






Investigating the Effect of Nintendo Wii Games on Clinical and Neural Properties of Ankle Spasticity in Patients with Stroke: A Randomized Clinical Trial

Saeideh Farahmand¹, Majid Ghasemi ², Keivan Basiri ², Ehsan Ghasemi ^{3,*}

¹ Department of Physiotherapy, School of Rehabilitation, Isfahan University of Medical Sciences, Isfahan, Iran

² Neurosciences Research Center, Isfahan University of Medical Sciences, Isfahan, Iran

³ Musculoskeletal Research Center, Isfahan University of Medical Sciences, Isfahan, Iran

*Corresponding Author: Musculoskeletal Research Center, Isfahan University of Medical Sciences, Isfahan, Iran. Email: eghasemi@rehab.mui.ac.ir

Received: 9 December, 2023; Revised: 10 February, 2024; Accepted: 14 May, 2024

Abstract

Background: Stroke is one of the most common causes of disability. Spasticity is a common clinical impairment that occurs after a stroke. Spasticity occurs due to changes in the mechanical properties of the muscle and the neural properties following a stroke.

Objectives: This study aimed to investigate the effect of Nintendo Wii games on ankle spasticity outcomes in stroke patients.

Methods: In this parallel single-blind clinical trial study, 30 patients with stroke were randomly assigned to one of the experimental and control groups. The subjects of both groups received conventional physiotherapy, including stretching of ankle plantar flexor muscles and walking exercises on parallel bars. In addition, the experimental group also received Nintendo Wii games for 30 minutes three times a week for a total of 12 sessions. Clinical outcomes of spasticity and neural properties were evaluated using the Modified Ashworth Scale and H-reflex latency and Hmax/Mmax ratio. All statistical analyses were performed using SPSS version 20.

Results: The intragroup results showed that the clinical outcome of spasticity was significantly reduced in the experimental group ($P = 0.001$). The comparison between the two groups showed no statistically significant difference in clinical outcome and neural properties between the experimental and control groups ($P > 0.05$).

Conclusions: Based on the results, the clinical outcome of spasticity was significantly reduced after the end of the treatment in the Nintendo Wii group. The use of Nintendo Wii can be suggested as a treatment modality alongside the usual treatments to achieve greater and faster effectiveness in patients with stroke.

Keywords: Stroke, Ankle Spasticity, Therapeutic Exercise, Virtual Reality

1. Background

Stroke is one of the leading causes of permanent disability in today's advanced societies, which imposes short-term and long-term costs on the family, society, and the medical system of countries (1). Spasticity is one of the most common clinical symptoms explored after stroke. About 30% to 40% of people experience spasticity after a stroke (2). Spasticity occurs as a result of changes in the mechanical properties of the muscle and the reflex properties following upper motor neuron syndromes (3). Patients with stroke often face functional mobility limitations because of spasticity, which may

improve some functional movements. For example, spastic ankle affect negatively on walking performance (4). In some studies, EMG has been employed to quantify the response stimulated by either the muscle (M-reflex) or electrical stimulation of the peripheral nerves innervating the muscle (H-reflex) in spastic patients where responses are exaggerated and related to the extent of spasticity (5).

Restoring upper and lower limb function is one of the most essential rehabilitation goals for people with central nervous system diseases. Both active and passive rehabilitation interventions improve strength and flexibility. Studies have reported that patients with

central nervous system diseases perceive rehabilitation protocols as repetitive, long-term, and monotonous, which decreases the motivation and participation of patients to participate in rehabilitation treatment programs (6). In recent years, the use of virtual reality-based treatments has increased as one of the types of interventions in neurorehabilitation (7). Virtual reality allows patients to interact with simulated environments that are similar to real environments (8). Among the various virtual reality devices, non-immersive virtual reality devices are the best for integration into rehabilitation treatment programs. Accordingly, the Nintendo Wii is one of the most widely used virtual reality devices for neurological diseases, including known strokes (9). Nintendo Wii requires the participant to actively participate in various sports and recreational activities, such as games, while standing or sitting and can be adapted to the patient's needs (10). Nintendo Wii is a valuable tool that provides flexibility, balance, strength, and coordination training in safe environments such as homes or clinical centers, which can be used to train individuals in a targeted manner (10). Many researchers have conducted studies on the effect of Nintendo Wii in improving upper limb function and balance (11). Saposnik et al. investigated the safety and practicality of using Nintendo Wii to facilitate the upper limb function of patients with Stroke (12). Studies have also described Nintendo Wii exercises improving balance, performing daily activities, and walking efficiently (13). Meanwhile, Yatar and Yildirim found that despite the effectiveness of this method, there was no significant difference between the Nintendo Wii and the Bobat method in treating patients with chronic stroke (14).

In previous articles, the positive effect of using Nintendo Wii has been proven to improve the balance and movement performance of the upper and lower limbs of patients with stroke. However, there is no evidence of the effect of this intervention in reducing or increasing spasticity in patients with stroke.

2. Objectives

This clinical trial study aimed to compare the effectiveness of conventional physiotherapy alone with the combination of conventional physiotherapy and the use of the Nintendo Wii game console on the outcomes of spasticity in patients with stroke. The authors of this article assume that adding Nintendo Wii to conventional physiotherapy can significantly reduce the spasticity of the ankle plantar flexor muscles in patients with stroke.

3. Methods

The present study is a parallel single-blind randomized clinical trial in which patients are randomly assigned to one of the two groups of conventional physiotherapy alone (control group) or the combination of conventional physiotherapy and games with a Nintendo Wii console (experimental group). The target population was male and female with stroke. In the present study, the sampling method was convincing and available. All stages of the current research, including clinical evaluations and treatment sessions, were conducted in the physiotherapy clinic of Ayatollah Kashani Hospital in Isfahan city between July and December 2022. Patients were assigned to two groups based on the random block method by the clinic secretary, who was unaware of the study. Using the appropriate formula and based on a survey (15) and considering the significance level $\alpha = 0.05$ and $Z = 1.96$, the statistical power = 80% ($Z_{1-\beta} = 0.84$) and the sample size of 15 people in each group were estimated. The protocol of this study was approved by the Ethics Committee of Isfahan University of Medical Sciences (ethic code: [IR.MUI.RESEARCH.REC.1399.309](#)) and prospectively registered in the Clinical Trials Center of Iran (IRCT code: [IRCT20200101045970N3](#)). The flowchart related to the number of people present in each stage of the study is shown in [Figure 1](#). As reported in a flowchart, 55 people with stroke were evaluated, and 21 were excluded from the survey for reasons such as lack of entry criteria and unwillingness to participate. A total of 34 patients with stroke were randomly assigned to one of the control and experimental groups. During the treatment period, a total of four eligible people did not complete the treatment period. Finally, the data obtained from 30 stroke patients who completed the treatment course were used for statistical analysis. The criteria for entering the study include age 18 to 85 years (16), the presence of a history of the first unilateral stroke that has been proven by a neurologist diagnosis through CT scan or MRI findings (17), the presence of spasticity in the ankle joint two or more. According to the Modified Modified Ashworth Scale (MMAS) criterion (18), the presence of appropriate cognitive status based on the Persian version of the mini-mental status exam (MMSE) was > 24 (3), and the ability to maintain a standing position without using aids for at least 30 seconds (19). In addition, exclusion criteria included a history of heart attack or high-risk heart disease (18), the presence of other neurological disorders such as neuropathy, epilepsy, convulsions (19), the use of botulinum injection or other antispastic drugs (4), participation in other physiotherapy interventions, (3)

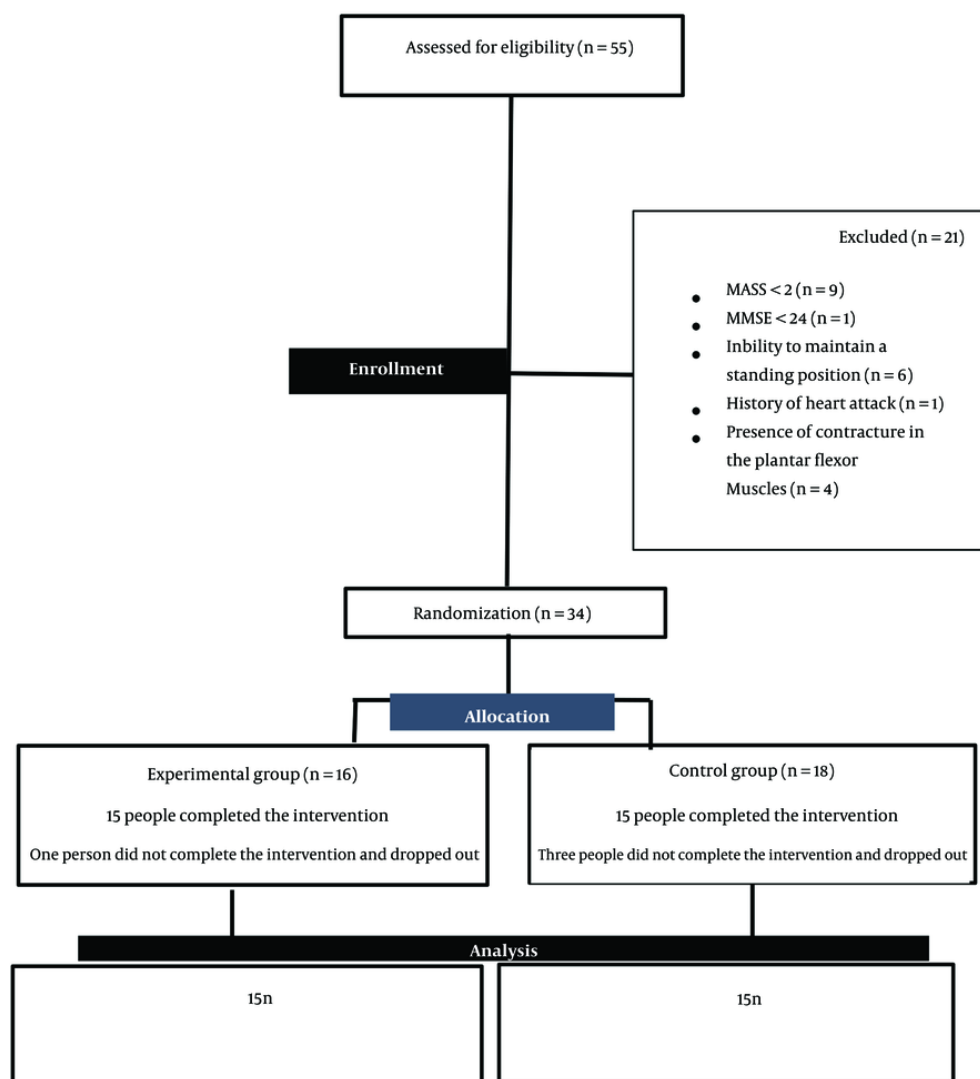


Figure 1. Clinical trial study flow chart (CONSORT flow chart)

and the presence of contracture in the plantar flexor muscles (4).

3.1. Outcomes Measure

The outcomes were the clinical outcome of spasticity and neural properties. The study outcomes were evaluated in two stages: Before the start of the treatment and at the end of the treatment period. This study assessed the clinical outcome of the spasticity level of ankle plantar flexor muscles using the MMAS. This is a common and reliable tool for measuring the

degree and amount of spasticity, which evaluates the amount of resistance to passive stretching of the involved muscles (20). The examiner, unaware of the groups, determines the degree of resistance to passive movement from 0 to 4 to determine the degree of spasticity based on the Persian version of the MMAS (21).

Neural properties, including H-reflex amplitude, H-reflex delay time, M wave amplitude, and the ratio of H-reflex amplitude to M wave amplitude, were measured in this study. Neural parameters were measured by an experienced neurologist unaware of the study subjects

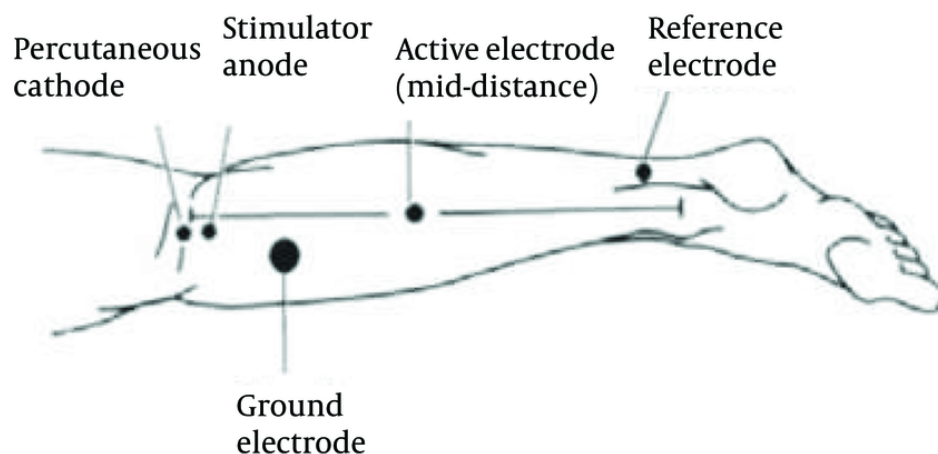


Figure 2. Diagram of placement of electrodes and stimulator for recording the H-reflex and M-response

and treatment groups. Patients were asked to sleep on the bed with their feet hanging over the edge of the bed. [Figure 2](#) illustrates how the tibial nerve is stimulated in the popliteal cavity after preparing the skin. The stability electrode is placed on the gastrocnemius muscle between the medial malleolus and medial epicondyle of the tibia, and the grand electrode is placed between the stimulating and receiving electrodes. Nerve stimulation was performed according to the Braddom and Johnson method with 1ms diversion and a frequency of one every 5s, and then electrophysiological indicators including the H-reflex amplitude, H-reflex delay time, M wave amplitude, the ratio of the H-reflex amplitude to the M wave amplitude in this study were recorded ([22](#)).

3.2. Treatment Protocol

Both groups were treated for 12 sessions four weeks after initial evaluations. Both groups received the therapeutic exercise protocol under the supervision of a physiotherapist three times a week for four consecutive weeks and a total of 12 sessions ([23](#)). Furthermore, the experimental group also used the Nintendo Wii console three times a week for four consecutive weeks and 12 sessions in addition to therapeutic exercise. The games were played using the Nintendo Wii console while the patient stood on the balance board. The patients had already received the necessary training from the physiotherapist and were controlled by him during the

game. In each session, three out of five games were selected based on the participation of the physiotherapist's opinion and the patient's preference. People were at a distance of three meters from the screen. Each session lasted 30 minutes.

3.3. Data Analysis Method

All statistical analyses were performed using (IBM Statistical Package for the Social Sciences) SPSS version 20. The Shapiro-Wilk test was used to evaluate the distribution of data. Mann-Whitney test was used for inter-group comparison of spasticity degree, and Wilcoxon test was used for intra-group comparison. An independent *t*-test was used to compare two groups before starting treatment for other outcomes with normal distribution. One-way analysis of variance/covariance "ANCOVA/one-way ANOVA" was used to compare the two groups after the start of the study. In the variance/covariance analysis, the results were reported once without controlling the values before the treatment (raw) and once with the control of the values before the treatment (corrected). In this study, the final model is the corrected model. Paired *t*-test was used for intragroup comparisons. Cohen's *d* effect size was used to examine the magnitude of intergroup differences and determine the effectiveness of the test (using the Nintendo Wii console). The level of significance in the present study was considered 0.05.

Table 1. Stroke Subject Characteristics (N = 30)

Groups	Age (y)	Weight (kg)	Height (cm)	Duration of Disease (mo)	Stroke Type	Stroke Side	Gender
Experimental	57.07 ± 12.21	66.80 ± 9.89	169 ± 8.24	17.33 ± 13.15	H = 5, I = 10	R = 9, L = 6	M = 11, F = 4
Control	60.33 ± 12.97	67.60 ± 10.43	164.53 ± 9.27	25.73 ± 13.53	H = 5, I = 10	R = 9, L = 6	M = 8, F = 7

Abbreviations: H, hemorrhagic; I, ischemic; R, right; L, left; M, male; F, female.

4. Results

A total of 30 stroke patients with lower limb spasticity completed this clinical trial study. Table 1 shows the demographic variables of both groups. As reported in Table 1, the average age of the participants in the experimental group is 57.07 years, and the average age in the control group is 60.33 years. In addition, there was no statistically significant difference between the two groups in quantitative background variables ($P > 0.05$).

Descriptive and analytical statistics of primary and secondary outcomes are presented in Table 2. The median intensity of spasticity before the start of treatment in the test and control groups was 3 and 2, respectively. After the end of the treatment, the median intensity of spasticity in both groups was 2. In the analytical statistics section, except for the result of spasticity degree, which did not have a normal distribution and non-parametric tests were used, other results had a normal distribution.

4.1. Intergroup and Intragroup Analysis of the Degree of Spasticity

Before the treatment, there was no significant difference in the mean of spasticity between the two groups ($P > 0.05$). In addition, the comparison of the average degree of spasticity between the two groups after treatment was not significant ($P > 0.05$). Comparing the degree of spasticity before and after the treatment within each group showed that in the experimental group, the degree of spasticity decreased significantly ($P < 0.05$). In contrast, in the control group, no significant difference was observed ($P > 0.05$).

4.2. Intergroup and Intragroup Analysis of H-reflex Latency

There was no significant difference in the average H-reflex latency between the two groups before the treatment ($P > 0.05$). The results of one-way analysis of variance/covariance showed no significant difference in the delay time of the H-reflex between the two groups with and without controlling the baseline values after

the end of the treatment period ($P > 0.05$). Based on the Cohen-Dham Effect Size Index, none of the two treatment methods had a significant advantage over the change in the delay time of the H reflex, and the magnitude of the difference between groups for this outcome was insignificant. The results of intragroup analysis showed no significant change in the delay time of the H-reflex in both the experimental and control groups after the treatment, compared to before the treatment ($P > 0.05$).

4.3. Intergroup and Intragroup Analysis of the Ratio of the Maximum H-reflex Amplitude to the M Wave Amplitude

Before the treatment, no significant difference was observed in the ratio of the H-reflex amplitude to the M wave amplitude between the two groups ($P > 0.05$). Based on the one-way analysis of variance/covariance with and without control of baseline values, there was no significant difference in the ratio of the H-reflex amplitude to the M wave amplitude between the two groups after the end of the treatment period ($P > 0.05$). According to Cohen's Effect Size Index, the magnitude of the difference between groups for this outcome was insignificant and insignificant. In the control and experimental groups, there was no significant difference in the ratio of the H-reflex amplitude to the M wave amplitude before and after the treatment ($P > 0.05$).

5. Discussion

This study showed a significant difference in the clinical outcome of spasticity in the experimental group compared to before the treatment. In contrast, in the control group, there was no significant difference between before and after the treatment. After treatment, the two groups had no significant difference in the clinical outcome of spasticity. Moreover, a comparison between control and experimental groups in this study revealed that neither had a significant change in H-reflex latency or ratio of H-reflex amplitude to M wave after the end of the treatment period, compared to before the treatment period. There was no significant difference between groups.

Table 2. Descriptive and Analytical Statistics of Outcomes

Variables	Experimental Group (n = 15)				Control Group, (n = 15)				Between Two Groups		Within the Group	
	Baseline	After Intervention	Baseline	After Intervention	P-Value		z Index/f Index		Cohen's d	P-Value		
					Baseline	After Intervention	Baseline	After Intervention		Experimental	Control	
Spasticity level (score)	3 (1)	2 (1)	2 (1)	2 (1)	0.72	0.21	-0.36	-1.26	-	0.001	0.096	
H-reflex latency (ms)	31.66 (4.93)	31.32 (3.74)	31.35 (4.5)	30.83 (3.18)	0.85	0.7 ^a , 0.69 ^b	0.18	0.15 ^a , 0.17 ^b	0.14 ^a , 0.15 ^b	0.64	0.45	
The maximum amplitude of the H-reflex (mv)	4.53 (2.45)	4.21 (2.26)	3.29 (1.35)	3.55 (1.27)	0.1	0.33 ^a , 0.66 ^b	1.71	0.97 ^a , 0.19 ^b	0.36 ^a , -0.16 ^b	0.64	0.48	
The maximum M-wave amplitude (mv)	13.13 (4.93)	11.88 (3.97)	11.34 (4.26)	11.99 (5.30)	0.3	0.95 ^a , 0.82 ^b	1.06	0.1 ^a , 0.37 ^b	-0.03 ^a , -0.33 ^b	0.25	0.54	
The ratio of the, H max / M max	0.37 (0.18)	0.36 (0.18)	0.34 (0.2)	0.34 (0.14)	0.84	0.77 ^a , 0.84 ^b	0.21	0.09 ^a , 0.04 ^b	0.11 ^a , 0.08 ^b	0.97	0.9	

^a Raw model.^b Corrected model.

Spasticity after a stroke can cause pain, impaired hand movements, limited range of motion, impaired walking and daily activities, and finally, a severe decrease in the quality of life in stroke patients (24, 25). There are many pharmacological and non-pharmacological therapeutic interventions aimed at reducing spasticity and improving function in stroke patients. Among conservative treatments, acupuncture, and dry needling can be mentioned (26). Exercise therapy is a key and cheap treatment for reducing muscle tone and improving function in people with a history of stroke. In a study, Park et al. investigated the effectiveness of therapeutic exercise and electrical stimulation (15). Exercise therapy included floor exercises and walking for thirty minutes in each session. Following the combination of electrical stimulation and exercise therapy, a significant reduction in the level of spasticity was observed compared to the exercise therapy group alone (15). Zhang et al. showed that therapeutic exercise in water is more effective than usual therapeutic exercise in improving function, but no difference was observed between the two groups in the degree of spasticity (27). The most common and widely used conservative treatment test for increasing the range of motion and managing spasticity is stretching exercises, which are prescribed as an essential component in rehabilitation and treatment protocols (28). In the present study, the control and experimental groups received gastrocnemius muscle stretching and were walked on a parallel bar.

Several studies have investigated the effects of using the Nintendo Wii on improving outcomes related to central nervous system diseases, including spasticity. In

Gatica-Rojas et al., the use of the Nintendo Wii game console for six weeks in children with spastic cerebral palsy, compared to before treatment, led to a significant reduction in the degree of spasticity and improved balance based on the decrease in pressure center fluctuations (29). In Atasavun Uysal and Baltaci, Nintendo Wii and conventional physiotherapy, including balance and posture correction exercises, were compared to conventional physiotherapy for children with hemiplegic cerebral palsy. Nintendo Wii can be an effective method for improving balance in children with cerebral palsy; however, there was no significant preference for Nintendo Wii over conventional interventions in other outcomes (30).

In this study, electrophysiological indicators were also used to evaluate the effectiveness of Nintendo Wii on neural properties and clinical outcomes. Among the many reflexes obtained by electrical stimulation, the H-reflex is better known than the others. H-reflex latency and Hmax/Mmax ratio are reliable indices to measure α motor neuron excitability (31). Several studies have demonstrated an increase in the ratio of the H-reflex to stretch reflex of the muscle (H/M ratio) in people affected by stroke in comparison to healthy people (5, 32). This ratio shows the readiness and excitability of motor neuron pools, which increases in spasticity. In this way, the amplitude of the H-reflex rises, and the amplitude of the M wave decreases (33). An increase in loop gain of the monosynaptic arc, enlarged excitation in postsynaptic afferents from descending pathways, or a decrease in presynaptic inhibition can account for this effect (32, 34).

In the present study, no significant change in H-reflex latency and the ratio of H-reflex amplitude to M wave amplitude was observed in any of the two groups of conventional treatment alone and the combination of conventional treatment and Nintendo Wii. In addition, the comparison between groups did not show a significant change. In other studies, no significant change was observed in the H-reflex latency and amplitude (22). Bakheit et al., for instance, suggested that a single session of isotonic and isokinetic stretching did not significantly affect the Hmax/Mmax ratio and H-reflex latency (22). According to the present study, there was no significant difference in neurological variables because both groups of people with stroke were in the chronic stage of the disease for an extended period of time since the stroke had occurred. At this time, recovery in the nervous system is minimized. A study showed that stroke patients could be divided into two groups in terms of neurological and mechanical factors: The larger group (seven out of 11 people) named Stroke with Low Reflex Torque (SLRT), and the smaller group named stroke with high reflex torque (SHRT) was divided (35). In hemiplegic spastic patients, the degree of facilitation of Ia fibers was similar to that of the control group during the H-reflex of the soleus muscle, indicating that presynaptic inhibition does not change in these patients. Therefore, stroke patients were expected to show reflex stiffness similar to the control group's.

The limitations of the present study were the small number of samples, the number of treatment sessions, and the lack of follow-up, which were not considered in this trial due to time constraints. Other limitations of the study included the lack of assessment of adherence and the degree of acceptability of the treatment by the participants.

5.1. Conclusions

The results showed that the clinical outcome of spasticity was significantly reduced after the end of the treatment in the Nintendo Wii group. Compared to conventional treatment alone, intergroup comparisons did not show a significant advantage in using Nintendo Wii for spasticity outcomes.

Acknowledgements

The authors of this study thank all of the participants in this project, especially the personnel at the Physiotherapy Department at Isfahan Kashni Hospital.

Footnotes

Authors' Contribution: Conception and design: E. Gh.; obtaining of funding: E. Gh.; administrative, technical, or logistic support: E. Gh., S. F.; provision of study materials or patients: K. B., M. Gh.; data collection: E. Gh., K. B., M. Gh.; data analysis and interpretation: E. Gh., S. F.; critical revising of the article for important intellectual content: E. Gh., S. F., K. B., M. Gh.; final approval of the article: E. Gh.

Clinical Trial Registration Code: [IRCT2020010101045970N3](https://www.clinicaltrials.gov/ct2/show/study?term=IRCT2020010101045970N3).

Conflict of Interests Statement: None of the authors has any conflict of interest to disclose.

Data Availability: The dataset presented in the study is available on request from the corresponding author during submission or after publication.

Ethical Approval: This study is approved under the ethical approval code of: [IR.MUI.RESEARCH.REC.1399.309](https://www.researchregistry.org/IR.MUI.RESEARCH.REC.1399.309).

Funding/Support: The study was supported by Isfahan University of Medical Sciences as part of a Physical therapy Master's degree thesis.

Informed Consent: It was not declared by the authors.

References

- Romero JR, Morris J, Pikula A. Stroke prevention: modifying risk factors. *Ther Adv Cardiovasc Dis*. 2008;2(4):287-303. [PubMed ID: 19124428]. [PubMed Central ID: PMC2729177]. <https://doi.org/10.1177/1753944708093847>.
- Zorowitz RD, Gillard PJ, Brainin M. Poststroke spasticity: sequelae and burden on stroke survivors and caregivers. *Neurol*. 2013;80(3 Suppl 2):S45-52. [PubMed ID: 23319485]. <https://doi.org/10.1212/WNL.0b013e3182764c86>.
- Ghasemi E, Khademi-Kalantari K, Khalkhali-Zavieh M, Rezasoltani A, Ghasemi M, Akbarzadeh Baghban A, et al. The Effect of Functional Stretching Exercises on Neural and Mechanical Properties of the Spastic Medial Gastrocnemius Muscle in Patients with Chronic Stroke: A Randomized Controlled Trial. *J Stroke Cerebrovasc Dis*. 2018;27(7):1733-42. [PubMed ID: 29706442]. <https://doi.org/10.1016/j.jstrokecerebrovasdis.2018.01.024>.
- Ghasemi E, Khademi-Kalantari K, Khalkhali-Zavieh M, Rezasoltani A, Ghasemi M, Baghban AA, et al. The effect of functional stretching exercises on functional outcomes in spastic stroke patients: A randomized controlled clinical trial. *J Bodyw Mov Ther*. 2018;22(4):1004-12. [PubMed ID: 30368324]. <https://doi.org/10.1016/j.jbmt.2017.09.021>.
- Kim KS, Seo JH, Song CG. Portable measurement system for the objective evaluation of the spasticity of hemiplegic patients based on the tonic stretch reflex threshold. *Med Eng Phys*. 2011;33(1):62-9. [PubMed ID: 20932794]. <https://doi.org/10.1016/j.medengphy.2010.09.002>.

6. Voinescu A, Sui J, Stanton Fraser D. Virtual Reality in Neurorehabilitation: An Umbrella Review of Meta-Analyses. *J Clin Med.* 2021;**10**(7). [PubMed ID: 33918365]. [PubMed Central ID: PMC8038192]. <https://doi.org/10.3390/jcm10071478>.
7. Amirthalingam J, Paidi G, Alshowaikh K, Iroshani Jayarathna A, Salibindla D, Karpinska-Leydier K, et al. Virtual Reality Intervention to Help Improve Motor Function in Patients Undergoing Rehabilitation for Cerebral Palsy, Parkinson's Disease, or Stroke: A Systematic Review of Randomized Controlled Trials. *Cureus.* 2021;**13**(7). e16763. [PubMed ID: 34367835]. [PubMed Central ID: PMC8343554]. <https://doi.org/10.7759/cureus.16763>.
8. Fong KN, Tang YM, Sie K, Yu AK, Lo CC, Ma YW. Task-specific virtual reality training on hemiparetic upper extremity in patients with stroke. *Virtual Real.* 2021;**26**(2):453-64. <https://doi.org/10.1007/s10055-021-00583-6>.
9. Massetti T, da Silva TD, Crocetta TB, Guarnieri R, de Freitas BL, Bianchi Lopes P, et al. The Clinical Utility of Virtual Reality in Neurorehabilitation: A Systematic Review. *J Cent Nerv Syst Dis.* 2018;**10**:1179573518813540. [PubMed ID: 30515028]. [PubMed Central ID: PMC6262495]. <https://doi.org/10.1177/1179573518813541>.
10. Gatica-Rojas V, Mendez-Rebolledo G. Virtual reality interface devices in the reorganization of neural networks in the brain of patients with neurological diseases. *Neural Regen Res.* 2014;**9**(8):888-96. [PubMed ID: 25206907]. [PubMed Central ID: PMC4146258]. <https://doi.org/10.4103/1673-5374.131612>.
11. Trinh T, Shiner CT, Thompson-Butel AG, McNulty PA. Targeted upper-limb Wii-based Movement Therapy also improves lower-limb muscle activation and functional movement in chronic stroke. *Disabil Rehabil.* 2017;**39**(19):1939-49. [PubMed ID: 27718640]. <https://doi.org/10.1080/09638288.2016.1213892>.
12. Saposnik G, Teasell R, Mamdani M, Hall J, McIlroy W, Cheung D, et al. Effectiveness of virtual reality using Wii gaming technology in stroke rehabilitation: a pilot randomized clinical trial and proof of principle. *Stroke.* 2010;**41**(7):1477-84. [PubMed ID: 20508185]. [PubMed Central ID: PMC4879973]. <https://doi.org/10.1161/STROKEAHA.110.584979>.
13. Bang YS, Son KH, Kim HJ. Effects of virtual reality training using Nintendo Wii and treadmill walking exercise on balance and walking for stroke patients. *J Phys Ther Sci.* 2016;**28**(11):3112-5. [PubMed ID: 27942130]. [PubMed Central ID: PMC5140810]. <https://doi.org/10.1589/jpts.28.3112>.
14. Yatar GI, Yildirim SA. Wii Fit balance training or progressive balance training in patients with chronic stroke: a randomised controlled trial. *J Phys Ther Sci.* 2015;**27**(4):1145-51. [PubMed ID: 25995576]. [PubMed Central ID: PMC4433997]. <https://doi.org/10.1589/jpts.27.1145>.
15. Park J, Seo D, Choi W, Lee S. The effects of exercise with TENS on spasticity, balance, and gait in patients with chronic stroke: a randomized controlled trial. *Med Sci Monit.* 2014;**20**:1890-6. [PubMed ID: 25300431]. [PubMed Central ID: PMC4206395]. <https://doi.org/10.12659/MSM.890926>.
16. Bower KJ, Clark RA, McGinley JL, Martin CL, Miller KJ. Clinical feasibility of the Nintendo Wii for balance training post-stroke: a phase II randomized controlled trial in an inpatient setting. *Clin Rehabil.* 2014;**28**(9):912-23. [PubMed ID: 24668359]. <https://doi.org/10.1177/026921514527597>.
17. Shin JW, Don Kim K. The effect of enhanced trunk control on balance and falls through bilateral upper extremity exercises among chronic stroke patients in a standing position. *J Phys Ther Sci.* 2016;**28**(1):194-7. [PubMed ID: 26957756]. [PubMed Central ID: PMC4756002]. <https://doi.org/10.1589/jpts.28.194>.
18. Ghotbi N, Nakhostin Ansari N, Naghdi S, Hasson S. Measurement of lower-limb muscle spasticity: intrarater reliability of Modified Modified Ashworth Scale. *J Rehabil Res Dev.* 2011;**48**(1):83-8. [PubMed ID: 21328165]. <https://doi.org/10.1682/jrrd.2010.02.0020>.
19. Chung EJ, Kim JH, Lee BH. The effects of core stabilization exercise on dynamic balance and gait function in stroke patients. *J Phys Ther Sci.* 2013;**25**(7):803-6. [PubMed ID: 24259857]. [PubMed Central ID: PMC3820398]. <https://doi.org/10.1589/jpts.25.803>.
20. Ghotbi N, Ansari NN, Naghdi S, Hasson S, Jamshidpour B, Amiri S. Inter-rater reliability of the Modified Modified Ashworth Scale in assessing lower limb muscle spasticity. *Brain Inj.* 2009;**23**(10):815-9. [PubMed ID: 19697170]. <https://doi.org/10.1080/02699050903200548>.
21. Ghotbi N, Nakhostin Ansari N, Naghdi S, Hasson S. Measurement of lower-limb muscle spasticity: Intrarater reliability of Modified Modified Ashworth Scale. *J Rehab Res Develop.* 2011;**48**(1). <https://doi.org/10.1682/jrrd.2010.02.0020>.
22. Bakheit AM, Maynard V, Shaw S. The effects of isotonic and isokinetic muscle stretch on the excitability of the spinal alpha motor neurones in patients with muscle spasticity. *Eur J Neurol.* 2005;**12**(9):719-24. [PubMed ID: 16128875]. <https://doi.org/10.1111/j.1468-1331.2005.01068.x>.
23. Hebert D, Lindsay MP, McIntyre A, Kirton A, Rumney PG, Bagg S, et al. Canadian stroke best practice recommendations: Stroke rehabilitation practice guidelines, update 2015. *Int J Stroke.* 2016;**11**(4):459-84. [PubMed ID: 27079654]. <https://doi.org/10.1177/1747493016643553>.
24. Cuenca Zaldivar JN, Calvo S, Bravo-Esteban E, Oliva Ruiz P, Santi-Cano MJ, Herrero P. Effectiveness of dry needling for upper extremity spasticity, quality of life and function in subacute phase stroke patients. *Acupunct Med.* 2021;**39**(4):299-308. [PubMed ID: 32815384]. <https://doi.org/10.1177/0964528420947426>.
25. Harrison RA, Field T. Post Stroke Pain: Identification, Assessment, and Therapy. *Cerebrovascular Dis.* 2015;**39**(3-4):190-201. <https://doi.org/10.1159/000375397>.
26. Stevenson VL. Rehabilitation in practice: Spasticity management. *Clinic Rehab.* 2010;**24**(4):293-304. <https://doi.org/10.1177/0269215509353254>.
27. Zhang Y, Wang YZ, Huang LP, Bai B, Zhou S, Yin MM, et al. Aquatic Therapy Improves Outcomes for Subacute Stroke Patients by Enhancing Muscular Strength of Paretic Lower Limbs Without Increasing Spasticity: A Randomized Controlled Trial. *Am J Phys Med Rehabil.* 2016;**95**(11):840-9. [PubMed ID: 27088480]. <https://doi.org/10.1097/PHM.0000000000000512>.
28. Medeiros DM, Martini TE. Chronic effect of different types of stretching on ankle dorsiflexion range of motion: Systematic review and meta-analysis. *Foot (Edinb).* 2018;**34**:28-35. [PubMed ID: 29223884]. <https://doi.org/10.1016/j.foot.2017.09.006>.
29. Gatica-Rojas V, Cartes-Velasquez R, Mendez-Rebolledo G, Guzman-Munoz E, Lizama LEC. Effects of a Nintendo Wii exercise program on spasticity and static standing balance in spastic cerebral palsy. *Dev Neurorehabil.* 2017;**20**(6):388-91. [PubMed ID: 27538127]. <https://doi.org/10.1080/17518423.2016.1211770>.
30. Atasavun Uysal S, Baltaci G. Effects of Nintendo Wii() Training on Occupational Performance, Balance, and Daily Living Activities in Children with Spastic Hemiplegic Cerebral Palsy: A Single-Blind and Randomized Trial. *Games Health J.* 2016;**5**(5):311-7. [PubMed ID: 27705006]. <https://doi.org/10.1089/g4h.2015.0102>.
31. Palmieri RM, Hoffman MA, Ingersoll CD. Intersession reliability for H-reflex measurements arising from the soleus, peroneal, and tibialis anterior musculature. *Int J Neurosci.* 2002;**112**(7):841-50. [PubMed ID: 12424824]. <https://doi.org/10.1080/00207450290025851>.
32. Levin MF, Hui-Chan C. Are H and stretch reflexes in hemiparesis reproducible and correlated with spasticity? *J Neurol.* 1993;**240**(2):63-71. [PubMed ID: 8437021]. <https://doi.org/10.1007/BF00858718>.
33. Pizzi A, Carlucci G, Falsini C, Verdesca S, Grippo A. Evaluation of upper-limb spasticity after stroke: A clinical and neurophysiologic

- study. *Arch Phys Med Rehabil.* 2005;**86**(3):410-5. [PubMed ID: [15759220](#)]. <https://doi.org/10.1016/j.apmr.2004.10.022>.
34. Pisano F, Miscio G, Del Conte C, Pianca D, Candeloro E, Colombo R. Quantitative measures of spasticity in post-stroke patients. *Clin Neurophysiol.* 2000;**111**(6):1015-22. [PubMed ID: [10825708](#)]. [https://doi.org/10.1016/s1388-2457\(00\)00289-3](https://doi.org/10.1016/s1388-2457(00)00289-3).
35. Galiana L, Fung J, Kearney R. Identification of intrinsic and reflex ankle stiffness components in stroke patients. *Exp Brain Res.* 2005;**165**(4):422-34. [PubMed ID: [15991034](#)]. <https://doi.org/10.1007/s00221-005-2320-z>.