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Unilatereal versus Bilateral Virtual Reality XBOX 360 Training on Rehabilitation of Stroke Patients

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Abstract
Background/aim: *A stroke is a neurological disorder resulted from an alteration in the cerebral blood flow leading to clinical affection of mental function, motor skills, sensory detection, perception, and language with higher mortality and morbidity rates. The most common symptom after stroke is the impairment of motor function which is considered an important factor affecting the functional recovery. Stroke patients with upper extremity functional limitation are dependent in performing the activities of daily living, such as eating, dressing, and selfcare which are usually done by both upper extremities. So, the main aim of different rehabilitation programs is to maximize the ability of stroke patients to be independent as much as possible. The aim of the present study was to compare the effects of bilateral virtual reality (VR) training program versus unilateral training on upper extremity function in patients with chronic stroke.*
Material and methods: *40 patients with chronic stroke, their ages ranged from 45 to 70 years old were randomly assigned into 2 groups: unilateral and bilateral groups. Fugl-Meyer motor Assessment and electromyographic activity (EMG) of the biceps and triceps muscles to calculate the cocontraction index were measured for all participants pre- and post-treatment period.*
Results: *There was a significant difference between the two groups in the Fugl-Meyer motor assessment (FMA) while there was no significant difference in the electromyographic activity (EMG) of the cocontraction index scores after treatment.*
Conclusion: *It is important to add virtual reality x box 360 training to the conventional physical therapy training programs of stroke patients rehabilitation either by training of the affected upper extremity only or by training of both upper extremities simultaneously.*
Key words: *Bilateral training, Fugl-Meyer Assessment (FMA), Cocontraction Index, Electromyography (EMG), Stroke, Rehabilitation, Virtual reality x box 360 training.*

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I. Introduction

Stroke Mortality has been decreased in all countries either of high, middle or low income. Despite the increase of stroke incidence and the decrease of mortality rates, there is an increase in patients suffering from disabilities. Stroke is considered the main leading cause of serious, complex, and long-term adult disability. According to the World Health Organization, 15 million people suffer from stroke worldwide annually. From them, there are five million die and another five million are suffering from permanent disability (1).

Patients with chronic stroke are hospitalized usually during the acute and sub-acute phases to receive rehabilitation treatment. However, after their discharge, they often do not continue their rehabilitation treatment till complete recovery. The number of stroke survivors continuing their rehabilitation program is very low (1).

Hemiparetic stroke patients usually suffer from many impairments such as spasticity, muscle weakness, and disturbed muscular coordination mainly accompanied by various muscle coactivation patterns. Although, spasticity and muscle weakness can be treated effectively, a lot of hemiparetic patients with stroke may still suffer from motor impairment associated with abnormal muscle coactivation (2).

Dewald et al reported that the most common cause for motor dysfunction and disability in most hemiparetic patients after stroke was abnormal movement coordination (abnormal muscle coactivation pattern). The combination of cocontraction of antagonist muscles and decreased activation of agonist muscles lead significantly to the impaired use of the hemiparetic upper extremity (3).

Although, most rehabilitation programs and training techniques are developed to improve function in the initial stages of stroke. Other studies reported that rehabilitation programs are also effective for chronic stroke patients even they are applied years after injury. Repetitive use of the affected limb has a positive effect on improving the motor function by neuroplasticity even in chronic stroke, regardless of its etiology either ischemic or hemorrhagic stroke (4, 5).

Virtual reality is an easy and low-cost rehabilitation program can be used in the treatment of individuals at different ages as it give the patient feedback and increase the patient motivation. Virtual reality can be used in the treatment of many diseases such as Parkinson's disease, burn patients, urinary incontinence in older women, cerebral palsy in children and adolescents, anterior cruciate ligament reconstruction, stroke, vestibular rehabilitation, traumatic brain injury, and in the improvement of physical functioning in older adults (6). The effectiveness of virtual reality does not depend on the patient age or sex (5).

Bilateral upper limb training is a new method of stroke rehabilitation. Therapists used pulleys as a method to move the most impaired upper limb simultaneously with the less impaired upper limb. Coupling (or interaction) in bilateral upper limb training effects between the two upper limbs was reported to facilitate the functional recovery of the paretic arm by moving both upper limbs in either in-phase (i.e., symmetrical movements) or anti-phase(i.e., alternating movements) rhythmic interlimb- coordination (7).

II. Materials and methods

Study design: This study presents a comparative study.

Inclusion criteria:

Forty chronic mild hemiparetic patients (at least 6 months post-stroke onset with grades 1 and +1 of the elbow flexors according to modified ashworth scale), between 45 and 70 years of age (60.75±6.35 years) were included after following clinical presentation of a single, unilateral stroke of ischemic or hemorrhagic etiology confirmed by neuroimaging prior to participation in the study.

Exclusion criteria:

The exclusion criteria were as follows: Individuals with brainstem or cerebellar involvement, bilateral involvement, aphasia, apraxia, hemineglect, auditory, visual, cognitive or communication impairments, history of seizure, problems with active range of motion (ROM) of the shoulder and the elbow more than 10 degrees, major neurologic or neurodegenerative conditions other than stroke, Serious cardiovascular disease (heart failure, arrhythmias, angina pectoris or myocardial infarction), inability to walk more than 10 m independently, balance impairment, pregnancy or refusal to use a video game.

Assessment procedure:

Modified ashworth scale was used to determine the degree of muscle tone and spasticity for all patients before starting of the treatment program. The individuals had to have a normal cognitive function to understand the game instructions for virtual reality therapy task training rehabilitation. The cognitive function of all patients was not less than 16/30 on mini-mental state examination.

Fugl-Meyer Motor Assessment (FMA) and electromyographic activity (EMG) of the biceps and triceps muscles to calculate the cocontraction index scores were measured for all participants pre- and post-treatment period. All patients should have a minimum score of at least 40/66 of the FMA-UE. Motor impairment was assessed with the upper limb component of the FMA on the same day with the EMG assessments pre- and post-treatment period. Each item was graded on a 3-point ordinal scale (0 cannot perform, 1 = perform partially, and 2 = perform fully) and summed to provide a maximum score of 66. The FMA is reliable and valid (8).

FMA-UE was conducted two times, one day before the beginning of the rehabilitation program and reassessed again one day after the end of the rehabilitation program by the same physiotherapist. physiotherapists responsible for assessment and data analysis were blinded. Signed informed consent was obtained from each patient before taking part in the study.

EMG instrument

The Kinesiological EMG (EMG MyoSystem 1400A, NoraxonInc, Scottsdale, AZ, USA) was used for the selected muscles biceps brachii and triceps muscles to calculate the cocontraction index before and immediately after eight weeks of the selected physical therapy intervention. Disposable Silver-Silver Chloride

(Ag-Ag Cl) self adhesive disposable electrode with active surface area 1 cm^2 was used to record the myoelectric activity RMS EMG of the biceps brachii, and triceps muscles. The maximum inter electrode spacing between the recording electrodes was 2 cm. Skin preparation for applying surface electrodes was started. Patients were prepared for applying EMG electrodes over the selected muscles. The hair was shaved at picking up areas and then cleaned with alcohol 70% to remove the dead layer of skin.

Electromyography electrode pairs were used with a center separation of 2cm were attached to the skin surface of the muscle belly of biceps brachii and lateral head of triceps brachii. For biceps brachii muscle, the active electrode was fixed over the muscle belly at the midpoint between the anterior aspect of the acromion, and the bicipital fossa. For the triceps muscles, the active electrode was fixed over the muscle belly at the midpoint between the posterior aspect of the acromion and the olecranon. The common reference electrode was placed on the lateral epicondyle (9). The electromyography electrode pairs were not moved once placed (2). Each patient was comfortably seated and was asked to perform functional reaching task that provoke elbow extension. Objects were placed at 1.5 forearm's length in front of the subject. Electromyographic signals of biceps and triceps of the affected arm were measured during the task (10).

The isometric maximum voluntary flexion and extension for five seconds were done three times with 5-minute rest in between to avoid muscle fatigue. Maximum extension and flexion torques could usually be found at 90° of the elbow angle for hemiplegic subjects after stroke (2). Signals were normalized to maximum voluntary contractions (MVCs) and subsequently used for calculation of biceps triceps co-contraction index (CI) (10). The electromyographic signals were preamplified, band-pass filtered (from 10 to 500Hz) with a sampling frequency of 1000Hz (2).

Treatment procedure:

- Participants were equally randomised into two groups each group consisting of 20 patients. the unilateral virtual reality group was treated through a selected physical therapy program in addition to a designed unilateral virtual reality x box 360 training, and the bilateral virtual reality group was treated through the same selected physical therapy program in addition to a designed bilateral virtual reality x box 360 training. All treatments were applied for 3 days a week for 8 weeks by the same physiotherapist. The physiotherapists responsible for the interventions and participants were not blinded for the interventions due to the specificity of each protocol.

The selected physical therapy program consisted of passive, active assisted, active free movements, neurodevelopmental approach, postural control,balance training, functional training and gait training (9).

Virtual reality rehabilitation protocol consisted of an active video game using the box fight game was selected to encourage the use of the upper extremities. For each session, the virtual reality protocol was consisted of four steps:

- Step one (warm-up): three sets (40 seconds each) of passive stretching were performed by the physiotherapist for the upper limb muscles (pectoral, flexors, internal rotators of the shoulder; elbow, wrist, and finger flexors) with a 40-second break among them. The passive stretching was conducted to the maintain the range-of-motion.
- Step two (instructions): the patient received the game instructions by the physiotherapist during the training, the participant was instructed to practice while standing at a safe distance between 1.5 - 2 meters away from the sensor bar to facilitate the positioning by the infrared camera sensor.
- Step three (training): the patient played the box fight game selected by the examiner for 15 minutes.
- Step four (cool-down): same as step one. At the end of each session, the patients received a feedback about their scores on the box fight game played (6).

VR Training Using Xbox Kinect Xbox Kinect (Xbox 360, Microsoft, United States) was used for the VR training. Xbox Kinect has an infrared camera sensor (Kinect sensor) that perceives the user's movement without the need for a special controller or buttons to be pressed, which allows users with impaired fine motor skills and impaired dexterity to interact with the game effectively. When the task is not properly performed in the VR environment visual auditory, and sensory feedback are provided. For the training, the screen and The infrared camera were set up in a suitable environment space to avoid disturbance. Patients participated while either sitting or standing approximately 1.5 - 2 m from the screen.

The Boxing fight game was choosen to encourage active movements of the elbow flexion, extension, shoulder flexion and extension to punch and block both at the head and body height Time for practice was allowed before the participants engaged in the games. The participants engaged in the games after receiving a full detailed explaination of game play from the physiotherapist (11).

Statistics

A statistical package program was used to evaluate the data obtained from the bilateral. Descriptive statistical methods (frequency, proportion, mean, and standard deviation) were used in the evaluation of research data as well as the Kolmogorov–Smirnov distribution test for examining normal distribution. The Pearson chi-square test was used in comparing qualitative data. In comparing quantitative data, the unpaired samples t-test was used in intergroup comparison of parameters. The Paired samples t-test was used for intragroup comparisons. The results were calculated at the 95% confidence interval, P < 0.05 significance level and P < 0.01 advanced significance level.

III. Results

No participant left the research project for any reason. No side effects or complications were observed during the treatment. Baseline characteristics of the patients are shown in Table 1. The unilateral group included 7 female and 13male patients and the bilateral group included 5female and 15male patients. The unilateral group included 14 right side and 6 left side patients and the bilateral group included 9 right side and 11left side. The average age was 61 ± 7.23 years in the unilateral group and 60.5 ± 5.52 years in the bilateral group. The average height was 165.45±5.23 cm in the unilateral group and 167.50 ± 5.23 cm in the bilateral group. The average weight was 78.75±7.16 kg in the unilateral group and 82.65 ± 6.6 kg in the bilateral group. The average duration of illness was 8.65±1.95months in the unilateral group and 10.2 ± 3.16 months in the bilateral group.

No statistically significant difference was found between the two groups regarding age, height, weight, and duration of illness, side of affection or sex (P > 0.05), as shown in Table 1.

There was a highly significant increase in the Fugl-Meyer Motor Assessment (FMA) scores at the end of the treatment in comparison to baseline (P < 0.01) in both groups, There was a highly significant difference between the two groups regarding the Fugl-Meyer Assessment Motor (FMA) at the end of the treatment (P < 0.01) in favor of the bilateral group , as shown in Table 2.

There was a highly significant decrease in the cocontraction index scores at the end of the treatment in comparison to baseline (P < 0.01) in both groups. There was no significant difference between the two groups regarding the electromyographic activity (EMG) of the cocontraction index scores after treatment (P > 0.05), as shown in Table 3.

IV. Discussion

Stroke patients have usually higher rates of mortality, morbidity and medication use, so, they have lower income leading to a negative socioeconomic impact for family and society. (12).

Many stroke patients live with permanent disability and may never completely recover their motor functions (13). Impaired motor function is the most common symptom after stroke; which can affect the functional recovery. Stroke survivors with upper extremity functional limitations have usually problems in performing the activities of daily living independently, such as eating, dressing, and selfcare activities. (14) So, the main goal of most rehabilitation programs is to improve the ability of stroke patients to live independent as much as possible (15).

Traditional approaches that require simple and repetitive movements may lose its effectiveness by monotony and boredom, which, in turn, lower the patient's motivation to complete the intervention effectively (16).

Virtual reality is an available rehabilitation technique used to rehabilitate patients with stroke. It consists of video game-based exercises that contribute to movement facilitation and functional training in different interesting ways (17). Virtual reality technique encourage movement repetitions which improve the motor functions at different virtual environments (18). The virtual reality technique has the advantage of providing the patients with a feedback about their performance, which is important for motor learning needed for improving the performance through brain plasticity (19).

Virtual reality provides feedback for both patients and therapists to work together to improve the patient's performance by increasing competency level and motivation to practice. Virtual reality is better than the traditional approaches because it facilitates exercises in an interesting way that stimulate different cognitive and motor skills through virtual environments that directly train different activities of daily living (20, 21).

Virtual reality (VR) can be used in stroke rehabilitation as VR system helps stroke patients to interact with many sensory environments during dealing with the computer technology which provide the patients with visual, auditory, and tactile feedback regarding their performance and function of the affected limb (22). Saposnik and Levin reported a positive effect of Virtual reality on motor impairment after either type of Virtual Reality intervension in Stroke Rehabilitation (23). Holden et al., and Piron et al., reported improvement of FM Post VR training for Chronic stroke (24, 25).

Kamper et al., also reported Improvement of both FM and grip strength after VR training in Chronic stroke with similar findings were observed when follow-up is repeated after four weeks postintervention (26). The present study reported that both unilateral and bilateral virtual reality x box 360 training is effective for poststroke rehabilitation of the affected upper extremity.

Recent systematic reviews reported mixed results about bilateral upper limb training effectiveness of either it is better or inferior to other interventions used in poststroke rehabilitation (27). There is a strong evidence support the effectiveness of bilateral upper limb training after stroke (28).

Stewart et al., reported a great effect of the use of bilateral training as a rehabilitation tool for the affected upper extremity in patients with stroke (29). Bilateral training is as similarly effective as other treatments but certainly not better (27, 30). These mixed results may be due to the heterogeneity of various types of bilateral upper limb training and the variation of the used devices in clinical rehabilitation (27).

Limitations

The main limitations were recorded in the present study were the cause of stroke and that the conventional therapy was done for both groups was not standardised. Also, different outcome measurement tools were needed to evaluate the performance of activities of daily living.

V. Conclusions

The repetitive use of the hemiparetic upper extremity through unilateral or bilateral virtual reality training has positive outcomes on motor skills in chronic stroke measured through the FMA-UE and the electromyographic activity. None of them has been proved to be more effective than the other in the current study; however, further studies are needed.

CONFLICT OF INTEREST

The authors whose names are listed immediately below certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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Author Contributions

MMM, MME, IMH, AIE and MA designed the research work, helped in the patients' selection and the assessment procedures for the patients. MA made the patients referral. MMM, MME, IMH and AIE performed the treatment procedures for the patients. MMM wrote the manuscript and made the data analysis. All authors reviewed the manuscript and approved the final version.

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Table 1. Baseline characteristics of the patients.

Characteristics	Unilateral (n = 20)	Bilateral (n = 20)	P
Age (years, mean ± SD)	61±7.23	60.5±5.52	.807 NS
Weight (kg)	78.75±7.16	82.65±6.6	.081 NS
Height (m)	165.45±5.23	167.50±5.23	.222 NS
Duration of illness (months, mean ± SD)	8.65±1.95	10.2±3.16	.070 NS
Sex (female/male)	7/13	5/15	.490 NS
Side of affection (right/left)	146	911	.110 NS

Data are presented as mean ± SD or number of patients. NS = Non significant P > 0.05.

Table 2. Fugl-Meyer motor assessment (FMA) scores pre and post treatment for both groups.

Fugl-Meyer motor assessment scores	Before	After	P
Unilateral (n = 20)	47.15 ± 4.97	50.5 ± 5.71	.000**
Bilateral (n = 20)	46.85 ± 5.6	55.95 ± 4.71	.000**
P	.859 NS	.002**	

Data are presented as mean ± SD. **= highly significant P < 0.01. NS = Non significant P > 0.05.

Table 3. Co contraction index scores pre and post treatment for both groups.

Co contraction index scores	Before	After	P
Unilateral (n = 20)	.76 ± .16	.53 ± .19	.000**
Bilateral (n = 20)	.83 ± .09	.42 ± .2	.000**
P	.067 NS	.102 NS	

Data are presented as mean ± SD. **= highly significant P < 0.01. NS = Non significant P > 0.05.

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