Virtual Reality Wii Therapy: An Efficacious, Safe, Feasible, Alternative Approach to Post-Stroke Rehabilitation

Sossan J. Al-Darraji

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Virtual Reality Wii Therapy: An Efficacious, Safe, Feasible, Alternative Approach to Post-Stroke Rehabilitation

Abstract

Background: Stroke is one of the largest causes of disability worldwide usually resulting in hemiplegia; however, there is no defined post-stroke protocol. Many stroke patients continue to experience motor deficits of the upper and lower extremity after discharge from hospital care and therapy which can affect the quality of life. Current literature and clinical guidelines suggest the patient should undergo intensive, repetitive, task-specific activities within the first 6 months of discharge to regain motor function. Current therapeutic resources are inadequate worldwide. Recent studies have demonstrated off the shelf virtual reality interventions, such as the Nintendo Wii, may be an effective alternative to conventional therapy. The primary aim of this literature review addresses whether virtual reality therapy using the Nintendo Wii post-stroke could effectively improve static balance, functional balance, walking mobility, body symmetry, walking speed, and independence in activities of daily in conjunction with conventional therapy in patients post-stroke with lower extremity hemiparesis. The secondary aim was to evaluate the feasibility and safety of Nintendo Wii therapy.

Methods: An exhaustive literature search of available medical literature was performed using MEDLINE-Ovid, MEDLINE-PubMed, Cochrane, EMBASE, EBSCO Host, Web of Science, CINAHL, and EBM Review Multifile. Keywords used included: Wii, Nintendo Wii, stroke, post-stroke, lower extremity, balance training, and virtual reality. Relevant articles were assessed for quality using GRADE.

Results: Twenty-four articles were found and reviewed for relevancy. Three studies fit the inclusion criteria and were included in this systematic review. All studies were randomized, single blind, controlled trials. Two studies were performed in an inpatient setting examining 30 and 50 subacute stroke patients, respectively. Both studies demonstrated a statistically significant improvement in functional balance and motor outcomes when using Wii therapy in addition to conventional therapy than that of conventional therapy alone. The third study was performed in an outpatient setting examining 20 chronic stroke patients. There was no intergroup statistically significant differences; however, the Wii therapy in addition to conventional therapy had greater outcomes than that of conventional therapy alone. Patients enjoyed the experience with preference for Nintendo Wii therapy over conventional therapy. They demonstrated greater motivation, learning, and interest in comparison with the control group.

Conclusion: Virtual Reality Nintendo Wii therapy is an efficacious adjunct to conventional therapy for patients post-stoke for increasing motor function and activities of daily living. Greatest benefits have been demonstrated in patients in the subacute phase. It should be strongly considered in clinical practice due to efficacy, feasibility, safety, and affordability as shown in small studies. It is imperative that more research be performed with a larger sample size to determine if these effects can be generalized. Longer study periods and follow-up are also needed to evaluate long-term efficacy and acceptability.

Keywords: Wii, Nintendo Wii, stroke, post-stroke, lower extremity, balance training, virtual reality

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Annjanette Sommers, PA-C, MS

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Virtual Reality Wii Therapy: An Efficacious, Safe, Feasible, Alternative Approach to Post-Stroke Rehabilitation

Sossan J. Al-Darraji

A Clinical Graduate Project Submitted to the Faculty of the School of Physician Assistant Studies
Pacific University
Hillsboro, OR
For the Masters of Science Degree, August 8, 2015

Faculty Advisor: James Ferguson, PA-C, MPH
Clinical Graduate Project Coordinator: Annjanette Sommers, PA-C, MS
Biography

Sossan Al-Darrajj is a native of New Hampshire and received her Bachelor of Science degree from Keene State College in 2011 with a major in Athletic Training. Directly after graduation she was selected to complete a one year Athletic Training Residency at the New Hampshire Musculoskeletal Institute in Manchester, New Hampshire where she provided outreach athletic training services at a local high school and drop-in clinic. She spent the next year at the Pomfret School in Pomfret, CT as the Head Athletic Trainer prior to the start of PA school.
Abstract

Background: Stroke is one of the largest causes of disability worldwide usually resulting in hemiplegia; however, there is no defined post-stroke protocol. Many stroke patients continue to experience motor deficits of the upper and lower extremity after discharge from hospital care and therapy which can affect the quality of life. Current literature and clinical guidelines suggest the patient should undergo intensive, repetitive, task-specific activities within the first 6 months of discharge to regain motor function. Current therapeutic resources are inadequate worldwide. Recent studies have demonstrated off the shelf virtual reality interventions, such as the Nintendo Wii, may be an effective alternative to conventional therapy. The primary aim of this literature review addresses whether virtual reality therapy using the Nintendo Wii post-stroke could effectively improve static balance, functional balance, walking mobility, body symmetry, walking speed, and independence in activities of daily in conjunction with conventional therapy in patients post-stroke with lower extremity hemiparesis. The secondary aim was to evaluate the feasibility and safety of Nintendo Wii therapy.

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Conclusion: Virtual Reality Nintendo Wii therapy is an efficacious adjunct to conventional therapy for patients post-stoke for increasing motor function and activities of daily living. Greatest benefits have been demonstrated in patients in the subacute phase. It should be strongly considered in clinical practice due to efficacy, feasibility, safety, and affordability as shown in small studies. It is imperative that more research be performed with a larger sample size to determine if these effects can be generalized. Longer study periods and follow-up are also needed to evaluate long-term efficacy and acceptability.

Keywords: Wii, Nintendo Wii, stroke, post-stroke, lower extremity, balance training, virtual reality
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To James Ferguson: Thank you for your desire and endless energy, and I mean endless, used to motivate the class up when we needed it most. We will always keep our heads on a swivel.

To Sage Davis-Risen: Thank you for always being there for me and pushing me to be my best self.

To my parents: Thank you for giving me the wings I needed to fly and for encouraging me to follow my dreams. Thank you for always answering the phone despite the hour and for purchasing last minute plane tickets home. I am blessed to have you both in my life.
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<tr>
<td>VR</td>
<td>Virtual Reality</td>
</tr>
<tr>
<td>COP</td>
<td>Center of Pressure</td>
</tr>
<tr>
<td>PP</td>
<td>Plantar Pressure</td>
</tr>
<tr>
<td>BBS</td>
<td>Berg Balance Scale</td>
</tr>
<tr>
<td>TUGT</td>
<td>Timed Up and Go Test</td>
</tr>
<tr>
<td>ADLs</td>
<td>Activities of Daily Living</td>
</tr>
<tr>
<td>BI</td>
<td>Barthel Index</td>
</tr>
<tr>
<td>FAC</td>
<td>Functional Ambulatory Category</td>
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<tr>
<td>MWT</td>
<td>Meter Walking Test</td>
</tr>
<tr>
<td>GRADE</td>
<td>Grading of Recommendations, Assessment, Development and Evaluation</td>
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<tr>
<td>STREAM</td>
<td>Stroke Rehabilitation Assessment of Movement</td>
</tr>
<tr>
<td>BG</td>
<td>Balance Group</td>
</tr>
<tr>
<td>ULG</td>
<td>Upper Limb Group</td>
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<td>LE</td>
<td>Lower Extremity</td>
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</table>
Virtual Reality Wii Therapy: An Efficacious, Safe, Feasible, Alternative Approach to Post-Stroke Rehabilitation

BACKGROUND

Stroke is one of the leading causes of disability worldwide. Approximately 1 in 6 people will suffer from a stroke in their lifetime. Up to 85% of these patients experience hemiparesis as a result of the stroke and 55 to 75% of survivors experience long-term sensory-motor deficits disabling them from performing their normal activities of daily living, leading to decreased quality of life.

Hemiplegia commonly causes reduced balance and difficulty transferring weight after a stroke as a result of impairment of the sensory-motor system. Balance is dependent upon sensory information which triggers motor actions. This can lead to falls, which have been reported in up to 73% of patients within 6 months after discharge, and further disability. There is evidence within the literature that suggests the injured brain can undergo neural reorganization with proper rehabilitation that focuses on high-intensity, challenging, repetitive, task-specific, and motivating exercises. Neurons in the adult human brain increase their firing rates via the activation of the mirror-neuron system. This occurs when a subject observes movements performed by others or when observing themselves performing the activity on their own.

Occupational and physical therapy post-stroke rehabilitation should utilize the mirror-neuron system; however, there is no defined post-stroke protocol for balance retraining and conservative measures can be unsafe for the elderly population. Additionally, there is a lack of dedicated stroke rehabilitation centers and resources worldwide. This has led researchers to
consider alternative approaches to post-stroke rehabilitation, including commercially sold virtual reality (VR) systems.

VR gaming systems allow the patient to activate their mirror-neuron system by immersion into a three dimensional world. The patient is able to view their movement as an avatar on a screen and receive immediate visual biofeedback in real time. It creates a stimulating and enjoyable environment with goal-oriented tasks, allowing for increased intensity, time of training, repetition, sensory feedback, and individual motivation. All of which are important to neural reorganization and restructuring\textsuperscript{12,13,20-22,24} which may lead to greater motor improvements. Gaming difficulty can also be tailored to the individual patient and their disability. Benefits from VR gaming have been shown for upper limb recovery\textsuperscript{4,6,14,18,20-22,24-26}, however, to date, there is no conclusive evidence that suggests it is beneficial for lower limb recovery of motor function and activity.

Therefore, the primary aim of this study was to investigate if VR therapy using the Nintendo Wii post-stroke could effectively improve static balance, functional balance, walking mobility, body symmetry, walking speed, and independence in activities of daily living (ADLs) in addition to conventional therapy in patients post-stroke with lower extremity hemiparesis. The secondary aim was to evaluate the feasibility and safety of Nintendo Wii as a therapeutic modality for patients post-stroke.

METHODS

An exhaustive literature search of available medical literature was performed using MEDLINE-Ovid, MEDLINE- PubMed, Cochrane, EMBASE, Web of Science, CINAHL, and EBM Review Multifile. Keywords used included: Wii, Nintendo Wii, stroke, post-stroke, lower extremity, balance training, and virtual reality. The search was narrowed to include only articles
written between 2012 and 2014. Studies were excluded if they were not a randomized control trial (RCT). The bibliographies of the articles were further searched for relevant sources. All RCT trials that fit the criteria were included. Relevant articles were assessed for quality using the Grading of Recommendation, Assessment, Development, and Evaluation (GRADE).^9

RESULTS

The initial result of the search yielded 24 articles for review. After screening relevant articles, a total of three articles met inclusion criteria. These articles include three randomized control trials published between 2013 and 2014, two of which were performed inpatient^4,19 and one which was performed in the outpatient setting.^2 Studies were performed in Italy, Brazil, and Australia, respectively.\textsuperscript{19,2,4} See Table I.

Italy Study

In this randomized, single blinded, control trial,\textsuperscript{19} 50 patients in the subacute phase of stroke, defined as less than three months since onset, were recruited to participate in this study in an inpatient rehabilitative setting in Italy. Researchers were looking at the effect of VR intervention using the Nintendo Wii on balance and functional recovery compared to conventional balance training in addition to conventional physical and occupational therapy.\textsuperscript{19}

Eligibility criteria for enrollment into the study included hemiparesis in the subacute phase with moderate gait deficits caused by first ever stroke and patients 18 to 85 years of age. Patients were excluded if they had any motor or cognitive deficits prior to the stroke, chronic disabling pathologies, orthopedic injuries affecting the lower extremity (LE), spasticity limiting the range of motion of the LE, mini mental status exam of less than 24, hemispatial neglect, and attention or memory deficit. Patients were randomly assigned to the experimental group
(conventional therapy plus VR Nintendo Wii Fit therapy) or the control group (conventional therapy plus conventional balance therapy) via computer generated numbers by a physician not involved in the assessment process. The physician assessor was blinded to treatment allocation and performed assessments at baseline, four weeks after the completion of the intervention, and a one month follow-up. VR Wii and conventional balance sessions occurred 3 times per week for 20 minutes for a total of 4 weeks in addition to conventional therapy sessions, which occurred for 40 minutes 2 times per day. Primary outcome measures were examining balance via the berg balance scale (BBS). Secondary outcome measures include walking speed assessed by the 10 meter walking test (MWT), walking ability assessed via functional ambulatory category (FAC), and disability measured by the barthel index (BI).\textsuperscript{19}

Patients in both groups were homogenous at baseline for demographics, variable of stroke, BI, and functional outcome measures. Of the 50 patients enrolled in the study, three patients in the control group were lost to follow up at the completion of the intervention while at one month follow-up 11 more patients were lost from the control group and six patients were lost from the Wii group due to no time or medical complications. At the completion of the intervention, there was a statistically significant difference in the BI and BBS for the Wii group when compared to the control group. At one month follow-up the difference was maintained in addition to a slight increase in FAC for the Wii Group. There was no statistical significance found for the 10 MWT as walking time decreased across both groups with increasing intervention time.\textsuperscript{19} See Table II and figure I.

Authors discussed that although there is limited evidence for the use of VR gaming systems as an intervention in post-stroke patients, it proved to be beneficial for improving balance when compared to an equal dose of conventional balance therapy in addition to conventional
physiotherapy. They also discussed that VR therapy helps to increase the intensity and repetition of task-specific activities performed, enhancing the motor recovery of the patient to a greater extent than conventional therapy alone. The authors concluded that balance training performed with VR Wii Fit is a successful add-on to conventional physiotherapy at improving balance, functional ability, and reducing disability in patients in the subacute phase of stroke. However, authors also discuss use of insensitive outcome testing, high drop-out rate, and insufficient follow-up may fail to fully evaluate the effects of VR Wii therapy. Authors suggest future research must be done to address these limitations.19

**Brazil Study**

In this randomized, single-blinded, control trial,² twenty patients with deficits in the chronic phase of stroke, defined as greater than 12 months since onset, were recruited from an outpatient physical therapy rehabilitation center in Brazil. The aim of this study was to assess if VR Wii therapy and conventional therapy would improve balance, body symmetry, and function among individuals with hemiplegia due to stroke compared to conventional therapy alone.

Inclusion criteria for this study included the ability to attend weekly physical therapy sessions at the rehabilitation center, the ability to remain in an orthostatic position without support, absence of osteoarticular deformities, and the ability to understand the visual feedback. Patients were excluded from the study if they had comorbidities or deficits not related to stroke. Patients were randomly allocated to the experimental group (conventional therapy plus VR therapy with Wii Fit) or control group (conventional therapy only) by numbers from a computer generated central office which were then sealed into opaque envelopes. Experimental group sessions included 2 sessions per week for 5 weeks total of 30 minutes of balance training with the Wii Fit and 60 minutes of conventional therapy. The control group only performed
conventional physical therapy. The evaluator was blinded to which groups the patients belonged and performed assessments at baseline and directly after the intervention. Primary outcome measures were static balance and body symmetry assessed via a pressure plate, functional balance measured by the BBS, functional mobility by the timed up and go test (TUGT), and independence of ADLs by functional independence measure (FIM).²

At baseline there was no statistical significance between groups for demographics or assessment measures. A total of 20 patients completed all treatment sessions. Body symmetry was measured using mean peak plantar pressure (PP) which revealed increase in mean peak PP on the paretic side and a decrease on the non-paretic side post-intervention when compared to pre-intervention, suggesting a more symmetrical distribution. Static balance measurements revealed a decrease in mediolateral oscillations from the center of pressure (COP) with the control group having a greater decrease with eyes open while the experimental group had greater improvements with both eyes open and closed. Conversely, both groups had a decrease in anterior-posterior oscillations from the COP with the control group having a greater reduction with eyes open and closed while the experimental group had a greater reduction with eyes closed and a smaller reduction with eyes open. The BBS, TUGT, and FIM showed improvements in both groups equally. At the completion of the study there was no statistically significant intergroup differences; however, the VR Wii therapy group showed greater improvements in an overall greater amount of functional outcome measurements than the control group, demonstrating positive outcomes when using VR Wii therapy.² See Table III.

Authors discussed that both groups showed neurological improvement after the 5 week intervention across all measures; however, there was no intergroup statistical significance. Authors state that the participants in the Wii Fit group showed greater motivation and preference
for the VR gaming over conventional rehabilitation. Authors suggest that VR therapy allows for
greater improvements in motor function due to task-specific intensive training with visual
biofeedback. Authors concluded that the Wii Fit program achieves positive functional results and
is an appropriate, fun, and acceptable add-on to conventional therapy. Authors discussed
findings may be limited due to insufficient sample size, convenience of the sample, and
insufficient follow-up time. Authors suggest future research should address these limitations.²

**Australia Study**

In this randomized, single-blind, control trial,⁴ researchers investigated the feasibility and
efficacy of the Nintendo Wii for balance training versus upper limb training post-stroke in the
subacute phase, defined as less than 3 months since the onset, in comparison to conventional
therapy. The study utilized only individuals in the inpatient setting at a hospital in Australia. The
primary focus was feasibility of VR therapy using the Nintendo Wii in the inpatient stroke
rehabilitation setting. The secondary aim was to investigate the efficacy of this type of
rehabilitation for balance and upper limb function.⁴

Inclusion criteria included patients 18 years and over, non-cerebellar stroke less than 3
months prior, able to stand unsupported for greater than 30 seconds, and have functional use of at
least one upper limb. Patients were excluded if they were medically unstable or had any
comorbidity that could possibly skew results, severe dysphagia, dyspraxia, or cognitive
impairment, and anticipated stay less than 3 weeks. A total of thirty patients met the inclusion
criteria and were enrolled into the experimental ‘balance group’ (BG) using the Wii Fit Plus
standing or the control ‘upper limb group’ (ULG) using Wii Sport and Wii Sport Resort sitting
based on their baseline assessment and stroke rehabilitation assessment of movement
(STREAM) score. Sessions with the Wii were 3 times per week for 45 minutes for at least 2
weeks and up to 4 weeks in addition to conventional physiotherapy and occupational therapy sessions. Therapists involved in conventional therapy intervention and assessors were blinded to which groups patients were allocated. Primary outcome measures assessed were the step test and functional reach test. Secondary outcome measures assessed were timed up and go test (TUGT), STREAM, Upper Limb Motor Assessment Scale, Falls Efficacy Scale and Wii Balance Board-derived COP measures.\(^4\)

There was no difference in session number or patient demographics and variables between the two groups at baseline. There were 17 patients allocated to the experimental BG and 13 to the control ULG, with session adherence of greater than 99% and 90%, respectively, after the first two weeks, dropping to 87% and 70%, respectively, after four weeks due to early discharge. All patients reported enjoying their overall experience with the Wii and 90% felt the system was easy to use. Many patients were able to navigate the menu by themselves by the third Wii session. All patients found the Wii as enjoyable as or more enjoyable than conventional physiotherapy. All patients in the BG and 77% of patients in the ULG reporting they felt it was beneficial to their recovery. For primary and secondary outcome measures, the BG had statistically significant increase in the number of steps completed in the Step Test with the affected leg as well as improvement in Wii Balance Board derived COP when compared to the ULG. Conversely, the ULG showed larger, non-significant increase in upper limb function compared to the BG. No statistical significance was found between groups for the functional reach test. No major adverse effects were reported; however in a small number of session’s pain and post-session fatigue were experienced, none lasting longer than twenty four hours or that interrupted the patient’s ability to continue sessions.\(^4\) See Table IV.
The authors concluded that exercises using the Wii for balance and upper limb function post-stroke is feasible, safe, and efficacious in the inpatient rehabilitation setting. They also discussed that while the ULG did not have any statistically significant improvement over the BG there was a trend for task-specific improvements across both groups, indicating this type of rehabilitative therapy is effective in improving clinical outcomes. They suggest Wii therapy can and should be implemented for patients in the subacute phase post-stoke. Due to the study design, limited number of patients and resources to carry out the study, authors suggest that this may be suitable for only a select group of inpatient post-stroke patients and suggest further research be conducted to address these limitations.  

**DISCUSSION**

This review aimed to investigate the efficacy of VR Wii therapy on balance retraining and independence of daily living in post-stroke patients. Although evidence is limited, evidence does suggest Wii therapy is as effective in enhancing balance and independence of activities of daily living in patients in subacute and chronic post-stroke phases when used in conjunction with conventional physical therapy. There is an indication it may positively impact static balance, functional balance, walking mobility, body symmetry, walking speed, and independence in ADLs in at least two of the three studies evaluated (see Table I). Based on results in this review, it is an efficacious, feasible, and safe therapeutic modality.

Motor function is regained both spontaneously and through learning and practice of specific tasks which allows for greater neural reorganization and restructuring. Studies\textsuperscript{8,12,13,20-22,24} state neuroplasticity is enhanced by repetitive, high intensity, task specific activities. VR Wii therapy provides real time visual biofeedback and allows patients to undergo task-specific, high intensity, repetitive activities that mimic real world activities in a safe environment. It also
allows for modifications of difficulty level based on the patient’s deficits. This allows for greater neuroplasticity and patient recovery. Therefore, VR Wii therapy is a suitable and promising add-on to conventional therapy to enhance patient recovery in both inpatient and outpatient settings. This will allow for patients to reintegrate into social aspects of society, something many stroke patients fail to do without appropriate rehabilitation. Conventional therapy still has its place in post-stroke recovery and should not be dismissed as part of the patient’s treatment plan.

This would be valuable to subacute stroke patients in the inpatient setting. Early introduction of mirror-neuron therapy, in addition to conventional therapy, would allow practitioners to incorporate static balance gained during VR Wii therapy into functional activities learned through conventional therapy. VR Wii therapy can also be continued at home post inpatient rehabilitation in patients who have the ability to navigate the system, maintain a static standing position on their own, and for patients who can sit upright position without assistance. This would allow for greater gains in motor function.

There were significant limitations to these studies which needs to be addressed, specifically in regards to sample size and large loss to follow up. All three studies\textsuperscript{2,4,19} had small sample sizes which could cause imprecision in the results. Compounding precision, loss to follow-up was extensive across both inpatient studies due to early discharge,\textsuperscript{4,19} while the outpatient Brazil\textsuperscript{2} study had 100% follow-up. At the completion of the Australia\textsuperscript{4} study only 21 out of an initial 30 patients remained, accounting for 70% total follow-up. The Italy\textsuperscript{19} study had 47 out of 50 complete the assessment post-intervention at four weeks; however, only 30 patients completed the one month follow-up post intervention completion due to lack of time, accounting for only 60% of the initial treatment group. However, all studies\textsuperscript{2,4,19} blinded the assessor to which group the patient was allocated. The Italy\textsuperscript{19} and Brazil\textsuperscript{2} studies used randomization of
patients with computer generated numbers while the Australia study\textsuperscript{4} used patient’s baseline assessment and STREAM score to assign participants to the experimental or control group.

Variability across studies must also be pointed out, most importantly examining the differences in control groups used. Two studies, Brazil\textsuperscript{2} and Australia,\textsuperscript{4} lacked an equivalent alternative to VR Wii therapy in the control groups. The control group for the Brazil\textsuperscript{2} study was conventional therapy alone with the experimental Wii therapy group also performing conventional therapy. This provided the experimental group longer training periods with task-specific activities using the Wii. Similarly, the Australia study\textsuperscript{4} used an upper limb Wii therapy comparison group with both groups performing conventional therapy to determine if VR Wii therapy is more successful regaining upper extremity or LE function.\textsuperscript{4} Therefore, the increase in positive results in the experimental group and upper extremity control group for these studies\textsuperscript{2,4} could be attributed to the increased rehabilitative time with the Wii therapy. However, these results suggest task-specific, intensive, repetitive training with the Nintendo Wii can further increase function when added to conventional therapy.

Other limitations include patient population variability with regards to convenience of the sample and insufficient length of follow up time. The Australia\textsuperscript{4} and Italy\textsuperscript{19} study examined inpatient subacute patients, both defined as less than three months after initial event while the Brazil\textsuperscript{2} study examined chronic post-stroke patients, defined as greater than twelve months after the event. All samples were of convenience and from specific locations in an inpatient hospital center or outpatient clinic. Additionally, follow-up time was very short for all studies, with the shortest follow-up of two weeks and a longest of eight weeks, failing to provide an ample time period to suggest long term efficacy. Due to these factors, it is difficult to generalize the results or evaluate long term feasibility.
Future studies should examine larger samples sizes in the subacute and chronic phases of stroke to determine if there is a best time to implement this type of intervention. It is pertinent that an appropriate control group be used to determine if the intervention rather than conventional therapy is responsible for the results. Sufficient follow up time with low attrition rates is necessary to determine long term efficacy and acceptability. Future studies should also examine ease of use and the ability of the patient to perform VR therapy at home without supervision.

CONCLUSION

In conclusion, balance training with VR Nintendo Wii therapy is an efficacious, feasible, safe adjunct to conventional therapy for post-stroke recovery that provides repetitive, high-intensity, task-specific activity which enhances motor function and quality of life in stroke patients. Early introduction of VR Wii therapy would allow for successful activation of the mirror-neuron system, allowing for greater neuroplasticity. Furthermore, it aides in regaining static balance which can be transferred into functional activities via physical therapy and occupational therapy. VR therapy should be implemented in clinical practice when suitable for the patient. Future research using randomized control trials with larger patient population and long term follow-up should be conducted to further examine its effects on balance training post-stroke.
References


## Table I: GRADE evidence profile

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<thead>
<tr>
<th>Grading Quality of Evidence</th>
<th>No. of Studies</th>
<th>Design</th>
<th>Limitations</th>
<th>Inconsistent Results</th>
<th>Indirectness of Evidence</th>
<th>Lack of Precision</th>
<th>Publication Bias Likely</th>
<th>Quality</th>
<th>Importance</th>
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<td><strong>Static Balance</strong></td>
<td>2 (RCT)</td>
<td></td>
<td>Not serious</td>
<td>Not serious</td>
<td>Not serious</td>
<td>Serious$^e$</td>
<td>Not likely</td>
<td>Moderate</td>
<td>Critical</td>
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<tr>
<td><strong>Functional Balance</strong></td>
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<td></td>
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<td>Not serious</td>
<td>Not serious</td>
<td>Serious$^e$</td>
<td>Not likely</td>
<td>Moderate</td>
<td>Critical</td>
</tr>
<tr>
<td><strong>Walking Mobility</strong></td>
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<td>Not serious</td>
<td>Not serious</td>
<td>Serious$^e$</td>
<td>Not likely</td>
<td>Moderate</td>
<td>Important</td>
</tr>
<tr>
<td><strong>Body Symmetry</strong></td>
<td>2 (RCT)</td>
<td></td>
<td>Not serious</td>
<td>Not serious</td>
<td>Not serious</td>
<td>Serious$^e$</td>
<td>Not likely</td>
<td>Moderate</td>
<td>Important</td>
</tr>
<tr>
<td><strong>Walking Speed</strong></td>
<td>3 (RCT)</td>
<td></td>
<td>Not serious</td>
<td>Not serious</td>
<td>Not serious</td>
<td>Serious$^e$</td>
<td>Not likely</td>
<td>Moderate</td>
<td>Of limited importance</td>
</tr>
<tr>
<td><strong>Independence in Activities of Daily Living</strong></td>
<td>2 (RCT)</td>
<td></td>
<td>Not serious</td>
<td>Not serious</td>
<td>Not serious</td>
<td>Serious$^e$</td>
<td>Not likely</td>
<td>Moderate</td>
<td>Critical</td>
</tr>
</tbody>
</table>

$^a$Brazil & Australia Studies, $^b$Italy & Brazil Studies, $^c$Italy & Australia Studies, $^d$All studies, $^e$poor follow up and small sample size
Table II: Summary of Findings, Italy Study

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Baseline</th>
<th>4 week (post intervention)</th>
<th>1 month f/u post tx</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experimental*</td>
<td>Control**</td>
<td>Experimental</td>
<td>Control</td>
</tr>
<tr>
<td>Functional Balance -BBS</td>
<td>44 (41-46)</td>
<td>42 (37-46)</td>
<td>50 (46-57)</td>
<td>47 (44-51)</td>
</tr>
<tr>
<td>Walking Mobility -FAC</td>
<td>3 (2-3)</td>
<td>3 (2-3)</td>
<td>4 (3-5)</td>
<td>4 (3-4)</td>
</tr>
<tr>
<td>Independence of ADLs -BI</td>
<td>87 (70-96)</td>
<td>78 (57-88)</td>
<td>98 (95-100)</td>
<td>94 (78-99)</td>
</tr>
</tbody>
</table>

Median and Interquartile Range

BBS, Berg Balance Scale; FAC, Functional Ambulatory Category; 10 MWT, 10 meter walking test; BI, Barthel Index

*aestimated from figure in the article

*Experimental: Wii balance + conventional therapy

**Control: Conventional balance therapy + conventional study
Table III: Summary of Findings, Brazil Study

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Baseline</th>
<th>5 week (post intervention)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experimental*</td>
<td>Control**</td>
<td>Experimental</td>
</tr>
<tr>
<td>Static Balance -Oscillations from COP, eyes open &amp; closed</td>
<td>4.93 (1.74)</td>
<td>7.49 (2.69)</td>
<td>2.96 (1.37)</td>
</tr>
<tr>
<td></td>
<td>4.55 (2.15)</td>
<td>6.16 (3.72)</td>
<td>5.00 (2.09)</td>
</tr>
<tr>
<td></td>
<td>4.55 (2.15)</td>
<td>6.16 (3.72)</td>
<td>5.00 (2.09)</td>
</tr>
<tr>
<td>Static Balance -Mediolateral oscillation, eyes open &amp; closed</td>
<td>4.55 (0.55)</td>
<td>5.40 (0.51)</td>
<td>2.87 (0.93)</td>
</tr>
<tr>
<td></td>
<td>4.3 (1.69)</td>
<td>4.17 (2.07)</td>
<td>3.97 (0.94)</td>
</tr>
<tr>
<td></td>
<td>4.55 (0.55)</td>
<td>5.40 (0.51)</td>
<td>2.87 (0.93)</td>
</tr>
<tr>
<td>Static Balance -Anterior-posterior oscillations eyes open &amp; closed</td>
<td>1.18 (0.06)</td>
<td>1.12 (0.08)</td>
<td>1.18 (0.07)</td>
</tr>
<tr>
<td></td>
<td>1.48 (0.27)</td>
<td>1.25 (0.27)</td>
<td>1.18 (0.07)</td>
</tr>
<tr>
<td>Functional Balance -BBS</td>
<td>39.6 (6.43)</td>
<td>37.2 (5.22)</td>
<td>41.9 (6.91)</td>
</tr>
<tr>
<td>Walking Speed -TUGT</td>
<td>27.9 (8.22)</td>
<td>28.1 (3.10)</td>
<td>24.3 (8.64)</td>
</tr>
<tr>
<td>Body Symmetry -Peak PP paretic vs non paretic side</td>
<td>1138.2 (333.3)</td>
<td>1232.1 (182.1)</td>
<td>1309.5 (260.1)</td>
</tr>
<tr>
<td></td>
<td>11465.7 (285.2)</td>
<td>1490.9 (196.1)</td>
<td>1350.4 (243.6)</td>
</tr>
<tr>
<td>Independence of ADLs -FIM</td>
<td>4.91 (0.96)</td>
<td>4.80 (0.63)</td>
<td>6.12 (0.68)</td>
</tr>
</tbody>
</table>

Mean and (standard deviation).
COP, center of pressure; BBS, Berg Balance Scale; PP, plantar pressure; FIM, Functional Independence Measure
*Experimental: Wii therapy + conventional therapy
**Control: Conventional therapy only
# Table IV: Summary of Findings, Australia Study

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Baseline</th>
<th>2 week</th>
<th>4 week f/u</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experimental*</td>
<td>Control**</td>
<td>Experimental</td>
<td>Control</td>
</tr>
<tr>
<td>Static Balance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-COP total velocity</td>
<td>(n = 17)</td>
<td>(n = 13)</td>
<td>(n = 11)</td>
<td>(n = 10)</td>
</tr>
<tr>
<td>eyes open &amp; closed</td>
<td>1.78 (0.80)</td>
<td>1.54 (0.36)</td>
<td>1.59 (0.49)</td>
<td>1.54 (0.42)</td>
</tr>
<tr>
<td></td>
<td>2.56 (1.25)</td>
<td>2.56 (0.84)</td>
<td>2.19 (0.69)</td>
<td>2.36 (0/67)</td>
</tr>
<tr>
<td></td>
<td>(n = 11)</td>
<td>(n = 10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.90 (0.76)</td>
<td>1.54 (0.38)</td>
<td>2.29 (0.70)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.89 (1.30)</td>
<td>2.62 (0.82)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking Mobility</td>
<td>66.3 (17.7)</td>
<td>68.8 (18.1)</td>
<td>82.0 (15.9)</td>
<td>85.0 (11.7)</td>
</tr>
<tr>
<td>-STREAM</td>
<td>(n=11)</td>
<td>(n=10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>59.9 (16.0)</td>
<td>68.7 (19.3)</td>
<td>80.9 (13.0)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>68.8 (17.7)</td>
<td>68.7 (18.1)</td>
<td>80.9 (13.0)</td>
<td></td>
</tr>
<tr>
<td>Body Symmetry</td>
<td>4.8 (5.2)</td>
<td>7.4 (5.6)</td>
<td>8.8 (6.0)</td>
<td>8.9 (5.4)</td>
</tr>
<tr>
<td>-Step Test</td>
<td>(n=11)</td>
<td>(n=10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.7 (3.8)</td>
<td>7.4 (6.0)</td>
<td>11.1 (6.4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.4 (5.6)</td>
<td>7.4 (6.0)</td>
<td>10.1 (4.7)</td>
<td></td>
</tr>
<tr>
<td>Walking Speed</td>
<td>24.4 (15.1)</td>
<td>28.1 (28.9)</td>
<td>19.2 (14.4)</td>
<td>16.0 (11.9)</td>
</tr>
<tr>
<td>-TUGT</td>
<td>(n=11)</td>
<td>(n=10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30.3 (15.9)</td>
<td>32.0 (32.2)</td>
<td>20.7 (24.9)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>28.1 (28.9)</td>
<td>32.0 (32.2)</td>
<td>19.2 (15.5)</td>
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</tr>
<tr>
<td>Independence of ADLs</td>
<td>69.0 (49.2-85.5)</td>
<td>74.0 (60.5-82.0)</td>
<td>Not mentioned</td>
<td>Not mentioned</td>
</tr>
<tr>
<td>-FIM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean and (standard deviation).
COP, center of pressure; STREAM, stroke rehabilitation assessment of movement; TUGT, timed up and go test; FIM functional independence measure

*Experimental: Wii BG + conventional therapy
**Control: Wii ULG + conventional therapy
Figure 1. Box-plot of clinical scores at T0 (white), T1 (green), and T2 (blue): the boxes show the lower quartile, median (bold line), and upper quartile values, the whiskers represent the most extreme values within 1.5 times the interquartile range from the ends of the box, and the circles represent the outliers (data with values beyond the ends of the whiskers). Stars indicate the statistically significant differences of the Wii group in respect of the control group.


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