2019 16th International Conference on Electrical Engineering, Computing Science and Automatic Control (CCE)
Mexico City, Mexico. September 11-13, 2019

Rehabilitation Paretic MMSS in a Patient with Traumatic Brain Injury/TBI: Efficacy of the use of Virtual Environments

Hugo S. Gamboa Zúñiga
Electrical Departament Bioelectronic Section
CINVESTAV IPN
México City
szuniga@cinvestav.mx

Laura Delgado Rangel
Phisical Medicine and Rehabilitation
ISSSTE
México City
Laura.delgador@issste.gob.mx

Fernando Perez Escamirosa
Departament of Surgery, Faculty of medicine
UNAM
México City
ferescamirosa@unam.mx

José Antonio Gutiérrez Gnecchi
Departament of Engineering Electronic
ITM
Morelia, México
Angugi98@netscape.net

Daniel Lorias Espinoza
Electrical Departament Bioelectronic Section
CINVESTAV IPN
México City
dlorias@cinvestav.mx

Abstract— the objective is to support with this orthosis intelligent to a patient with TBI can perform physical activities in his upper extremity. Glove Smart Hybrid (GSH) is an Orthosis Intelligent of neurorehabilitation therapeutic approaches that facilitates the use of the paretic upper extremity in activities of daily living (ADL) by combining rehabilitation therapies: a). *Neuromuscular dynamic rehabilitation*, where the patient can flex and extend the fingers of the hand. b) *Virtual Reality Rehabilitation System* (VRRS), Software or programming language developed in CINVESTAV IPN for data processing and creation of the virtual environment through virtual interactive training games, these games displayed wirelessly and remotely on the screen of a smart electronic device. Technological innovation is that this combination of rehabilitation therapies they are presents in the same device.

Keywords— Traumatic Brain Injury, Upper extremity, Orthosis, Glove Smart Hybrid, Neuromuscular dynamic rehabilitation, Virtual reality rehabilitation system, Neuroplasticity, Neurorehabilitation.

I. INTRODUCTION

Impairment of the Upper extremity is common after a traumatic brain injury, rehabilitation therapy will be more effective if supported with a functional orthosis [1]. The use of Virtual Reality programs specifically designed for the rehabilitation of patients with brain injury is increasing as is the use of virtual gaming devices in clinical settings [2]. Virtual reality-based training has found increasing use in neurorehabilitation to improve upper limb training and facilitate motor recovery [3]. Virtual reality approaches are effective in improving upper extremity function and independent activities in stroke survivors [4]. Due to the importance of hands and the prevalence of hand issues, there is an increasing effort toward developing hand orthotics. These efforts have resulted in active hand orthoses that have been used for rehabilitation training and restoring partial hand function [5]. The development of powered hand orthoses and exoskeletons for treatment of chronic motor deficits due to stroke, traumatic brain injury, and cerebral palsy has been widely explored by the robotics engineering community [6]. Dynamic wrist orthoses and Dynamic Hand Splints are useful for correcting a flexor/extensor imbalance at the wrist related to spasticity. Many patients who have had a stroke or brain injury regain active finger flexion and are capable of grasping objects. Not surprisingly, good hand function depends on the patient being able to open the hand [7]. The Smart Glove made in Korea is a biofeedback system designed for distal upper extremity rehabilitation in stroke survivors. It includes a glove-shaped sensor device and a software application. The sensor device tracks the motion and posture of the wearer's distal limb and recognizes functional movements, such as forearm pronation/supination, wrist flexion/extension, radial-ulnar deviation, and finger flexion/extension [8].

II. MATERIAL AND METHODS

A. Clinical Case.

Male of 25 years, with diagnosis hemiparesis upper limb left hand semiflexion, scarce arm, functional right hemi body, and left hemi body with poor volitional activity of predominance to carpus and hand, with very poor finger extension, complete mobility arches except pronosupination. Botulinum (Dysport) toxin application Fig.1.

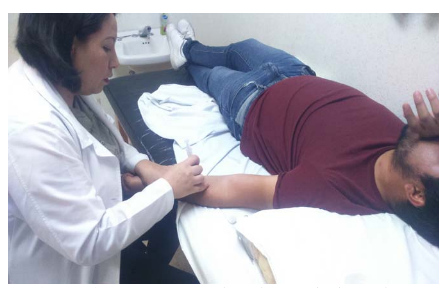

Fig. 1. (Botox), ISSSTE Regional Hospital. 1° de Octubre

B. GSH technical characteristics

Glove Smart Hybrid is an Orthosis Intelligent of neurorehabilitation therapeutic with Bluetooth technology, with sensors to measure the movements or gestures of the fingers and wrist of hand. Technical characteristics: *Smart sensor*; Bending sensor is a variable resistance that changes as it is bent, is a 9 axis motion and position sensor that consist of 3 acceleration channels, 3 angular velocity channels and 3 magnetic field channels that measure the movements of the carpals, metacarpals and phalanges, connected to a computer system that can accurately calculate the number of hand individual movements. *PCB;* Composed by two electronic cards, MCU integrates a triaxial accelerometer, triaxial gyroscope, magnetometer or digital compass and a microcontroller and the other is a Bluetooth module where the Android APP application of interactive virtual rehabilitation training games is generated. *Code;* Software or programming language developed in CINVESTAV IPN for data processing and creation of the virtual environment. The software application manipulates virtual hands or virtual objects in training games according to the received data. In addition, this system can evaluate the active and passive range of motion for each functional movement. *BLE;* Bluetooth low energy, is a new digital technology of Wireless radio interoperable for small devices developed by Bluetooth. It is the first open Wireless communication technology, which offers communication between mobile devices. Fig.2

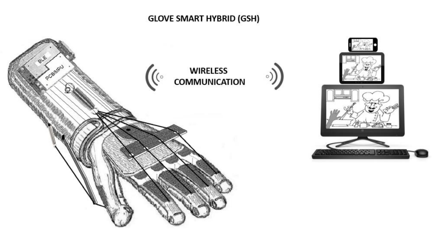

Fig. 2. Glove Smart Hybrid is designed and technologically developed by CINVESTAV IPN

C. Rehabilitation hybrid therapy using the GSH.

Neuromuscular dynamic rehabilitation. Finger extension is supplied by a dynamic orthoses with elastic mechanisms to span the dorsal forearm to the dorsal aspect of the thumb and fingers proximal to the proximal interphalangeal. The fingers are controlled through slings that put pressure on the palmar aspect proximal to the proximal interphalangeal. This elastic tension causes the fingers to be held in an open position with the thumb abducted. The patient can more easily position the hand to grasp an object. Fig 3. *Virtual reality rehabilitation system*. The patient can perform simple movements such as extending or closing the fingers or turning the wrist to perform basic tasks within the interactive virtual rehabilitation training games displayed wirelessly and remotely on the screen of a smart electronic device. The training games in the Smart *This* Glove Hybrid system are categorized according to the intended movements as follows: forearm pronation/supination, wrist flexion/extension in the vertical plane, wrist flexion/extension in the horizontal plane with gravity eliminated, wrist radial/ulnar deviation in the vertical plane, wrist radial/ulnar deviation in the horizontal plane with gravity eliminated, finger flexion/extension, and complex movements. In each game, the pacient is required to successfully perform a task that is related to the specific intended movement in order to obtain high scores. Fig. 4

Fig. 3. *Glove Smart Hybrid*

Fig. 4. The Glove Smart Hybrid system and the task-specific games of this system.

The games simulate ADLs, such as catching butterflies or balls, squeezing oranges, fishing, cooking, cleaning the floor, pouring wine, painting fences, and turning over pages, which allows to patient to easily familiarize themselves with the training program and motivates to perform the tasks. The movements are based on commonly used clinical therapies and a learning programming algorithm, this will help adjust the difficulty to optimize the challenge and motivation of interactive virtual rehabilitation training games. The gamification elements and the easy-to-use interface motivate the patient throughout the rehabilitation process, helping to induce Neuroplasticity for hand function, while play, see and hear the sounds of the virtual interactive training game. Fig. 5.

Fig. 5. We can observe the patient using GSH to induce Neuroplasticity.

D. Test evaluation using the GSH.

The tests of (evaluation and degree neuromotor deterioration) will be measured with the Fugl-Meyer / FMA-UE scale and the test (hand functional) with the Jebsen-Taylor / JHFT scale in upper extremity, carried out in department physical medicine and rehabilitation/ISSSTE, in the 1st and 4th week and after the month of rehabilitation therapy, the patient using the Glove Smart Hybrid on average half an hour daily for 5 days a week, is compared the conventional rehabilitation CR.

III. RESULTS

Glove Smart Hybrid is designed and technologically developed by CINVESTAV IPN; the manufacture of this device is custom size. In the world commercial market there are orthoses able to provide neuromuscular dynamic rehabilitation or virtual rehabilitation but not both, this device of training, combines neuromuscular dynamic rehabilitation and virtual rehabilitation at the same time in the same device. Although the low cost of Glove Smart hybrid, was not the only objective of our study if it is a very important variable for the acceptance of the device in the market commercial. Glove Smart Hybrid is portable, and the patient can take their hybrid rehabilitation therapy at home. The Glove Smart Hybrid involved the categories of movements of the distal upper extremity to achieve goals in a specific task-based feedback. The result showed changes in the scores the evaluation and degree neuromotor deterioration in the Fugl-Meyer scale (FMA-UE) and changes in the results in the objective assessment of the function Jebsen-Taylor Hand Test (JHFT). Fig.6, 7.

- ***Fugl-Meyer scale (FMA-UE):***

The Fugl-Meyer Assessment for upper extremity – FMA-UE

Motor impairment of the affected upper limb was evaluated using the upper extremity Fugl–Meyer assessment (FM-total; 33 items with a 3-point ordinal scale; range, 0–66), with higher scores indicating lower impairment. We further divided the FM-total score into proximal (shoulder, elbow, and forearm; FM-prox) and distal (wrist and hand; FM-dist) scores. The primary outcome was the change in the FM scores. FMA-UE Specifics:

The four domains assessed include:

Motor function (UE maximum score = 36)
wrist (maximum score = 10)
Hand (maximum score = 14)
Speed coordination (maximum score = 6)
Total: Motor function 1-4 (maximum score = 66)

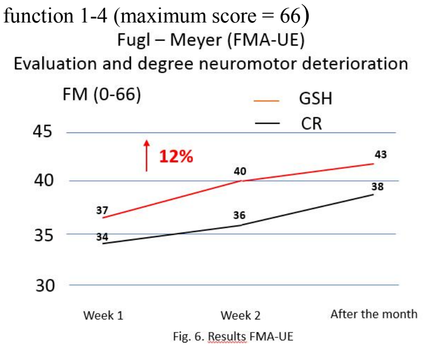

Fig. 6. Results FMA-UE

- ***Jebsen–Taylor Hand function test: JHFT.***

The JHFT was used to asses hand function mimicking ADLs. It involves a series of 7 timed subtests, including writing, simulated page turning, picking up small objects, to line up stacking checkers, picking up large light objects and picking up large heavy objects. Quantification is not possible if a subtest cannot be completed within a certain time, as the result is a continuous time variable, and a subtest is considered to have a missing value if it cannot be completed. Therefore, we used a scoring system (each subtest score ranges from 0 to 15, and the total score calculate as the sum of each subtest score ranges from 0 to 105). Table 1.

PURPOSE. To assess a broad range of uni-manual hand functions required for ADLs. ***AREA OF ASSESSMENT***. Activities of Daily Living, UE Function***ASSESSMENT TYPE***. Performance Measure ***ADMINISTRATION MODE***. Paper and Pencil ***DESCRIPTION***. A test kit commercial which usually includes instructions, all items needed to perform seven subtests, a carrying bag, and pad of 50 blank record forms.

KEY DESCRIPCTION*: *TIME TO ADMINISTER: 15 minutes

- **7 subtests**, performed on both non-dominant and dominant hand:

1. Writing a 24-letter, 3rd grade reading level difficulty sentence.
2. Card Turning.
3. Picking up small common objects (eg. Pennies, paper clips, bottle caps) and placing them in a container.
4. Stacking checkers
5. Stimulated feeding
6. Moving light objects (eg. Empty cans)
7. Moving heavy objects (eg. 1lb weight cans)

	Non-Dominant Hand			Dominant Hand		
Subtest	*Actual time*	*Standard score*	*Compared to Norms*	*Actual time*	*Standard score*	*Compared to Norms*
1	23.87	-0.71	WNL	10.94	-0.36	WNL
2	3.56	-1.04	WNL	4.00	0.00	WNL
3	5.87	-0.37	WNL	10.44	4.54	BN
4	5.94	-1.51	WNL	5.66	-0.82	WNL
5	3.25	-0.92	WNL	3.03	-0.39	WNL
6	2.64	-0.97	WNL	3.03	-0.68	WNL
7	2.72	-0.95	WNL	2.47	-1.06	WNL

Table 1. Results JHFT

- Subtest score= time (seconds) to complete task
  Total score= sum of times for each subtest
- Max time allotted per subtest in 120 seconds
- Lower score= greater function
- Each item performed with each hand separately – non-dominant hand first.
- Measures unilateral hand function
- Assesses speed, non-quality of performance.

***EQUIPMENT REQUIRED*:**

- Stopwatch
- Chair (18" seat height), desk/table (30" high)
- Black ball point pen, for 8x11" sheets of unruled white paper stacked and fastened to a clipboard.
- Sentences typed in all capital letters and centered on a 5x8" index card on a bookstand.
- Five 3x5" index card (ruled on one side only)
- Empty 1-pound coffee can
- Two 1" paper clips
- 2 regular sized bottle caps (1" diameter)
- 2 pesos M.N.
- 5 kidney beans (prom-5/8" long)
- 1 regular teaspoon
- Wooden board (41 ½" long, 11 ¼" wide, ¾" thick), Clamp, plywood (20" long, 2" wide, ½" thick) glued to the board.
- Four standard size (1 ¼" diameter) red wooden checkers
- Five cans

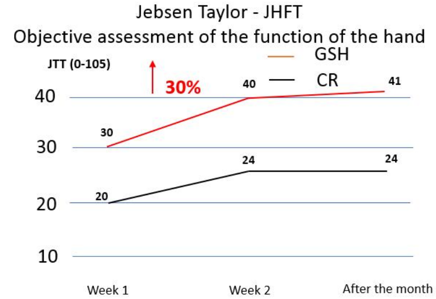

Fig. 7. Results JHFT

Our study found that the functional improvements of the distal upper extremity were better using VR-based rehabilitation than using conventional rehabilitation according to the FMA-dist and JHFT-total scores. Table 2.

	BEFORE THERAPY	AFTER THERAPY
GSH - CR Clinical parameters FMA-EU score JHFT score	 34.0 ± 4.0 20 ± 2.0	 37.0 ± 6.0* 30.0 ± 11.0*
All values are indicated as, mean ± SD; (*) p< 0.05		

Table 2. The graphics show the mean differences pre and post treatment in RFVE-CR, respectively in the FMA-UE and JHFT scale; (*) p<0.05.

Furthermore, the functional improvements of the distal upper extremity using VR-based rehabilitation were more definite for gross hand function than for fine hand function, as a significant difference was noted in the JHFT-gross score but not in the JHFT-fine scores. The patient did not complain about any discomfort caused by the interaction with the "virtual world". Through of the use frequent of the device, the patient incorporated his hand functionally into the rehabilitation therapy RFVE, which allowed an objective record of the neuronal evolution of the patient. The result is presented for the moment with only one patient, therefore it is necessary to do more tests and studies with patients, as future work will be implemented in another pathology and with more patients. The study will be carried out at the ISSSTE October 1° Hospital in the department of physical medicine and rehabilitation.

IV. DISCUSSION

Therefore, the improvements in distal upper extremity function using VR-based rehabilitation might have resulted from the task-specificity of the Glove Smart Hybrid system, as the intervention mainly consisted of gross movements of the distal upper extremity without fine movements involving individual fingers. As the name says, virtual reality it consists of a Simulation of everyday Reality to which we are faced with simulation that is created based on a computer system (software and hardware) which is responsible of generating the synthetic environments with which he patient you can interact in a similar way as you would in the real world. TBI is a brain pathology of growing importance in developed societies its management is a dynamic process that starts from the period prehospital until rehabilitation. Attention is of the utmost importance. There are many cases of TBI that present neuropsychological sequelae, so it is of special relevance to know the physiological substrate and anatomical to better understand the neuropsychological pattern and be able to propose an appropriate evaluation and rehabilitation. The weakness or paralysis is very common after a TBI, of done, about 9 out of 10 survivors of a TBI experience limitation in movement typically more in upper limbs, hands. That's why with this smart glove indicated for patients with injury neurological: Arthritis, Brain Injury, Spinal Cord Injury and Stroke Recovery.

V. CONCLUSIONS

The study found that the patient who had problems with grip and release exercise showed greater rearrangement in the cortical area of the brain after participating in reinforced feedback therapy in a virtual environment RFVE. Without dedicated feedback the brain cannot reconstruct the neural networks that were damaged during the TBI. The Reinforced feedback therapy in a virtual environment RFVE is emerging as an innovative method in the rehabilitation and treatment of upper limb affected by brain injury. VR-based rehabilitation combined whit the neuromuscular dynamic rehabilitation might be more effective than amount-matched conventional rehabilitation for improving distal upper extremity function HRQoL. The neuromuscular dynamic rehabilitation in hand, fingers, wrist and the forearm, and virtual rehabilitation with support of various interactive training games, we help improve plasticity and movement to learn again with brain The brain is able to form new connections in response to TBI (Neuroplasticity) and to restore communication between the damaged parts of the brain and the body, this phenomenon is partly what allows TBI survivors recover motor function in the hands and other areas of the body.

ACKNOWLEDGMENT

ISSSTE. REGIONAL HOSPITAL OCTOBER FIRST, the professional medical support of the area of Physical Medicine and Rehabilitation and to the patient's willingness in his neuromotor recovery of his upper limb.

REFERENCES

[1] Virtual Reality for Stroke Rehabilitation. Stroke is available at http://stroke.ahajournals.org 2018 American Heart Association, Inc DOI:10.1161/STROKEAHA.117.020275

[2] Virtual Reality for Stroke Rehabilitation. Stroke is available at http://stroke.ahajournals.org 2018 American Heart Association, Inc DOI:10.1161/STROKEAHA.117.020275

[3] Effect of a four-week virtual reality-based training versus conventional therapy on upper limb motor function after stroke: A multicenter parallel group randomized trial. 2018 Oct 24; 13(10): e0204455. DOI: 10.1371/journal.pone.0204455.eCollection 2018.

[4] Virtual rehabilitation of upper extremity function and independence for stroke: meta-analysis. Journal of exercise Rehabilitation 2019. Published online: June 30, 2019.
DOI: https://doi.org/10.12965/jer.1938174.087

[5] A helping hand: Soft Orthosis with integrated optical strain sensors and EMG control. Publisher IEEE Robotics & Automation Magazine (Volume 23, Issue 3, Sept. 2016) 18 august 2016 DOI: 10.1109/MRA.2016.2582216

[6] Design Criteria for Hand Exoskeletons: Measurement of Forces Needed to Assist Finger Extension in traumatic Brain Injury Patients. Publisher IEEE Robotics and Automation Letters (Volume 3, Issue 4, Oct 2018). DOI: 10.1109/LRA.2018.2852769

[7] Upper Limb Orthoses for the stroke – and Brain- Injured Patient. Atlas of Orthoses and Assistive Devices (Fifth Edition) 2019 pages 146-156. e2. https://doi.org/10.1016/B978-0-323-48323-0.00013-5

[8] Effects of virtual reality-based rehabilitation on distal upper extremity function and health-related quality of life: a single-blinded, randomized controlled trial. Jneuroeng Rehabil 2016; 13:17 htps://doi.org/10.1186/s12984-016-0125-x