UPPER LIMB TRAINING USING VIRTUAL REALITY IN PATIENTS WITH CHRONIC SEQUELS OF STROKE

Joyce Xavier Muzzi de Gouvêa[2], Danielle Borrego Perez[2], Camila Souza Miranda[1], Tatiana de Paula Oliveira[1], Maria Elisa Pimentel Piemonte[1,2]

[1]Department of Physical Therapy, Speech Therapy and Occupational Therapy, Faculty of Medicine, University of São Paulo

[2] Institute of Psychology, University of São Paulo

+551130918427

E-mail: elisapp@usp.br

ABSTRACT

Objectives: A large number of studies have showed a positive effect of training associated to virtual reality (VR) to improve the function of paretic upper limb (PUL) in patients with Stroke. However, there is a lack in the evidences about the transfer's potential of the gains obtained in the VR to real environment. Thus, the purpose of this study was to investigate the transfer of gains obtained through training in VR to motor function of the PUL tested in real environment (RE) in individuals with chronic sequels of stroke (CSS).

Participants: Twenty-two patients with chronic sequels of stroke with a mean age of 66.4 ±7.14 years, 15 men and 7 women, mean time post stroke, 4.1± 5.14 years; 13 with left hemiparesis.

Interventions: Three sessions of training in VR using four games of the Nintendo Wii (NW) that elicited large and fast upper limb movements.

Main outcome measures: Goniometric measures were used as the main outcome to evaluate the transfer of gain to range of motion. As well as a computerizing test was used to evaluate the transfer of gains to movement velocity. Additionally, the scores obtained from the patients in the four games were also used as measure of learning. All measures were evaluated in two assessment time points: baseline (BA) and at end of study (EA).

Results: The ANOVA for repeated measure showed that there were statistically significant improvements for all trained games and transfer tests (range of motion and movement velocity).

Conclusions: Patients with CSS were able to transfer the gains obtained in the VR to motor function, specifically in range of motion and movement velocity in the PUL.

CCS Concepts

• Human-centered computing – Human computer interaction – Interaction paradigms – Virtual Reality.

Keywords: Virtual reality exposure therapy; stroke; rehabilitation; upper limb

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1. INTRODUCTION

In the recent years, a growing number of researches in rehabilitation of patients with stroke have emerged, increasing the evidence base on the subject. The upper limb impairment has been considered the most frequent sequels of Stroke, affecting 75% of the cases [1]. The main disabilities consist in paralysis or paresis, loss of manual ability, presence of abnormal synergies and selective movement difficulty [2,3]. Even after the rehabilitation, around 30-66% of the patients remains unable to use their PUL during their routinely activities and this brings an important limitation in their independence for activities of daily living (ADLs) and consequently decreases their quality of life [1,4]. In order to change this reality, searching for more efficient forms of training has been a challenge for rehabilitation researches.

The training using VR is one of most promising strategy to improve the therapeutic results for PUL rehabilitation. This kind of training offers as main advantages: the large number of repetitions and high frequency of feedback [1,5,6,7,8,], which are key to trigger the neural processes that promote learning [9,10].

Among the VR options, Nintendo Wii® (NW) is a cheap and easy handling alternative that have been a viable option [11].

In fact, several studies have showed the positive effects after the training using VR on PUL function in patients with stroke [6,11,12,13,14]. However, these studies have used different combinations of games, exercises and conventional therapy and measured the effects on a large number of functions. This hamper a criterial analysis about the real potential for gain transferring obtained in RV to motor function, fundamental to sustain the therapeutic usage of the VR for PUL rehabilitation in patients with stroke.

Thus, the aim of this study was to investigate the transference of expected improvements obtained by training in VR using NW games to motor function of the tested PUL in RE in patients with CCS.

2. METHODS

2.1 Participants

Twenty-two stroke patients, with a mean age of 66.4 ±7.14 years,15 men and 7 women, mean time post stroke, 4.1± 5.14 years, 13 with left hemiparesis. The patients were recruited from the Department of Physical Therapy, Speech Therapy and Occupational Therapy, Faculty of Medicine, University of São Paulo, Brazil. Inclusions criteria for the study were: patients with age between 18 and 65 years old; confirmed diagnosis of hemiparetic resulting from a single Stroke at least 6 months earlier at the beginning of the study (proofed by the date of the first computed tomography or magnetic resonance imaging); ability to perform with MS paretic, shoulder and elbow actively flexion, against gravity, in a minimum amplitude of 50º measured through a goniometry the absence of serious visual impairment or a hearing disorder; able to understand and follow simple instructions; not participating in any other rehabilitation program. The exclusions criteria were: patients with severe cognitive impairment according to Montreal Cognitive Assessment; with signals of aphasia, hemispatial neglect and other cerebellar symptom detectable by clinical evaluation; participation in other studies or rehabilitation programs. All participants signed in an informed consent form prior to study commencement. The study was performed in accordance with the CONSORT guidelines; it was approved by the Ethics and Research Committee of Faculty of Medicine of University of São Paulo (USP), Brazil, number 816.464.

2.2 Training

Four games, Wakeboarding (WB), Canoeing (CN), Rhythm Parade (RP) and Big Top Juggling (BT), were selected on the NW within the repertoire of games available on the Nintendo Wii Sports Resort® (NWSR) and Nintendo Wii Fit® (NWF) packages. The games were selected by four physiotherapists specialized in neurology, following as the main criteria (1) therapeutic potential for the rehabilitation of paretic upper limb; (2) applicability and gameplay; (3) safety for the patient. All selected games were played with both arms, trough alternately or simultaneously movement, in the same or contrary direction. The movements involved mainly flexion and extension of shoulder and/or elbow in speed and amplitude variables (Table 1).

Table 1. Main motor components trained by game

	SI	**AL**	**OD**	**SD**	**SF**	**EF**
WB	X		X	X	X	
CN	X			X		X
RP		X	X	X		X
BT		X		X	X	X

WB- Wakeboarding, CN- Canoeing, RP- Rhythm Parade, BT- Big Top Juggling, SI- simultaneous, AL- alternate, OD- opposite direction, SD- same direction, SF- shoulder flexion, EF- elbow flexion

Games were played sitting on the NWF platform, using the Wii Remote (For better hand fit of the patients, in *Canoeing* and *Wakeboarding* games two adaptions were done – figure 1) and Nunchuk in the paretic upper limb and guided by auditory feedbacks and visual stimuli projected into a screen placed in front of the patient.

Figure 1. Digital Picture showing Wii Remote wooden handle adaptation and patient´s hand fixed at Wii Remote and wooden handle

Patients performed three training sessions in one week. The first session, which included the familiarization with the games, was held in 60 minutes, consisting in five trials of each game. During the familiarization time, a physiotherapist provided verbally and proprioceptive feedback in order to help patients to achieve the best way of moving to achieve the game's objectives and avoid compensatory movements. The other two sessions had 30 minutes time, consisting in one trial of each game.

2.3 Main outcome measures

The learning was evaluated by mean scores in the games, at two assessment time points: baseline (BA) and at end of the study (EA), (Figure 2).

The transfer tests, performed in RE, were selected according to its similarity with the main motor components trained by game. The first of them, the goniometric test, was used in order to evaluate the changes in the range of motion of elbow and shoulder flexion. This test was applied with patients in seating position, following the rigidity recommendation for application of this kind of test.

The second test, involving a computational system, was used in order to evaluate the speed of repetitive movements of arm in different directions. In this test, patients were asked for moving their arm repetitively, as fast as possible. The first tested direction involved the flexion-extension movement in the elbow and the second involved the flexion-extension movement in the shoulder. All test was performed only for PUL in two-assessment point (BA and (EA)

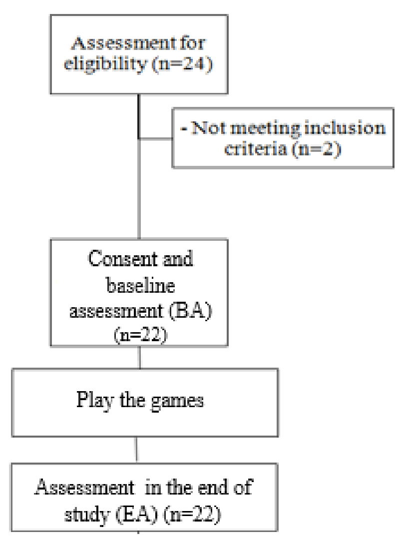

Figure 2. Flow diagram with detailed information about the sessions

2.4 Statistical Analysis

The Lilliefors and Levene tests were used to examine the normality and homogeneity of variance for NWF game scores and transfer tests.

Patients' performance on the NWF games was analyzed by four repeated-measures analyses of variance, one for each game, with assessments time points (i.e., BA, EA) as the within-group factor.

The transference effects for four tests (i.e., elbow's goniometry; shoulder's goniometry, elbow's speed and shoulder's speed) were analyzed at the two assessment time points (BA; EA) using a RM-ANOVA, considering the assessment time points as within-group factor.

The effect sizes (ES) were calculated for all comparisons at alpha=0.05. A Tukey HSD post-hoc test was used for multiple comparisons. The statistical software Statistica 11 from StatSoft (USA) was used for all analyses, and p-values below 5% were considered statistically significant.

3. RESULTS

The mean scores in games are shown in table 2. Analyses of the score in the games at baseline and at end of the study revealed statistically significant effects of the training session for all games. The post-hoc test showed statistically significant improvements in the scores for all games.

Table 2. Mean scores in games

	BA	EA	p-value
WB	154.70 (108.98)	286.80 (152.02)	.00064
CN	92.44 (43.97)	140.05 (42.70)	.00001
RP	86.59 (36.04)	113.36 (58.49)	.00246
BT	34.85 (44.29)	179.33 (197.87)	.00001

Data shown as mean (standard deviation). BA- Baseline Assessment, EA- Assessment in the end of study, WB- Wakeboarding, CN- Canoeing, RP- Rhythm Parade, BT- Big Top Juggling

Two RM-ANOVA used as factor assessment time points (BA and EA) as repeated measures for joint range of motion (degrees of range), movement's speed (time in seconds to perform 10 repeated movement), showed a significant effect of the assessment points for all measures. Tukey pos-hoc test (TT) showed a significant increase in all the measures (table 3).

Table 3. Mean scores in transfer tests

	BA	EA	p-value
Elbow flexion goniometry (degree)	127.90 (15.02)	134.04 (14.18)	.0006
Shoulder flexion Goniometry (degree)	114.66 (47.96)	134.14 (44.68)	.0001
Elbow flexion speed test (sec)	5.09 (3.83)	3.69 (2.24)	.0093
Shoulder flexion speed test (sec)	21.18 (11.24)	13.77 (6.94)	.0004

Data shown as mean (standard deviation). BA- Baseline Assessment, EA- Assessment in the end of study

4. DISCUSSION

Improving upper limb function is a core element of stroke rehabilitation in order to maximize patient functionality and reduce disability

The main evidence that emerge from this study is that there was a positive transfer of the gains obtained in VR to motor function (speed and range of motion) in the PUL of patients with stroke.

This evidence offers an important contribution to sustain the therapeutic use of the training in VR in order to improve the motor function.

According to International Classification of Functioning, Disability and Health (ICF), from World Health Organization, the functionality can be divided into two dimensions: (1) function and structure, (2) activity and (3) participation.

Function and structure have a strong relation in the level of participation and performance activity. The function can interfere in the performance of activity and the level of participation. Thus, to improve function is fundamental to restoration of the functionality.

Thus, the improvement of motor function (range of motion and velocity) are considered as fundamental components for efficient motor control. These components gains could be consider relevant for restoration of PUL functionally.

The present study showed that even after a short period of training in VR there were significant improvements in the function, in the velocity and range of motion of important elbow and shoulder flexion. These movements are involved in the majority of the ADLs.

One important factor that may contributed for positive results was the selection of the games and the assistance of the physical therapists during the training. The instructions provided by the therapist during training coupled with potential of the games reinforced the AM. Regardless of the fact that the present study has not included the impact of selection of the games and the assistance of the Physical therapists on training's results as its main purpose, we suppose that both might have been fundamental for obtained positives results.

Finally, new studies in order to verify the effects of the long extensive training in RV on the other ICF domains are fundamental to validate this kind of the intervention for improving of the PUL's functionality in individuals with CSS.

5. CONCLUSIONS

Patients with chronic sequels of stroke showed a significant learning and, most important, gain transferring obtained by training in VR to motor function in the PUL. Based on this evidence, the training in VR using Nintendo Wii may be considered a useful strategy to improve joint range of motion and movement velocity of the paretic upper limb, even in patients with chronic stroke.

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