Effects of Exergame on Patients' Balance and Upper Limb Motor Function after Stroke: A Randomized Controlled Trial

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Background: Stroke is a major cause of motor incapacity in adults and the elderly population, requiring effective interventions capable of contributing to rehabilitation. Different interventions such as use of exergames are being adopted in the motor rehabilitation and balance area, as they act as motivating instruments, making therapies more pleasurable. *Objective*: The aim of this study was to investigate the effects of exergame on patients' balance and upper limb motor function after stroke. *Methods*: This study is a randomized controlled trial. Thirty-one participants of both genders, mean age of 76 years, were assigned to the experimental or control groups; the experimental group (n = 16) underwent exergame rehabilitation using Motion Rehab AVE 3D, and the control group (n = 15) underwent conventional physiotherapy. Both EG and GC sessions happened twice a week, for 30 minutes each, over a 12 weeks period, resulting in 24 sessions. All sessions were composed of similar exercises, with same purpose and elapsed time (5 minutes). Instruments applied to verify inclusion criteria were a sociodemographic questionnaire and clinical aspects and a Mini-Mental State Examination. At baseline and after 12 weeks of intervention, the Modified Ashworth Scale, the Fugl-Meyer Assessment, and the Berg Balance Scale were used. *Results*: In both groups, patients obtained significant improvement from baseline values in all analyzed variables (shoulder, elbow, and forearm; wrist; hand; and balance) ($P < .001$). In the intergroup comparison, there were significant differences between the 2 groups for changes in values from preintervention to postintervention of shoulder, elbow and forearm ($P = .001$), and total ($P = .002$). *Conclusion*: Exergame rehabilitation in poststroke patients can be an efficient alternative for restoring balance and upper limb motor function and might even reduce treatment time.

Key Words: Stroke—video games—physical therapy modalities—randomized controlled trial

Introduction

Stroke is the main worldwide cause of persistent and acquired disability in adults and one of the leading death causes.[1] Considering that the world's population is aging, an increase in stroke rates is expected.

The consequences of strokes may have a significant impact on the individual's life quality, especially in performing daily-life activities with autonomy.[2] Therefore, rehabilitation is necessary for all poststroke patients, it is essential to functional recovery and requires a dynamic training program to maintain patient engagement,[3] which is a prerequisite for positive rehabilitation outcome and the incorporation of interactive game into stroke rehabilitation treatments has currently been widely accepted.[4]

In the last decade, exergames have been increasingly used to engage patients in their treatment, specifically for combining entertainment and body movement.[5] Exergames are

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video games that use motion sensors to capture the real user's movements and to promote a physical interaction with them. Exergames have a stimulating and an integrative nature amidst an enriched and engaging environment, offering greater motivation to learn motor skills alongside. Besides, auditory and visual feedback may increase the efficacy of rehabilitation therapy and increase the level of patient adherence to training.[6]

In this perspective, playing exergames has emerged as a valuable method for rehabilitation of the motor function of patient with disabilities. They allow high intensive repetitive practice, bilateral arm training, feedback, and self-controlled practice.[7] Many studies about exergames have been analyzing its effects on upper limb recovery,[2,8] balance,[9,10] and independence and functional ability.[11,12] For stroke survivors, especially, the use of exergames has proven to be an effective therapeutic approach on improving motor function.[3,7]

In spite of the many studies in this area, some limitations must be pointed out. First, total intervention time was not the same for the control and the experimental group.[2,3,13] Second, many studies use commercial games. These games do not focus the expected upper extremity movement in stroke survivors, as they do not have special consideration towards the spasticity that these patients might have.[6,7] When a game is specifically developed for this kind of patients, it could bring better results to improve their balance ability as it would take into account the sensitivities of the paralyzed and nonparalyzed sides.[13] Finally, no significant results were found between the game time duration and the gains with rehabilitation,[7] neither that playing exergames could reduce treatment time.

Thus, all innovations associated with exergames need to acknowledge their efficiency in order to be inserted in treatment protocols. Thereby, this study aimed on investigating the effects of exergame on the balance and upper limb motor function of poststroke patients.

Methods

Design and Setting

A randomized clinical trial was conducted at Physiotherapy School Clinic in Erechim, RS, Brazil, where people can receive both medical advice and treatment.

Participants

To recruit the 31 patients, the following inclusion criteria were considered: chronic ischemic stroke diagnosis (computed tomography); over 6 months poststroke; to be 55 or older; both genders; not to perform any other type of physiotherapeutic treatment for stroke rehabilitation during the intervention; a total score of 19 or greater on the Mini-Mental State Examination according to the participants' years of schooling[14]; and no problems with auditory or visual functioning. The exclusion criteria were: global aphasia; blindness; and exacerbated upper limb spasticity, with muscle tone between grades 3 and 4 (Modified Ashworth Scale[15]).

Ethical Consideration

Participation in the study was voluntary. Purpose and methods of the research were fully explained to individuals before providing a written informed consent. The study was approved by the Research Ethics Committee University of Passo Fundo (RS), in view of National Health Council No. 466/2012 Resolution (report 1.689.231).

Randomization

Sample calculation was performed based on sample size in finite populations, which resulted in 30 patients, as shown below.

$$n = \frac{N.p.q.Z^2_{\frac{\alpha}{2}}}{\left[(N-1).E^2 + p.q.Z^2_{\frac{\alpha}{2}}\right]} \quad n = \frac{32.0{,}5.0{,}5.1{,}96^2}{[(32-1).0.05^2 + 5.0{,}5.1{,}96^2]}$$

$$n = \frac{30.7328}{[0.0775 + 0.9604]} = \frac{30.7328}{1.0379} = 29.61 \cong 30$$

n = sample size; N = population; p = proportion of patients expected to show improvement; q= proportion of patients expected not to show improvement; $Z^2_{\frac{\alpha}{2}}$ = critical value corresponding to desired confidence level; E = maximum estimation error.

The sample was stratified in 2 groups: experimental group and control group. Participants were orderly selected through a written informed consent to take part in the project, until the limit of individuals stipulated and randomized for each group was reached, to pair the samples considering age and event time.

Interventions

The 16 patients in the experimental group (GE) underwent exergame rehabilitation using Motion Rehab AVE 3D and the 15 patients in the control group (GC) underwent conventional physiotherapy (Fig 1). Both GE and GC sessions were organized to happen twice a week, for 30 minutes each, over a 12-week period, resulting in 24 sessions. All sessions were composed of similar exercises, with same purpose and elapsed time (5 minutes). Patient's vital signs were checked at the beginning and at the end of each session. Participants did not perform any other type of treatment for stroke rehabilitation during the research or any other type of physical activity.

At baseline and after 12 weeks of intervention, the upper extremity and the balance were measured using the Fugl-Meyer Assessment (FMA) and the Berg Balance Scale (BBS), respectively.

All intervention sessions were individual and conducted by the responsible researcher, following a protocol elaborated specifically for this study, based on Piassaroli et al.[16] Protocol features shoulder abduction exercises with elbow and wrist extension; hip flexion; shoulder

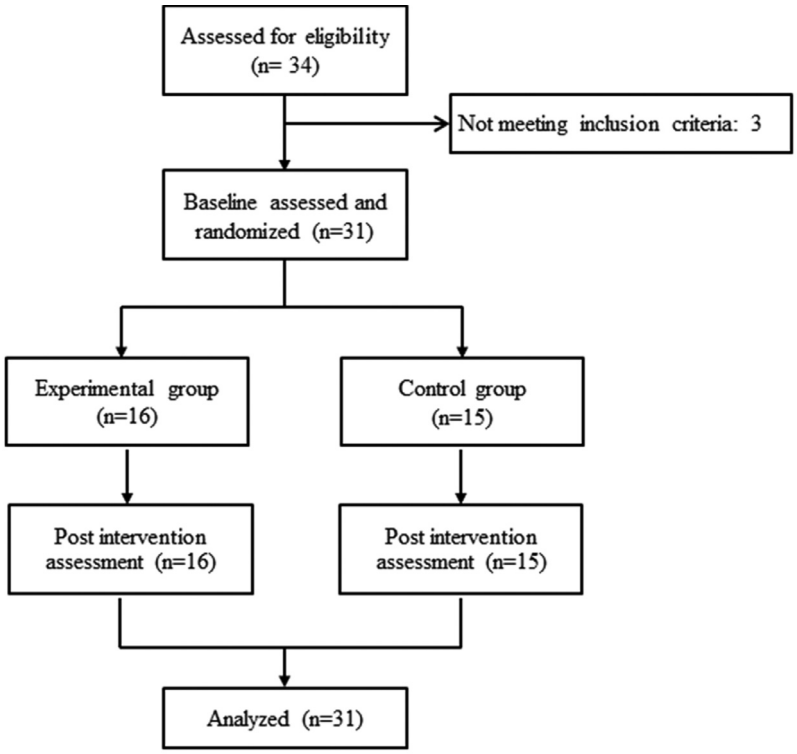

Figure 1. *Flowchart of participants through the trial.*

flexion; hip extension; shoulder horizontal abduction and adduction, and hip abduction.

GE patients interacted with Motion Rehab AVE 3D through a projector connected to Kinect and a computer. The researcher responsible for the interventions guided GC patients on the exercises executions through verbal stimuli, as described in the following subsections.

Experimental Group (GE)

The game Motion Rehab AVE 3D is an exergame with an immersive scenario, exploring interaction through virtual elements.[17] It is designed for upper limb motor function and balance rehabilitation of stroke survivors, including flexion exercises, shoulder abduction and adduction, horizontal shoulder abduction and adduction, elbow extension, wrist extension, knee flexion, hip flexion and abduction, all of each taking the 3D space into consideration. All activities developed for the game are part of conventional physical therapy exercises.

The purpose of the game is to simulate 6 activities where user must move hands, upper limb, lower limb and torso, in order to collect objects and score points. Body movements are recognized by Kinect motion sensor, equipped with a RGB video detection camera; a depth range sensor; an infrared sensor to capture spatial changes; and a microphone for voice commands.

In order to play the game, user must access a menu with hand gestures to select difficulty level, choose an avatar (male or female), and start the game. The 3D game script consists of a character, standing on a beach, representing the player's body which is motion-mapped by Kinect. Some information such as user points, difficulty, and remaining time are displayed on screen.

In the first activity the patient must stay in orthostasis and perform shoulder adduction and abduction movements, elbow and wrist extension, working on upper limb motor function. The second activity explores lower limb as the patient must be in orthostasis and perform hip flexion movements to touch objects dropping from top to bottom of the screen in the game scene with their feet, working on patient's balance. The third activity works with upper limb. Patient should remain in orthostatic position and perform shoulder horizontal abduction and adduction movements, along with elbow and wrist extension in order to work on upper limb motor function as well. The fourth activity exercises the lower limb, where patient must remain in orthostasis and perform hip abduction and adduction movements. In this phase patient must reach for objects with their feet. The fifth activity works on upper limb when the orthostatic patient performs shoulder flexion movements to touch objects falling in front of him/her. Finally, the sixth activity involves hip and knee flexion exercises, as the patient must reach for objects with their knee, thus working on balance.

The game also monitors users' score. Hits and errors are checked and presented to the physiotherapist at the end of each activity to assess patients' progress. Rest interval between each activity is 2 minutes, as to avoid muscle

fatigue. If an exercise is not performed correctly (ie user forgets to touch an object), the game's scoring system counts as an error.

Visual feedback containing score information and motivational messages are also displayed during activities. Additionally, alert sounds are triggered for each feedback presented.

Control Group (GC)

Conventional rehabilitation physiotherapy sessions were composed of the same exercises employed in the GE, such as flexion exercises, shoulder abduction and adduction, abduction and horizontal shoulder adduction, elbow extension, wrist extension, knee flexion, hip flexion, and abduction. As Piassaroli et al[16] suggest, this protocol was designed to fulfill the justification which recommends avoiding performance of exercises which can stimulate the characteristic pattern exhibited by stroke survivors. All the CG intervention sessions occurred in the Clinical School of Physiotherapy room with the same sequence of activities, interspersing the upper and lower extremities so that there was no muscle fatigue. The rest time between each of them was of 2 minutes, with verbal stimulations of the physiotherapist.

Outcome Measures

The clinical profile of each participant was verified through clinical aspects survey, including age, gender, type of stroke, and time after stroke.

The motor function of the upper extremity was measured by the FMA. The FMA was designed by Fugl-Meyer et al[18] to provide a numeric score of motor function (upper and lower extremities) after stroke. The FMA has a 3-point ordinal scale: 0 (no function), 1 (partial function), and 2 (perfect function). The maximum score is 66 points for the upper motor function.

Balance was measured using the BBS. The BBS is a 14-item scale designed to measure the ability of an individual to maintain balance while performing movements required on everyday life.[19] Maximum score is 56 and each item has an ordinal scale of 5 alternatives ranging from 0 to 4 points.

Data Analysis

Quantitative data was analyzed with statistical package SPSS 17.0 for Windows, applying t test for independent samples to confirm homogeneity between groups. The Shapiro-Wilk test indicated that the data are not normal. The data were analyzed using a nonparametric test. To determine percentage improvement, rule of 3 was used for each segment before and after intervention.

Results

No significant differences were observed between the 2 groups with regard to age ($P = .997$), time since onset of stroke ($P = .637$), and gender ($P = .892$), which indicated homogeneity between groups. The general characteristics of the subjects are outlined in Table 1.

After the intervention, this homogenization between experimental and control groups is also verified in the measured variables (Table 2). Only preintervention balance (BBS) differs ($P = .021$) between the 2 groups. The other variables presented homogeneity ($P > .05$).

There were significant improvements on values in FMA scores and BBS scores in the experimental and control groups ($P < .001$) from preintervention to postintervention. When comparing evaluation results from preintervention to postintervention between groups (Change), the variables shoulder, elbow and forearm ($P = .001$), and total ($P = .002$) were a significant statistical change.

Figure 2 shows a comparison between GE and GC, distinguishing the items evaluated during research. Both GE and GC patients showed improvement in the shoulder, elbow, forearm, and wrist segment. Regarding hand segment, out of the 16 GE participants, only 2 (12.5%) did not present score improvement, showing the same value as the initial evaluation. Still considering hand segment, 11 (73.3%) out of the 15 participants in GC improved their scores and 4 (26.7%) maintained their results.

Discussion

Analyzing this study's results comprehensively, both GE and GC showed improvement in all measured variables, comparing preintervention and postintervention results. Many researchers have previously reported similar training effects when using exergames in stroke survivors on upper extremity function,[2,8] on motor recovery[3,7], and on functional balance.[9,10] In spite of the many studies in this area, no significant results were found between the game time duration and the gains with rehabilitation (change), neither that playing exergames could reduce treatment time. Still, many studies use commercial games, that is,

Table 1. *Comparison of groupś characteristics*

Characteristics	Control group (n = 15)	Experimental group (n = 16)	*P*
Age, yrs	76.20 ± 10.41	76.19 ± 10.09	.997
Time since onset of stroke, mos	17.07 ± 10.00	15.63 ± 6.60	.637
Gender (male/female)	7/8	7/9	.892

Values express absolute, relative, or mean ± standard deviation. Significant value for $P \leq .05$.

Table 2. *Intergroups and intragroups comparison*

Variables	GC	GE	P^1
Pretest shoulder, elbow, and forearm	10.53 ± 5.33	9.06 ± 4.54	.414
Posttest shoulder, elbow, and forearm	16.07 ± 5.95	19.13 ± 4.85	.127
P^2	<.001	<.001	
Change	5.53 ± .74	10.06 ± .87	.001†
Pretest wrist	4.87 ± 2.03	3.88 ± 1.71	.151
Post-test wrist	6.87 ± 1.99	5.94 ± 2.11	.219
P^2	<.001	<.001	
Change	2.00 ± .24	2.06 ± .23	.922
Pretest hand	4.67 ± 2.87	3.93 ± 1.95	.412
Post-test hand	6.60 ± 3.20	6.19 ± 2.85	.707
P^2	<.001	<.001	
Change	1.93 ± .38	2.25 ± .39	.711
Pretest total	20.33 ± 9.48	16.56 ± 6.99	.216
Post-test total	29.40 ± 10.72	31.25 ± 8.02	.589
P^2	<.001	<.001	
Change	9.07 ± 1.34	14.69 ± .67	.002‡
Pretest BBS	22.93 ± 8.96	15.75 ± 5.16	.021*
Post-test BBS	28.53 ± 9.45	23.63 ± 6.10	.247
P^2	<.001	<.001	
Change	5.60 ± .69	7.87 ± .86	.054

Abbreviation: BBS, Berg Balance Scale.
Values express relative frequency or mean ± standard deviation.
P^1: Values found with *t* test for independent samples or by Mann-Whitney test. Significant value for $P \leq .05$.
P^2: Values found with *t* test for paired samples or by Wilcoxon test. Significant value for $P \leq .05$.
*$P = .021$, significant difference between groups in pretest.
†$P = .001$, significant difference between experimental group and control group on the change of the pretest to post-test.
‡$P = .002$, significant difference between experimental group and control group on the change of the pretest to post-test.

they do not develop the personalized game that considers individual needs and conventional physiotherapy. Games for use in upper-limb stroke rehabilitation should be personalized, to ensure maintenance of an appropriate level of challenge, dependent on individual need.[20]

In the group comparison, the only variable with significant difference was balance before the intervention, which showed GC was superior to GE in this segment. This difference was eliminated after the intervention. Although there was no significant difference between the groups in

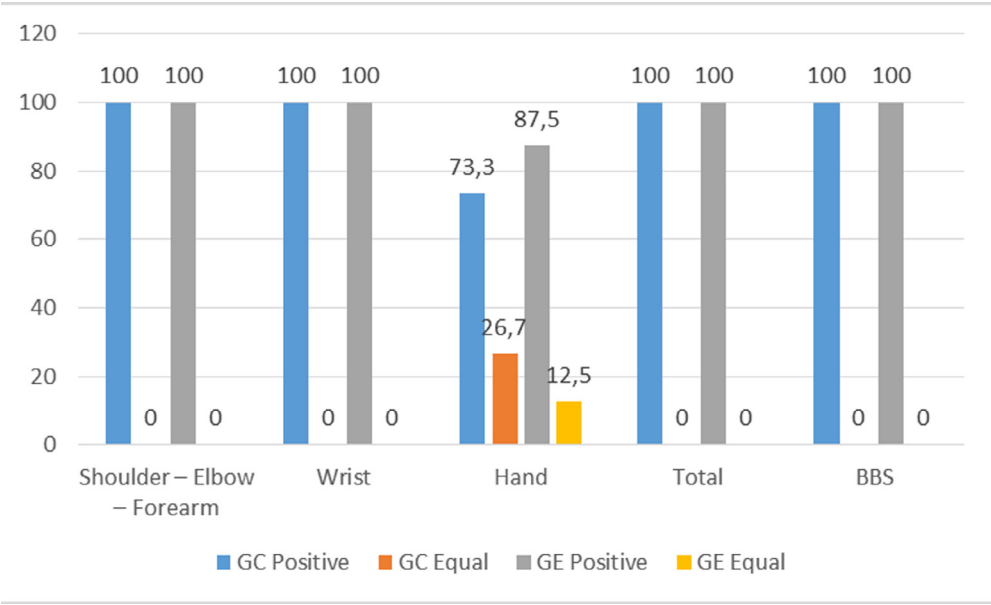

Figure 2. *Results direction analysis (positive or negative) after treatment in GC and GE.*

the postintervention for this variable, the GE presented superior change to GC. This result indicates that exergame is an efficient option to improve balance in patients with chronic injury due to stroke. GE presented better results with the same intervention time. A previous study regarding the correlation between BBS scale in patients with stroke reported that there were statistically significant improvements in the experimental group.[9] The experimental group combined 30 minutes of virtual reality-based stepping exercise with 30 minutes of conventional training. According to the authors, this exercise replicates the load−unloading sway strategy at the hip, an important feature for the balance ability.

As to the other variables, as in Park et al,[3] there was no intergroup difference on the FMA. For the experimental group, the results were not significantly greater than those for the control group, demonstrating that both treatments are efficient.

However, the major finding of this study is that playing exergames can significantly enhance patients' evolution during rehabilitation and might even reduce treatment time in the rehabilitation of motor function, especially in the shoulder, elbow and forearm, and total variables. There were significant differences between the 2 groups for changes in values from preintervention to postintervention of these variables when following the same treatment time. Although both groups benefited from rehabilitative intervention, exergame training contributed more to the improvement of motor function of affected chronic stroke patients, similar to Aşkın et al[21]. Auditory and visual feedback and the combination of entertainment and body movement present in exergame may increase the efficacy of rehabilitation therapy and increase the level of patient adherence to training.[5,6] Other studies testing exergame for stroke rehabilitation have shown high levels of satisfaction and adherence to the training intervention.[8,22] Chen et al[8] observed that patient enjoyment was significantly greater in the video game group than in the conventional group. A sample of 24 stroke patients was treated for 6 weeks. Exergame provides a visual feedback-mediated exercise, which results in very high patient motivation, strong positive impressions of the treatment, and high level of acceptance by patients,[4] encouraging users to improve their performance.[7]

When analyzing the evolution of each item, most results were positive, except for the hand segment, which obtained 4 equal results for GC, and 2 for GE. Difficulty in rehabilitating hemiparetic patient's hand was also reported by Soares et al,[23] who stated 80% of stroke survivors present acute upper limb paresis, and only a third of them recover full function. However, Hoda et al[24] found positive hand rehabilitation results, suggesting the use of a glove equipped with sensors capable of measuring forces exerted by the affected hand on the unaffected hand, that is, a specific piece of equipment was developed for that rehabilitation.

GE and GC participants' rehabilitation was more effective in improving shoulder movements because all exergame activities for upper limb motor function performed shoulder joint movement. Previous studies demonstrated that repetition of tasks proved to be effective in improving the function of the affected upper limb in the rehabilitation of poststroke patients.[25−27]

There is a substantial number of studies in which a growing approach to physiotherapeutic rehabilitation is performed using exergames, since they have a playful and interactive proposal, which can provide an additional motivation in physiotherapy sessions. However, even with so many relevant results, rehabilitation with physiotherapy without exergames remains important, since in this study the group which performed exercises with this type of treatment also obtained promising results in rehabilitation.

The limitations of this study include lack of a group combining the 2 therapies and the fact this is a single-center study.

Conclusion

Results showed exergames are an efficient alternative for upper limb motor function and balance rehabilitation of individuals affected by stroke.

Despite the significant results revealed by both groups, the experimental group achieved higher gains for 2 variables, revealing that the motivational aspect contributed to a better performance in the accomplishment of tasks. Furthermore, exergame innovates physiotherapeutic practice by incorporating health technologies.

Interventions performed with Motion Rehab AVE 3D had an expressive result which can be used as a safe and efficient way in rehabilitation in stroke survivors, promoting as a result, greater autonomy.

Future work suggestions include rehabilitation of lower limb motor function; investigating patient's engagement to the treatment; applying this study's method to other pathologies, such as Parkinson's disease; add a new intervention group combining the 2 therapies, and extend the study to other centers.

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