ORIGINAL ARTICLE

Virtual reality applied to the lower limb motor function in post-stroke individuals

Marcos Paulo Braz de Oliveira[1], Daiane Marques Ferreira[1], Josie Resende Torres da Silva[2], Andreia Maria Silva[2], Daniel Ferreira Moreira Lobato[2], Carolina Kosour[3], Luciana Maria dos Reis[2]

ABSTRACT

Strokes can generate significant motor, tonic and sensitive changes. Virtual reality (RV), focused on rehabilitation, can bring several benefits such as improvements on physical fitness, motor skills and balance. **Objective:** To assess the effects of the RV intervention to the static and dynamic balance, weight load on the affected limb, tone and muscle recruitment, functional independence and sensorimotor function in post-stroke individuals. **Methods:** Quasi-experimental and prospective clinical study with 6 subjects with diagnosis of stroke. Before and after the intervention with Nintendo Wii Fit Plus, the subjects were assessed by the Berg Balance Scale, Timed "Up and Go" and Dynamic Floor Index; Gait Test (GT); Modified Ashworth Scale (MAS); Electromyography; Barthel Index and Fugl-Meyer Scale (FMS). The Statistical analysis used Kolmogorov-Smirnov test, *t* test and Wilcoxon. **Results:** The 1st and 15th session evaluations have shown that GT (p = 0.03, d = 1.96, P = 96%), MAS for hip extensor muscles (p = 0.04; d = 3.77; P = 99%), knee extensors (p = 0.04; d = 3.23; P = 99%), plantar flexors (p = 0.01; d = 3.18; P = 99%), FMS in coordination/velocity dimensions (p = 0.02; d = 6.74; P = 100%) and sensitivity (p = 0.01) presented significant results, large effect size and power above 90%. Significant values were not found to the other evaluations. **Conclusion:** The RV rehabilitation program was effective and improved the weight-load in affected limb, muscle tone and sensorimotor function of the subjects.

Keywords: Stroke, Postural Balance, Lower Extremity, Rehabilitation, Virtual Reality Exposure Therapy

[1] Physiotherapy student, Universidade Federal de Alfenas - UNIFAL - Brazil.
[2] Physiotherapy Professor, Universidade Federal de Alfenas - UNIFAL - Brazil.
[3] Professor at the Physiotherapy course, Universidade Federal de Alfenas - UNIFAL - Brazil, Collaborating Professor at the Faculdade de Ciências Médicas - Unicamp - Brazil.

Mailing address:
Universidade Federal de Alfenas - UNIFAL
Marcos Paulo Braz de Oliveira
Av. Jovino Fernandes Sales, 2600, Prédio A
CEP 37130-000
Alfenas - MG
E-mail: marcospbraz@gmail.com

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INTRODUCTION

According to the World Health Organization (WHO), the cerebrovascular accident (stroke) is a cerebrovascular disease with sudden beginning of the clinical signs resulted from the interruption of the normal cerebral circulation or hemorrhage.[1] In Brazil, stroke is responsible for the high mortality rate and an elevated socioeconomic cost, which generates significant demand on diagnosis resources, treatment, and realibilitation.[2]

The most common impairments after stoke are motor, tonus, sensitive, and cognitive disabilities.[3] The motor changes lead to postural imbalance and instability, increase in risk for falls, which compromises the functional independence, and the quality of life of these individuals.[3]

The neurofunctional physiotherapy plays an important role in the rehabilitation after stroke, providing the patients with motor and balance control as acquired due to the frequency of the exercises, optimization in the strength gain, physical conditioning, functional capacity and body support.[1,3]

The therapies and trainings with Virtual Reality (VR) have been researched since 1990 as to develop effective techniques of extrinsic feedback (tactile, visual and auditory) towards rehabilitation. The feedback given by the VR exercises brings benefits on physical fitness, motor and balance activities, and the performance of the Activities of Daily Living (ADL).[3]

Even though there are reports on the literature on the efficacy of VR on rehabilitation of stroke patients, most studies are related to the upper limb rehabilitation, with little emphasis on the recovery of the lower limbs function.[2,3]

OBJECTIVE

To assess the effects of the VR therapy on the static and dynamic balance, mobility, weight-bearing on the affected limb, tonus and muscle recruitment, functional Independence, and the motor-sensor function of patients with stroke.

METHODS

This is a quasi-experimental prospective clinical trial. The sample was composed of 6 subjects with diagnosis of stroke who were recruited, evaluated and treated at the Physiotherapy Clinic "*Profa Dra Ana Cláudia Bonome Salate*" at the Universidade Federal de Alfenas (UNIFAL), Alfenas - MG, Brazil.

The inclusion criteria accepted patients with clinical diagnosis of chronic hemorrhagic or ischemic stroke, considered a minimum of 6 months after the stroke, aging 50 to 65 years and a functional cognition level, as assessed by the Mini Mental State Examination (MMSE).[4] Patients with history of neurologic diseases and with incapacity to maintain orthostatic position were excluded.

This study was approved by the Ethics Review Board of UNIFAL (CAAE 36990414.2.0000.5142) and all patients signed the Informed Consent Form, per resolution 466/2012 of the Brazilian National Committee of Health.

Before and after the intervention with Nintendo Wii Fit Plus (NWFP®), the patients were evaluated on the static and dynamic balance and mobility of the Berg Balance Scale (BBS), Timed Up and Go (TUG) and by the Dynamic Gait Index (DGI), weight-bearing on the affected limb by the Gait Test (GT), tonus by the Modified Ashworth Scale (MAS), muscle recruitment of lower limb by the electromyography (EMG), functional independence by the Barthel Index (BI), and the motor and sensorial function of the lower limbs by the Fugl Meyer Scale (FMS).

The BBS evaluates the balance during the ADL and is constituted of 14 items whose punctuation ranges from 0 to 4 (maximum score of 56 points), where 0 stands for maximum assistance and 4 stands for total independence in the performance of the ADL.[5]

The TUG assesses functional mobility, risk for falls, transfer capacity and dynamic balance. It measures the time spent by the subject to stand up, walk three meters, turn around, return to the initial position, and sit down again. Results above 20 seconds corresponds to low risk for falls, 20 to 29 moderate risk, and 30 or more, high risk.[6]

The DGI measures the functional ability, dynamic balance, ADL, and the risk for falls. It is an evaluation instrument composed by 8 gait tasks, with punctuation from 0 to 3, 0 meaning severe compromise and 3 no compromise, and maximum score of 24 points.[7]

GT is a NWFP® test which evaluates the weight load of lower limbs during gait. For performing this test, the subject stands on a balance board at stationary gait and performs 20 steps. The result, in percentage (%), is given by the program which allows the evaluation whether there are imbalances in the weight load. The patients were assessed by the GT in the beginning and at the end of the 1st and 15th sessions, when the data collected concerned only the affected side for further comparison.

The MAS assesses the degree of spasticity which is measured according to the resistance against a passive and fast movement. Each movement ranges from 0, normal tonus, to 4, spastic in flexion or extension.[8] In the study, the MAS was applied to the extensors, adductors and internal rotators hip muscles, knee extensors, ankle inversion muscles, and plantar flexors. To avoid bias, this scale was applied by an independent and trained evaluator.

For executing the EMF of the tibialis anterior muscle, a four channel electromyograph was used (EMG System do Brasil Ltd®). The data analysis regarded the mean of the three measurements for median frequency values. The mean of the values divided by the Root Mean Square value (RMS) was used to normalize the data.

The BI evaluates the capacity to perform the ADL by classifying the subject as independent, at a maximum of 100 points, and dependent, for a score of 0 points.[9]

At last, the FMS assesses the motor and sensorial impairment of strokes patients. Its punctuations are 0, no movement; 1, partial movement; and 2, complete movement. The total score is 226 points, given that 100 points is the score for motor function.[10] In this study, this scale was applied only on lower limbs.

Three balance games were used in the videogame NWFP®: Soccer Heading, Balance Bobble and Table Tilt. According to each game, data on round, meters, punctuation, and level regarding the evolution of the patients were collected in the 1st and 15th sessions.

The protocol was designed for 15 interventions, with a frequency of 2 sessions a week along 2 months.

Concerning the analysis of the results, the Kolmogorov-Smirnov test was used to test normality, the *t*-Student statistics was used for parametric data, and the Wilcoxon test for non-parametric data. The p-value was $p < 0.05$. The effect size was classified as Cohen[11] as small (0 - 0.39), medium (0.4 - 0.79), and large (> 0.8). The power was 80%.

RESULTS

The sample was composed of 6 subjects, aging 58 ± 4.70 years, 66.7% men and 33.3% women, with right and left hemiparesis in 50% of the cases respectively, and time after stroke above 5 years. No difference was observed regarding the BBS (p = 0.58), TUG (p = 0.13) and DGI (0.07). The GT has shown significant increase in the 15th session as compared to the 1st (p = 0.03), with large effect size (d = 1.96 and a statistical power of 96% (Table 1).

The MAS has presented significant reduction in the spasticity, with large effect size and power > 90%, in the hip extensor muscles (p = 0.04; d = 3.77; P = 99%), knee extensors (p = 0.04; d = 3.23; P = 99%), and plantar flexors (p = 0.01; d = 3.18; P = 99%). There was no significant difference in the adduction muscles (p = 0.16), internal rotators hip muscles (p = 0.05), and ankle inversion muscles (p = 0.05). The electromyographic data has shown RMS and median frequency as not significant (p = 0.57 and p = 0.34 respectively) (Table 2).

In the parameters of BI, no statistically significant difference was found (p = 1.00) (Table 3). Concerning the FMS, there was significant increase with large effect size and power above 90% in the coordination/speed dimensions (p = 0.02; d = 6.74; P = 100%) and sensitivity (p = 0.01). In the dimensions of lower extremities (p = 0.65), total motor function (p = 0.18), and passive articular movement (p = 0.37) no significant differences were found.

Regarding the Balance Bubble game, the variables time (p = 0.02; d = 1.08; P = 57%) and meter (p = 0.02; d = 2.04; P = 97%), and point (p = 0.00; d = 2.55; P = 99%) have shown significant increases. No significant difference was observed in the punctuation of the game Soccer Heading (p = 0.07) nor the round in the games Balance Bubble (p = 1.00), Table Tilt (p = 0.46) and Soccer Heading (p = 0.74) (Table 4).

DISCUSSION

The most important scientific use of NWFP® have been interventions of balance in neurological rehabilitation, such as stroke, with improvements in the corporal symmetry, dynamic and static balance, and mobility. This technology may provide a favorable environment for neuroplasticity.[12,13]

In this study, no significant results were observed regarding the comparisons of BBS, TUG, and DGI collected before and after the intervention. This results may be related not only to the musculoskeletal alterations, but to the proprioceptive, visual and vestibular systems which interfere with the motor ability and with the balance.[14]

Another study has compared the conventional physiotherapy with physiotherapy combined with visual biofeedback of hemiparetic patients, however no significant differences were found by the evaluations BBS and TUG.[13] A clinical research with stroke patients[15] and another with healthy subjects,[16] both applying VR intervention, did not observe significant increase in the BBS score, what agrees with the findings of the present study.

Concerning the BI score, no significant differences were found as well. These results agree with a previous study in which no significant differences in the performance of the ADL were found when the conventional physiotherapy for stroke patients was compared to VR.[14] However, a systematic review has suggested that the visual and auditory biofeedbacks provided by the VR environment lead to a greater control over static balance, without influencing the functional dependence of stroke patients.[13]

The present study has used a VR balance training as to improve the symmetry and the weight distribution on the lower limbs of stroke patients, in which lighter loads are usually applied in the paretic limb.[12,17] The results suggest a significant increase in the load applied in the paretic limb, as assessed by the Gait Test of NWFP®, and improvements in the body weight distribution, after comparing the results of the 1st and 15th session evaluations.

Nonetheless, the weight load evaluation on the paretic side performed at the 15th session did not show significant difference, a result that can be justified due to a possible muscle fatigue after the activity. This hypothesis can be confirmed, given that a study reported that muscle fatigue of stroke patients may be promoted due to physical activity because of neurological deficits, leading to a greater activity limitation and fatigue persistence.[18]

In the present study, the efficacy of the games Table Tilt and Balance Bubble was observed in the improvement of balance and motor learning, as assessed by evaluations of the game itself. These data yield important information about NWFP® games, once they have shown positive results in the balance of stroke patients. According to some authors, no study has investigated the feasibility or efficacy of the NWFP® games designed for balance,[12,19] what assures the importance of this investigation.

Table 1. Comparisons of results before and after intervention with the Nintendo Wii Fit Plus®

	Pre-intervention	Post-intervention	P	d	Power
	Mean ± SD	Mean ± SD			
BBS	34.50 ± 8.01	33.17 ± 8.98	0.58ᵃ	0.15	0.06
DGI	11.00 ± 2.39	14.50 ± 3.06	0.07ᵇ	1.25#	0.66
TUG	19.80 ± 4.10	16.37 ± 3.97	0.13ᵃ	0.84#	0.39
	Mean ± SD		P	d	Power
GT	1st session	15th session			
Initial (paretic side)	0.33 ± 0.04	0.42 ± 0.05	0.03ᵃ*	1.96#	0.96&
Final (paretic side)	0.30 ± 0.04	0.36 ± 0.05	0.12ᵃ	1.30#	0.72

BBS: Berg Balance Scale; IAD: Dynamic Gait Scale; TUG: Timed "Up and Go"; GT: Gait Test; SD: Standard Deviation; ᵃ Paired t test; ᵇ Wilcoxon test; * $p < 0.05$; # d large effect size; & Power > 80%.

Table 2. Comparisons before and after intervention with Nintendo Wii Fit Plus®

		Pre-intervention	Post-intervention	P	d	Power
		Mean ± SD	Mean ± SD			
MAS	Hip extensors	1.10 ± 0.27	0.20 ± 0.18	0.04ᵇ*	3.77#	0.99&
	Hip adductors	0.40 ± 0.22	0.20 ± 0.18	0.16ᵇ	0.98#	0.45
	Hip internal rotators	1.10 ± 0.09	0.40 ± 0.22	0.05ᵇ	3.75#	0.99&
	Knee extensors	1.50 ± 0.46	0.20 ± 0.18	0.04ᵇ*	3.23#	0.99&
	Ankle inversion muscles	1.40 ± 0.36	0.20 ± 0.18	0.05ᵇ	3.84#	0.99&
	Plantar flexors	1.40 ± 0.36	0.40 ± 0.22	0.01ᵃ*	3.18#	0.99&
EMG	RMS (paretic side)	87.57 ± 2.96	84.42 ± 3.73	0.57ᵃ	0.92#	0.61
	MF (paretic side)	95.28 ± 2.49	93.08 ± 1.83	0.34ᵇ	0.98#	0.46
	RMS (non-paretic side)	88.52 ± 3.72	85.83 ± 3.82	0.72ᵃ	0.71	0.44
	MF (non-paretic side)	89.31 ± 5.35	91.72 ±1.41	0.91ᵇ	0.50	0.16

MAS: Modified Ashworth Scale; EMG: Electromyography; RMS: Root Mean Square; MF: Median Frequency; SD: Standard Deviation; ᵃ Paired t test; ᵇ Wilcoxon test; * $p < 0.05$; # d Large effect size; & Power > 80%.

Table 3. Comparisons before and after intervention with Nintendo Wii Fit Plus®

		Pre-intervention Mean ± SD	Post-intervention Mean ± SD	P	d	Power
	BI	90.83 ± 8.41	92.50 ± 7.93	1.00[b]	0.20	0.06
FMS	Lower extremity	18.17 ± 1.85	19.00 ± 0.89	0.65[a]	0.51	0.17
	Coordination/speed	1.67 ± 0.33	3.83 ± 0.31	0.02[b]*	6.74[#]	1.00[&]
	Total motor function	19.83 ± 2.02	22.83 ± 1.11	0.18[a]	1.71[#]	0.91[&]
	Sensitivity	8.17 ± 1.01	12.00 ± 0.00	0.01[a]*	-	-
	Passive articular movement	12.83 ± 1.66	14.33 ± 2.01	0.37[a]	0.80[#]	0.36
	Articular pain	20.00 ± 0.00	20.00 ± 0.00	-	-	-

BI: Barthel Index; FMS: Fulg-Meyer Scale; SD: Standard Deviation; [a] Paired *t* test; [b] Wilcoxon test; * $p < 0.05$; [#] d Large effect size; [&] Power > 80%.

Table 4. Evolution comparison in the games Balance Bubble, Table Tilt and Soccer Heading of Nintendo Wii Fit Plus®

	Mean ± SD 1st session	Mean ± SD 15th session	P	d	Power
Balance Bubble					
Round	8.33 ± 1.71	8.33 ± 1.28	1.00[a]	0	0.05
Time	269.67 ± 68.50	355.00 ± 85.71	0.02[a]*	1.08[#]	0.57
Meter	4173.67 ± 1185.46	7659.17 ± 1948.87	0.02[a]*	2.04[#]	0.97[&]
Table Tilt					
Round	3.33 ± 0.80	4.00 ± 0.36	0.46[b]	0.96[#]	0.54
Level	11.83 ± 3.98	22.17 ± 4.12	0.00[a]*	2.55[#]	0.99[&]
Point	118.33 ± 39.78	221.67 ± 41.18	0.00[a]*	2.55[#]	0.99[&]
Soccer Heading					
Round	6.83 ± 1.25	7.17 ± 0.94	0.74[a]	0.30	0.09
Point	68.83 ± 14.88	229.50 ± 82.52	0.07[a]	2.10[#]	0.98[&]

SD: Standard Deviation; [a] Paired *t* test; [b] Wilcoxon test; * $p < 0.05$; [#] d Large effect size; [&] Power > 80%.

The present study has shown significant increases in the coordination/speed and sensibility of lower limbs as assessed by FMS. The scientific content concerning the use of FMS for lower limbs is limited, whereas data on upper limbs are more common in the literature.[10] These findings evidence the relevance of the results of this study on the clinical decision making of neurologic rehabilitation of lower limbs based on this assessment tool.

The MAS evaluation has shown significant decrease in the spasticity of knee and kip extensors and plantar flexors. The decrease in active movement range due to increase of muscle tonus jeopardize the motor function and postural deviation,[8] and the plantar flexors is the main cause of gait asymmetry,[8] what emphasizes the importance of the findings of this study on the decrease of spasticity of stroke patients.

Finally, no significant difference was observed in the contraction activation standard of the tibialis anterior muscle of the spastic limb, as measured by the EMG. It was also observed in a clinical trial which used a vibration platform to improve the motor function of 43 stroke patients.[20] These findings can also have been influenced by muscle fatigue, caused by intensity related processes evoked by physical exercise, which causes reduction in the maximum voluntary force during the performance of tasks.[20]

CONCLUSION

The rehabilitation program, aided with VR, was efficient to improve the weigh load applied on the paretic limb, muscle tonus and the motor-sensitive function of the study patients. However, the collected data did not show significant improvements on static or dynamic balance, mobility, muscle recruitment, and functional independence of these patients.

The literature reports few studies concerning VR for neurological rehabilitation, what requests the execution of new studies to evaluate whether the benefits found in this type of rehabilitation of stroke patients can be maintained in the long term, as well as to analyze the psychosocial aspects of this intervention, once the emotional behavior can interfere in the motor function and the visual environment may offer benefits in the process of social reintegration.

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