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Effects of Using Virtual Reality in Balance and Mobility of Post Stroke Individuals: A Pilot Study

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Abstract

The aim of this study was to investigate the effects of using virtual reality games in addition to conventional rehabilitation on balance and mobility of subjects with stroke. The study included 10 subjects with chronic hemiparesis that were divided into two groups, Virtual Reality Group (VRG) and Control Group (CG). The VRG participated in interventions that included traditional rehabilitation practices and games in virtual reality and the CG participated exclusively in traditional rehabilitation. It was used as evaluation tools to Berg Balance Scale (BERG), the Functional Reach Test (FRT), the Dynamic Gait Index (DGI) and Timed Up and Go Test (TUG). The results showed no significant difference between the groups, suggesting that the two methods of treatment promoted similar effects.

Keywords: Stroke, nintendo WII, static balance, dinamic balance, gait

Introduction

The stroke is the third leading cause of death and the major cause of disability acquired around the world [1]. The individual who survives the stroke may have alterations in cognitive processing, in the detection and integration of visual, vestibular and somatosensory stimuli, and motor deficits [2-4]. These disabilities imply deficits in Activities of Daily Living (ADL) and loss of autonomy [1].

Among the aspects that affect the quality of life of post-stroke individuals stand out the loss of balance and mobility [5]. These impairments are strictly related to greater dependence in ADLs, less social involvement and increased chance of falling [6].

The loss of balance and the gait deficits after stroke are derived from a multifactorial etiology [7], which involves: abnormalities in the detection and integration of sensory modalities, resulting in irregularities in exteroception and proprioception [8]; biomechanical constraints derived from hemiparesis, spasticity, lack of segmental coordination, loss of isometric and isokinetic strength [9-11], alterations in the cognitive processing and attention mechanisms [12,13] and inappropriate use of postural strategies and anticipatory postural control [14].

Given the need to propose new rehabilitation programs to improve these disabling features and to increase motivation and intensive training, new techniques as a complement to traditional rehabilitation approaches have been used, such as virtual reality [15].

As an advantage of the use of virtual reality in rehabilitation: (1) the practice of movements in contextualized environments [16]; (2) the possibility of intensity adjustment; (3) control the number of repetitions; and (4) the realization of the task-oriented training for the paretic extremity [17]. These advantages are considered essential for the occurrence of motor learning [18]. Furthermore, the use of virtual reality has been shown to be a challenge tool to the motor [19] and sensory systems as a source of augmented feedback in different sensory modalities, such as vision and hearing [16]. In addition the use of virtual reality experiences promotes physiological changes, psychic and somatic, similar to those existing in real-life situations [17].

Considering the results showed in recent studies in favor of using isolated virtual reality for the balance and gait of post-stroke individuals [20] and knowing the potential of traditional interventions already consolidated in the rehabilitation of these individuals, we expected with this study, to identify the effects of using a virtual reality system based on Nintendo Wii virtual games as a complement to conventional rehabilitation in post-stroke patients.

Thus, the aim of this study was to investigate the effects of using virtual reality games in addition to conventional rehabilitation on balance and mobility of subjects with stroke. The primary outcomes of this study were the dynamic balance and mobility and the secondary outcome was the static equilibrium.

Methodology

Subjects

Ten subjects were recruited from the Adult Neurology of the Physiotherapy Clinic and were adequately informed about the research procedures to be performed. They signed a Free and Clarified Consent Term to participate to the study. The subjects were 40-65 years old, male, right-handed, that presented a minimum of 6 months of hemiparesis due to one episode of stroke. These subjects did not have any experiences in electronic games in a virtual environment. This study was approved by the Ethics Committee of the University of the Sao Paulo City (protocol number 13420665).

Exclusion criteria were: cardiac instability with cardiac symptoms, uncontrolled blood pressure (>190/110 mmHg); chest pain in the 24 hours prior the initial assessment, presence of cardiac arrhythmia or signs of deep venous thrombosis; significant orthopedic or chronic pain, or the presence of pain during the experiments; joint deformities, active neoplastic disease, severe pulmonary disease and Wernicke's aphasia that prevented them from following simple commands or perform the task.

The Orpington Severity Scale [21] was selected to characterize the sample. The Orpington Scale includes the assessment of motor impairment, proprioception, balance and cognition classifying the impact of stroke as mild, moderate or severe. After selected inclusion criteria, the participants were randomized into 2 groups: control group (CG) and Virtual Reality Group (VRG).

Procedures

This study was composed of the following stages: recruitment of participants, characterization and randomization, pre-test (assessment and performance tests), intervention and post-test (same conditions as the pre-test), as shown in **Figure 1.**

The dependent variables of the study were: (1) Berg Balance Scale (BBS) that evaluates static and dynamic balance and the maximum score achieved is 54 points; (2) the Dynamic Gait Index (DGI) which assesses the dynamic balance of the subject during gait; (3) Functional Reach (FR), which assesses the limit of stability and static balance, and finally, (4) Timed Up and Go (TUG), which evaluates the change of posture from sitting to standing, and mobility.

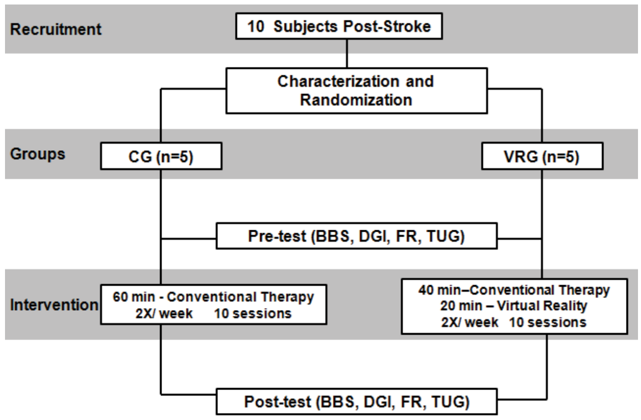


Figure 1 Design of the study phases. CG: control group; VRG: virtual reality group; BBS: Berg Balance Scale; DGI: Dynamic Gait Index; FR: Functional Reach Test, TUG: Timed Up and Go.

In addition to the use of these scales, the literature provides parameters of correlation between the scores of the scales and the risk of falling and functional independence. In this study the critical value scores for each scale were: More than 30 seconds on the TUG, which is correlated with dependence in ADLs [22]. The relationship between the probability of falling and BBS score used in this study was derived from a study of Shumway-Cook et al. [23]. The critical measure of the functional reach used in this study was appointed by Duncan et al. [24]. And finally, regarding DGI it was assumed the critical score less than 19 points as meaningful for the increased risk of falls [25].

The dependent variables defined as the primary outcomes were the DGI, TUG and BBS. And, as a secondary outcome it was used the FR.

In the intervention phase, the members of CG participated in 10 sessions of 60 minutes of conventional physiotherapy twice a week, in which performed the following exercises: (1) to stretch the iliopsoas, hamstrings, latissimus dorsi muscles and triceps sural (Gastrocnemius Lateral and Medial and Soleus); (2) overall muscle strengthening (including exercises of the bridge, abdominal, trunk rotation exercises, exercises for knee extension in closed and open kinetic chain, and exercises of dorsiflexion and plantar flexion in standing); (3) static balance, with the participant standing with closer base o support, feet together, tandem position, unstable surfaces (eg: foam) with eyes open and closed, and (4) dynamic equilibrium, in which the individual performed gait training, activities in standing position with tasks requiring body displacement, training of posture changes and circuits with all activities described.

The participants of the VRG performed 10 sessions of 40-minutes of conventional therapy plus training with Nintendo Wii games twice a week for 20 minutes, provided by a physical therapist. During the first two sessions, the physiotherapist provided manual and verbal cues to the patient in order to facilitate the movements required to interact with the game, and to promote postural correction. Such virtual reality tool as well as the games that were used to compose the virtual reality sessions are properly analyzed and validated to stroke rehabilitation in a study previously developed by Deutsch et al. [15].

The game used for the treatment was Wii Fit games in the ways of Yoga (Half Moon and Chair), Balance (Tilt Table, Penguin Slide, and balance bubble) and aerobics (basic step). The choice of games had as objective the development of skills and abilities similar to the trained CG, such as amplitude and muscle strengthening (with emphasis on the lower limbs) and static and dynamic balance (integrating cognitive demand, dual task training and greater attention demand the performance of the proposed activities). The main demands offered for each game are shown in **Figure 2**.

Nintendo Wii game sessions were performed in a room which a multimedia projector placed 4 meters from the wall and with a display measured 2 meters long by 1.5 meters wide. During all the sessions, a physical therapist accompanied the patients assuring them the necessary security. For each session all the games described above were used, in a homogeneous proportion of time and with random presentation. The time required to change one game to another was approximately 3 minutes. During this period, the patient was able to rest seated on a chair.

The characterization data of the sample were analyzed descriptively in relation to age and score in Orpington. We chose not to use inferential statistical analysis, since the sample size was small, and the it is a pilot study, to avoid high probabilities of occur errors type I or II. For these circumstances Bonett and Price [26] suggested descriptive analysis provided of the use of medians, interquartile ranges, medians obtained from the difference between pre-test and post-test and with confidence intervals at 95%.

Results

In the **Table 1** are presented the results of characterization of the subjects. It was verified that 4 individuals in CG and 4 subjects in the VRG were categorized as mild to moderate impairment (score <3.2). The others 2 participants, 1 VRG and CG 1 were classified as moderate to moderately severe (score between 3.2 and 5.2). Therefore, there is an equality between groups at measures of baseline in relation to the degree of impairment.

The **Table 2** presents the results obtained before and after training the CG and VRG groups on the scales BBS, FR, TUG and DGI, as well as the difference between the pre-test and post-test. Moreover, we verified the effects of interventions on the risk index by each scale, shown in **Table 2** by the median and interquartile range on the pre-test and post-test.

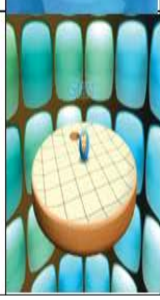
Game	Graphic Illustration	Description and Objective of the Task	Major Motor Demands Required	Major Conditional Demands Required	Game	Graphic Illustration	Description and Objective of the Task	Major Motor Demands Required	Major Conditional Demands Required
Yoga - Half Moon		The purpose of the task was to imitate the illustrated posture, holding the position for a specified time. Between trials was change of the side of the body to be inclined..	Static balance, with displacement of the center of mass outside of the limits of reduced support base..	Static flexibility and isometric strength of the core muscles.	Balance Buble		The goal of the task was to get through the anteroposterior and mediolateral displacement of the center of mass a bubble scroll through a winding path in the shortest time possible.	Dynamic balance, accurate to displacement the center of mass. Requirement of strategy of hip of the postural control.	Dynamic flexibility of the muscles of the pelvis and trunk
Yoga - Chair		The purpose of the task was to imitate the illustrated posture, holding the position for a specified time.	Static balance, with approximation of center of mass in relation of the base of support with the influence of fatigue in the lower limb.	Isometric force of Deltoid, Femoral Quadriceps, Hamstrings and Gluteus.	Pinguin Slide		The purpose of the task was move the center of mass mediolateral for a iceberg causes a sliding penguin on it and reap the fish that fall on its surface.	Dynamic balance, precision displacement and abrupt changes in direction of the center of mass. Requirement of strategy of hip of the postural control.	Dynamic flexibility of the muscles of the pelvis and trunk
Basic Step		The goal of the task was coincide visual stimuli (feet in red), with the rise in the platform balance board. Was necessary to match the side of the stimulus with the corresponding foot (right or left).	Laterality (differential sense between right and left), Coincident Timing, Dynamic Balance with transfer of asymmetric weight.	Cardio-respiratory capacity, endurance strength of the lower limbs.	Table Tilt		The goal of the task was to get from the anteroposterior and mediolateral displacement of the center of mass that is matched with the displacement of a mobile structure, a ball hit some targets.	Dynamic balance, accurate to displacement the center of mass. Requirement of strategy of hip of the postural control.	Dynamic flexibility of the muscles of the pelvis and trunk

Figure 2 General characteristics of the games used for interventions in virtual reality.

Table 1 Characterization of subjects : Orpington - Orpington Prognostic Scale; VRG: Virtual Reality Group; CG: Control group.

Group	Subjects	Age	Orpington (Pontuation)
VRG	1	45	2,6
	2	58	4,55
	3	53	3
	4	64	1,8
	5	55	3
Mean		55	2,99
CG	6	57	1,8
	7	62	2,6
	8	42	1,8
	9	61	3
	10	48	4,6
Mean		54	2,76

It is known that in BBS, higher scores at post-test indicate performance improvement resulting from intervention. Thus, negative values in the difference between the pre-test and post-test express effectiveness of the proposed intervention. This condition was observed in both groups, showing the similarity of the effectiveness of the interventions.

A complement to this finding was that the BBS improvement of the two groups was expressed in the critical indices pointed by Shumway-Cook et al. [23] **(Table 2)**. Both groups showed improvement in the median, the 25th percentile and 75th percentile, when comparing the pre-test and post-test. This made the two groups reached a higher functional characteristic scale after the intervention.

In DGI, negative values in the difference between the pre-test and post-test express improvement of performance, so our findings indicate that the VRG improved and, surprisingly, CG worsened yours performances after the intervention.

According to the study of Woollacott et al. [25] on the DGI, only the 25th percentile of the CG in the pre-test (score 21) was within the measure of decreased risk, suggesting that only 25% of subjects showed these characteristics. This tendency worsened in the post-test, in which the median, 25th percentile and 75th percentile of CG were classified as measure of tendency to falls, according to the DGI. In VRG, the DGI pre-test and post-test data mean increased risk of falls.

It is known that the TUG, the smaller the execution time of the task, the better the performance. Thus, negative values of the difference between pre-test and post-test indicate worse performance after the implementation of the proposed interventions, which occurred in both groups, with greater magnitude for CG. Both groups showed values above the critical performance in the pre-test and post-test [22].

Already, for the FR, higher values in the post-test indicate performance improvement, so the difference between the pre-test and post-test with express negative value due to improvement intervention. As can be seen in **Table 2**, this condition is observed only in the CG and not in VRG. However, this improvement was not expressed by functional change, according to the rules determined by Duncan et al. [24], so that both groups remained critical values in the pre-test and post-test **(Table 2)**.

Discussion

The aim of this study was to investigate the effects of using virtual reality games in addition to, conventional rehabilitation in post-stroke subjects.

The results from the BBS showed that both groups had a tendency of improvement expressed in better functional classification according to parameters of the study of Shumway-Cook et al. [23]. For the TUG, both groups showed a tendency to worsen, maintaining the estimate independence in ADLs [22]. For the DGI, only the VRG showed tendency towards improvement, which was not expressed in better functional classification in the risk of falling. Therefore, both groups showed critical values after intervention estimated by Woollacott et al. [25]. Finally, in FR, only the CG showed tendency towards improved, but both groups remained in critical classifications, according to the criteria of Duncan et al. [24].

These results together do not corroborate with the current data in the literature, which claims for the use of virtual reality associated with conventional therapy has improved dynamic balance in patients after stroke, compared to the exclusive use of conventional physiotherapy [27-29]. This difference can be attributed to the intervention time and maybe the clinical assessment scales used.

Intervention time

In our study both groups participated in a total time of therapy (60 minutes), which only differed in relation to the type of intervention. This aspect has provided the possibility to examine the effectiveness of a conventional mixed program (virtual reality + conventional physiotherapy) compared to conventional physiotherapy. In previous studies, virtual reality has been added to conventional therapy, causing disproportion between the time of the intervention of groups [27,28] expressing a possible effect regarding the amount of practice and not for the type of practice.

Our findings differ from the study by Cho, Lee and Song [27] that found the greater effectiveness of outcomes involving dynamic balance in favor of the VRG, which received the same time traditional interventions that CG, associated with another 30 minutes of activity in virtual reality, three times a week. Thus, the total time of intervention received by VRG was superior to the CG, which can evidence the effect of the volume of training offered rather than the type of rehabilitation offered. This same situation can also be observed in the study by Kim et al. [28] in which the VRG was more effective in all clinical analysis of dynamic balance used in the study. However, the VRG performed 30 minutes of practice in a virtual environment for each session, in addition to the load of training of CG.

Our results demonstrate that equating the groups according to the total time of training received by the conventional physiotherapy

Table 2 Descriptive analysis of the results of pre-test and post-test.

		Median Pre-Test (interquartile range) (25º per to 75º per)	Median Post-Test (interquartile range) (25º per to 75º per)	Median of diference between pre-test and post- test (confidence interval 95%)
TUG	VRG	12 (11 to 15)ɵ	16,3 (13,7 to 17,1)ɵ	-1,3 (-7,1 to 1,3)Ŧ
	CG	13 (13 to 15)ɵ	16,3 (15,9 to 16,5)ɵ	-2,6 (-3,5 to 0,3)Ŧ
FR	VRG	19,83 (19 to 21)Ɣ	11 (10 to 17,3)Ɣ	8,2 (-2,7 to 10,03)Ŧ
	CG	19,6 (16,8 to 21)Ɣ	19,6 (16,66 to 23,5)Ɣ	-2,8 (-16,5 to 23,8)*
BBS	VRG	48 (48 to 50)Ɣ	51 (50 to 51)ɵ	-2 (-8 to 0) *
	CG	48 (47 to 48)Ɣ	50 (50 to 51)ɵ	-4 (-5 to 1) *
DGI	VRG	12 (12 to 13)ɵ	16 (15 to 17)ɵ	-2 (-6 to 1) *
	CG	16 (16 to 21)ɵ	16 (15 to 19)ɵ	2 (-3 to 2)Ŧ

per – percentile,* tendency to improve, Ŧ tendency to worsen, Ɣ measure of increased risk according to the parameters of the scale, ɵ measure of decreased risk according to the parameters of the scale.

group and the combined group that received both conventional physiotherapy and virtual reality, the effects are similar. Thus, it is proposed that the results of previous studies could have been influenced by the increased the training load groups who have added training in virtual reality to conventional therapy, which could skew specific effects of virtual reality on the superiority of the results.

Characteristics of the assessment scales

It was found that the VRG showed improvement in scores after the intervention, but did not achieve scores below 19, which correspond to cutoff score for the risk of falls. Thus, despite the improvement promoted by the combined training, patients still have continued at risk of falling. So, the improvements of performance promoted on the DGI by the additional use of virtual reality may be assigned by the acquisition of compensatory movements and not by a significant change in disabilities in the musculoskeletal system. This aspect is related to what has been found in the literature, in which the studies have observed improvement in the performance of daily activities and social participation that do not necessarily reflect changes in neuromuscular or musculoskeletal structures and functions [17,20].

However, the stimulation of the compensatory mechanisms by the VRG may explain the lower performance of this group in the TUG. Because the compensation developed by hemiparetic patients can impair postural exchange of sitting to standing, which can result in low rates of vertical force during elevation body, accentuated postural sway (especially medial-lateral), greater weight support in unaffected limb and slowness of movement [12,13]. Therefore, considering the stimulation of compensatory movements, it can be speculated that the characteristics of the intervention through virtual reality could improve independent walking but note the sit to stand transfer (postural changes).

Thus, considering that the BBS presents a similar proportion of tasks of postural changes and mobility improvement, the total score on the VRG and CG could be explained by the fact that there was an improvement in the tasks of postural changes in CG and there was an improvement in mobility tasks in VRG.

In fact, it appears that interventions in virtual environment favoring acquisitions of anticipatory motors adjustments in individuals after stroke [27,28], which implies gains in adaptation and not stability of postural control [23], expressed by the FR data from the VRG.

Thus, the characteristics of the dynamism of activities in virtual environment and, consecutively, the acquisition of compensatory motors patterns could maybe explain the poor performance in FR by VRG when compared to CG. When these compensatory patterns are developed, individuals affected by stroke tend to have higher body sway and consequently greater disability in tasks of static balance [30,31].

Therefore, the use of electronic games (Nintendo Wii) in virtual reality environment associated with conventional rehabilitation is beneficial in dynamic balance and mobility, promoting benefits, which are similar to obtained by exclusive conventional physiotherapy sessions. However, must be attentive to potential risks related to the acquisition of compensatory movements that eventually the dynamism of virtual reality can stimulate in post-stroke patients.

Study Limitations

Given that this is a pilot study, prudence is required in the generalization of these results. Our study has some limitations that must be considered, especially in regards the size of the sample and the absence of a Follow-up test.

This is a pilot study with a small number of participants whose results will be used to design a randomized clinical trial.

Further research with improvements on these methodological limitations should be made to ensure greater support to the findings.

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