

Review Article

Virtual reality-based functional recovery in burn population: a systematic review

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Abstract: Objective: To evaluate the effectiveness of virtual reality-based interventions in promoting functional recovery among individuals with burn injuries. Data Sources: PubMed/Medline, Scopus, Ovid, CINAHL, PEDro, Google Scholar, and Cochrane Library. Methods: Multiple data sources were explored from beginning to March 31, 2024, with study design of randomized clinical trials describing Range of Motion, enhanced ability for self-care (ADLs) and independence, quality of life in adult with burn injury. ROM was primarily measured using goniometers and electronic digital goniometers to assess the degrees of movement at affected joints before and after VR-based rehabilitation sessions. Two independent authors analyzed the results and selected the data. Cochrane Criteria Risk of Bias version 2 was used to measure risk of bias. Patient demographics, treatment regimen and outcome measuring tool, results and change in the patients' conditions were also extracted. Each study was appraised to check the level of evidence. Results: 8 publications were selected with a total of 293 patients included in these studies. Level of evidence analysis revealed that 8 studies were classified as level of evidence A2. The lowest PEDro score was 6 for one study only while other studies scored 7, 8, and 9 accordingly. In this review, seven studies were categorized as low risk of bias, while one study had some risk of bias. Our results showed that virtual reality can increase range of motion, enhanced ability for Self-Care (ADLs) and independence, improved quality of life in patients with burn injury, though strength of conclusion for mobility and ADLs was moderate. Conclusion: Preliminary evidence indicates that virtual reality "V.R." interventions could be beneficial in promoting functional recovery in patients with burn injuries. The studies reviewed suggest Virtual Reality can reduce pain during rehabilitation, improve range of motion, and increase patient engagement. However, the limited number of studies and the variability in VR methods and outcome measures restrict the generalizability of these findings. Further rigorous research with standardized protocols is needed to validate these results and guide clinical practice. Future investigations should aim for larger sample sizes and longer follow-up periods to thoroughly evaluate the effectiveness of VR in burn rehabilitation.

Keywords: Burn survivor, exergaming, functional mobility, gamification, virtual reality, physiotherapy

Introduction

Burn injuries are a big clinical challenge due to their complicated structure and the extensive rehabilitation required for functional repair [1]. Serious burn victims frequently require extended hospital stays, significant medical and psychological aftereffects, and ongoing rehabilitation to regain their ability to operate independently. Conventional rehabilitation procedures may be dull, painful, and require minimal patient participation, even if they are effective. This could impede the best possible healing outcomes. Scar contracture is a most prevalent issue after burn injury to the skin which impairs

joint mobility and causes restriction in executing the daily life activities. Even after the acute phase of injury, the patient assumes it's a before injury role. With the advancement in treatment and patient management there is a shift to enhance the function and quality of life. Burn injury affects the physical, psychological and social aspects of the patient [2]. When daily activities cannot be performed, both actual and perceived physical health can be affected, and a person's quality of life is in danger. Following the burn injury particularly by flame or electrical damage, sustained pressure on nerves has been reported which may result into major disabilities [3, 4].

Virtual reality “V.R.” is an emerging treatment for several diseases in recent times. There are several types of this technology. Non-immersive, semi-inversive, and complete inversive. Virtual Reality permits users to interact with a simulated environment and receive continuous, immediate feedback related to performance. VR has the potential to apply basic concepts of patients, such as intensive, repetitive, and task-oriented training and customized care for individual patients is one of the many advantages of VR in rehabilitation [5-7].

VR-based rehabilitation can increase motivation via gamification and decrease distraction and decrease pain perception via immersive environment. By shifting attention focus away from painful stimuli, VR is thought to attenuate neural activity in pain-processing brain regions, as supported by functional MRI studies. Randomized clinical trials in pediatric and adult burn populations have demonstrated significant reductions in procedural pain - often in the range of 20-50% - when VR is used alongside standard analgesic care.

This systematic review aims to assess VR therapies' effectiveness in aiding burn injury survivors' functional rehabilitation [8]. By analyzing the available data, we aim to assess the effect of VR on many elements of functional rehabilitation, including range of motion, functional Independence, mobility, and overall quality of life. Our main research objective was to assess the effectiveness of virtual reality interventions in promoting functional recovery among individuals with burn injuries. These questions were covered by the review: What effect does virtual reality-based rehabilitation have on burn patients' functional outcomes? How successful and patient-engaged are virtual reality and conventional rehabilitation techniques? What are the known advantages and difficulties of using virtual reality in burn rehabilitation?

We intend to present a thorough overview of VR-based burn patient rehabilitation through this analysis and may be able to suggest possible directions for further investigation. The results of this review may have a potential to improve outcomes for this vulnerable population by guiding the integration of VR technologies into burn rehabilitation programs and evidence based informed clinical practice [6, 9, 10].

Methods

Search strategy

We followed the guidelines of Preferred Reporting Items for Systematic Reviews and Meta-analyses statement for this systematic review (**Figure 1**).

Comprehensive electronic databases were explored such as PubMed, Scopus, IEEE with Keywords and Medical Subject Headings “MeSH” terms included variations of “virtual reality”, “burn injuries”, and “functional recovery”. Along with main keywords we also used Boolean operators (AND, OR) and combined the keywords effectively (**Table 1**). Details of database search syntax are listed in on-line [Appendix 1](#).

Eligibility criteria

Inclusion criteria: (1) Research with randomized controlled trials “RCTs” study design was selected. (2) Studies published in English language only were selected. (3) All the studies focus on virtual reality interventions for functional recovery in individuals with burn injuries. (4) Research included burn population from chemical, flame, scald, and electric burn with age from 18 years who were followed up at least 6 months for the treatment. (5) Outcome measures were related to functional recovery such as range of motion, activities of daily living “ADLs”.

Exclusion criteria: (1) Studies with interventions unrelated to virtual reality. (2) Studies with interventions unrelated to Burn injury. (3) Studies with intervention are irrelevant to functional recovery. (4) Non-human studies. (5) Non-randomized controlled Trials. (6) Studies lack outcome measures related to functional recovery.

Study selection process

Two independent reviewers (Sanaullah M, and Riaz HM) completed and evaluated the titles and abstracts for relevance. Full-text articles of potentially relevant studies were retrieved for further assessment. Disagreements in study selection were fixed through arguments and involving a third reviewer (Mansha H). No Automation Tool was used for this purpose.

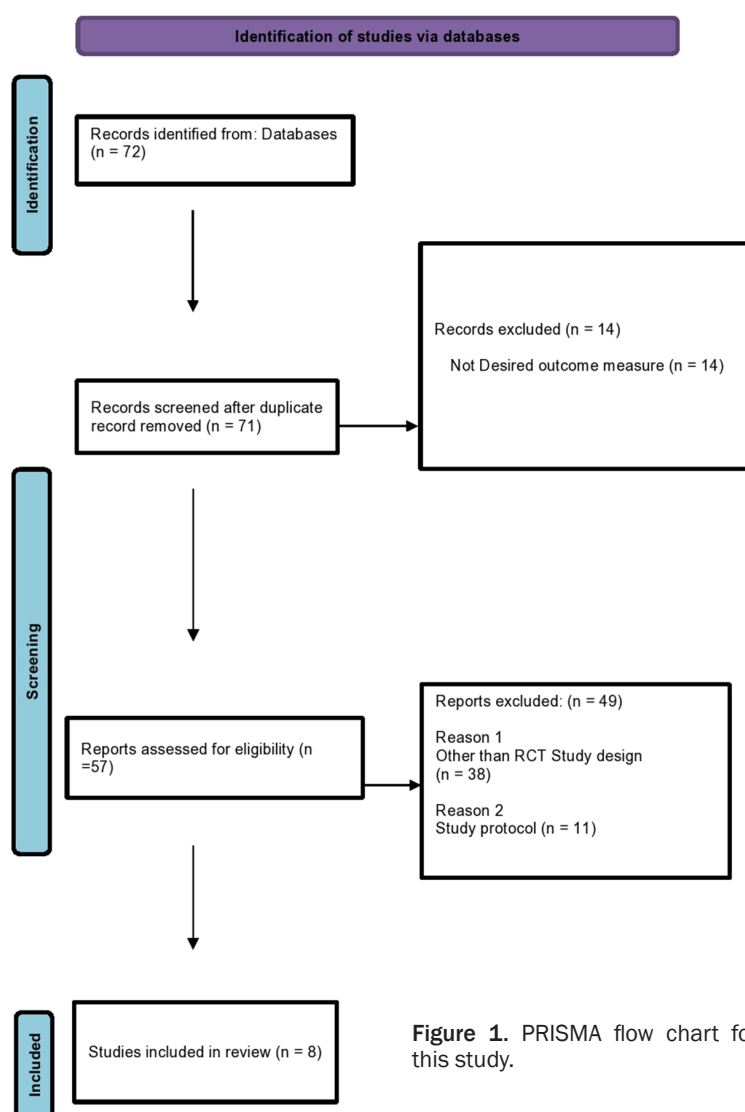


Figure 1. PRISMA flow chart for this study.

Data collection process

Studies were distributed equally among the all the authors and each one of them independently evaluated the assigned studies and used the PEDro Scale to check the PEDro Score. After the completion of the task, they reviewed each other's study to confirm the data collected similarly and the required data collected from each selected article.

Data extraction and analysis

Three non-blind persons (Sanaullah M, Riaz HM, and Mansha H) extracted the data from the selected studies independently using a uniform table. This data included "Author, Country, Setting, Participants, Age, Mean "S.D.", TBSA,

Study Design, Sample Size, Type of Intervention, Dose of Treatment, Outcome Measures/Assessment Tools, Result". After this step, another author reassessed data to remove the mistakes. This systematic review focused only on description and qualitative synthesis of the identified studies. The statistical methods used in the studies include descriptive statistics (mean, standard deviation, median), paired t-tests, independent t-tests, ANOVA, linear regression, Graphic Rating Scale (GRS), *p*-values, Chi-square tests, risk of bias assessment (PEDro scale), and follow-up analysis.

Level of evidence and strength of conclusion

Each selected article's level of evidence was determined as per PEDro scale. The outcome of this step was classified as: 1 - high, 2 - moderate, 3 - low, and 4 - very low [11].

Risk of bias assessment

Assessment of risk of bias in included studies was assessed by the Risk of Bias tool (ROS) current version/Cochrane method. This was analyzed by two independent reviewers (Riaz HM and Mansha H). The guideline examines six specific domains of bias, and the scoring criteria for each item in each of the domains are "Yes", "No", and "Unclear" if there is insufficient information to make an accurate judgment.

Results

Study selection

72 records from selected databases were found from the initial query. After duplicated data records screened, 14 records were excluded because they did not have the desired outcomes. 57 reports were assessed for eligibility. The total reports excluded were 49

Table 1. Search keywords

(((((Quality of life) OR (Physical Therapy)) OR (physiotherapy)) OR (Function)) OR (ADL)) OR (Mobility)) AND ((virtual reality) AND (Burn))

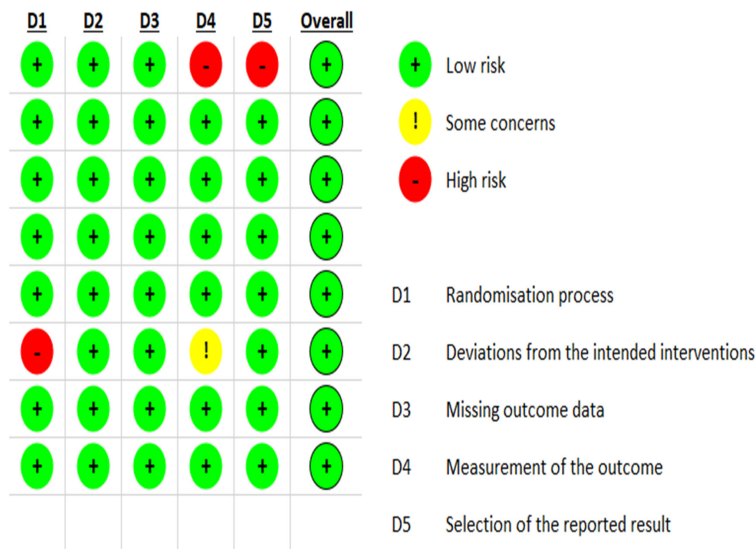
virtual reality AND “burn” AND “mobility” NOT dressing NOT Anxiety

virtual reality AND “burn” AND “function” NOT dressing NOT Anxiety

virtual reality AND “burn” AND “Physiotherapy” NOT dressing NOT Anxiety

virtual reality AND “burn” AND “Physical therapy” NOT dressing NOT Anxiety

virtual reality AND “burn” AND “Quality of life”

**Figure 2.** Risk of bias score for each selected study.

because 39 were other than RCT design and the other 10 did not have the desired study protocol. A total of 8 studies were included in the review because they fall under our desired study protocols.

Risk of bias in studies

Using Cochrane method 13 item criteria one study at a high risk of randomization, one study has a high risk of measurement of the outcome bias with one study has some concern measurement of the outcome bias (**Figure 2**). One study shows the bias in the selection of the reported result with high risk. The other seven studies show very low risk of bias. The overall all of the 8 studies show a lower risk of bias.

Results of individual studies

A total of 293 patients were included in the selected studies. There is a variation in the groups. A total number of seven studies included only 2 groups. One is experimental and the

other is control group. One study also included the third group. Seven studies have a common outcome measure of Range of motion (**Table 3**). One study measured muscle strength and overall quality of life. The control group either received the traditional physiotherapy treatment at home or at clinic and experimental group received the Virtual reality environment-based treatment in addition to the other treatments methods. Out of eight studies, 6 studies claimed to have a significant difference in the outcome measures whether it was range of motion or decrease in the pain intensity. One study claimed to

have a slight difference and in one study out of eight there was not a significant difference in the outcome measure.

Out of 8 studies 2 were conducted in Saudi Arabia 3 were conducted in USA and 3 were conducted at Egypt. The effect of virtual reality was reported in literature in different conditions.

Results of synthesis

All the eight studies showed very low risk in overall bias. Only 10.0% showed bias in selection of the reported result. 10.0% of the studies showed measurement of outcome bias and 10.0% of the study showed some concerns in the risk of bias in selection of the reported result. All the 8 studied showed no risk of bias in missing outcome data and deviation from intended interventions. Only 10.0% of the studies showed biases in randomization process with high risk.

Table 2. PEDro scale scores for the selected studies

PEDro scale item	MA Basha 2022	RR Ali 2022	M Soltani 2018	GJ Carroug-er 2009	FAH Kamel 2021	YS Schmitt 2011	MA Basha 2022	AF Samhan 2020
1 Random allocation	1	1	1	1	1	1	1	1
2 Concealed allocation	1	1	1	1	1	0	1	1
3 Baseline comparability	1	1	1	1	1	1	1	1
4 Blind subjects	1	1	1	1	1	1	1	1
5 Blind therapists	0	0	0	0	0	0	0	0
6 Blind assessors	1	1	1	1	1	1	1	1
7 Adequate follow-up	1	0	0	0	1	0	1	1
8 Intention-to-treat analysis	1	1	1	1	1	1	1	1
9 Between-group comparisons	1	1	0	0	0	0	0	0
10 Point estimated variability	1	1	1	1	1	1	1	1
Score	9/10	8/10	7/10	7/10	8/10	6/10	8/10	8/10
Quality	High	High	High	High	High	High	High	High

PEDro scale = Physiotherapy Evidence Database scale.

Reporting biases

Randomization was clear in eight studies while deviation from the intended interventions was clear in all the 8 studies similarly there was no missing data outcome in all the 8 studies' environment of outcome seven studies showed low risk and two studies showed some risk one is at high risk, and the other one is at some concerns. Of all the 8 studies, only one showed high risk bias in the selection of reported results and the other seven showed lower risk in selection of reported results.

Certainty of evidence (Pedro scale score assessment)

Eight selected studies are high-quality studies according to the PEDro scale assessment. One study has 9 out of 10 score because he didn't blind the therapist, four studies have 8 out of 10 score two studies have 7 out of 10 score and one have 6 out of 10 score. In all of these studies therapist blindness was not possible. 1 study did not conceal the allocation. Four studies did not have adequate follow up seven study does not have done the between group comparison (**Table 2**).

By using immersive virtual reality in postburn physical rehabilitation, hospitalized patients reported reduced discomfort. Numerous studies have shown that both adults and children can experience the same analgesic effect while using the same or a similar version of the soft-

ware. In a similar vein, VR dramatically decreased the amount of time patients reported thinking about their discomfort during physical therapy. The VR condition showed a marginally higher average gain in ROM (pretherapy to post-therapy); however, this difference was not statistically or clinically significant (p -value .243).

Subjects acquired 10.2 degrees (S.D. = 5.9) of joint range on average when using VR, as opposed to 9.2 degrees (S.D. = 4.6) when not using V.R. Every participant had multiple joints and body parts tested and quantified. The average increase from pre-therapy to post-therapy, as well as the number of subjects for each body location measured. According to pre- and post-physical therapy range of motion measurements, no patient lost range of motion while taking part in the trial. V.R. did not, therefore, negatively impact joint range of motion results during ten-minute therapeutic exercise sessions.

It is of therapeutic interest that V.R. reduced pain complaints without significantly improving range of motion. It is crucial to remember that ROM and pain management are two distinct factors that do not always follow from one another. It is impossible to ascertain empirically if the patient's reported reduced discomfort affected the therapist's decision to exercise a particular joint to that extent. These conclusions can have been reached using criteria like felt joint resistance or contracture rigidity,

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Table 3. Details of selected studies

Author	Country and Location	Age, Mean (S.D.), Median	Type of Study	Sample Size	Type of Intervention	Dose of Treatment	Outcome Measures/ Assessment Tools	Result
Maged A. Basha, Nancy H.A, Sobhy M. Aly, Fatma Alzahraa (2021)	Rehab center, Qassim University, Saudi Arabia. Teaching Hospitals and Institutes, Cairo, Egypt	Mean experimental = 12.7 (1.56) years Mean Control = 13.3 (1.29) years	Randomized Controlled Trial	N = 40 Xbox training group (n = 20) control group (n = 20)	Experimental group: Xbox + home program rehabilitation Control group: home program rehabilitation	Base line and 12 weeks	Cardio-pulmonary fitness (VO ² peak), -muscle strength (peak torque), -lean mass -quality of life	-The Xbox training group reported significantly more enjoyment than did the control group (<i>p</i> -value 0.001). -the groups significantly differed in VO ² peak, peak torque, quality of life (<i>p</i> -value 0.001), lean mass and leg lean mass (<i>p</i> -value 0.05) in favor of Xbox training.
Rania R Ali, Ali Osman Selim, Mohamed A Abdel Ghafar, Osama Ragaa, Ibrahim Ali (2022)	-Physical Therapy Program, Batterjee Medical College for Science & Technology, Jeddah, Saudi Arabia. -Cairo University, Giza, Egypt	9 to 16 years old	Randomized Controlled Trial	N = 22 control group (n = 11) Experimental group (n = 11)	Control group: -passive ROM -stretch exercises Experimental Group: -VR training -passive ROM -stretch exercises	Before and immediately after the rehabilitation session.	-VAS -electronic digital goniometer	-significant decrease in pain intensity. -increase of ROM - <i>p</i> -value 0.05.
Soltani M, Drever SA, Hoffman HG, Sharar SR, Wiechman SA, Jensen MP, Patterson DR (2018)	Department of Rehabilitation Medicine, University of Washington	Age 15 to 66 (M = 36)	Randomized controlled study	N = 39	Control group: -unassisted active ROM exercises -Self stretches Experimental Group: -unassisted active ROM exercises -Self stretches -VR	Before and immediately after the rehabilitation session.	-goniometer -0-100 Graphic Rating Scale (GRS)	-No significant effect was found for worst pain GRS ratings; <i>F</i> (1, 36) = .50, <i>p</i> -value .05. -significant effect was found for maximum joint ROM, <i>F</i> (1, 36) = 24.29, <i>p</i> -value .001.
Fatma Alzahraa H. Kamel, PhD Maged A. Basha, PhD (2021)	-Rehab center, Qassim University, Saudi Arabia. -Teaching Hospitals and Institutes, Cairo, Egypt	Mean 10.70 ± 1.64y	Randomized Controlled Trial	N = 50	3 groups: the motion-sensing, hands-free gaming device group that used interactive video games plus traditional rehabilitation (TR); the TOT group that used real materials plus TR; the control group that only received TR	3 days per week for 8 weeks	-Jebesen-Taylor Hand Function Test, -Duruoz Hand Index (DHI), -Canadian Occupational Performance Measure (COPM). -ROM of the digits, -grip strength, -pinch strengths	Significant increase in all measurements of the motion-sensing, hands-free gaming device and TOT groups compared with that of the control group post intervention (<i>p</i> -value .05). No significant change in Jebesen-Taylor Hand Function Test, COPM performance, ROM, grip strength, pinch strengths.
Gretchen J. Carrougner, RN, MN, Hunter G. Hoffman, PhD, Dana Nakamura, OTR/L, Dennis Lezotte, PhD, Maryam Soltani, MEd, Laura Leahy, BA, Loren H. Engrav, MD, and David R. Patterson, PhD. (2009)	Burn center Pacific Northwest region, US, Washington	aged 21 to 57 years (mean 35 years)	prospective, randomized controlled study	N = 41 (2 withdraw during study)	EG: VR + active-assisted ROM ex. CG: active-assisted ROM ex.	Immediately before and after therapy on two consecutive days	-0 to 100 Graphic Rating Scale, -Goniometer	-Average ROM improvement was slightly greater with the VR condition; (<i>p</i> -value .243).

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Schmitt YS, Hoffman HG, Blough DK, Patterson DR, Jensen MP, Soltani M, Carrougner GJ, Nakamura D, Sharar SR	Washington, Seattle	12.0 ± 3.9 years	RCT (Crossovers design)	31	Part 1: VR + analgesic + Physiotherapy. Part 2: analgesic + Physiotherapy	5 days Each session: 6-20 min Divided in two part (each part 3-10)	1. Graphic Rating Scale (Cognitive affective and sensory) 2. ROM 3. report of fun	GRS and report of fun had significant result in Part 1. ROM had significant result in part 2.
Basha MA, Abdel-Aal NM, Kamel FAH.	Egypt	31.3 ± 7.3 years	RCT (parallel)	34	1.Wii Fit program (WFP) 2.Standard PT program (SPTP)	12 week 3 sessions/ week WFP = 30 min SPTP = 60 min	1. high mobility assessment tool 2. Lower Limb Functional Index 3. timed Up and Go test. 4. 6-minute walk test 5. Isokinetic muscle strength assessment. 6. stability index	WFP had significant result than SPTP.
Samhan AF, Abdelhalim NM, Elnaggar (RK.2020)	Out-Patient Physical Therapy Clinic, Al-Kharj, Saudi Arabia	6-12, EG 9.64 ± 1.98) CG 8.41 ± 2.39 TBSA CG 21.14 ± 3.4% EG 20.35 2.92	Randomized, Controlled Trial	n = 36 (3 excluded) Control Group (16) Experimental Group (17)	-Standard Physiotherapy treatment -Interactive robot-enhanced hand rehabilitation	Consecutive 60 min sessions 3 times per week for 8 weeks followed by additional 30 minutes	-ROM by Goniometer -Hand grip strength by Digital Hand Dynamometer -Objective assessment of a range of gross and fine motor skills etc. by Jebsen Taylor Hand Function Test	Significant difference in total active ROM in experimental group as compared to control group (<i>p</i> -value .015, <i>p</i> -value .013), HGS in Experimental Group was (<i>p</i> -value .001) than control group (<i>p</i> -value .004). JHFT scores was significantly different (<i>p</i> -value .012). In comparison to the control group.

VR = Virtual Reality, JHFT = Jebsen Hand Function Test, HGS = Hand Grip strength, ROM = Range of Motion, RCT = Randomized Control Trail, VO² = Maximum volume of oxygen body can process.

regardless of the patients' subjective experiences.

Researchers have hypothesized that V.R. may exhibit a dose-response relationship, like how higher doses of opioids frequently result in greater pain alleviation. More precisely, more immersive VR environments and systems - which include things like larger and higher-quality visual input, sound effects, the visual and aural exclusion of real-world surroundings, and increased user interaction with the virtual world - reduce pain more successfully than less immersive environments [8, 12]. New virtual worlds and better V.R. devices have been developed since this study was finished. Greater variations in ROM outcomes may be observed if these more recent environments and hardware offer a stronger "dose" of V.R. analgesia, particularly if patients are in excruciating pain during physical therapy.

Immersion V.R. frequently raises concerns about the possibility of simulator sickness, or nausea, especially when combined with opioid painkillers. A computer that allows for minimal lag, the interval between head movements in the real world and the time it takes the computer to produce the altered viewpoint shown in the computer-generated world - was specifically created to be used with the computer-generated world used in much research. Because the virtual environment's architecture was purposefully kept simple and the subjects' movement within the 3D snowy canyon was constrained, less head and neck rotation were needed. Movement in the surroundings was perceived to be moving slowly and along a pre-determined course. When combined, these design elements reduce the chance of experiencing nausea and disorientation when using virtual reality.

Virtual reality is a safe non-pharmacologic supplementary analgesic that is easy to utilize in a hospital setting. It does, however, necessitate the acquisition of specific gear.

Because people with burn injuries are often afraid of moving and frequently refuse to participate in rehabilitation programs due to discomfort, anxiety, or anguish, children vary from adults in that they require additional incentive tactics and programs.

A study determines the Wii-fit rehabilitation along with standard rehabilitation program on function and balance of 34 patients of 31.3 ± 7.3 . The participant who has more than 40.0% burn of partial and full thickness were included. The exercise duration was 60 min. the participants were given total 36 sessions for 12-week 3 session/week. The study findings showed that Wii fit addition with standard exercise program provide better improvement in patient functional capacity and mobility, exercise capacity, balance and muscle strength [7].

A study determines the effect of immersive virtual reality snowball game effect on 65 burn patients of 6-19 years. The duration of treatment was 5 days, and study was crossover design have virtual reality treatment and opioid (analgesic agents) treatment. The outcome measures were Graphic rating scale "GRM" and ROM. The results showed that in single group either VR or opioid ROM was not improved but in cross over after 2nd treatment ROM improves regardless of sequence. The GRM has three pain components including cognitive, affective and sensory. VR with opioid as compared to VR alone have significant effect on pain reduction. The other category of GRM was nausea. The study showed that 80.0% of patients don't have nausea but remaining 60.0% patient have sign of nausea. But it was not clear whether nausea is due to VR or opioids [6].

The management of pediatric hand burns often faces hurdles like movement fear, pain, distress, and anxiety, which can impede traditional rehabilitation methods. This study evaluated the effectiveness of interactive robot-enhanced hand rehabilitation on children's range of motion "ROM", hand grip strength "HGS", and hand function [10].

Children who underwent the robot-enhanced rehabilitation program showed significant improvements in the ROM of their thumb, index, middle, ring, and little fingers compared to those who received traditional therapy. For instance, the total active ROM of the thumb increased from 69.82 ± 14.72 degrees before treatment to 96.82 ± 13.77 degrees after treatment (p -value .015), and these gains were still evident three months later (94.76 ± 13.14 degrees, p -value .013). Similar improvements

were noted for the other fingers, with p -values indicating significant differences post-treatment and at follow-up for the index (p -value .02, p -value .01), middle (p -value .034, p -value .02), ring (p -value .016, p -value .005), and little (p -value .03, p -value .023) fingers, while the control group showed lesser and more variable improvements.

The children in the experimental group exhibited a marked increase in HGS after the robot-enhanced therapy (p -value .001), and this improvement persisted over the three-month follow-up period (p -value .001). In contrast, the control group showed an initial significant increase in post-treatment (p -value .005), but this improvement was not maintained at the follow-up (p -value .08).

Significant enhancements in hand function were also observed in the experimental group, as measured by the Jebsen Hand Function Test "JHFT". Post-treatment, the experimental group scored significantly better on the JHFT compared to the control group (p -value .005), and these improvements were sustained at the three-month follow-up (p -value .012). Within both groups, there was a notable reduction in the time taken to complete JHFT tasks after treatment and at follow-up, but the experimental group consistently outperformed the control group.

Overall, these findings highlight the potential of interactive robot-enhanced rehabilitation to effectively improve the functional outcomes for children with hand burns. The significant improvements in ROM, HGS, and hand function suggest that this approach not only makes rehabilitation more engaging for pediatric patients but also yields better and more sustainable results compared to traditional methods. Future research should focus on the long-term benefits of robot-enhanced rehabilitation and explore its applicability to various types and severities of hand burns.

Discussion

The VR treatment included Wii Fit [13], Xbox [14], interactive games [11], and interactive robot-enhanced hand rehabilitation [15], VR oculus [14], a 3-dimensional canyon with a river and waterfall, as snowflakes drifted down [16]. The VR was compared with standard physical

therapy protocol [15, 17], analgesics [13], home base rehabilitation protocols [13]. The age ranged from 6-66. Most studies were conducted on pediatric patients [11-13, 15, 16]. The outcome measures used were pain, range of motion, grip strength, function and mobility, balance, graphic rating scale, occupational measure, and cardiopulmonary fitness. With standard physical therapy protocol in most cases the anxiety, pain, discomfort, and fear of movement proved to be the biggest challenge to the rehabilitation team in all ages, especially pediatric burns. The problems of poor recovery in outcomes faced by burn survivors are due to scarring, muscle weakness, contracture, cardiopulmonary insufficiency, and poor cooperation with the program [13]. The VR use engaging patients more actively, movement repetition and feedback which lead to neural plasticity and reorganization eventually all of these enhanced motor learning [11].

Pain

Generalized pain: Burn patients often experience significant pain during wound care, although standard care for procedural pain control in the inpatient burn population often incorporates systemic opioids and/or benzodiazepines. Furthermore, a broad range of adverse effects may restrict the application of these medications [12].

The immersive VR showed more optimistic outcomes than less immersive VR because of larger and better-quality visual input, sound effects, the visual and aural exclusion of the real world and enhanced user interaction [17, 18]. The addition of VR in the rehabilitation program for burn victims has speedy and immediate outcomes for pain reduction [13]. According to earlier research, immersive virtual reality can significantly reduce pain in non-burn situations like dental discomfort as well as post-burn wound care and rehabilitation settings [12].

Pain and categories: There are three categories of pain which are cognitive, affective and sensory [12]. The neuromatrix theory of pain covers pain's behavioral aspects, perception of wellbeing, homeostasis and pathological aspects. VR uses an engaging environment target perception and behavioral aspects of neuromatrix theory. VR distracts attention and somatic sensory input which are mostly dis-

rupted. It leads to decreased pain perception in post burn patients. VR demonstrated a significant reduction in the amount of time patients spent reflecting on their pain while receiving physical therapy [16].

VR and distraction

The use of VR causes intention diversion and the emotional component of the pain significantly improves in burn victims [19]. This VR effect leads to pain pattern changes in the brain. The theory determine that a simple distraction can easily change the perception of pain [16, 20].

Due to more engagement and attention of the burn patients in the virtual games played as a component of the interactive robotic assisted exercise, this distraction reduces pain, kinesiophobia for encouragement and stimulation. The routine exercise regimen most often aggravate the pain and discomfort while performing the exercise in the burn population [15].

VR and opioids: VR might show a dose-response relationship, much like how increasing an opioid's dosage usually results in less discomfort [17, 21]. VR with opioids as compared to VR alone had a significant effect on pain reduction.

The Nausea was reported by some of the burn patients after using VR. This nausea, either caused by VR or analgesic effects, was not clear. Further research can determine the exact cause of nausea is either VR environment or analgesics effects. Few researchers also looked at whether the analgesic effects of immersive virtual reality could be sustained via repeated use but further research are needed to answer this affect [12].

Range of motion

With the artificially created environment the new treatment achieved more improvement in the mobility at the joint involved. The treatment given by using a VR device was interesting and of an interactive nature that led the patients to spend more time in performing the exercises and enabled more involvement, ultimately leads to the higher range of motion at the joints and increased flexibility of the muscles [13, 15, 19].

The fact that VR decreased pain complaints without appreciably increasing the range of motion is therapeutically interesting. It is important to remember that pain management and range of motion are two different things that don't necessarily go hand in hand. If patients are experiencing severe pain while undergoing physical therapy. The exercises with VR environment alone with analgesics is more effective in improving the range of motion [17].

Strength

The increased muscle strength was of much importance to perform the routine activities of daily life as it led to functional use of the hand. The VR environment with weight-bearing tasks or with robotics-assisted environment improves muscle strength. As compared to the conventional treatment group, the muscle power and strength were noted as a stronger hand grip with the integration of robotic-assisted therapy [15].

Function, mobility and balance

Traditional rehabilitation exercises are difficult to perform by burn patients because of pain, scar and psychological burden. Exercise performance using VR creates interest in burn patients which increase their strength, range of motion and cardiopulmonary fitness. The overall functional capacity and quality of life of burn patient also increased. The patient give remarks that they felt so much relieved and had a better social interaction than before while using VR [13].

The rehabilitation program of another study resulted in significant enhancements in hand function because of integrating robotic-assisted VR exercises. The games integrated here were focused on tasks inside the computer-generated setting that were very similar to the daily life routine activities. So, the burn patients were getting goal-oriented treatment plan that improved function efficiently than traditional approaches alone. The constructive improvements in the burn patients influenced the quality of life positively. Improved functionality of the hand and less distress led to more participation in routine tasks. The virtual environment in this study also impacts mental health with the improvement of physical health and this also further improved the quality of

life. As the robotic system improved the mental health and distracted the patient from the stressful condition caused by the burn injuries, the more attractive virtual environment led to the better psychological relief [22]. This may be because the virtual environment games were of interactive in nature that changed the focus from fear and anxiety, promoting better overall psychological well-being [15].

The results of a study revealed that after undergoing physical treatment in an immersive virtual reality, participants' subjective assessments of "fun" increased by three times, which may suggest that the virtual reality experience improved their mood or affect. During burn rehabilitation, there is a subjective improvement in mood accompanied by a reduction in pain perception. There were also the reports of nausea to the patients that were due to a common opioid side effect or plausible virtual reality-induced "simulator sickness" because nausea assessments were only obtained in the standard analgesia plus virtual reality condition and were not obtained in the standard analgesia without virtual reality condition [12].

Conclusion

Preliminary evidence indicates that virtual reality interventions could be beneficial in promoting functional recovery in patients with burn injuries. The studies reviewed suggest VR can reduce pain during rehabilitation, improve range of motion, and increase patient engagement. However, the limited number of studies and the variability in VR methods and outcome measures restrict the generalizability of these findings. Further rigorous research with standardized protocols is needed to validate these results and guide clinical practice. Future investigations should aim for larger sample sizes and longer follow-up periods to thoroughly evaluate the effectiveness of VR in burn rehabilitation.

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Disclosure of conflict of interest

None.

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