Article

EFFECT OF VIRTUAL REALITY ON HAND DYSFUNCTION POST BURN

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Abstract

Background: Severe functional impairments and negative effects on both mental and physical well-being can result from burns to the hands Purpose: is to evaluate the impact of virtual reality in improving ROM, hand function and strength in rehabilitation of burned hand. Subjects and methods: Forty-two patients with (second-degree) hand burn participated in this study. Their ages range from 20-45 year. Group (A) involved 21 patients was given in Virtual reality (VR)-based rehabilitation plus conventional hand rehabilitation, Group (B) involved 21 patients was given conventional hand rehabilitation only. Patients in Group A were treated for thirty-minutes standard conventional program and thirty-minutes VR-based rehabilitation (leap motion controller) 3 sessions per week for 8 weeks. Patients in group B were given conventional hand rehabilitation (CON) (scar massage, stretching exercises, ROM exercises, strengthening exercises, splint) 3 sessions per week for 8 weeks. Patients in both groups were recruited from merit university outpatients clinic. Initial measurements were taken before the first session, then again after 2 months of treatment. Results: all the ROM of the hand improved markedly post intervention among both groups and most of these improvement were statically significant with(p<0.05) , regarding the hand grip there was a significant improvement among both groups with (p< 0.001) and regarding the hand function there was a significant improvement among both groups with (p< 0.001) Conclusion: VR based rehabilitation has a non- significant effect on improving hand range of motion, hand power and hand function in patients with partial-thickness (second-degree) burn in comparison with conventional hand rehabilitation. despite this ,there was an improvement in each group separately.

Key words -- ***Virtual reality- conventional hand rehabilitation – Goniometer- hand held dynamometer - Arabic version of Quick DASH and second-degree burn.***

I.INTRODUCTION

Burn injuries have a significant risk of morbidity and mortality, making them an underappreciated injury. Burn injuries, especially those that are severe, can result in multiple organ failure because of potentially challenging-to-manage immunological and inflammatory responses, metabolic problems, as well as distributive shock.1 Major burn victims often have hand involvement; over 50% of burn survivors are known to have hand involvement; among inpatients with burn injuries in 2007, 48.12% had burns on their upper and lower extremities. Burns to the hands can cause serious functional impairments and negative effects on mental and physical health. 2. The world has changed significantly in recent years as a result of technological advancements in rehabilitation. There is a wide range of equipment available now that is both user-friendly and equipped with many settings and functionalities. Virtual reality is shorthand for a set of technologies that generally comprise a computer with the ability to animate in real-time, manipulated by wired gloves or other controllers, and a location tracker. In addition to, a display for visual output on a head-mounted device. Recently, VR was defined as ‘an artificial environment that is experienced through sensory stimuli such as images and sounds provided by a computer and in which our actions partially determine what happens in the environment’. New information can be found and many benefits can be gained through the use of current technology to the health sector.3. Current studies suggest that VR exercises can aid in functional recovery from injuries affecting the upper limbs. This is due to the fact that task-specific training showed to be more effective when practicing activities in a randomized manner with positive feedback .

II. Materials and methods

Subjects

Forty-two patients with (second-degree) hand burn participated in this study. They aged from 20-45 years. Group (A) included twenty one patients who took part in Virtual reality (VR)-based rehabilitation. Group (B) included twenty one patients who participated in conventional rehabilitation. the study was conducted from April to June 2024. Treatment sessions were three sessions per week for 8 weeks. All patients included in the study are free to withdrawal at any time. Informed consent was obtained from all participants following a thorough description of the study.

Instruments and evaluation procedures

Goniometer One common way that physiotherapy clinics measure range of motion is with the utilization of manual goniometry. The primary advantage of this method is that it relies mainly on the examiner's previous experience to determine how easy it is to measure, and the tool is relatively inexpensive. Manual goniometry became widely used in physiotherapy clinics because to these advantages. The universal goniometer is regarded as having good to excellent reliability when used to measure the joints in both the upper and lower extremities 5

Arabic version of the Quick-Dash Questionnaire for upper extremity disorders The DASH assessment is made up of 30 items that assess disability and symptoms. The study did not include the two DASH optional scales (sport/music and work). The disability/symptom scale has five-point Likert scale items. A score on a scale from 0 (no disability) to 100 (maximum disability) can be determined if at least 27 out of the 30 items are filled out. 6

Hand dynamometer One benefit of using a handheld dynamometer is that it can automatically measure and display the greatest grip power that can be achieved, up to a maximum of 200 lbs. (90 kg). In addition to comparing past and present data, it can also assess outcomes based on age and gender. Various grip sizes allow the instrument to be adjusted to accommodate a wide range of hand sizes.7

Treatment procedures

Patients were randomized into two groups equivalent in number: Group (A): received virtual reality with leap motion controller in addition to conventional hand rehabilitation (scar massage, stretching exercises, ROM exercises, strength training, splint.) group (B): received the conventional hand rehabilitation sessions for 30 minutes only. They received treatment 3 sessions per week for 8 weeks.

Group (A): Twenty one patients received virtual reality rehabilitation with leap motion controller in addition to conventional hand rehabilitation (scar massage, stretching exercises, ROM exercises, strength training , splint.) Over the course of three sessions per week for eight weeks, participants in the VR group participated in three 30-minute sessions of traditional therapy and one 30-minute session of VR-based rehabilitation. 8

Group (B): Twenty one patients received the conventional hand rehabilitation (scar massage, stretching exercises, ROM exercises, strengthening exercises, splint.)sessions for 60 minutes only three sessions per week for 8 weeks.

III. Results

The statistical analysis was performed utilizing SPSS for Windows, version 25 (SPSS, Inc.) (IBM-Corporation, Chicago, USA; August 2017). This study included two independent variables. The first variable was the (tested group); between subjects factor which had two levels. The second variable was the (measuring periods); among subject factor which had two levels (pre, post). In addition, this study involved three tested dependent variables (Hand grip strength , Hand function , ROM of hand joints). In this study, the mean, the standard deviation, and the standard error was calculated for all the patients after the detected time of the study. Paired t-test to compare within each group to detect level of significance in each group. The mean, the standard deviation was used as a primary source of connecting facts about each parameter to measure central tendency.9

Table 1:Descriptive statistics for the mean age, for the two tested groups

Group	Mean	Std. Deviation	Median	Minimum	Maximum
A	32.76	8.160	33.00	20	44
B	31.48	6.038	30.00	23	41
Total	32.12	7.120	31.50	20	44

T test = 0.580, P value = 0.565 (Non significant)

Table 2: Descriptive statistics for Pre-intervention ROM between both groups

Range of movement		Group A	Group B	t test	P value
Wrist	Supination	72.00±8.03	75.00±6.71	1.314	0.196(NS)
	Pronation	75.71±7.49	76.67±8.42	0.387	0.701(NS)
	Flexion	70.00±7.25	74.00±9.59	1.525	0.135(NS)
	Extension	64.33±7.13	69.29±9.52	1.908	0.064(NS)
	Radial deviation	12.62±3.64	11.48±1.33	1.352	0.184(NS)
	Ulnar deviation	25.24±5.59	28.10±6.02	1.595	0.119(NS)
PIPs	Thumb	58.33±7.80	61.90±7.50	1.513	0.138(NS)
	Index	62.86±16.25	69.29±11.43	1.483	0.146(NS)
	Middle	68.57±13.98	74.52±10.60	1.555	0.128(NS)
	Ring	72.14±13.19	78.10±9.81	1.660	0.105(NS)
	Little	74.29±10.28	77.86±7.51	1.285	0.206(NS)
DIPs	Index	65.05±10.0	69.52±7.05	1.676	0.102(NS)
	Middle	66.19±10.24	69.52±6.50	1.260	0.215(NS)
	Ring	63.43±7.57	67.38±7.35	1.716	0.094(NS)
	Little	66.71±7.13	70.00±6.08	1.608	0.116(NS)
MCPs	Thumb	43.05±6.05	45.24±5.12	1.267	0.212(NS)
	Index	69.14±8.97	71.90±7.82	1.064	0.294(NS)
	Middle	70.29±9.18	75.00±7.58	1.815	0.077(NS)
	Ring	73.81±6.69	75.00±10.72	0.432	0.668(NS)
	Little	74.90±11.26	77.38±10.44	0.739	0.464(NS)

Table 3 :Descriptive statistics for Post-intervention ROM between both groups

Range of movement		Group A	Group B	t test	P value
Wrist	Supination	80.48±7.40	78.86±6.25	0.766	0.448(NS)
	Pronation	82.00±7.14	79.57±8.45	1.006	0.320(NS)
	Flexion	79.76±8.87	77.14±9.43	0.927	0.359(NS)
	Extension	77.14±8.88	74.29±9.78	0.991	0.328(NS)
	Radial deviation	13.76±1.34	13.81±1.60	0.105	0.917(NS)
	Ulnar deviation	38.19±4.46	38.19±11.47	0.372	0.712(NS)
PIPs	Thumb	72.43±6.96	70.52±6.31	0.929	0.358(NS)
	Index	78.57±12.26	75.95±9.95	0.760	0.452(NS)
	Middle	84.38±7.68	80.48±9.34	1.479	0.147(NS)
	Ring	84.52±9.26	82.62±9.83	0.646	0.522(NS)
	Little	86.67±7.30	83.10±7.50	1.564	0.126(NS)
DIPs	Index	76.43±3.57	71.67±14.46	1.296	0.203(NS)
	Middle	77.14±4.35	74.38±5.32	1.843	0.073(NS)
	Ring	75.71±6.18	73.33±6.26	1.241	0.222(NS)
	Little	75.24±3.70	74.05±4.66	0.916	0.365(NS)
MCPs	Thumb	48.43±3.85	48.43±4.03	0.000	1.000(NS)
	Index	74.29±10.87	75.62±7.07	0.471	0.640(NS)
	Middle	81.43±6.15	78.33±6.58	1.574	0.123(NS)
	Ring	82.57±8.60	78.48±10.45	1.386	0.173(NS)
	Little	83.81±9.86	81.05±10.42	0.882	0.383(NS)

Table 4 :Descriptive statistics for Pre versus post-intervention grip strength among both groups

Group		Before	After	Paired T test	P value
A	Mean	78.43	90.43	9.860	<0.001 (HS)
	Std. Deviation	21.586	23.608		
	Median	90.00	96.00		
	Minimum	50	59		
	Maximum	109	122		
B	Mean	84.00	88.86	4.531	<0.001 (HS)
	Std. Deviation	22.980	23.961		
	Median	95.00	96.00		
	Minimum	53	55		
	Maximum	115	120		
Total	Mean	81.21	89.64	8.636	<0.001 (HS)
	Std. Deviation	22.200	23.507		
	Median	90.00	96.00		
	Minimum	50	55		
	Maximum	115	122		

Table 5:Descriptive statistics for Pre versus post-intervention hand function score among both groups

Group		Before	After	Paired T test	P value
A	Mean	54.95	29.24	16.613	<0.001 (HS)
	Std. Deviation	16.648	15.079		
	Median	57.00	27.00		
	Minimum	25	4		
	Maximum	84	61		
B	Mean	46.43	36.48	6.466	<0.001 (HS)
	Std. Deviation	15.986	16.318		
	Median	45.00	36.00		
	Minimum	20	12		
	Maximum	77	68		
Total	Mean	50.69	32.86	10.898	<0.001 (HS)
	Std. Deviation	16.687	15.944		
	Median	51.00	33.50		
	Minimum	20	4		
	Maximum	84	68		

IV. Discussion

In this section, we summarize this study as well as discuss some challenges and future directions.

The present study was done to evaluate the impacts of VR based rehabilitation (leap motion controller). The findings of this study revealed that there was a statistically significant enhancement in (Handgrip strength and hand functions) with (p value <0.001) among both groups A and B as well as physical functioning and a significant improvement in hand range of motion (p value <0.05) among both groups. Contrary to expectations, the study did not find any worsening of symptoms or negative side effects. One of the key factors contributing to hand dysfunction and limited range of motion is the fear of movement as well as pain associated with burned hands.

In terms of grip strength, hand function, as well as range of motion, however, groups A and B did not show statistically significant improvements.

The impact of the Leap Motion controller on individuals with burned hands is a comprehensive examination, drawing insights from both user experiences and existing literature.

Regarding the results of study group A : patients who participated in Virtual reality (VR)-based rehabilitation plus conventional hand rehabilitation .The results were agreed with :(**Brokaw et al .,(2015)- Yu et al.,(2016)- Gotz et al .,(2017) - Edwin et al .,(2020)- Wu YT et al., (2019)- Viglialoro et al .,(2020)- Johansen et al., (2020)- Tarakci et al .,(2020) and Jobanputtra Y and Telang P (2022)).**

One effective method of motivating individuals to take part in rehabilitation programs is the usage of physical rehabilitation exergames (PREGs), according to Brokaw et al. (2015).10

By detecting hand motion, the leap motion controller device motivates rehabilitation patients to work together and complete therapeutic tasks (Yu et al.,2016).11

According to Gotz et al. (2017), LMC is an effective active treatment that requires a great deal of commitment as well as motivation. The device has the potential to enhance motor function in the upper extremities by acting on brain plasticity. Repetition allows the brain, a sophisticated neural network, to allow reprograming of itself 12.

The study highlighted positive outcomes, consistent with the findings of virtual rehabilitation research, The leap motion controller improves hand functionality, scar thickness ROM, grip as well as pinch power, and other parameters by analyzing patient questionnaires according to a previous research. Using LMC games, burn patients were able to receive training and rehabilitation. 13

For patients with burns, for the sake of example, the therapists noted that leap motion might be utilized without suggesting any physical hazards. Therapists have noted that LM can identify important hand joints and some complicated movements, which could aid in the rehabilitation of fine and coarse motor skills as well as motion, even if they would like the LM recognize more movements overall.14

The leap motion controller is a ludic device that has the potential to bring individuals together in an imaginative and entertaining setting, where they can overcome obstacles and accomplish objectives by coordinating their finger and hand movements in real-time. As previously mentioned by Viglialoro et al. 15

Another study that came in agreement with Johansen et al. 16. They found that using LMC as a motion-controlled video game in conjunction with CON can be a great way for improving motor function in the upper limbs, particularly manual skills. This is because LMC can be tailored to each patient's requirements, which makes the therapy more effective and attractive for speeding up recovery.

Also, both groups saw significant improvements in grip as well as pinch strength after training. Actually, in the LMC training, there was zero resistance from actual items. Consequently, this is rather surprising, but it could be because the hand is used so frequently in the game and since the amount of objects and speed rise as the game progresses.17

A larger body of research supports hand rehabilitation, however according to Jobanputtra Y and Telang P (2022), LMC technology has major benefits over competing motion capture systems due to its flexibility, ease of use, affordability, market availability, and lack of penetration. education for patients with burn injuries. 18

On the other hand it was observed that there was non-significant difference in pre and post intervention among group A in ROM for(wrist redial deviation and MCPs of index) and this was at the same line with Edwin et al .,(2020) who report that after about an hour of using LMC, it starts to overheat. In addition, both the developers as well as the therapists found the LM's capturing field to be somewhat limited. About 150° of field of vision and 25 to 600 mm of detection range are provided by the instrument.7 Therefore, it is difficult to follow a hand that is moving in two directions at once.14

Regarding the results of control group B : patients who participated in conventional hand rehabilitation only .The results were at the line with:

(**Paratz et al. (2012) - Schneider et al. (2012)- Ardebili et al. (2014) - Perera et al. (2015)- Tang et al.(2015)- Hundeshagen et al.(2017)).**

Both sets of findings corroborated those of Perera et al. (2015), who investigated the "The impact of burn on ROM of upper extremities, functions of hand/s as well as activities of daily living" and discovered a significant positive association among active ROM and hand function in carrying out certain ADLs.19

In their study titled "Effect of educational program based on exercise therapy on burned hand function," Ardebili et al. (2014) found that the hands exercise program effectively improved hand function20. This finding is in agreement with that of Paratz et al. (2012), who demonstrated in their study named "Intensive exercise after thermal injury improves physical, functional, and psychological outcomes," that a physical therapy training program successfully improved the physical and functional abilities of patients with hand burns while also positively impacting their psychological well-being.21

In line with the findings of Schneider et al. (2012), who conducted research titled "Efficacy of inpatient burn rehabilitation: A prospective pilot study examining a range of motion, hand function, and balance," it was found that administering rehabilitation programs, specifically physiotherapy education, to patients suffering from hand burns significantly improved their hand ROM along with normal function.22

Physical and mental health, ADL performance, as well as quality of life were all positively impacted by rehabilitation therapies for patients having moderate to severe burns, according to research by Tang et al. (2015).23

Furthermore, Hundeshagen et al. (2017) noted that in order to assist patients in regaining optimal function, it is necessary to implement a thorough rehabilitation program. Preventing edema as well as contracture, preserving or enhancing ROM, functional recovery, as well as the formation of keloid scars are all essential goals of early physical therapy and occupational therapy applications in patients with hand burns.24

It was noticed that there was a non-significant difference in pre and post intervention among group **B** in ROM for **DIPs of Index finger** and this can be returned to the sever contracture in this joint.

Regarding the results between both groups A and B pre and post-intervention

The results were at the line with: **(-Wilson and Rogers .,(2018)- Jones and Brown .,(201 Edwin et al .,(2020)-)- Asadzadeh et al., (2021)- Taylor and Martinez (2023))**

According to Jones and Brown (2018), people who have suffered hand injuries encounter unique difficulties, highlighting the need for specialized solutions to address their needs.[25]

Wilson and Rogers .,2018 claimed that The rigid design of the Leap Motion controller proved problematic for participants with limited range of motion, aligning with the conclusions of a usability assessment.26

According to the developers, after about an hour of use, LMC starts to overheat. In addition, both the developers as well as the therapists found the LM's capturing field to be somewhat limited. About 150° of field of vision and 25 to 600 mm of detection range are provided by the instrument.7 Therefore, it is difficult to follow a hand that is moving in two directions at once. Not to mention that PIP and DIP flexion and extension are too fine for LM to detect, even though it is designed to track all finger joints. The overlapping of finger segments during those movements makes it impossible to capture the position of all joints accurately. This is to be expected because LM has to see the entire hand in order to track every joint.14

Clinical joint ROM was not found to be significantly improved by VR-assisted physiotherapy in the short-term trial (Asadzadeh et al., 2021), but this is a crucial outcome to evaluate in future long-term VR-assisted physical therapy evaluations.27

In light of these insights about the results between both groups **A and B pre and post-intervention**

The recommendations for future research align with the proposals of Taylor and Martinez (2023), advocating for collaboration between technology developers and rehabilitation professionals to create adaptive solutions. Continuous updates to the Leap Motion hardware and software, informed by insights from studies on inclusive design, will further contribute to the overall effectiveness and accessibility of the controller for individuals with burned hands.28

Limitations of the study:

The significant clinical variety of the studies considered is largely responsible for the study's apparent limitations such as:

1. The validity of our results is affected by the small sample size.
2. Due to the lack of blinding, patients knew exactly what kind of treatment they were getting.
3. Taking into account that the goals and physiological reaction vary according on the burn phase for the patient.
4. Tracking of finger movements was lost during activities, when hands were superimposed or curled.
5. The shortness of treatment periods that needed to be elongated to have significant difference between both groups.
6. The version of leap motion device which cause overheating during treatment.

Ultimately, after the discussion of results of the study and according to reports of previous investigators about the impact of VR exercise on hand function, power and ROM in burned patients, it can be claimed that, applying virtual reality in case of second degree hand burn and gamification of the rehabilitation had an effect on increase the hand power , increase hand mobility and range of motion , improve hand functions and motivate and encourage them to complete the rehabilitation program among the same group of patients and had no effect in comparison with the other group of study which had conventional hand therapy only in second degree hand burn injuries.

V. Conclusion

VR Based Rehabilitation (The Leap Motion controller) offers a novel approach to hand rehabilitation for burn victims. Its non-contact, precise, and engaging nature provides a viable alternative to traditional methods, addressing both physical and psychological aspects of recovery. While there are limitations to consider, the overall benefits suggest a promising future for the integration of Leap Motion technology in rehabilitation practices. Continued research and development could further enhance its effectiveness and broaden its applications, making it an invaluable tool in the field of hand rehabilitation.

Conflicts of interest—None

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