ORIGINAL ARTICLE

Exergaming With Additional Postural Demands Improves Balance and Gait in Patients With Multiple Sclerosis as Much as Conventional Balance Training and Leads to High Adherence to Home-Based Balance Training

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Abstract

Objective: To assess the effectiveness of and adherence to an exergame balance training program with additional postural demands in patients with multiple sclerosis (MS).

Design: Matched controlled trial, assessment of balance before and after different balance training programs, and adherence to home-based balance exercise in the 6 months after the training.

Setting: A neurorehabilitation facility and center for MS.

Participants: Patients with balance problems (N=70) matched into 1 of the training groups according to age as well as balance and gait performance in 4 tests. Nine patients dropped out of the study because of scheduling problems. The mean age of the 61 remaining participants was 47±6 years, and their Expanded Disability Status Scale score was 3±1.

Interventions: Three weeks of (1) conventional balance training (control), (2) exergame training (playing exergames on an unstable platform), or (3) single-task (ST) exercises on the unstable platform.

Main Outcome Measures: Test scores in balance tests and gait analyses under ST and dual-task (DT) situations. Furthermore, in the 6 months after the rehabilitation training, the frequency and type of balance training were assessed by using questionnaires.

Results: All 3 groups showed significantly improved balance and gait scores. Only the exergame training group showed significantly higher improvements in the DT condition of the gait test than in the ST condition. Adherence to home-based balance training differed significantly between groups (highest adherence in the exergame training group).

Conclusions: Playing exergames on an unstable surface seems to be an effective way to improve balance and gait in patients with MS, especially in DT situations. The integration of exergames seems to have a positive effect on adherence and is thus potentially beneficial for the long-term effectiveness of rehabilitation programs.

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Persons with multiple sclerosis (MS) have an higher fall and fracture risk than do age-matched control groups.1 Most studies examining falls of persons with MS report fall rates of about 50% over the course of a year.2,3 These high fall rates have been mainly attributed to poor postural control,4 as balance and gait impairments can be used to distinguish fallers and nonfallers.5

One situation that has been identified to have a particularly high fall risk is multitasking while walking,6-8 for example, performing 1 or more cognitive or motor tasks in addition to walking. To reduce this high fall risk in multitask situations, it would be reasonable to incorporate balance exercises with simultaneous motor or cognitive tasks into balance training programs. Surprisingly, there are only few studies that investigated the effects of...
dual-task (DT) balance training\textsuperscript{10-12} or compared it with conventional single-task (ST) balance training.\textsuperscript{13,14} The results of these studies suggest that DT balance training improves balance in DT test situations more than does ST balance training,\textsuperscript{13,15} whereas ST balance training shows higher effects in ST test situations, but no or only small improvements in DT test situations.\textsuperscript{16} However, to our knowledge, no study has yet examined the effects of DT balance training in persons with MS.

Another important aspect that has to be taken into consideration when designing a training intervention is adherence. Adherence seems to be closely linked to the enjoyment of the training: studies monitoring adherence to training programs found that in addition to factors such as personal goals, practical barriers, or social support for the program, the reaction to the program, that is, whether the participants enjoyed it or not, was a factor discriminating between continuing participants and dropouts.\textsuperscript{17,18} One way to achieve high levels of training enjoyment might be the use of exergames, that is, video games that incorporate some kind of physical exercise. The efficacy of exergames (particularly those that incorporate the Nintendo Balance Board) as an alternative form of balance training has been examined in several studies with positive results. Recent studies reported balance improvements in ST tests after several weeks of Wii Fit exergames in healthy older adults,\textsuperscript{19-21} and in patients with Parkinson's disease,\textsuperscript{22-24} acquired brain injury,\textsuperscript{25} and MS.\textsuperscript{26-29} However, it is worth noting that these studies trained and tested only under ST conditions and some had no control group. The studies that assessed enjoyment or adherence in addition to balance usually reported high enjoyment and good adherence to the training program for Wii Fit training.\textsuperscript{21,26} However, when compared with other forms of training, Wii Fit training appears to improve balance to a lesser extent.\textsuperscript{20,22} In persons with MS, 1 study even found no significant differences between a Wii Fit training group and a control group with no training.\textsuperscript{30} Therefore, Wii Fit training alone seems to be a motivating and enjoyable form of ST balance training, but it should be combined with other forms of balance training to achieve results that are comparable to improvements observed after conventional forms of balance training.

The aim of our study was to compare a new kind of balance training that combines exergames with additional postural demands to 2 ST balance training programs with respect to efficacy and adherence in persons with MS. We hypothesized that the new exergame training would show higher effects than would the other 2 forms of training, especially in the DT tests and the adherence to home-based balance training after the training period.

Methods

Patients

Seventy patients with MS volunteered to participate in this study. Participants were recruited from inpatients with MS of the Clinics Schmieder, a neurorehabilitation facility and center for MS in Konstanz, Germany. Nine patients dropped out of the study because of scheduling problems for the clinic or the experimenters. Of the remaining 61 participants, 44 were women and 17 were men (mean age, 47±9 y; height, 171±8 cm; body mass, 72±14 kg; and Expanded Disability Status Scale score, 3±1). Before taking part in the study, all participants gave written informed consent for the experimental procedure, which was in accordance with the latest revision of the Declaration of Helsinki and approved by the ethics committee of the University of Konstanz. The study was registered as a clinical trial in the German Register for Clinical Trials (Clinical Trial Registration No.: DRKS00004520). Inclusion criteria were an EDSS score of ≤6, no relapse in the past 3 months, and the recommendation from the physiotherapists that the patient needed balance training (assessed with questionnaires and Romberg and 1-leg stance tests). To avoid group differences due to randomization, participants were then matched to 1 of 3 training groups: exergame training group (21 participants), Posturomed\textsuperscript{e} training group (20 participants), or conventional training group (20 participants). Group matching was performed according to age as well as balance and gait performance in 4 tests (1-leg stance on the preferred leg, Romberg stance with eyes closed, 1-leg stance on the Posturomed, and DT gait velocity).

Study design and tests

To test effects of the 3-week training regimen, all participants were tested before and after the training period. Before the tests, all participants were familiarized with the various tests and practiced performing them correctly. The tests consisted of 6 static balance tests on a forceplate,\textsuperscript{b} 4 balance tests on an unstable surface (Posturomed), and 2 gait analyses (Optogait\textsuperscript{c}). For the balance tests, participants were instructed to stand as still as possible for 10 seconds. The 6 forceplate tests included twice Romberg stance (once with eyes open, once with eyes closed) and 4 times 1-leg stance (preferred leg, nonpreferred leg, preferred leg with eyes closed, prefereed leg with the additional task of typing a given random number sequence into a mobile phone). On the Posturomed, participants underwent 4 tests: they had to stand on both legs without an additional task, stand on their preferred leg without an additional task, stand on both legs with the additional destabilizing task of performing a Wii\textsuperscript{g} golf pitch with a defined amplitude (that each participant had to practice about 20–30 times beforehand), and stand on one of their preferred leg with the additional golf pitch task. The gait analysis consisted of normal walking in a 10-m Optogait corridor and walking while having to answer questions (eg, “How many surfaces does a cube have?”). Each test was performed twice. The order of the tests was balanced between participants to control for confounding effects such as fatigue.

Training

All the participants trained over a period of 3 weeks, with a total of 9 supervised training sessions lasting 30 minutes each. A training session for the exergame training group consisted of playing Wii Sports/Sports Resort/Fit games that require arm movements (tennis, table tennis, boxing, archery, and sword fight) or displacements of the whole body to control the game avatar (ski slalom, balance bubble, penguin picnic, soccer heading, and tilt city). The games that were chosen most often were table tennis, tennis, and tilt city. While playing these games, patients stood on an unstable surface (the Posturomed) that swings when the patient moves his or her limbs or is not in balance. So, to keep their balance while playing, they constantly had to make postural adjustments, thus increasing the postural demands of the

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\textsuperscript{a} Posturomed (Konstanz, Germany). 
\textsuperscript{b} 4 balance tests on an unstable surface (Posturomed). 
\textsuperscript{c} Posturomed. 
\textsuperscript{d} Optogait (Konstanz, Germany). 
\textsuperscript{e} Posturomed (Konstanz, Germany). 
\textsuperscript{f} Optogait (Konstanz, Germany). 
\textsuperscript{g} Wii (Nintendo). 

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List of abbreviations:

- DT: dual task
- MS: multiple sclerosis
- ST: single task
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During the 6 months after their treatment in the rehabilitation clinic, each participant was asked to do weekly prospective reports about the amount and type of balance training performed, with possible answers including the following: Wii on unstable surface; unstable surface; conventional training as in the clinic; other (describe); no home-based training, only general physiotherapy; none. In addition, they had to report how many falls they had had that week. Note that no training prescription was given to any of the participants. If they did not return these training and fall reports, they were contacted at the end of the 6 months and asked about their training type and duration as well as the number of falls. Three of the 61 participants could not be contacted and were therefore excluded from adherence analyses. Sixteen of the 58 included participants regularly returned the weekly reports (exergame training group, 6; Posturomed training group, 6; conventional training group, 4), and the other 42 were contacted at the end of the 6 months.

Data processing

The parameters that were exported for analysis were the accumulated sway path during the 10-second test intervals (forceplate and Posturomed) and the gait velocity and the step length for each step in the 10-m walkway (gait analysis). The results were averaged over the 2 trials performed for each test. Failed trials were not repeated and excluded from data analysis. From the fall and training reports, the following data were analyzed: cumulative number of falls, predominant type of balance training, and average weekly training time. The person in charge of the data analysis was blinded with respect to participants’ group affiliation.

Statistics

Group data are presented as mean ± SD. The required sample size was estimated to be 66 participants (power of 0.8, α error probability of .05, and effect size of 0.2). The effect of the training on the recorded balance and gait parameters was evaluated using 2-factor analyses of variance, Group (3 levels: exergame training group, Posturomed training group, conventional training group) × Time (2 levels: pre- and posttraining). The false-discovery rate was controlled according to the Benjamini-Hochberg-Yekutieli method. To reveal differences between ST and DT improvements, post-training values were normalized to pretrained values and analyzed using an analysis of variance, Group (3 levels: exergame training group, Posturomed training group, conventional training group) × Task (2 levels: DT, ST). Significant interaction effects were followed up using paired t tests. The training and fall reports were analyzed with the chi-square test, except for the training time, which was analyzed using the Kruskal-Wallis test and Mann-Whitney U post hoc tests. The analyses were performed with SPSS 19.0.

Results

Most of the statistical tests showed significant improvements in the recorded balance and gait parameters, as indicated by the significant main effect of time (tables 1–3). None of the balance tests showed a significant Group × Time interaction effect, that is, all 3 groups showed similar improvements after the training.

Table 1 Forceplate data

<table>
<thead>
<tr>
<th>Group</th>
<th>Romberg</th>
<th>Romberg EC</th>
<th>Preferred leg</th>
<th>Preferred leg DT</th>
<th>Preferred leg EC</th>
<th>Other leg</th>
</tr>
</thead>
<tbody>
<tr>
<td>EG pre</td>
<td>120±42</td>
<td>290±169</td>
<td>335±167</td>
<td>456±303</td>
<td>654±295</td>
<td>339±146</td>
</tr>
<tr>
<td>EG post</td>
<td>128±56</td>
<td>246±110</td>
<td>298±126</td>
<td>376±176</td>
<td>611±361</td>
<td>275±109</td>
</tr>
<tr>
<td>PG pre</td>
<td>122±41</td>
<td>297±130</td>
<td>298±143</td>
<td>366±122</td>
<td>464±77</td>
<td>297±85</td>
</tr>
<tr>
<td>PG post</td>
<td>112±41</td>
<td>275±201</td>
<td>251±111</td>
<td>344±164</td>
<td>441±161</td>
<td>268±111</td>
</tr>
<tr>
<td>CG pre</td>
<td>104±41</td>
<td>285±174</td>
<td>293±123</td>
<td>369±127</td>
<td>456±129</td>
<td>312±102</td>
</tr>
<tr>
<td>CG post</td>
<td>109±51</td>
<td>254±171</td>
<td>260±91</td>
<td>337±106</td>
<td>484±98</td>
<td>252±78</td>
</tr>
<tr>
<td>Main effect of time</td>
<td>NS (P=.12)</td>
<td>P&lt;.001</td>
<td>P&lt;.05</td>
<td>P&lt;.05</td>
<td>NS (P=.20)</td>
<td>P&lt;.001</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± SD (mm) or as otherwise indicated. Averaged results from all participants of the balance tests on the forceplate (center of force displacement during 10s) before (pre) and after (post) the 3-wk training. The different tests were Romberg stance test, once with eyes open and once with eyes closed; 1-leg stance on the preferred leg with eyes open/closed and with an additional task (typing numbers into a mobile phone), and finally 1-leg stance on the nonpreferred leg. P values of the main effect of time are given below; there were no significant Group × Time interaction effects. Abbreviations: CG, conventional training group; EC, eyes closed; EG, exergame training group; NS, not significant; PG, Posturomed training group.
However, when comparing the step-to-step variability improvements during ST with those during DT (fig 1), a significant Group × Task interaction was evident ($F_{2,52} = 9.3; P < .001$; partial $\eta^2 = .26$). Post hoc tests revealed significant differences between DT and ST only for the exergame training group ($t_{18} = 2.9; P = .01$), not for the Posturomed training group ($t_{17} = -1.2; P = .25$) or the conventional training group ($t_{17} = 3.4; P = .04$).

Adherence to some kind of balance training in the 6 months of time (1 leg on the forceplate while entering a telephone number into a mobile phone and performing a Wii golf swing on an unstable surface) was lower in the exergame training group than in the conventional training group, but there were no statistically significant group differences regarding the number of fallers and nonfallers ($\chi^2 = 2.9; df = 2; P = .24$) (see fig 3).

### Discussion

The 3-week exergame balance training program on the unstable surface improved balance and gait measures in persons with MS as much as the ST balance training on the unstable surface and the conventional ST rehabilitation balance training on the ground. In addition, the participants in the exergame group had by far the highest adherence to balance training in the 6 months after their stay in the rehabilitation clinic.

These results are in line with other studies demonstrating improvements in balance scores in persons with MS after training interventions consisting of Nintendo Wii balance exergames. However, previous studies that compared Wii Fit training with other forms of training found the Wii Fit balance improvements to be smaller, and the study of Nilsagard et al even found no differences between a group with Wii Fit training and a control group with no training. In contrast to these studies, our study combined Wii exergames with an unstable surface to increase the training stimulus. This might have been the decisive factor in achieving results that are similar to the results of conventional forms of balance training, regarding not only static balance but also dynamic balance and the transfer to gait.

When analyzing the improvements in the DT tests, we observed a significant Group × Task interaction effect in the step-to-step variability during the gait analysis test in which subjects were asked additional questions. However, in the other 2 DT tests—standing on 1 leg on the forceplate and performing a Wii golf swing on an unstable surface—we could not find statistically significant differences between the exergame training group and the other 2 groups, although the exergame training group had been the only group to train under DT conditions. There are several possible reasons that might explain this unexpected result. One reason is that persons with MS show a high intersubject variability due to the diversity of MS symptoms. They also demonstrate day-to-day performance variability, particularly those with fatigue syndrome. Consequently, high intersubject and intrasubject variability might have masked possible effects (see, eg, table 1: in the DT test, the improvement of the exergame training group is the highest, but so is the variability). Another possibility is that the nature of the additional task is of high importance, although the Wii exergaming in combination with the additional postural task can be considered to be a DT situation in the broader sense of the term, most of the DT tests we used use a combination of 2 tasks that affect each other only indirectly, as opposed to the exergame training, in which the 2 tasks affect each other directly. For
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**Fig 1** Averaged results from all participants of the gait analysis (coefficient of variance of the step length) before (pre) and after (post) the training. The first test consisted of normal walking at self-selected speed with an additional task (DT, answering questions). There were no significant Group × Time interaction effects, but a significant Group × Task interaction effect, that is, the DT cost decreased for EG. Abbreviations: CG, conventional training group; EG, exergame training group; PG, Posturomed training group.

**Fig 2** Balance training type the participants adhered to in the 6 months after the rehabilitation training. (A) EG, in which 75% adhered to some kind of home-based balance training (playing Wii games on some kind of unstable surface, balance exercises on unstable platforms, conventional balance training as practiced in the Clinics Schmiederc, or other types of balance training at home) and only 25% did not continue to train at home, that is, no balance training or only as part of their physiotherapy. (B) PG, with only 26% adhering to home-based balance training. (C) CG, with 20% adhering to home-based balance training. Abbreviations: CG, conventional training group; EG, exergame training group; PG, Posturomed training group.

What are the possible reasons for the good adherence observed in the exergame training group? Factors that other studies identified as being able to discriminate between continuing participants and dropouts were personal goals, practical barriers, social support, reinforcement, and the reaction to the program, that is, whether the participants enjoyed it or not. In our study, these factors might have contributed to the high adherence to Wii exergames on an unstable surface as follows: practical barriers were low because many participants already had a Nintendo Wii at home or could buy one because of its relatively low price; the social support was probably also high (several participants reported that they regularly played with their children or grandchildren); reinforcement is given by most of the Wii exergames in the form of performance feedback; and the enjoyment of this kind of balance training was very high. The compliance with and high enjoyment of the training was probably partly caused by the large number of Wii games participants could choose from, so that every participant found at least 1 game that suited his or her taste. This free choice of games has been suggested to promote compliance and enhance a sense of control and self-efficacy.

**Study limitations**

For ethical reasons, there was no true control group. Therefore, primarily interaction effects and group differences are of interest when analyzing the results, while main effects of time should be interpreted with caution. A follow-up test was not possible owing to financial limitations. Thus, it was not possible to verify whether...
higher adherence translated to higher balance scores in follow-up tests scores. Furthermore, only 16 of the 58 participants returned weekly fall and training diaries, whereas the other 42 participants returned this information at the end of the 6 months, potentially introducing a recall bias. However, this bias would be present in all groups, so it should not affect the analyzed group differences.

Conclusions

Playing Wii exergames on an unstable platform seems to be a type of balance training that is at least as effective—particularly in DT situations—as conventional balance training during rehabilitation, and also results in a much higher adherence to home-based balance training after rehabilitation. This is a promising finding, and future work should further explore how serious games can be designed and implemented into rehabilitation programs to increase the adherence and long-term effectiveness of rehabilitation programs.

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Keywords

Accidental falls; Postural balance; Rehabilitation; Video games

Suppliers

a. Posturomed; Haider Bioswing, Dechantseesser St 4, 95704 Pullenreuth, Germany.
b. Forceplate Leonardo GRFP; Novotec Medical GmbH, Durlacher St 35, 75172 Pforzheim, Germany.c. Optogait; Microgate, Via Stradivari, 4, 39100 Bolzano, Italy.d. Wii; Nintendo, Nintendo Center, 63760 Gosselheim, Germany.e. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.

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