The Use of Kinect to Improve Balance and Postural Control in Patients with Multiple Sclerosis

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Abstract

**Background:** Multiple sclerosis (MS) is a leading cause of disability in young adults, affecting women more than men. Many MS patients experience gait difficulties due to muscle weakness and loss of balance and postural control. Standard interventions for maintaining or improving balance are addressed with conventional physical therapy, but this is often costly, time-consuming, and geographically inaccessible, all of which impact patient compliance. The primary goal of this systematic literature review investigates and addresses whether virtual reality therapy using Xbox Kinect improves balance and postural control in MS patients.

**Methods:** An exhaustive literature search using MEDLINE-Ovid, Web of Science and CINAHL was performed using keywords: multiple sclerosis, Xbox, and Kinect. All articles were screened with eligibility criteria. The remaining relevant articles were assessed for quality using GRADE.

**Results:** Two studies met eligibility criteria and were included in this systematic review. Each study was a randomized controlled trial. Both studies demonstrated significant improvement in balance when using the Kinect therapy. Significant improvement in postural control with use of Kinect therapy was also demonstrated in one of the studies.

**Conclusion:** Virtual reality (VR) Kinect therapy is effective in improving balance and postural control in patients with MS. Although it should not replace conventional therapy as the studies both demonstrated, it can aid as an important alternative to MS patients with mobility and accessibility difficulties and for those who cannot afford costly therapy sessions. Future studies that provide more evidence about patient compliance and cost-effectiveness will help determine the long term effect VR Kinect therapy has on the disease course.

**Keywords:** Multiple sclerosis, Xbox, Kinect

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The Use of Kinect to Improve Balance and Postural Control in Patients with Multiple Sclerosis

Theresa Jones

A Clinical Graduate Project Submitted to the Faculty of the
School of Physician Assistant Studies
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For the Masters of Science Degree, August 13, 2016

Faculty Advisor: Saje Davis-Risen, PA-C
Clinical Graduate Project Coordinator: Annjanette Sommers, PA-C, MS
Biography

[Redacted for privacy]
Abstract

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Acknowledgements

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List of Abbreviations

MS  Multiple Sclerosis
VR  Virtual Rehabilitation
BBS Berg Balance Scale
SLB Single Leg Balance
10MW 10 Meter Walking
TUG Time Up and Go
SEQ Suitability Evaluation Questionnaire
TR Telerehabilitation
SOT Sensory Organization Test
MCT Motor Control Test
CES Composite Equilibrium Score
The Use of Kinect to Improve Balance and Postural Control in Patients with Multiple Sclerosis

BACKGROUND

Multiple sclerosis (MS) is an autoimmune-mediated, inflammatory, demyelinating disease of the central nervous system of unknown etiology.\(^1\) The damaged myelin forms scar tissue which disrupts the flow of information within the brain and to the body, resulting in a wide variety of symptoms. MS affects more than 2.3 million people worldwide with most people being diagnosed between the ages of 20 and 50. More women than men are affected by the disease with prevalence more prominent in Caucasians of Northern European descent.\(^2\) MS is the leading cause of disability in young women and the second leading cause of disability in young men. Difficulties with gait is the most common mobility limitation in MS patients and are related to several factors including muscle weakness, spasticity, loss of balance, sensory deficits, and severe fatigue.\(^3\)

The reduction or loss of balance and postural control reduces mobility and increases the risk of falls, thus contributing to disability. To address mobility issues, standardized assessment tools are used by physical therapists to determine the degree of mobility impairment. These tests include the MS Functional Composite, Expanded Disability Status Scale, Disease Steps, and the MS Walking Scale-12.\(^4\) Table I provides a list of assessments tools and their clinical importance. Standard interventions for maintaining or improving balance and posture in MS patients are addressed with physical therapy; the emphasis of physical therapy is on walking and mobility to promote and maintain functionality by use of a variety of strengthening, balance, and posture exercises.\(^2\) However, physical therapy proposes its own issues in that it is costly, time-
consuming, and not always easily accessible due to geographic isolation or impaired mobility,\textsuperscript{5} all of which impact patient compliance. This has led researchers to consider alternative approaches to improve balance and postural control in MS patients by implementing exergaming with use of virtual reality (VR) systems.

Exergaming is gaming technology used to facilitate exercise and is a growing training tool in research.\textsuperscript{6} VR gaming systems, such as Nintendo Wii and Xbox Kinect, allow the patient to do physical therapy exercises without leaving the comfort of their home. Various studies have addressed the effectiveness of rehabilitation exercises with the use of the Nintendo Wii in MS patients who have balance impairment.\textsuperscript{7-11} The results of these studies vary but the general conclusion is that VR rehabilitation exercises show improvement in balance; however, these results have also shown this type of therapy to not be as effective as traditional rehabilitation exercises. One study\textsuperscript{7} directly addressed patient adherence to the balance training program 6 months after the study and found adherence rates were highest in the experimental group using Nintendo Wii. The Nintendo Wii system requires a hand held controller and additional accessories in order to play specific games. With these limitations, researchers have ventured out to explore the impact that exergaming has on MS patients with balance and postural control impairments via use of Xbox Kinect.

Xbox Kinect uses cameras and infrared sensors to recognize the physical position and size of the user.\textsuperscript{5} It has voice recognition via multi-array microphone and does not require a hand held controller or additional accessories such as a balance board when compared to the Nintendo Wii.\textsuperscript{5,6} The Kinect software has the capability to be customized to fit individual needs and clinical measurements can be reviewed by a physical therapist via internet connection,\textsuperscript{6} thereby allowing this system to be easily used for rehabilitation without the need of direct supervision.
Therefore, the goal of this systematic review was to investigate if VR rehabilitation using the Kinect system improves balance and postural control in patients with MS.

METHODS

An exhaustive literature search was performed using MEDLINE-Ovid, Web of Science and CINAHL. The following search terms were used: multiple sclerosis, Xbox and Kinect. The search was narrowed to include articles that used the Kinect gaming system for rehabilitation exercises in MS patients versus traditional therapy, outcome measurements of balance and postural control, and studies published in English language. Additionally, conferences, with abstract availability only, that did not report study details were excluded. All relevant articles were assessed for quality by using Grading of Recommendation, Assessment, Development and Evaluation (GRADE).12

RESULTS

The initial results of the search yielded nine articles for review. Duplicates were eliminated and after screening the remaining relevant articles, a total of two articles met inclusion criteria. These articles were randomized control trials and were both conducted in Spain.5,13

Lozano-Quilis et al Study

In this randomized control, single-blinded study,13 56 patients with MS were recruited to participate at the Multiple Sclerosis Association of Castellon in the neuro-rehabilitation service. The researchers were looking to compare the influence of virtual rehabilitation exercises, by use of a Kinect based system called RemoviEM versus traditional rehabilitation exercises on motor function in patients with MS.13
Eligibility criteria for enrollment in the study included men and women 18-65 years old, patients with relapsing-remitting and secondary-progressive MS, patients with minimum score of 6 on all items of the domain of the Functional Independence Measure, patients who do not need assistive devices for ambulation or at most a cane, and patients without cognitive impairment. Patients were excluded if they had flare-up symptoms or couldn’t complete rehabilitation sessions. A total of 12 patients met the eligibility criteria and were randomly assigned to either the control group (traditional physiotherapy) or the experimental group (RemoviEM therapy) via a basic random number computer generator. One patient dropped out of the clinical trial and that data was not included in the study. Five patients were in the control group while the remaining six patients were in the experimental group. Primary outcome measures examined balance before and after treatment by use of the Berg Balance Scale (BBS), Tinetti balance scale, Single Leg Balance test (SLB), 10-Meter Walking test (10MW), and Time Up and Go test (TUG). Secondary outcome measures used subjective information to obtain feedback about the treatment via the Suitability Evaluation Questionnaire (SEQ).13

Patients in both groups had no prior experience with virtual rehabilitation exercises. Each patient participated in 10 one-hour sessions with one session occurring per week. The control group performed standard balance and gait rehabilitation exercises while the experimental group performed virtual rehabilitation exercises via RemoviEM. The experimental group spent 45 minutes performing standard balance and gait rehabilitation exercises with the remaining 15 minutes spent performing virtual rehabilitation exercises. The virtual rehabilitation exercises performed included: TouchBall (balance and weight transfer with lateral trunk movements), TakeBall (upper limb coordination involving moving virtual objects from one position to another), and StepBall (balance and weight transfer with lateral trunk movements).13
At the completion of the study, there was significant improvement over time in BBS, SLB right and left feet and 10MW test for the experimental group. There was significant improvement over time in Tinetti for the control group. There was no significant difference between the experimental and control groups in TUG over time. There was significant improvement in group effect only in TUG for the experimental group. No significant difference was seen in group effect between the experimental and control groups in BBS, Tinetti, SLB right and left feet and 10MW test. Significant improvement was seen in group-by-time effect in BBS and SLB right foot for the experimental group. No significant difference was seen in group-by-time effect in Tinetti, SLB left foot, TUG and 10MW test. SEQ score was 55.560 out of 65.13 Overall, Kinect therapy demonstrated equivalent if not improved balance outcomes when compared to standard therapy. See Table III.

**Gutiérrez et al Study**

In this randomized control trial,5 50 patients with MS, according to the revised McDonald criteria, were recruited by the Neurology Unit at San Carlos University Hospital in Spain to participate in this study. The researchers were aiming to demonstrate the potential for improvement in balance and postural control in MS patients with the use of VR telerehabilitation (TR) program, via Xbox Kinect, at home as an effective alternative to conventional therapy when it is not available.5

Eligibility criteria for enrollment in the study included men and women 20-60 years old, confirmed diagnosis of MS for over 2 years based on McDonald criteria, medically stable during the 6 months prior to baseline, impaired balance associated with demyelinated lesions in the cerebellum demonstrated by MRI, Expanded Disability Status Scale score from 3-5, Hauser ambulatory index value greater than 4, absence of cognitive impairment according to Mini
Mental State examination test (MMES ≥ 24), no visual deficits, and internet connection at home. Patients were excluded if they were diagnosed with another disease or pathological condition that affects balance, if they had a relapse in the month prior to baseline or during the intervention process, or if they received an intravenous or oral steroid prior to beginning the evaluation protocol and within the 4 month duration of the project intervention. An additional criteria of availability and accessibility was applied to patients who did not receive conventional therapy and were thus enrolled in the experimental group if they met one or more of the following criteria: on the waiting list, had limited geographic accessibility, unable to reconcile working hours and therapy schedule, or dependent on others to arrive at the treatment center. Of the 50 patients enrolled, 23 met the availability and accessibility criteria. The remaining 27 patients were randomly assigned to either the control group (conventional rehabilitation) or the experimental group (TR program using VR video game) by use of QuickCalcs program. Twenty-five patients were in the control group and the remaining 25 were in the experimental group. Two patients in the control group and one in the experimental group dropped out. Primary outcome measures examined balance and postural control before and after treatment by use of the Sensory Organization Test (SOT), Motor Control Test (MCT), BBS, and Tinetti test. The SOT consisted of dependent variables which include the Composite Equilibrium Score (CES), Somatosensory Ratio, Visual Ratio, Vestibular Ratio, and Visual Preference Ratio.\(^5\) Secondary outcome measures were not evaluated or addressed.

Each patient participated in 40-minute sessions for 10 weeks. The control group received physiotherapy exercises twice per week at the MS Madrid Association and Foundation. Control group exercises included 10-minute load strength exercises, 20-minute proprioception exercises on unstable surfaces and gait facilitation exercises, and 10-minute muscle tendon stretching. The
The experimental group received VR gaming activities four times per week at home. The gaming activities included: throwing and hitting objects with hand and feet, hitting and receiving balls with different body parts, dodging objects, overcoming obstacles, and imitating posture. Only the independent evaluator was blinded to the intervention.\(^5\)

At the completion of the study, there was significant improvement in CES-SOT, MCT, BBS, and Tinetti for both groups, with more significance seen in the control group.\(^5\) See Table IV.

**DISCUSSION**

In reviewing the results, both studies demonstrated patient improvement in balance and the Gutiérrez et al study\(^5\) demonstrated improvement in postural control after completion of VR Kinect therapy. This suggests that Kinect therapy might be an important alternative to conventional therapy, especially when considering patient accessibility limitations, mobility difficulties, financial restrictions, and compliance.

The importance of BBS and Tinetti tests is to assess balance in a static position.\(^13\) Comparison of both studies\(^5,13\) reveal significant improvement in both tests for the experimental group and control groups. However, more significant improvement occurred in the control group in BBS for the Gutiérrez et al study\(^5\) and in Tinetti for both studies.

In regards to the remaining tests assessed in the Lozano-Quilis et al study\(^13\), the SLB test is another static balance assessment tool. Although there was significant improvement for both groups in SLB right and left feet, there was more significance seen in the experimental group, especially in the right foot when comparing time effect. TUG and 10MW tests are clinical assessments used to measure balance in dynamic conditions, such as walking. A negative difference in pre and post treatment means indicates the patient’s ability to walk faster and thus
signifies that improvement in balance occurred, which is seen more significantly in the experimental group for both tests. It is also important to note that the VR rehabilitation exercises were considered to be fun, according to the patient feedback questionnaire (SEQ).\textsuperscript{13}

The CES-SOT assessed in the Gutiérrez et al study\textsuperscript{5} includes multiple dependent variables that assess postural control. The SOT is the gold standard for studying postural control and has a 95% sensitivity and 92% specificity rate. The high sensitivity and specificity of this test further supports the significant postural improvement seen in both groups, although more significance was seen in the control group. The MCT is another test used in the Gutiérrez et al study\textsuperscript{5} to assess balance after recovery from displacement of center of gravity. The higher the score mean the worse the performance. Pre and post treatment means showed a reduction of scores in both groups, indicating improvement in balance; however, more improvement was seen in the control group.

Based on the results of these two studies it is evident that VR Kinect therapy improves balance and postural control, but the evidence also supports conventional therapy as the gold standard in MS rehabilitation. Although conventional therapy still has its place in MS rehabilitation, Kinect therapy offers important features that conventional therapy doesn’t: the convenience of performing therapy at home, patients can easily be followed and monitored by the therapist for follow-up at home, and therapists can provide weekly feedback even from a remote location. All of these factors have the potential to increase patient compliance thus help improve the disease course.

There were various limitations that impact the quality of evidence in these studies, some of which the authors addressed. Both studies lacked allocation concealment, which can lead to a risk of bias. In the Lozano-Quilis et al.,\textsuperscript{13} the data collectors were not blinded, which can lead to a
risk of bias and the study had a small sample size, which can cause imprecision of results. The Gutiérrez et al study\textsuperscript{5} was not blinded and randomization was not complete, which can also lead to a risk of bias.

Other limitations include the lack of establishing patient follow up in both studies. The Lozano-Quilis et al study\textsuperscript{13} only included patients with relapsing-remitting and secondary-progressive MS, didn’t address what standard balance and gait rehabilitation exercises were performed in the control group, and only provided the experimental group with the SEQ. The Gutiérrez et al study\textsuperscript{5} didn’t specifically design the VR Kinect exercises to serve a rehabilitation purpose although the exercise protocol was developed by experts who treat MS. This study also didn’t provide feedback about patient experiences which is important in determining patient compliance and motivation.

The presence of variability across studies is also important to address. In the Lozano-Quilis et al study\textsuperscript{13}, the experimental group performed standard exercises in addition to Kinect exercises. This might be the cause of the positive increase in results seen in BBS, Tinetti, and SLB right and left feet. In the Gutiérrez et al study\textsuperscript{5}, the experimental group attended more sessions per week compared to the control group. This provided the experimental group longer training periods which may have contributed to the significant results seen in all four tests; however, there was still more improvement seen in the control group.

Future studies should be double-blinded to prevent bias, examine larger sample sizes to obtain more precise data, establish patient follow up to determine if improvements remain stable over time, provide patient feedback to obtain information about their experience and to determine patient motivation and rate of compliance, design VR exercises specific to MS rehabilitation while keeping VR exercises and traditional physical therapy exercises as similar as possible, and
analyze the cost-effectiveness of VR Kinect therapy. The combination of conventional therapy along with at home exercises for patients could greatly improve the rate of improvement for MS patients.

CONCLUSION

VR Kinect therapy is effective in improving balance and postural control in patients with MS. Although it should not replace conventional therapy, as the studies show, it can aid as an important alternative to MS patients with mobility and accessibility difficulties and for those who cannot afford costly therapy sessions. Therefore, VR Kinect therapy should be implemented when such barriers are present, or it could also be studied as an at home supplement to conventional therapy. VR Kinect exercises should be designed specifically for MS patients that are similar to traditional exercises to better determine the therapy’s efficacy. Future studies that provide more evidence about patient compliance and cost-effectiveness will also help determine the long term effect VR Kinect therapy has on the disease course.
References


### Table I. Physical Therapy Assessment Tools for Multiple Sclerosis Patients

<table>
<thead>
<tr>
<th>Assessment Tool</th>
<th>Clinical Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>MS Functional Composite (MSFC)- includes 25 foot walk test</td>
<td>Fatigue, walking, balance, ataxia</td>
</tr>
<tr>
<td>Expanded Disability Status Scale (EDSS)</td>
<td>Neurological impairment</td>
</tr>
<tr>
<td>Disease Steps (DS)</td>
<td>Walking</td>
</tr>
<tr>
<td>MS Walking Scale-12 (MSWS-12)</td>
<td>Walking</td>
</tr>
<tr>
<td>Berg Balance Scale (BBS)</td>
<td>Balance</td>
</tr>
<tr>
<td>Tinetti Gait and Balance</td>
<td>Balance, Walking</td>
</tr>
<tr>
<td>Activities Specific Balance Confidence (ABC)</td>
<td>Balance</td>
</tr>
<tr>
<td>Time Up and GO (TUG)</td>
<td>Balance, Walking</td>
</tr>
<tr>
<td>Dynamic Gait Index (DGI)</td>
<td>Balance</td>
</tr>
<tr>
<td>Six Spot Step Test</td>
<td>Walking</td>
</tr>
<tr>
<td>Functional Independence Measure (FIM)</td>
<td>Independence, Ataxia</td>
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<tr>
<td>2-minute walk, 6-minute walk</td>
<td>Balance, Walking</td>
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### Table II. GRADE and Quality Assessment of Reviewed Articles

<table>
<thead>
<tr>
<th>Outcome</th>
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<th>Study Design</th>
<th>Limitations</th>
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<th>Inconsistency</th>
<th>Imprecision</th>
<th>Publication bias</th>
<th>Quality</th>
<th>Importance</th>
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<td>RCT</td>
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<td>Not Serious</td>
<td>Serious(^e)</td>
<td>Unlikely</td>
<td>Very Low</td>
<td>Important</td>
</tr>
<tr>
<td>Postural control</td>
<td>1</td>
<td>RCT</td>
<td>Very Serious(^{a,b,c})</td>
<td>Not Serious</td>
<td>Not Serious</td>
<td>Serious(^e)</td>
<td>Unlikely</td>
<td>Very Low</td>
<td>Important</td>
</tr>
</tbody>
</table>

\(^a\) Lack of allocation concealment in both studies
\(^b\) Lack of blinding of data collectors in both studies
\(^c\) Lack of complete randomization in Gutiérrez et al study
\(^d\) Short study duration in both studies
\(^e\) Small sample size in Lozano-Quilis et al study and only a few studies (one study regarding postural control)
Table III. Summary of Findings, Lozano-Quilis et al Study

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>Pre-treatment</th>
<th>Post-treatment</th>
<th>Difference</th>
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<td>Mean</td>
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<td>BBS</td>
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<td>Tinetti</td>
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<td>Control</td>
<td>25.000</td>
<td>26.000</td>
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<tr>
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<td>Experimental</td>
<td>10.721</td>
<td>17.440</td>
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<td>foot</td>
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<td>18.672</td>
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<tr>
<td>foot</td>
<td>Control</td>
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<td>18.517</td>
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<tr>
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<td>8.318</td>
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<td></td>
<td>Control</td>
<td>8.590</td>
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<tr>
<td>10MW</td>
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<td>0.472</td>
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<td>Control</td>
<td>16.625</td>
<td>14.490</td>
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</table>

BBS: Berg Balance Score; SLB: Single Leg Balance; TUG: Time Up and Go; 10MW: 10-Meter Walking; G: Group; T: Time

Table IV. Summary of Findings, Gutiérrez et al Study

<table>
<thead>
<tr>
<th>Variable</th>
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<th>Post-treatment</th>
<th>p-value</th>
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<td>Mean</td>
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<td>Experimental</td>
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<td>76.714-84.784</td>
<td>81.9</td>
</tr>
<tr>
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<td>Control</td>
<td>83.69</td>
<td>80.623-86.771</td>
<td>89.47</td>
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<td>Tinetti</td>
<td>Experimental</td>
<td>71.09</td>
<td>66.198-75.986</td>
<td>73.01</td>
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<tr>
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<td>Control</td>
<td>72.61</td>
<td>68.002-77.229</td>
<td>80.54</td>
</tr>
</tbody>
</table>

CES of SOT: Composite Equilibrium Score of Sensory Organization Test; MCT: Motor Control Test; BBS: Berg Balance Scale