higher degree of exposure to be achieved than traditional treatment since the manipulation of a virtual environment makes it easier to emphasize those situations to be recreated; this is why the feeling of immersion is a key aspect. Therefore, VR can be considered an effective method to increase the

range of joint movement. It also allows a greater variety of therapeutic exercises, and this could contribute to achieving greater joint ranges without the sensation of effort or the monotony of repetition **(24).**

The study **(16)** measured the quality of life revealed moderate evidence of the effectiveness of VR in improving quality of life as it showed that the Xbox Kinect training could increase the quality of life, cardiopulmonary fitness, muscle strength, and lean mass in burned children. It is one of the most enjoyable, motivated, and efficient treatment modalities that should be widely introduced into pediatric burn rehabilitation.

This systematic review had many strength points as it summarized the evidence regarding the effect of VR in the rehabilitation of pediatric burn; it included only RCT design to find the best evidence **(25).** The included studies in this systematic review had a mean PEDro score of 7 of good quality. The main limitation of the current review was the small number of included RCTs and the difference in their interventions, outcomes, and measures. The heterogeneity of study methods did not allow meta-analysis of results **(26).**

Future directions are recommended for more well-designed RCTs into the effects of VR on different outcomes such as ADL activities and improvement of lower extremity function, gait, and balance post-pediatric burn.

The results of this systematic review need to be interpreted cautiously in the context of limited number of RCTs and the relatively small sample size in some trials. More well-designed research is needed to confirm the present evidence.

Conclusion:

The present evidence supports that VR could be an effective intervention in improving pain, ROM, grip strength, hand function and quality of life for children post-burn. More high-quality research with larger samples sizes is still needed to confirm and update the current evidence.

Conflict of interest disclosure:

The authors stated no conflict of interest

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