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Pain Relief & Movement Recovery in Upper Limb Paediatric Burn: Is Immersive Virtual Reality Effective?

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ABSTRACT

Background: Worldwide attention for paediatric burns that affect long-term functionality and quality of life. Potential evidence regarding virtual reality (VR) systems have also been researched and demonstrated some promise in managing pain and promoting functional activities. In addition, well-known support systems and multimodal therapy techniques may lessen general anxiety, which in turn may lessen the perception of pain during the healing process.

Purpose: This study aimed to declare the difference between using immersive virtual reality versus traditional physical therapy on pain management, and improvement of joints` mobility in paediatric burn patients.

Method: Sixty participants of both genders with acute burn patients have 2nd degree thermal burn injury affected upper limb from Al Kasr El-Aini and Om El-Misryeen Hospitals. They were divided into two equal groups at random: Group A underwent splinting and three sessions of traditional physical therapy per week for eight weeks, along with an immersive virtual reality programs and group B received only traditional physical therapy for eight weeks, three sessions each week, and splinting. Evaluation involving color visual analogue scale & digital goniometer. Statistical analyses with significance level 0.05 level.

Result: Baseline analysis showed no significant differences following treatment, both groups showed a large rise in digital goniometer reported values and a significant drop in colour visual analogue scale reported values. However, following therapy, group A showed a considerable decrease in discomfort and increase in mobility in their upper limb joints when compared to group B.

Conclusion: Application of immersive virtual reality and/or traditional physical therapy were valuable for managing paediatric burn patients, with superiority for immersive virtual reality in terms of pain management, and joints` mobility. Therefore, could be recommended in immersive virtual reality for paediatric burn patients' management.

Keywords: Color visual analogue scale, Digital goniometer, Immersive virtual reality, Paediatric burn, Traditional physical.

INTRODUCTION

According to the World Health Organization's most recent statistics, paediatric burns are a worldwide burden that have significant socioeconomic effects and drive-up healthcare expenses. with obvious negative impact on quality of life [(1)]. Current estimated evidence that paediatric burns cause unpredictable and devastating trauma that affect long-term functionality, quality of life and general health status and are associated with high morbidity and mortality [(2)].

As well, burn degree and its TBSA often were variable across most of epidemiological studies, as well the 2nd degree of burn was the most reported one among pediatric burn victims [(3)]. No debut that restriction in resources at low- and middle-income regions, also poor environments could easily be defined as the prime challenging issue within preventive programs targeting reducing mortality, and comorbidities among burn victims, mainly among pediatric population [(4)].

Recent comprehensive and robust mainly quality of care provided for pediatric burn victims focuses on gaining appropriate burn care services, even within poor resource settings. Any intervention's scale-up depends on several elements, such as the intervention itself and if it is reliable, pertinent, simple to implement, and offers a proportionate benefit [(5)].

Often, anxiety among pediatric burn victims was reported post-burn those almost reported pain accompanied 6-12 months burn injuries [(6)]. **Duke *et al.*** [(7)] revealed that pediatric burn population were double and a half more likely requires health care services compared to other children, regardless their burn criteria.

Inadequate pain management has a poor effect on burn patients' recuperation as well as their confidence, physical and emotional well-being, and compliance with their treatment plan [(1)]. One of the cutting-edge techniques for diverting patients' attention from pain and promoting an immersive, individualised fitness program is virtual reality (VR). Patients can divert their attention from unpleasant treatments by immersing themselves in the virtual world [(8)].

As well, virtual reality (VR) technologies have become popular non-pharmacological pain management tools. Using virtual reality or exergaming is a novel, innovative therapeutic modality that immerses targeted individuals in a computerized generated, three-dimensional environment, multi-sensory status wherein being interact with virtual environment [(9)].

In addition, a combined physiological and psychological therapeutic gains were ensured in terms of

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physical exertion across VT training strategy in line to encourage sedentary of overcome fear of targeted therapeutic procedures [10]. Furthermore, immersion virtual worlds give users the impression that they are physically present. The degree of presence is determined by the VR features that users can access. Virtual reality has a great variety ranged from fully immersive to completely passive approach with surrounding environments, including active interacting with virtual environment [11].

Recently, VR could permit pediatric burn population a non-pharmacological approach for real pain modulation. Such therapeutic modality may be recognized as a behavioral approach that utilized early through toy distraction, particularly for children, as well relaxation modalities in case of adult population [12].

No debut that fully immersive virtual reality provides both burn heath care team, also pediatric burn victims, and their family's obvious satisfaction as the receiving individuals feels VR like a fun, realistic gaming [13]. Therefore, current study was conducted to declare the difference between using immersive virtual reality versus traditional physical therapy on pain management, and improvement of joints` mobility in paediatric burn patients.

MATERIALS AND METHODS

Study design: This double-blinded, randomized controlled trial was carried out through the period from January 2024 to September 2024 at Burn Units of Kasr - Ani and Om El-Misryeen Hospitals, Giza City, Cairo.

Ethical approval: The Ethics Committee of College of Physical Therapy, Cairo University approved this study, which met with the Helsinki Declaration (No.: P.T.REC/012/005156)). The study's goals had been communicated to the participants & their ability to discontinue participation at any moment. Prior to participation, a formal consent form was filled out by each participant. This study followed the guidelines of CONSORT.

Calculating the sample size: To get sufficient statistical power, a sample size of 60 patients was estimated using the G*POWER statistical program (version 3.1.9.4; Franz Faul, Universität Kiel, Germany). **Hoffman *et al.*'s earlier study** [14] served as the basis for estimating the sample size. As a result, it was decided that 30 patients per group was the necessary sample size. The computations were predicated on an effect size of 0.86, a power of 80%, and a two-sided 5% significance level.

Randomization: Sixty participants with thermal burns of upper extremity were randomized to either group A (Immersive VR) or group B (Traditional physical therapy) using the block randomization program generated by computer at http://www.randomization.com/. To reduce bias and group variability, participants were randomized with 1:1 allocation ratio. Randomization was conducted by a single author who did not participate in treatment, gathering data, or recruitment. To make sure of the concealed allocation, randomization codes were consecutively labelled and kept confidential in concealed opaque envelopes.

Outcomes measures: Before and after the 8-week intervention, measurements were made.

Participants: Sixty paediatric burned participants '7-15 years old' of both genders with 2nd degree thermal burn injury that affected upper limb in Al Kasr El-Aini and Om El-Misryeen Hospitals, were allocated randomly into two equal groups (twenty patient for each), with age range was 7-15 years old. They were referred for physical therapy management.
Group A got splinting, three sessions per week for eight weeks, and an immersive virtual reality program in addition to a traditional physical therapy program. Group B received merely a traditional physical therapy program, consisting of three sessions per week for eight weeks, along with splinting.

Inclusion Criteria: Age of **p**articipants range was 7-15 years old of both genders. All paediatric burn patients were suffering from 2nd degree acute stage thermal burn injury affected upper limb diagnosed by their physicians, and referred for physical therapy management.

Exclusion Criteria: Participants with cardiac, diabetic, or peripheral vascular, central nervous system disorders and those who had dermatological lesions or have life-threating disorders (renal failure or myocardial infarction). Also, those who had unstable fractures, facial or hands burn, or incapacity to handle visual stimuli, such as migraines that are exacerbated by light, especially those who can't handle head-mounted displays.In addition, those with visual or auditory lesions or held medical red flags or uncooperative children.

Assessment instrument: Colour visual analogue: A validated subjective scale used to assess both acute and chronic pain. A handwritten mark on a 10-cm line that depicts a continuum between "no pain" and "worst pain" is used to record scores [15].

Digital goniometer: It is is a commonly used assessment instrument for objective mobility evaluation, it is 6 inches, 2.53 oz, 1x360 degree stainless steel goniometer [Outlev/ Outlev-01, China]. It was used to monitor improvement of loss of mobility including joints ''shoulder flexion/abduction, elbow flexion/ extension, forearm supination/pronation, and wrist; flexion/ extension' [16].

Therapeutic instrument:

Immersive virtual reality (VR) devices: It looks like monitors installed on the head with motion-tracking capabilities, allow users to engage fully with interactive 3D environments. These devices have been shown to effectively distract pediatric patients from painful stimuli during burn care by providing engaging, immersive experiences that reduce anxiety and discomfort. Research supports the use of immersive VR to improve patient tolerance during procedures like dressing changes and rehabilitation exercises [17].

Assessing methods: History taking: At the beginning of the current investigation, a thorough medical history was obtained from each participant and documented.

Specific outcome measures

Color visual analogue scale measurement procedures: It was used to assess pain intensity level. Each paediatric burn patient was asked to record by making the handwritten mark on the shaped like a thermometer, with color that represented actual pain felt on the back of the scale that is a 10-cm line continuum between 'no pain' gradually gets darker red up to 'worst pain' before and after the intervention of this study [18].

Digital goniometer measurement procedures: For each paediatric burn patient had undergone affected upper limb range of motion measurement for 'shoulder; flexion/abduction, those were conducted by this study trained investigator in order to eliminate inter-investigator error [16].

Figure (1). Shoulder flexion measurment procedures.

Therapeutic procedures

Immersive virtual reality treatment (Group A only): immersive VR session that entailed spending thirty to forty minutes each session, three times a week for eight weeks, embodying three different characters: A rock climber, a superhero, and a powerful boxer [19]. Each paediatric burn patient in groups (A) have been instructed briefly, researcher prepared the Oculus VR unit with supported immersive VR video session, then connected immersive VR unit headset glasses, and applied on the patient`s eyes, and secured in a comfortable manoeuvre.

Figure (2). Immersive VR procedures

Paediatric burn patients (Depending on their personal preferences and tolerance for standing and sitting) were given the option to complete these tasks either way. Three experiences, each lasting roughly six minutes, were finished in a single session with five-minute breaks between embodiments. Muscular boxer/Super hero, also Rock climber, where the pediatric patients had fully engaged in immersive VR. Initial familiarization with game, and scoring system was explained based on kinect motion sensor record of pediatric burned participants` movements through mapping of body position. Afterwards, the players` avatar was visualized in the game, thus replicating each game with guidance, verbal instructions in order to complete one round of boxing. The pediatric burned patient had to control targeted burned upper extremity in shoulder flexion and abduction. Those were components required for successful boxing match and also in order to gain awarded points as possible without errors [19].

Traditional physical therapy protocol (Group A & B): Each paediatric burn patient in both groups received ROM exercise for all Joints, muscle strengthening exercise, functional training and stretching exercise of affected upper limb musculatures. Each session lasts 30-40 minutes, three sessions per week for eight weeks, and splinting.

Statistical Analysis

The statistical package for social studies (SPSS) version 25 for Windows (IBM SPSS, Chicago, IL, USA) was used for all statistical analyses. Descriptive statistics were calculated as mean ± standard deviation (SD). The chi squared test and unpaired t-test were used to compare the subject characteristics of the various groups. Data with a normal distribution were examined using the Shapiro-Wilk test. The homogeneity between groups was assessed using Levene's test for homogeneity of variances. A mixed MANOVA was used to examine how the therapy affected shoulder ROM and VAS. Post-hoc tests using the Bonferroni correction were carried out for subsequent multiple comparison. The level of significance for all statistical tests was set at $p \leq 0.05$.

RESULTS

- Subject characteristics: The subject characteristics of groups A and B were displayed in table (1). TBSA, upper limb TBSA, and sex distribution did not significantly differ across groups ($p > 0.05$).

Impact of the intervention on shoulder and elbow range of motion, DASH, and VAS: Significant main effects of treatment ($F = 41.16$, $p = 0.001$, partial eta squared = 0.82) and time ($F = 1276.12$, $p = 0.001$, partial eta squared = 0.99) were also shown by mixed MANOVA, along with significant interaction effects of treatment and time ($F = 165.86$, $p = 0.001$, partial eta squared = 0.95).

Within group comparison: Both groups' VAS significantly decreased after therapy when compared to before ($p > 0.001$). Group A's and Group B's respective VAS change percentages were 62.87 and 51.05%, and 48.10 and 47.60% respectively (Table 2).

Both groups' shoulder range of motion significantly increased after treatment when compared to before ($p > 0.001$). Group A's shoulder flexion and shoulder abduction changed by 8.41, 36.80, 27, and 29.72%, while Group B's changes were 3.44, 12.93, 12.03, and 12.13% respectively (Table 3 & 4).

Between group comparisons: Prior to therapy, there were no discernible differences between the groups ($p > 0.05$). Following treatment, group A's shoulder flexion (effect size = 1.52) and shoulder abduction range of motion (effect size = 7.29) significantly increased in contrast to group B ($p > 0.01$), while the VAS significantly decreased (effect size = 1.71) (Tables 2-4).

Table (1): Comparing the characteristics of participants between both groups

	Group A Mean ± SD	Group B Mean ± SD	MD	t-value	p-value
Age (Years)	9.63 ± 2.85	10.21 ± 3.19	-0.58	-0.73	0.47
TBSA	24.3 ± 3.37	25.17 ± 3.71	-0.87	-0.94	0.34
Upper Limb TBSA	3.95 ± 0.94	4.44 ± 3.47	-0.49	-0.73	0.46
Sex, n(%)					
Boys	16 (53.3%)	14 (46.7%)	$\chi2 = 0.27$		0.61
Girls	14 (46.7%)	16 (53.3%)			

SD, standard deviation; MD, mean difference; $\chi2$, Chi-squared value; p-value, probability value, TBSA: total body surface area, n: number, %: percentage.

Table (2): Mean cVAS before and after treatment of both groups

	Group A Mean ± SD	Group B Mean ± SD	MD (95% CI)	p-value	Effect Size
VAS					
Pre-Treatment	7.73 ± 0.74	7.90 ± 0.76	-0.17(-0.55, 0.22)	0.39	
Post-Treatment	2.87 ± 0.63	4.10 ± 0.80	-1.23 (-1.61, -0.86)	0.001	1.71
MD (95% CI)	4.86 (4.54,5.19)	3.80 (3.47, 4.13)			
% of change (effect size)	62.87 (7.07)	48.10 (4.87)			

SD, standard deviation; MD, mean difference; CI: confidence interval; p-value, probability value, effect size by Cohen d (small 0.2, medium 0.5, large more than 0.8), VAS: Visual analogue scale.

Table (3): Mean shoulder flexion and abduction ROM before and after treatment of both groups

Rom (Degrees)	Group A Mean ± SD	Group B Mean ± SD	MD (95% CI)	p-value	Effect Size
Shoulder Flexion					
Pre-Treatment	156.93 ± 4.49	158.07 ± 6.38	-1.14 (-3.98, 1.72)	0.43	
Post-Treatment	170.13 ± 3.46	163.50 ± 5.09	6.63 (4.38, 8.88	0.001	1.52
MD (95% CI)	-13.20 (-14.23, -12.17)	-5.43 (-6.4, -4.40)			
% of change (effect size)	8.41 (3.29)	3.44 (0.94			
	p = 0.001	p = 0.001			
Shoulder abduction					
Pre-treatment	118.33 ± 5.14	120.40 ± 5.02	-2.07 (-4.69, 0.56)		
Post-Treatment	161.87 ± 3.70	135.97 ± 3.40	25.9 (24.06, 27.74)	0.001	7.29
MD (95% CI)	-43.54 (-45.11, -41.96)	-15.57 (-17.14, -13.99)			
% of change (effect size)	36.80 (9.72)	12.93 (3.63)			
	p = 0.001	p = 0.001			

SD, standard deviation; MD, mean difference; CI: confidence interval; p-value, probability value, effect size by Cohen d (small 0.2, medium 0.5, large more than 0.8), ROM: Range of motion.

DISCUSSION

Up to date, Children burn management has an extended influences on their functionality, their quality of life and their general health status. There are numerous pharmacological and non-pharmacological interventions, where the later approaches have the superiority in avoiding major side-effects of analgesics. Nevertheless, paediatric distraction throughout receiving medical procedures could be gained across highly interactive artificial world multisensory immersion in a controlled virtual environment that fortunately led to burned child feeling cut off [(20)].

Our results revealed a significant decrease in color visual analogue scale output in terms of pain management, and significant increase in digital goniometer values in terms of upper extremity joints mobility in both groups at post-treatment compared to pre-treatment ($p < 0.001$). There were highly significant differences between both groups A, and B pre- and post-treatment cVAS scores and digital goniometer values.

Usage of various distraction strategies involving virtual reality in paediatric burn management reveals significant therapeutic benefits, thus it designed to enhance painful stimuli distraction in a more neutral approach [(21)]. This could explain our findings that ensured superiority of immersive over traditional physical therapy program done individually based on main targeted underlying distractive technologies that has a crucial role of various interactive videos, or games mainly involved in immersive virtual reality modality that was superior in terms of paediatric burn management.

According to **Xiang *et al.*** [(22)], who proved that immersive virtual reality as a distractive noninvasive approach ensured that most children received virtual reality modality who reported mild up to moderate pain scores have a significant improvement in terms of pain distraction while conducting all painful therapeutic procedures in case of receiving virtual reality modality. In the same line, could explains our findings based on that virtual reality is regarded as an additional tactic that has been shown to be effective in distracting children's focus during uncomfortable procedures.

On historical point of view, according to **Taylor *et al.*** [(23)], children undergoing minor surgery with virtual reality and local anaesthesia showed no difference in their pain scores compared to historical controls (no virtual reality), as well earlier clinical trial has stated that no significant variations in terms of pain intensity, unless virtual reality permits better satisfaction while utilizing virtual reality modality [(24)]. On the other hand, **Canares** [(25)] had reported that application of virtual reality modality within early healing and middle phases of paediatric burned population has no differences in distraction. Other clinical trials stated that virtual reality application ensured better management outcomes, which could be explained based on the modulated pulse

rates, which stated that virtual reality aids in lowering raised pulse rates [26].

Current therapies aimed at reducing discomfort while conducting traditional physical therapy via application of virtual reality, which were found to reduce the burden of painful procedures on paediatric burned patients on their physiological parameters and actual response for their received procedures [27]. Moreover, another recent clinical trial conducted by **Ozalp *et al.*** [28] ensured that sex in the control group was negatively correlated with children's behavioural discomfort. It might be because both sexes react similarly to unpleasant operations during this time, particularly when they are young [28].

According to **Gerber *et al.*** [29] virtual reality as a non-invasive modality could be used as a better acceptability of computer game-based intervention in order to enhance paediatric population engagement rehabilitation with extra entertaining games that gain additional motivation and compliance among children. Unless, children with upper limbs impairments always undergo painful repetitive therapeutic and rehabilitative procedures in order to gain best improvement in their functional capabilities of affected regions. That easily gained through additional benefits f involving virtual reality in those children rehabilitation that provides opportunities for modulating painful complains [30]. Additionally, **Wong *et al.*** [26] reported that virtual reality is an inexpensive, simple intervention that can be set up in a matter of minutes, unless a child life specialist is needed to assist with installing it on the child's head and offering direction and information prior to the game starting. Furthermore, **Dascal *et al.*** [31] stated that virtual reality's adaptability and diversity of material make it a potentially effective therapeutic tool for pain management, making targeted individual be able to receive painful medical procedures in order to optimize their improvements.

In the same line with our findings, **May *et al.*** [32] ensured usage virtual reality through therapeutic intervention for managing burned children in terms of reducing utilization of analgesic medicines requirements, and actual pain reduction and modulation of anxiety throughout painful medical procedures on managing their prospective clinical trial on twenty children (7-17 years old) received video game Dreamland® virtual reality approach. May and his colleagues stated that virtual reality provides superiority in terms of pain modulation and anxiety management in management of paediatric burned patients.

The findings of the current study indicated that physical therapists and other medical practitioners should think about the effects of adding either immersive virtual reality and/or passive virtual reality, which are valuable for managing paediatric burn patients, with superiority for immersive virtual reality in terms of pain management, and joints` mobility. Therefore, immersive virtual reality must be recommended for paediatric burn patients management. The study's authors noted that additional investigations are required before this can be deemed unquestionably beneficial.

CONCLUSION

Application of immersive virtual reality is valuable for managing paediatric burned patients in pain management, and joints` mobility, therefore could be recommended.

Conflict of interest: The writers stated that there were no conflicts of interest in the content of this paper.

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