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# Virtual reality-based exercises to improve balance and hand grip strength in patients with hemiparesis caused by an electrical burn: A randomized controlled study

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## ABSTRACT

There are many complications after an electrical burn injury, including neuromuscular defects, paresis or paralysis, Gillian barre syndrome, transverse myelitis, or amyotrophic lateral sclerosis. The aim of this study was to investigate the effect of virtual reality-based exercises on balance and hand grip strength in post electrical burn-induced hemiparetic patients. A randomized control trial pre- and post-experimental design with intra-rater reliability and inter-rater agreement was undertaken. Thirty post-electrical burn-induced hemiparetic patients (19 males and 11 females, aged 15 to 25 years) were randomly allocated into two equal groups (group A and B). Group A (n = 15) received virtual reality-based exercise in addition to the conventional physical therapy program. Group B (n = 15) received conventional physical therapy program only. The treatment was applied 3 sessions per week for 12 consecutive weeks. Posture stability and hand grip strength were measured by the Biodex balance system and handheld dynamometer, respectively. Data was collected prior to the first treatment and at the end of the 12-week trial and all statistical calculations were done using the computer program IBM SPSS. A statistically significant increase in the overall stability index and the power of hand grip strength was observed in both groups after treatment ($p < 0.05$), especially in group A, which received VR - based exercise training. Thus, group A showed a greater improvement in postural stability and hand grip strength than group B ($p < 0.05$). Virtual reality-based exercises as well as conventional physical therapy program were effective in improving posture stability and hand grip strength in post electrical burn-induced hemiparetic patients.

**KEYWORDS**

Virtual Reality-Based Exercise; Electrical Burn; Biodex; Handheld Dynamometer

## 1. INTRODUCTION

An electrical burn injury can affect all systems and organs, including the central and peripheral nervous system (Shih et al., 2017). There are many complications after electrical burn injury, for example neuromuscular defects, paresis or paralysis (Yiannopoulou et al., 2020).

The weakness in the extremities experienced after electrical burn injury may be attributed to electrolyte imbalance, dehydration, thermal injury, hypoxic encephalopathy, cerebral hypoperfusion, and mostly, vascular injury leading to aneurysm formation and rupture, dissection, electrical coagulation, and vasospasm. Electric shock injury with a prolonged contact period may cause ischemic stroke. Vasospasms caused by the electrical burn injury may be the etiology of the stroke (Huan-Jui et al., 2010).

Hemiparesis is a weakness or immobility on one side of the body that makes it difficult to carry out daily tasks like dressing or eating. One-sided weakness in arms, hands, face, legs, or feet can lead to unsteadiness, trouble moving, decreased movement precision, muscle exhaustion, and a lack of coordination. It can also impede the ability to hold objects (Bernal et al., 2018).

Virtual reality (VR) is a simulation in which a world with a realistic appearance is made using computer graphics. Additionally, the synthetic world responds to the user's input and is not static (verbal command, gesture, etc.). A computer's ability to create a 3D graphical environment out of numerical data forms the foundation of the VR concept (Burdea et al., 2009).

Neural rehabilitation may benefit greatly from VR-based therapy. Subjects interact with the virtual environment and receive continuous feedback that is often visual and audible and may also be kinesthetic[5]. VR-based intervention is more effective than conventional therapy in recovering upper limb functionalities (Massetti et al., 2018).

Reduced balance and postural control are major contributors to functional limitations and barriers to performing activities of daily living in patients with stroke (Vistamehr et al., 2017). Various methods have been used to evaluate balance performance. These methods range from simple clinical scores such as the Berg Balance Scale (BBS) and Dynamic Gait Index (DGI) to more comprehensive laboratory-based measures such as margin of stability (MOS) and whole-body angular momentum (Cho et al., 2014).

The laboratory-based assessments are continuous and generated from kinematic and kinetic data when walking, frequently on a treadmill, whereas clinical balance scores are based on discrete score assignments while completing a range of movement activities (Cho et al., 2012).

Hand grip function is also affected in post electrical burn-induced hemiparesis. Numerous equipment can measure hand grip strength both statically and dynamically. However, the majority of them only measure static grip strength (An et al., 2008).

Because of the proven effect of both virtual reality-based exercise, as well as conventional physical therapy program in improving posture stability and hand grip strength in post-electrical burn-induced hemiparetic patients, this study is conducted to compare the effects of both of them in improving posture stability and hand grip strength in post electrical burn-induced hemiparetic patients.

## 2. METHODS

### 2.1. Study Design

A randomized control trial pre- and post-experimental design with intra-rater reliability and inter-rater agreement was undertaken.

### 2.2. Participants

Thirty patients, of both sexes (19 males and 11 females), aged from 15 to 25 years, who were hemiparetic (longer than 6 months) after an electrical burn, participated in this study. They were selected from the Department of Plastic Surgery of El Kaser El Aini Teaching Hospital of Cairo University and the outpatient clinics of the Faculty of Physiotherapy of the Modern University of Technology and Information (MTI). Subjects were included in this study according to the following criteria: independent ambulant patients with mild spasticity (according to the modified Ashworth scale), limited wrist joint range of motion (ROM), weak hand grip strength, and balance disorders. The exclusion criteria included patients with recurrent stroke, rheumatoid arthritis, aphasia, blindness, deafness, any orthopedic complications that would affect balance or hand grip as fractures, and patients who cannot follow instructions.

The study was conducted in the outpatient clinic of the Faculty of Physiotherapy at MTI University in Egypt for twelve consecutive weeks (three sessions per week) from February 2022 to the end of May 2022. It was approved by the Ethics Committee of the Faculty of Physiotherapy, MTI

University, Egypt. The guidelines of the Declaration of Helsinki for the conduct of research involving human subjects were followed. Before data collection began, all patients signed an informed consent form after the nature and purpose of the study were explained to them. Each participant was free to decline participation or to withdraw from the study at any time. Coding of all data ensured the confidentiality and anonymity of all information collected.

The sample size calculation is critical and fundamental for designing a study protocol. The sample size calculation was performed by using the G*Power analysis software version 3.1, Heinrich Heine-University, Düsseldorf, Germany for a one-tailed test, and it was determined that the appropriate sample size was n = 30.

## 2.3. Randomization

As shown in Figure 1, the patients were randomly assigned using rolling dice into:

Study group (A): Group A included 15 patients (9 males and 6 females) who received 12 weeks of VR- based exercise using VR city view rope crossing and walking the plank by VR Box gear 3D, and Bowling game using X-Box 360 Kinect, in addition to their conventional physical therapy program (stretching ex., strengthening ex., balance training on balance board, and ROM ex. for 20 minutes). The patients attended 3 times per week for 30 minutes.

Control group (B): Group B included 15 patients (10 males and 5 females) who received only their conventional physical therapy program (splinting, stretching ex., strengthening ex., balance training on balance board, and ROM ex. for 20 minutes) 3 times per week for 12 weeks.

## 2.4. Measurements

### 2.4.1. Mini-Mental State Examination (MMSE)

The MMSE is a 30-point questionnaire that was used to measure cognitive impairment to ensure proper comprehension of the study. The MMSE test consists of straightforward questions and issues in a variety of domains, such as the date and location of the test, lists of words that recur, simple math problems like the serial sevens, language use and understanding, and fundamental motor skills (McWilliam et al., 2018).

### 2.4.2. Biodex balance system

Patients underwent pre- and post-treatment assessment using the Biodex balance system (Biodex-medical system. Inc., brook baren R&D plaza, 20 Ramsey road, box 702, Shirley, Newyork 11967-0702). This machine consists of a multiaxial standing platform which adjusted to provide varying degrees of platform tilt or platform instability (level 1 to level 8) (Waleed et al., 2019).

2.4.3. Handheld dynamometer

Patients underwent a baseline assessment before and after treatment to evaluate the patient's initial hand function and determine how he or she responded to the continuous therapy. The handheld dynamometer (Jamar Plus+ Digital Dynamometer. Inc. Sammons Preston, 1000 Remington Blvd., Ste. 210 Bolingbrook, IL 60440 A Patterson Company 800-228-3693) was utilized (Helen et al., 2011).

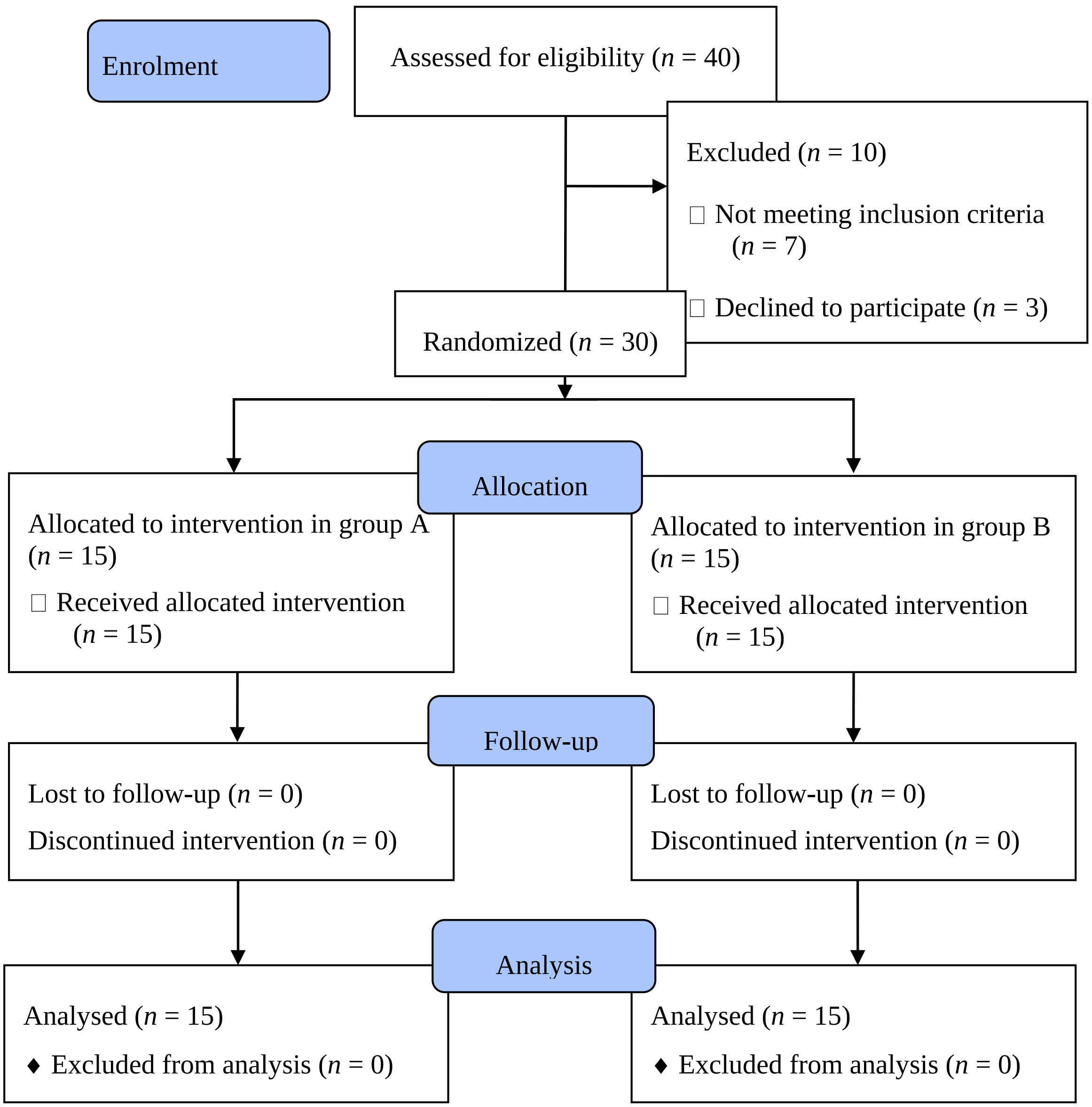


**Figure 1.** The study flow chart

## 2.5. Interventions

2.5.1. Protocol for measuring hand-held dynamometer testing results for hand flexor power (per kilogram)

The patient was seated and holding the dynamometer with the arm that would be tested at a straight angle and the elbow placed at the patient's side. The dynamometer's handle was adjusted as needed; the base rested on the first metacarpal (heel of the palm), and the handle was supported by the middle of the four fingers. When ready, the patient squeezed the dynamometer as hard as they could while maintaining that position for roughly five seconds. No further body movement was permitted, and they were strongly urged to exert their greatest effort. To counteract the effects of muscle fatigue, each session was followed by a wait of between 10 and 20 seconds (Helen et al., 2011).

2.5.2. Evaluation protocol to measure the posture stability by Biodex balance system

The most stable level, level eight, was chosen, followed by the postural stability testing mode and the patient's data being entered into the device. When the platform started moving, the patient was told to try to place themselves in the middle of it. This is achieved by moving the patient's feet into a position that makes it simple to maintain the cursor in the center of the visual feedback screen. The platform was kept level beneath the patient's feet after the cursor was centered, and the patient was then allowed to stand comfortably upright.

## 2.6. Statistical Analysis

All statistical calculations were done using the computer program IBM SPSS (Statistical Package for the Social Science; IBM Corp, USA) release 22 for Microsoft Windows. Before statistical analysis, the Shapiro-Wilk test was performed, which showed that the data were not normally distributed, so a nonparametric test was used. The paired t-test was used for comparison within each group, and the unpaired (independent) t-test was used for comparison between groups. A p value less than 0.05 was considered statistically significant, and less than 0.01 was considered highly significant (Razali et al., 2011).

# 3. RESULTS

Age, weight, height, and BMI of participants in both groups showed no statistically significant difference ($p > 0.05$) (Table 1).

**Table 1.** General demographic data

| Variable | Group A (n=15) Mean ±SD | Group B (n=15) Mean ±SD | F | p value |
|---|---|---|---|---|
| Age (Year) | 45.42 ± 5.26 | 47.60 ± 4.92 | 0.179 | 0.837 |
| Weight (kg) | 82.20 ±6.23 | 79.23 ±6.27 | 1.444 | 0.247 |
| Height (cm) | 173.73 ±5.07 | 170.67 ±5.77 | 1.183 | 0.316 |
| BMI (kg/m$^2$) | 27.23 ±1.64 | 26.80 ±1.84 | 1.663 | 0.202 |

*SD (Standard deviation); p-value (statistical significance); BMI (body mass index)*

Paired t-test revealed a statistically significant decrease in overall stability index (OSI) post-treatment in groups A and B (p = 0.001, p = 0.001, respectively). There was also a statistically significant decrease in handheld dynamometer assessment for the power of hand grip (per kilogram) before and after treatment in groups A and B (p = 0.001, p = 0.001, respectively) (Table 2).

**Table 2.** Comparison of mean values within each group (pre- and post-treatment)

| Group \ Variable | | OSI | | Handheld dynamometer assessment scores | |
|---|---|---|---|---|---|
| | | **Pre** | **Post** | **Pre** | **Post** |
| Group A (n=15) (VR-based exercise) | Mean ± SD | 4.07 ± 1.44 | 1.22 ± 1.13 | 14.96± 2.48 | 42.78 ± 3.35 |
| | t value | 13.65 | | 8.76 | |
| | p value | ≤ 0.001* | | ≤ 0.001* | |
| | | **Pre** | **Post** | **Pre** | **Post** |
| Group B (n=15) (Conventional program) | Mean ± SD | 4.21 ± 1.17 | 2.27 ± 0.78 | 15.14± 3.13 | 30.90 ± 2.67 |
| | t value | 13.425 | | 5.213 | |
| | p value | ≤ 0.001* | | ≤ 0.001* | |

**p value significant at ≤ 0.05; OSI (overall stability index); SD (standard deviation)*

The independent t-test revealed that there was no statistically significant difference between both groups in overall stability index pre-treatment (p = 0.903) while, there was a statistically significant difference between both groups in post-treatment overall stability index (p = 0.001), being significantly lower in group A (Table 3). There was no statistically significant difference between both groups in hand-held dynamometer assessment scores for the power of hand grip (per kilogram) pre-treatment (p = 0.332) while, there was a statistically significant difference between both groups in hand-held dynamometer assessment scores for the power of hand grip (per kilogram) post-treatment (p = 0.001), being significantly higher in group A (Table 3).

**Table 3**. Comparison of mean values between both groups (pre- and post-treatment)

| Variable | | Group A (n=15) | Group B (n=15) | F | p value |
|---|---|---|---|---|---|
| | | Mean ± SD | | | |
| OSI | Pre-Test | 4.07 ± 1.44 | 4.21 ± 1.17 | 0.330 | 0.903 |
| | Post-Test | 1.22 ± 1.13 | 2.27 ± 0.78 | 3.133 | ≤ 0.001* |
| Handheld dynamometer assessment scores | Pre-Test | 14.96± 2.48 | 15.14± 3.13 | 0.268 | 0.332 |
| | Post-Test | 42.78 ± 3.35 | 30.90 ± 2.67 | 0.373 | ≤ 0.001* |

**p-value significant at ≤ 0.05; OSI (overall stability index); SD (standard deviation)*

## 4. DISCUSSION

In the current study, a statistically significant increase in overall stability index was observed in both groups after treatment ($p < 0.05$), especially in group A, which received VR -based exercise training. Moreover, there was a statistically significant increase of power of hand grip strength post-treatment in both groups ($p < 0.05$), especially in group A. All patients received the commonly used conventional physical therapy intervention program, but it was obvious that the use of VR-based exercises showed a higher statistically significant difference in outcomes and improvements.

Reduced balance and postural control are major contributors to functional limitations and barriers performing activities of daily living in patients with hemiparesis caused by an electrical burn. Research on the effects of VR training on balance and postural control was reviewed in this study. Virtual reality training is safe and economical, and it may encourage user interest (Chen et al., 2015).

The results of this study were assured by Chen et al. (2016) who demonstrated that the strongest evidence supports the fact that VR balance training is an effective adjunct to routine physiotherapy to improve dynamic balance and static balance in patients with hemiparesis. Also, Yeong et al. (2014) came in agreement with the result of this study, as their study mentioned that interventions using virtual reality may improve the balance and gait of hemiparetic patients and develop their fine motor function, gross motor function, and coordination. Virtual reality training is a safe and useful tool for enhancing the sensorimotor functions of hemiparesis patients, and for improving balance and gait during rehabilitation treatment. It is an effective alternative to physical therapy at home (In et al., 2016).

Another study confirmed the result of this study published by Cho & Song (2012) in the Tokyo Journal of Experimental Medicine, which was undertaken to investigate the effects of 6 week of rehabilitation program by using a virtual reality game on static balance ability by measuring postural sway velocity and dynamic balance ability with Berg Balance Scale (BBS) and Time Up and Go test (TUG) in chronic stroke patients. The study showed that after 6 weeks of training, BBS and TUG were significantly improved, whereas static balance abilities were not significantly improved. These findings imply that virtual reality balance training is superior to static balance training for enhancing dynamic balance control. They believe that these results provide basic information on improvement in balance ability.

The potential for VR-based therapies to help patients with abnormal mobility caused by neurological dysfunction has been demonstrated in recent studies. Sveistrup (2004) proposed that the well-known neurophysiological and behavioral benefits of movement observation, imagery, repetitive massed practice, and imitation therapies can be easily incorporated into VR to optimize the training experience and allow the clinician to use sensory stimulation through VR as a tool to facilitate targeted brain networks, such as the motor areas, important for neural and functional recovery (Sveistrup., 2009).

A study conducted by Holden & Dyar (2002) developed a VR training system based on the principle of learning by imitation. Virtual "teacher" movements that have been prerecorded are shown as either arm movements or movements of the limb's terminus. An electromagnetic tracking device for the arm and hand section or a Cyber-Glove for hand kinematics are used to capture patient motions. The patient is shown by the "teacher" the endpoint (hand) path's trajectory for replicating the movement. Other facets of the teacher-patient connection, such as the frequency of visual feedback, motion speed, degree of movement synchrony, and others, can be modified. Clinical tests of upper extremity function, including strength, showed varying improvements in eight chronic post-stroke patients.

Adamovich et al. (2009) conducted another study that established that the potential for functional recovery can be maximized by utilizing several neurophysiological processes that take place after a brain lesion, such as the enhanced potential for neuroplastic changes early in the recovery phase and stimulation of sensorimotor areas that may otherwise deteriorate due to disuse. VR could be helpful for these processes in a variety of ways and could even result in compensatory neuroplastic alterations. Piron et al. (2007) used a virtual reality task to assess the functional motor progress of a group of 20 post-stroke patients undergoing conventional rehabilitation. The patients had to place a magnetic receiver-equipped envelope in a simulated mailbox slot. The participant received a view of the associated virtual envelope's motion's trajectory. With the adjustments connected to improvements in a clinical measure of upper extremity voluntary movement, patients improved on reach velocity and reach duration. Although few data were provided, the authors claim that the reach trajectory parameters also improved.

Shin et al. (2017) conducted a study that noted a greater improvement in multiple outcomes of the distal upper extremity, including motor impairment (FM-total, FM-prox, and FM-dist scores), hand functions (JTT-total and JTT-gross scores), and HRQoL (composite SIS, overall, SIS, SIS-social participation, and SIS-mobility scores) using VR-based rehabilitation on Patients with Stroke. Finally, Prasad et al. (2016) concluded that the virtual reality Wii gaming system is feasible, promotes motor recovery after spinal injury, increases patient motivation, and enriches the treatment. After reconstructive operations, facilitative approaches and VR-based exercise therapy are efficient ways to improve hand functions and applying any of these modalities added evidence for improvement of hand function to performing traditional rehabilitation protocol alone. This study was constrained by patients' reduced comprehension of VR orders during therapy sessions and certain patients' irregular attendance.

## 5. CONCLUSIONS

Virtual reality-based exercises as well as conventional physical therapy program were effective in improving posture stability and hand grip strength in post electrical burn-induced hemiparetic patients. Nonetheless, virtual reality-based exercise with conventional physical therapy program was shown to be superior to the conventional physical therapy program alone, in terms of improving posture stability and hand grip strength in those patients.

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## CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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