Virtual rehabilitation via Nintendo Wii® and conventional physical therapy effectively treat post-stroke hemiparetic patients

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Background: The Nintendo® Wii is a simple and affordable virtual therapy alternative. It may be used at home, and it is a motivating recreational activity that provides continuous feedback. However, studies comparing the use of the Nintendo® Wii to conventional physical therapy are needed.
Objective: To compare the effect of a rehabilitation treatment using the Nintendo® Wii (NW) with conventional physical therapy (CPT) to improve the sensorimotor function and quality of life for post-stroke hemiparetic patients.
Methods: The present study applied a randomized, blind, and controlled clinical trial. In total, 30 patients with post-stroke hemiparesis were evaluated. A total of 15 patients were randomly assigned to each group. The SF-36 quality of life and Fugl–Meyer scales were used to evaluate the patients.
Results: After treatment, the only variable that differed between the groups was the physical functioning domain of the SF-36 in the group that received conventional physical therapy. A significant difference was observed between both groups before and after treatment in terms of the following Fugl–Meyer scale items: passive movement and pain, motor function of the upper limbs (ULs), and balance. The CPT group also showed a significant difference with regard to their UL and lower limb (LL) coordination. The SF-36 scale analysis revealed a significant difference within both groups with regard to the following domains: physical functioning, role limitation due to physical aspects, vitality, and role limitation due to emotional aspects. The NW group also exhibited a significant difference in the mental health domain. The results indicate that both approaches improved the patients' performance in a similar manner.
Conclusion: Virtual rehabilitation using the Nintendo Wii® and CPT both effectively treat post-stroke hemiparetic patients by improving passive movement and pain scores, motor function of the upper limb, balance, physical functioning, vitality, and the physical and emotional aspects of role functioning.

Keywords: Stroke, Virtual reality exposure therapy, Hemiparesis

Introduction

Hemiparesis is the major post-stroke sequela. Other symptoms are often associated with stroke such as coordination difficulties, apraxia, postural control deficit, and balance disorders,[1,2] thereby negatively affecting the lives of individuals. These sequelae might cause individuals to lose independence, creating the potential for social isolation, depression, and the disruption of the lives of their families.[3]

The rehabilitation process is complex in several ways. One such complexity arises when the duration of therapy extends beyond a patient's financial resources.[4] When considering all post-stroke phases, however, strong evidence indicates that interventions should promote high intensity, repetitive, task-oriented physical therapies.[5,6] Conventional physical therapy has been shown to produce positive results over time.[5] Nevertheless, patients tend to find these

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DOI 10.1179/1074935714Z.0000000017

movements tedious and monotonous over time and can lose motivation for treatment adherence.[7]

Active video game systems such as Nintendo® Wii Sports are an innovative technology that might be used to improve the daily physical activity levels of people with chronic physical disabilities.[8] In addition, these games might provide real-time responses with regard to performance and progress as well as stimulate and motivate participants by honing the skills necessary to accomplish tasks.[9–11]

The Nintendo® Wii (NW) is a simple and affordable virtual therapy alternative that is being used in stroke and rehabilitation units worldwide.[12] This device became the focus of much attention due to its low cost, ability to be used independently by the patient, ability to be used for individual training and suitability for use in the home.[13] However, injuries following its use have been reported, including shoulder[14,15] and knee[16] injuries, ischemic stroke,[17] and fracture of the seventh cervical vertebra (C7).[18]

Bateni analyzed twelve individuals aged 53–91 years old who used either the Wii Fit alone, the Wii Fit combined with physical therapy training or physical therapy training alone. The results showed that although the use of the Wii Fit alone was associated with improvement in balance, the benefit was greater following physical therapy training alone or combined with the Wii Fit.[13] Kim *et al.* found significant improvement ($P<0.005$) on the Modified Motor Assessment Scale scores in the experimental group compared to the control group after three weeks of training using Wii Sports games (tennis and boxing).[19]

Nevertheless, additional studies are needed to establish the types of games that should be indicated following a functional assessment and to compare treatment using the Nintendo® Wii to conventional physical therapy.

The present study compared the effect of a rehabilitation treatment using the NW with conventional physical therapy (CPT) to improve the sensorimotor function and quality of life of post-stroke hemiparetic patients. Both the NW and conventional physical therapy represent potential therapeutic options, provided they exhibit efficacy in their outcomes.

Methods

Patients with post-stroke hemiparesis were evaluated in this prospective, randomized, controlled, and single-blind study between July 2012 and September 2013.

To be included in this study, participants must have been male or female, aged between 18 and 60 years of age to avoid the effect of advanced age on the results, with an exclusive diagnosis of stroke (performed by a neurologist based on computerized tomography or magnetic resonance imaging) presenting with hemiparesis. Furthermore, the participant must have been able to ambulate and hold the game controller without assistive devices. The last stroke episode occurred at least 6 months prior to the study.

Patients were excluded from participation if they had associated disorders such as hemineglect or pusher syndrome, an intellectual disability that made it difficult to understand the games, or a history of orthopedic diseases that promoted dysfunction in the upper limbs (ULs), lower limbs (LLs), or both that prevented the performance of the proposed activity.

Following a confidential allocation into blocks of 10 patients, a physical therapist randomly assigned the patients into groups using Random.org, which randomly selects numbers from one to ten. Two groups were formed; those assigned odd numbers were considered the virtual (NW) intervention group, and those assigned even numbers were considered the CPT group. The envelopes were sealed and stored in the patients' files.

An examiner with previous training with regard to the scales to be used evaluated the participants. An evaluation was performed before beginning therapy and after its completion. The evaluator did not know to which group the patient belonged at any point during the evaluations. Demographic data were recorded, and evaluations were performed using the SF-36[20] and the Fugl–Meyer (FM)[21] scales.

Patients underwent 60-minute treatment sessions twice a week for two months. The activities were monitored under the direct supervision of physical therapists trained by the researcher to standardize care.

The conventional physiotherapy protocol consisted of two weekly sessions. The first included a 10-minute session of bilaterally sustained stretching of the UL and LL muscles and trunk musculature; passive, active-assisted, and active-resisted mobilization of the trunk for 10 minutes; straightening and balance reactions with rapid shifts for 10 minutes; scapular mobilization for 5 minutes; active or active-assisted diagonal movement of the UL for 15 minutes; and gripping activities for 10 minutes.

The second weekly session consisted of the stretching and trunk activities that were performed during the first session as well as active or active-assisted diagonal movement of the LLs for 15 minutes; balance training while standing for 10 minutes; stationary and side gait, standing on tiptoe, and working with a proprioceptive balance

board while performing anteroposterior and latero-lateral movements for 15 minutes; and gait training for 10 minutes with the following emphases: weight transfer, swing phase, step and stride length, average speed, and training with obstacles.

The group who underwent virtual rehabilitation was treated in a 20 m^2 room equipped with the NW and a multimedia projector. The image was projected on the wall 1.2 m from the ground. In both weekly sessions, the UL, LL, and trunk muscles were stretched for 10 minutes. Subsequently, the patients underwent a 50-minute protocol of NW games. During rehabilitation, patients had a 1-minute rest interval between each games. The tennis and hula-hoop games were applied during the first session; the soccer and boxing games were applied during the second weekly session. The difficulty level of the games was increased as the patients progressed.

The games were selected so as to attain goals similar to those used for the CPT exercises. The motor learning ability exhibited by each patient was the criterion used to increase the level of difficulty of the games.

Statistical analyses

The data were analyzed using SPSS v. 16.0. Initially, the sample was described using means, medians, standard deviations (SDs), and the 25th (P25) and 75th (P75) percentiles for the quantitative variables and the absolute and relative frequencies for the qualitative variables.

After analyzing data normality using the Kolmogorov–Smirnov test, between- (intergroup) and within-group (intragroup) comparisons were made before and after the treatment. Student's *t*-test, the Mann–Whitney test, and the Wilcoxon test were used for the quantitative data, and the Chi-square test or Fisher's exact test was used for the qualitative data. The significance level was set at 5%.

Results

A total of 72 patients were recruited for this study. Of these patients, 42 were excluded: 7 refused to participate, and 35 met at least one exclusion criterion. The analysis of the remaining 30 patients is described below; patients were equally divided into the CPT and NW groups.

Table 1 shows patient demographics and clinical characteristics. Significant between-group differences were not found with regard to age, gender, time since injury, compromised hemibody, or segment predominance. Thus, the CPT and NW groups were homogeneous regarding these variables.

Significant between-group differences were not found before treatment with regard to the scale outcomes. Intragroup comparisons of the FM scores (Table 2) revealed a significant difference between pre- and post-treatment values for the following variables in the CPT group: passive motion and pain, UL motor function, UL coordination, LL coordination, balance, and total score; in the NW group, significant differences were found with regard to passive motion and pain, UL motor function, balance, and total score. The following SF-36 scale variables significantly differed within the CPT group: physical functioning, role limitation due to physical aspects, vitality, role limitation due to emotional aspects, and total score; the following SF-36 scale variables significantly differed within the NW group: physical functioning, role limitation due to physical aspects, vitality, role limitation due to emotional aspects, and mental health (Table 3).

No significant between-group differences were found for any of the FM and SF-36 variables, except the SF-36 domain physical functioning in the CPT group (Tables 4 and 5).

Discussion

The present study showed that CPT and the use of the NW both promoted improved sensorimotor recovery (as measured by the FM) and some quality of life aspects (as measured by the SF-36) of patients with post-stroke hemiparesis.

After the intervention, improvements were observed in both groups with regard to the FM domains passive motion and pain, upper limb motor function, balance, and total score. A major structural change was observed because both groups performed wide movements that involved large joint and muscle mobilization. These movements decreased the effect of immobility and disuse, which limits amplitude and exacerbates pain.

Mouawad *et al.* used the NW as a therapeutic tool and observed an increase in FM scores, with an emphasis on the range of motion of the ULs for passive and active movements. A decrease in mean performance time was observed on the Wolf Motor Function Test. The patients in that study exclusively played using the NW under supervision for 14 days, but practice was performed at home, which increased the time of contact with the game.[22] The results relative to passive motion are similar to the ones in our study but emphasize the therapeutic reinforcement gained by using this technique at home.

Veerbeek *et al.* performed a meta-analysis regarding the use of CPT for stroke rehabilitation.

Table 1 Patient characteristics

Variable		CPT N=15	NW N=15	P value
Gender, *n* (%)[b]	M	05 (33.3%)	06 (40.0%)	1.000
	F	10 (66.7%)	09 (60.0%)	
Age (years)[a]	Mean (SD)	52.8 (8.6)	53.7 (6.1)	0.732
	Median (P25-P75)	54.0 (50.0–60.0)	55.0 (49.0–59.0)	
Time since stroke (months)[a]	Mean (SD)	60.4 (44.1)	42.1 (26.9)	0.181
	Median (P25-P75)	48.0 (24.0–96.0)	36.0 (24.0–60.0)	
Affected side, *n* (%)[b]	Right	09 (60.0%)	08 (53.3%)	1.000
	Left	06 (40.0%)	07 (47.7%)	
Predominance, *n* (%)[c]	Brachial	11 (73.3%)	14 (93.3%)	0.321
	Crural	04 (26.7%)	01 (06.7%)	

Note: No significant differences were found.
[a] Unpaired Student's *t*-test.
[b] Chi-squared test.
[c] Fisher's exact test.

They found strong positive results with regard to specific high intensity, repetitive, and task-oriented physical therapy and training. Kinesitherapy as a means of physical therapy showed positive results for UL functioning and the performance of daily activities.[5]

When motor function is effective, coordinated muscle activation with selective activity is expected. The exercises performed by the patients of both group in the present study reached these objectives based on the observation of improved UL action.

Table 2 Intragroup comparisons of Fugl–Meyer scores

Fugl-Meyer variables	Time period: Before treatment Mean (SD)	Time period: After treatment Mean (SD)	P value
CPT group (*n*=15)			
Passive motion and pain[b]	85.5 (6.6)	87.3 (2.1)	0.048*
Sensitivity[b]	20.1 (5.8)	22.5 (2.5)	0.120
UL motor function[b]	34.1 (19.8)	44.7 (14.2)	0.002*
UL coordination[b]	4.7 (0.9)	5.3 (0.9)	0.030*
LL motor function[a]	22.0 (6.4)	24.8 (4.5)	0.064
LL coordination[b]	4.7 (1.5)	5.3 (1.1)	0.014*
Balance[b]	9.6 (2.2)	11.9 (1.8)	0.001*
Total[a]	180.7 (30.1)	201.8 (22.6)	0.000*
NW group (*n*=15)			
Passive motion and pain[b]	83.5 (9.9)	86.9 (2.3)	0.042*
Sensitivity[b]	16.9 (7.2)	19.3 (7.5)	0.073
UL motor function[a]	31.1 (20.5)	38.7 (19.6)	0.000*
UL coordination[b]	4.3 (1.6)	4.2 (2.2)	0.891
LL motor function[b]	21.5 (7.0)	23.4 (5.6)	0.065
LL coordination[b]	4.8 (1.5)	5.5 (1.0)	0.120
Balance[b]	9.9 (2.4)	12.9 (1.8)	0.001*
Total[a]	172.0 (35.7)	190.6 (28.3)	0.001*

Note: SD=standard deviation; P25=25th percentile; P75=75th percentile.
[a] Student's *t*-test.
[b] Wilcoxon test.
* Significant difference.

In the study by Saponisk *et al.*, the motor function of the upper limb was assessed using the Wolf Motor Function Test (WMFT) and the Box and Block Test (BBT). The results in the fourth week after intervention showed an improvement in mean motor function of 7 seconds on the WMFT in the experimental compared to the control group when the bowling and tennis games were used. No significant difference was found in the BBT score between the groups, but motor performance improved in both.[23]

Turolla *et al.* divided patients into two treatment groups: one group underwent virtual rehabilitation combined with conventional UL therapy, and the other group received conventional therapy alone. Both treatments led to significant improvements on the FM scores regarding the ULs and the Functional Independence Measure scale; however, the improvements obtained via virtual rehabilitation were significantly greater.[24] However, the use of combined therapy makes the analysis of the effects of virtual reality compared to conventional therapy difficult. The protocol used in our groups can lower on the results of the isolated NW therapy or conventional physical therapy.

An improvement in balance was observed with regard to the NW rehabilitation because the body weight of the patient is transferred to the hemiparetic leg and the trunk. Because of the features of the game played and to participate more efficiently, participants were required to transfer their weight automatically. In our study, all CPT group activities emphasized transferring the patients' body weights to their paretic legs and their trunks. The activities of

Table 3 Intragroup comparisons of SF-36 scores

SF-36 variables	Time period: Before treatment Mean (SD)	Time period: After treatment Mean (SD)	*P* value
CPT group (n=15)			
Physical functioning[a]	40.3 (24.7)	65.0 (21.5)	0.000*
Physical aspects[b]	5.0 (10.4)	55.0 (39.2)	0.003*
Pain[b]	62.6 (9.5)	66.9 (4.7)	0.257
General health status[a]	48.2 (26.4)	61.3 (19.4)	0.099
Vitality[a]	54.7 (26.9)	71.3 (24.5)	0.018*
Social aspects[b]	45.0 (33.0)	63.3 (35.2)	0.092
Emotional aspects[b]	40.0 (50.7)	71.1 (41.5)	0.026*
Mental health[a]	60.0 (14.8)	60.0 (12.9)	1.000
Total[a]	355.8 (110.0)	513.9 (131.6)	0.000*
NW group (n=15)			
Physical functioning[b]	54.0 (21.2)	94.0 (12.0)	0.007*
Physical aspects[b]	1.7 (6.5)	65.0 (38.7)	0.001*
Pain[b]	67.7 (5.7)	64.4 (7.5)	0.191
General health status[a]	62.5 (20.8)	63.7 (19.4)	0.356
Vitality[b]	69.0 (22.6)	87.0 (14.1)	0.016*
Social aspects[b]	56.7 (43.8)	52.5 (33.5)	0.592
Emotional aspects[b]	46.7 (51.6)	77.8 (37.1)	0.026*
Mental health[a]	67.5 (17.4)	60.8 (10.1)	0.002*
Total[a]	425.7 (112.5)	565.2 (94.7)	0.109

Note: SD=standard deviation; P25=25th percentile; P75=75th percentile.
[a] Paired Student's *t*-test.
[b] Wilcoxon test.
* Significant difference.

both groups reinforced rectifying responses as well as LL and trunk-stabilizing muscle action, thereby working mobility and stability, which are necessary for positive feedback on all of the scale items.

Barcala *et al.* studied the balance of twelve individuals with hemiparesis after either CPT or using Wii Fit™ combined with CPT, twice a week for 5 weeks. The results indicated both groups of patients showed improvements in balance; however, the effect of the NW is difficult to determine, though it is possible to distinguish the effect of conventional physical therapy.[25]

However, Mouawad *et al.* used the NW in hemiparetic patients and found improvement in the mean balance scores on the Berg Balance scale after treatment.[22]

In the present study, improvements in UL and LL coordination were also observed after CPT, a result that might have been because of the exercises involving fine motor control and gait training with and without obstacles. The NW exercises only emphasize

Table 4 Intergroup comparisons of SF-36 scores after treatment

SF-36 variables	CPT Mean (SD)	NW Mean (SD)	*P* value
Physical functioning[b]	65.0 (21.5)	94.0 (12.0)	0.000[b]*
Physical aspects[b]	55.0 (39.2)	65.0 (38.7)	0.461
Pain[b]	66.9 (4.7)	64.4 (7.5)	0.624
General health status[a]	61.3 (19.4)	63.7 (19.4)	0.730
Vitality[b]	71.3 (24.5)	87.0 (14.1)	0.050
Social aspects[b]	63.3 (35.2)	52.5 (33.5)	0.389
Emotional aspects[b]	71.1 (41.5)	77.8 (37.1)	0.713
Mental health[a]	60.0 (12.9)	60.8 (10.1)	0.851
Total[a]	513.9 (131.6)	565.2 (94.7)	0.231

Note: SD=standard deviation; P25=25th percentile; P75=75th percentile.
[a] Unpaired Student's *t*-test.
[b] Mann–Whitney test.
* Significant difference.

Table 5 Intergroup comparisons of Fugl–Meyer scores after treatment

Fugl–Meyer variables	CPT Mean (SD)	NW Mean (SD)	*P* value
Passive motion and pain[b]	87.3 (2.1)	86.9 (2.3)	0.713
Sensitivity[b]	22.5 (2.5)	19.3 (7.5)	0.512
UL motor function[b]	44.7 (14.2)	38.7 (19.6)	0.486
UL coordination[b]	5.3 (0.9)	4.2 (2.2)	0.217
LL motor function[a]	24.8 (4.5)	23.4 (5.6)	0.457
LL coordination[b]	5.3 (1.1)	5.5 (1.0)	0.653
Balance[b]	11.9 (1.8)	12.9 (1.8)	0.106
Total[a]	201.8 (22.6)	190.6 (28.3)	0.242

Note: SD=standard deviation; P25=25th percentile; P75=75th percentile.
[a] Unpaired Student's *t*-test.
[b] Mann–Whitney test.
* Significant difference.

weight transfer in the LL; the UL movements required were not sufficient for training precise coordination.

The results from both groups provide evidence suggesting that skill improvements were generalized to the functional tasks tested by the scale.

After intervention, improvements were observed in both groups with regard to the SF-36 domains physical aspects, vitality, physical functioning, and emotional aspects. The NW group also showed improvements in mental health, and the CPT group showed improvements in the total score. There was also a significant difference in the physical functioning domain exhibited by the CPT group compared to the NW group.

The exercises performed in both groups interfered with the amount of time required to perform the activities that comprise physical aspects. Pain reduction and improvements in the motor function of the ULs and balance were the keys to this result. The activities yielded gains in muscle quality, and patients consequently became more able to perform their daily tasks, favoring autonomy and independence.

The finding that patients performed physical therapy or played NW affected their perceptions of how they felt with regard to their vigor, strength, will, and exhaustion. The demand from both the games and physical therapy required effort and aerobic activity, thereby directly affecting the gain of energy and vitality.

In our study, patients felt safer when performing the tasks. The emotional aspect stopped representing a limitation to the performance of daily activities. The positive sensory motor recovery results influenced patients' emotional health because both CPT and NW groups showed improvements, indicating a positive influence on their self-image, self-perception, and self-esteem.

The games influenced negative aspects of mental health such as stress, depression, and anxiety but influenced positive aspects such as self-efficacy, which affected the final results. Importantly, the games were fun, and victories appeared to stimulate the patients.

The groups showed a significant difference with regard to physical functioning. The exercises performed influenced transferring object activities, tasks while standing, walking, and climbing stairs, all of which are important for mobility and dual tasks, which in turn affect the daily lives of these patients.

Studies comparing CPT and the use of the NW using the SF-36 are scarce; however, studies using isolated therapy indicate the benefits of these activities on patient quality of life.

Rangel *et al.* conducted a cross-sectional that evaluated quality of life after stroke and reported that quality of life is decreased and correlated with limitations in performing the daily activities. However, scores increased after patients performed rehabilitation activities, and most of these patients received physical therapy.[26]

Sardi *et al.* performed functional training using the NW for two months twice a week and were able to increase quality of life scores among hemiplegic patients according to the Brazilian version of the Stroke Specific Quality of Life scale.[27]

The proper choice of NW game according to the functional impairment of the patient and the intended objective is important. As Lange *et al.* stated, these games have the potential to be used as a therapeutic tool, but it is important that the type of game chosen be centered on the needs of the patient population.[28]

The present study had some limitations such as the high rate of participation of patients with predominantly brachial hemiplegia, without using a specific scale. Patient follow-up assessments or evaluations of the learning transfer to their everyday lives were also not performed.

Conclusion

Virtual rehabilitation using Nintendo Wii® and CPT effectively treats post-stroke hemiparetic patients. Improvement was found in passive motion and pain scores, motor function of the upper limb, balance, physical functioning, vitality and the physical and emotional aspects of a patient's role functioning.

Disclaimer Statements

Contributors

All authors contributed equally.

Funding

The São Paulo State Research Foundation (Fundação de Amparo à Pesquisa do Estado de São Paulo; FAPESP) sponsored this study (Proc. 09/52145-7).

Conflicts of interest

The authors declare no conflicts of interest.

Ethics approval

All participants provided written consent for the experimental procedure, which was approved by the Ethics Committee of The Federal University of São Paulo.

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