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ORIGINAL ARTICLE

# Does Nintendo Wii Balance Board improve standing balance? A randomized controlled trial in children with cerebral palsy

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## ABSTRACT

BACKGROUND: Evidence on the effect of systemic exercise programs to improve the standing balance with the Nintendo Wii system is very limited and its post-treatment effectiveness is unknown in cerebral palsy (CP) patients.
AIM: Primary aim was to compare the effect of Nintendo Wii balance board (Wii-therapy) and standard physiotherapy (SPT), on the performance of standing balance in children and adolescents with CP. Secondary aim was to determine the post-treatment effectiveness of Wii-therapy and SPT.
DESIGN: Two-arm, matched-pairs, parallel-groups, randomized, controlled clinical trial.
SETTING: Outpatient Rehabilitation Centre in the city of Talca.
POPULATION: Patients with CP type spastic hemiplegia (SHE) and spastic diplegia (SDI), aged 7 to 14 years, and level I or II of GMFCS or GMFCS-ER. Were excluded patients with FSIQ<80, epilepsy, previous surgeries and application of Botulinum Toxin-A in the lower limb, uncorrected vision and hearing disorders. METHODS: Thirty-two CP patients (10.7±3.2 years old) were randomly assigned to either Wii-therapy (SDI=7; SHE=9) or SPT intervention (SDI=7; SHE=9). In each group, patients received three sessions per week over a period of 6 weeks. Standing balance was assessed at baseline and every 2 weeks. Additionally, two follow-up assessments (4 additional weeks) were performed to determine post-treatment effectiveness. Standing balance was quantified on force platform obtaining the outcomes area of center-of-pressure (CoP) sway ($CoP_{Sway}$), standard deviation in the medial-lateral ($SD_{ML}$) and the anterior–posterior ($SD_{AP}$) directions, and velocity in both directions ($V_{ML}$ and $V_{AP}$).
RESULTS: Compared to SPT, Wii-therapy significantly reduced the $CoP_{Sway}$ (P=0.02) and $SD_{AP}$ in the eyes-open condition (P=0.01). However, the effects wane after 2-4 weeks. *Post-hoc* analysis revealed that only SHE children benefited from Wii-therapy.
CONCLUSIONS: Wii-therapy was better than SPT in improving standing balance in patients with CP, but improves the balance only in SHE patients. Also, Wii-therapy effectiveness waned 2–4 weeks after the end the intervention.
CLINICAL REHABILITATION IMPACT: A systematic exercise program like Wii-therapy using the Nintendo Wii Balance Board device can be considered to improves the standing balance in patients with CP, specifically in the SHE type. This program is easy to transfer to physiotherapists and rehabilitation centers.

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**Key words:** Cerebral palsy - Postural balance - Child - Virtual reality exposure.

The prevalence of cerebral palsy (CP) is 2.11 per 1000 live births,[1] where spastic hemiplegia (SHE) and diplegia (SDI) are the most common subtypes.[2, 3] Motor disability is one of the main consequences of CP treated by clinicians working in the neurological rehabilitation of children and adolescents.[2] A common man-

ifestation of this disability is impaired balance control during standing, which is associated with poorer motor performance during daily life activities.[4-6] Balance control relies on visual, vestibular and proprioceptive inputs, but also on the sensorimotor integration process that occurs at a central level.[7]

During childhood, the central nervous system (CNS) exhibits great neural plasticity, and hence high-intensity physical therapy interventions at this stage can enhance rehabilitation outcomes.[8] The neural maturity of sensory systems responsible for the control of postural balance is sequential and dependent on age, and fully matures by 15-16 years of age.[7, 9] This is the key reason for providing postural balance rehabilitation programs during childhood and adolescence, a period in which the CNS exhibits high plasticity in response to multisensory stimulation environments. Nintendo Wii and other commercially available virtual reality (VR) devices offer a relative low-cost, accessible and highly transferable option to CP patients and neurological care centers to perform rehabilitation interventions.[10, 11] Furthermore, providing immediate feedback, VR environments can elicit multisensory interactions that motivate and engage the patient in longer and more intensive sessions.[11] Although there is evidence of the effectiveness of VR systems in improving balance in some clinical populations (*e.g.* post-stroke, Parkinson's disease, older adults and knee replacement),[12-15] evidence regarding CP patients is scarce.

In a 3-week intervention with interactive video gaming using the Nintendo Wii, a group of 14 SHE children (7-14 years old) improved motor performance as measured with the Bruininks–Oseretsky test.[16] Similarly, in a longer Wii intervention study (12 weeks), a group of 14 CP children (seven SDI, five SHE and two dyskinetic) showed an improved performance in several clinical tests.[17] Although these results are promising, few randomized controlled trials have studied the effectiveness of Wii interventions compared with standard therapy or used posturographic measures of balance.[18, 19] Posturography has been widely used to quantify balance, as it is able to measure the amount of sway by using the center-of-pressure (CoP) displacements. Overall, greater values of CoP sway (*i.e.* sway area) indicate poorer balance control when standing still.[20]

The primary aim of this two-arm, matched-pairs, parallel-groups, randomized, controlled clinical trial was to compare the effect of two therapy programs, the Nintendo Wii balance board (Wii-therapy) and standard physiotherapy (SPT), on the performance of standing balance in children and adolescents with CP. The secondary aim was to determine how long the effects of Wii-therapy and SPT were retained after the intervention. We hypothesized that Wii-therapy will improve standing balance more than SPT, this effect is CP-subtype-specific and lasts at least 4 weeks. The results of this study will support clinicians in using the Wii-therapy as a treatment tool for improving balance in CP children.

## Materials and methods

### *Study design*

A matched-pairs (type of CP and age) randomized controlled trial investigated was designed to compare the effect of Wii-therapy and SPT 6-week protocols to improve the standing balance in CP patients. Four weeks postintervention measures were included to determine post-treatment effectiveness. The trial was performed between October 2012 and June 2014. Written informed consent was obtained from all parents/guardians and participants. The study was approved by the Bioethics Committee of the University of Talca (Ref. No. 00068) and was conducted in accordance with the Declaration of Helsinki. The study was registered in the Brazilian Registry of Clinical Trials (RBR-3sc9zc).

### *Participants and setting*

Children and adolescents with congenital SHE and SDI CP were recruited from an outpatient rehabilitation center for children and adolescents with neurological disorders in the city of Talca, Chile. Wii and SPT interventions were delivered in the aforementioned center whereas posturography was measured at the Motor Control Laboratory, University of Talca, Chile. Inclusion criteria were: 1) CP type SHE and SDI; 2) level I or II of the Gross Motor Function Classification System (GMFCS) [21] or Expanded and Revised Gross Motor Function Classification System (GMFCS-ER); [22] and 3) males and females aged between 7 and 14 years. Exclusion criteria included: 1) full-scale intelligence quotient (FSIQ) <80; 2) patients with other neurological disorders, such as epilepsy; 3) patients with uncorrected vision and hearing disorders; 4) previous surgeries in lower limb over the last 18 months or application of

Botulinum Toxin-A in the lower limb over the past 10 months; and 5) participants with access to a Nintendo Wii at home. Inclusion and exclusion criteria were assessed by two physiotherapists and a clinical neurologist. It is noteworthy that all participants included in this study had little or no experience of using the Nintendo Wii balance board.

Each participant that met the inclusion criteria was randomly allocated to either the Wii-therapy or the SPT group by an independent statistician not involved in the study using IBM-SPSS 20.00 (SPSS Inc., Armonk, NY, USA).

The baseline demographics and clinical characteristics of all participants are shown in Table I.

TABLE I.—*Baseline participants' characteristics in both groups*

| Characteristics | Wii-therapy (N.=16) | Standard-therapy (N.=16) |
|---|---|---|
| Mean age (SD) | 10.2 (3.1) | 11.2 (3.6) |
| Mean height (SD), m | 1.38 (0.16) | 1.38 (0.19) |
| Mean weight (SD), kg | 39.66 (15.41) | 40.54 (18.90) |
| Mean BMI (SD), m/kg$^2$ | 20.00 (4.20) | 20.10 (4.24) |
| Sex, male (%) | 10 (62.50) | 9 (56.25) |
| Hemiplegia, left side (%) | 4 (44.44) | 5 (55.55) |
| GMFCS, N. (%) | | |
| Level I | 3 (37.50) | 3 (33.33) |
| Level II | 5 (62.50) | 6 (66.66) |
| GMFCS-ER , N. (%) | | |
| Level I | 2 (25.00) | 3 (42.86) |
| Level II | 6 (75.00) | 4 (57.14) |
| Other diagnoses, N. (%) | | |
| Hearing impairment corrected | 2 (12.5) | 1 (6.25) |
| Vision impairment corrected | 6 (35.5) | 5 (31.25) |
| Prior surgery, N. (%) | | |
| Lower limb, right | 2 (12.5) | 3 (18.75) |
| Lower limb, left | 1 (6.25) | 1 (6.25) |
| Geographic location, N. (%) | | |
| Major city | 5 (31.25) | 6 (37.50) |
| Surrounding cities | 9 (56.25) | 7 (43.75) |
| Rural town | 2 (12.50) | 3 (18.75) |
| Socioeconomic level, N. (%) | | |
| High | 1 (6.25) | 2 (12.50) |
| Middle | 6 (37.50) | 4 (25.00) |
| Low | 9 (56.25) | 10 (62.50) |

BMI: Body Mass Index; GMFCS: Gross Motor Function Classification System; GMFCS-ER: Expanded and Revised Gross Motor Function Classification System. Prior surgeries were gastrocnemius tenotomies at least 2 years prior to the study. None of the participants had a score <80 in the full-scale intelligence quotient (FSIQ) and application of Botulinum Toxin-A over the past 10 months.

### *Procedure*

Posturographic measures were obtained at baseline (week 0) and every 2 weeks for 6 weeks (weeks 2, 4 and 6). Additionally, two follow-up assessments were performed post-intervention (weeks 8 and 10). To ensure consistency of the measurements, posturography was assessed at the same time of day for each measurement. Each participant performed six 30-second standing-still trials under two visual conditions: three trials with eyes open (EO) and three trials with eyes closed (EC).[20] For the latter trials, participants were provided with an eye mask to ensure no visual inputs. Trials were performed on an AMTI OR6-7 force plate (Watertown, MA, USA) at 200 Hz.

### *Acquisition and processing*

The AMTI NetForce software was used to collect momentum and force data, which were then used to calculate the CoP. Data was low-pass filtered at 40 Hz (second-order Butterworth). CoP excursion data were used to determine balance control values during standing, including CoP sway area ($CoP_{Sway}$), and CoP velocity and standard deviation of the CoP in the medial-lateral ($V_{ML}$ and $SD_{ML}$) and anteroposterior ($V_{AP}$ and $SD_{AP}$) directions. All variables were calculated using MATLAB R2012 software (MathWorks Inc., Natick, MA, USA).

### *Interventions*

Both groups (Wii-therapy and SPT) received 18 sessions delivered at a frequency of three times per week over 6 weeks (Supplementary Table I, online content only). To avoid interference between the groups, a different room within the rehabilitation center was assigned to deliver each intervention therapy at a similar time of day. All participants in the SPT group received similar therapy sessions, which included stretching, flexibility, strengthening, and balance exercises for 40 minutes in each session. Wii-therapy consisted of training sessions using the Wii Fit Plus with the Nintendo Wii Balance Board for 30 minutes, divided into three series.[12] For the first two series, the Snowboard, Penguin Slide and Super Hula Hoop games were used. Between the first and the second series of exercises, there was a 1-2-minute break, where the children sat on a chair until they had recovered. The third series involved deep breathing in the Yoga game with eyes open and closed. For those participants who were not able to perform the first two series of games, less challenging games, such as the Run Plus and Heading Foot-

ball, were used. Overall, all games demand continuous weight shifting in the medial-lateral (left-to-right), anteroposterior (heel-to-toes) directions, as well as their combinations. Furthermore, these games do challenge the sensorimotor integration by utilizing continuous feedback to perform motor tasks as accurately and precisely as possible. Qualified physiotherapists previously trained in the use of the Wii games delivered the intervention therapies for the Wii-therapy group.

### *Outcome measurement*

The primary outcome measure is the CoP sway area ($CoP_{Sway}$), which is defined as the total trajectory that the CoP makes in the medial-lateral (ML) and anterior–posterior (AP) directions.[20] Previous studies using $CoP_{Sway}$ have shown that this is a reliable and valid measure of balance during standing in different clinical and non-clinical populations.[23, 24] Furthermore, CoP sway has been shown to be more sensitive to CP subtypes (SHE and SDI) than other posturographic measures.[5, 9]

The secondary outcome measures were: 1) standard deviation of the CoP in the medial-lateral direction ($SD_{ML}$); 2) standard deviation of the CoP in the anteroposterior direction ($SD_{AP}$); 3) velocity of the CoP in the medial-lateral direction ($V_{ML}$); and 4) velocity of the CoP in the anteroposterior direction ($V_{AP}$).[20] These measures have also been shown to be reliable for the assessment of balance control.[23]

### *Sample size*

The sample size was calculated to detect postural balance changes in response to Wii-therapy and SPT based on clinical data and previous measurements.[3] We proposed a mean difference of 21.5 $cm^2$ ($CoP_{Sway}$) as the minimum difference required for substantial clinical relevance and a standard deviation of 20.68 $cm^2$. A significance alpha level of 0.05, 80% power, and allowing for 8% attrition, a minimum of 16 participants were required in each group (total sample of 32).

### *Statistical analysis*

Descriptive statistics were calculated for all demographic and clinical measures, and unpaired *t*-tests and $\chi^2$ tests were used to compare these measures between the participants in each intervention group. Assumptions of normality and homogeneity of the outcome measures were assessed using Shapiro-Wilk and Levene tests. The Mann-Whitney Test was used to determine differences between the effects of the therapies in the sixth week. Friedman's one-way ANOVA with post hoc pairwise comparisons (Wilcoxon Signed-Ranks Test) was used to determine the effect over time for each type of therapy and subtypes of CP (SHE and SDI).

To allow repeated measures analysis, missing data in the follow-ups of the 8th and 10th weeks were adjusted in the following two ways: 1) missing data was replaced with the non-missing average values for each variable/week; 2) multiple imputations were performed for missing outcomes and adjusting variables. Both methods were used to make sure that the results were concordant. For all analyses, a $P \leq 0.05$ was considered statistically significant. All statistical analyses were performed using IBM-SPSS 20.0 (SPSS Inc., Armonk, NY, USA).

## Results

During recruitment, 70 patients were screened. Thirty-two children (16 matched pairs) were randomly as-

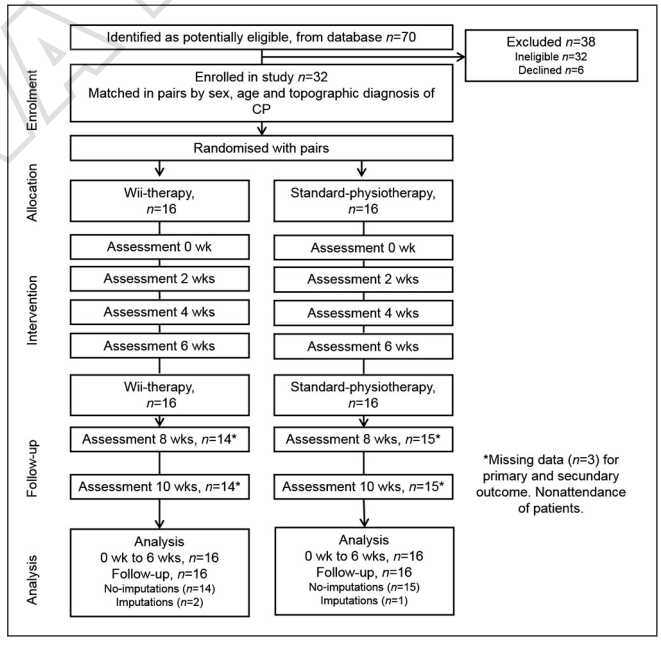


Figure 1.—Flow chart according to the Consolidated Standards of Reporting Trials (CONSORT). Participants, assessments and interventions through the two groups of the trial.

signed to each therapy protocol. Compliance was 100% for Wii-therapy (9 h) and 100% with standard therapy (12 h) (Figure 1). There were no differences between groups for demographics, clinical characteristics (Table I) and baseline in standing balance.

The mean age was 10 years and 5 months, and the children were predominantly classified as Level II on both the GMFCS and the GMFCS-ER scales. None of the children had received any physical therapy prior to the study in the previous 3 months, and 12% were enrolled in a regular weekly painting workshop or occupational therapy.

### *Wii-therapy* vs. *SPT: effects of the therapies in the sixth week*

The measurement data for each therapy over time is presented in Table II. The Wii-therapy group exhibited better balance than the SPT group, with a significantly decreased $CoP_{Sway}$ (95% CI: -2.92 to -4.92; P=0.02) and $SD_{AP}$ (95% CI: -2.92 to 4.92; P=0.01) only under the EO condition.

### *Wii-therapy and SPT: effect over time*

Missing data was noted for follow-up assessments for two children from the Wii-therapy group (one SHE and one SDI) and one child from the SPT group (spastic hemiplegia) (Table II). The SPT had no effect over time for the primary and secondary outcomes in either of the measurement conditions.

Wii-therapy decreased the $CoP_{Sway}$ with EO ($F$=17.42, P=0.004). The post hoc analysis showed a reduction in $CoP_{Sway}$ from weeks 0 to 6 (P=0.044), and from weeks 2 to 6 (P=0.023). In contrast, from weeks 6 to 10 (P=0.001) and from weeks 8 to 10 (P=0.034), the $CoP_{Sway}$ increased significantly, and therefore the effects of the Wii-therapy wane at weeks 8 and 10. Wii-therapy had no effect over time for the $CoP_{Sway}$ in EC.

Wii-therapy group showed significant differences over time in $SD_{AP}$ ($F$=15.38, P=0.009) and $V_{AP}$ ($F$=11.37, P=0.045) only in EC condition. In this condition, the post hoc analysis showed an increase in $SD_{AP}$ between weeks 0 and 2 (P=0.015), followed by a decrease that was not significant by week 6, and finally an increase at week 8 (P=0.03). $V_{AP}$ reduced during Wii-therapy in weeks 2 to 6 (P=0.03), followed by an increase from weeks 0 to 8 (P=0.044), 4 to 8 (P=0.023) and 6 to 8 (P=0.011) (Table II).

Only SHE patients of the Wii-therapy group exhibited significant effects on $CoP_{Sway}$ over time for both measurement conditions (EO: $F$=11.35, P=0.045 and EC: $F$=13.90, P=0.016). In EO, SHE exhibited a decrease that was not significant in the $CoP_{Sway}$ between weeks 2 and 6. However, between weeks 6 and 10 (P=0.011) and between weeks 4 and 10 (P=0.021), the increase was significant. In EC, post hoc analysis showed that Wii-therapy significantly reduced the $CoP_{Sway}$ between weeks 4 and 6 (P=0.028); however, this effect was lost at week 8 (P=0.017) and week 10 (P=0.008) (Figure 2). In the secondary outcomes, SHE patients showed no effect over time in the EO condition. However, in the EC condition, children with spastic hemiplegia in the Wii-therapy group showed effects over time for the $SD_{AP}$ variable ($F$=14.02, P=0.016). In this outcome, Wii-therapy produced an increase between weeks 0 and 2 (P=0.028), followed by a significant decrease between weeks 0 and 4 (P=0.021) until week 6 (not significant). This effect had waned by week 10 since the post hoc analysis showed an increase from weeks 0 to 10 (P=0.008) and from weeks 6 to 10 (P=0.021). Finally, children with SDI showed no significant effect over time for either of the two therapies, both primary and secondary variables.

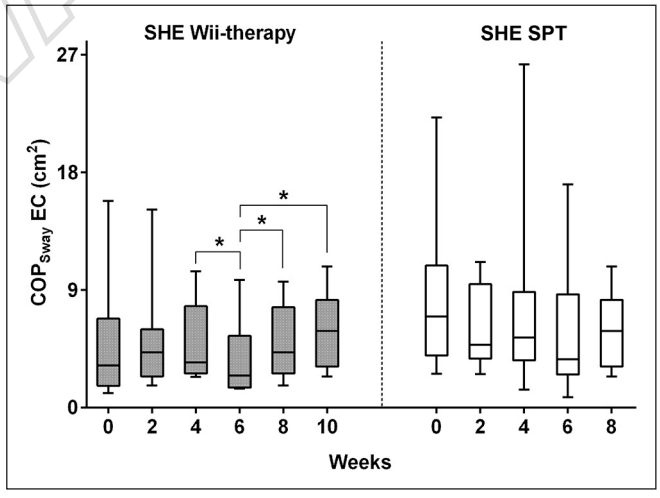


Figure 2.—Boxplots illustrating of $CoP_{Sway}$ for spastic hemiplegia (SHE) in the time. Wii-therapy reduced the $CoP_{Sway}$ in eyes closed (EC) between weeks 4 and 6 (P=0.028). Instead, $CoP_{Sway}$ increased between the weeks 6 and 8 (P=0.017), and weeks 6 and 10 (P=0.008). SHE patients showed no improvement over time in standard physiotherapy (SPT). *P value <0.05.

TABLE II.—*Outcome measures during standing balance for both groups over time.*

| Measure | Group | Baseline Median (IQR) | 2 weeks Median (IQR) | 4 weeks Median (IQR) |
|---|---|---|---|---|
| Primary outcome | | | | |
| $CoP_{Sway}$, open-eyes, $cm^2$ | Wii-therapy | 3.75 (1.66 to 8.15) | 3.58 (1.74 to 9.01) | 3.06 (2.08 to 6.38) |
| | Standar-therapy | 3.92 (2.73 to 5.25) | 4.08 (1.65 to 0.24) | 4.84 (3.29 to 7.42) |
| $CoP_{Sway}$, closed-eyes, $cm^2$ | Wii-therapy | 4.17 (1.94 to 7.40) | 4.73 (3.00 to 2.04) | 4.85 (2.80 to 9.68) |
| | Standar-therapy | 6.64 (4.28 to 8.94) | 6.26 (3.55 to 8.60) | 5.36 (3.35 to10.30) |
| Secondary outcomes | | | | |
| $SD_{ML}$, open-eyes, cm | Wii-therapy | 0.43 (0.26 to 0.73) | 0.39 (0.31 to 0.75) | 0.42 (0.35 to 0.54) |
| | Standar-therapy | 0.46 (0.34 to 0.60) | 0.42 (0.31 to 0.53) | 0.46 (0.29 to 0.58) |
| $SD_{ML}$, closed-eyes, cm | Wii-therapy | 0.45 (0.29 to 0.74) | 0.42 (0.32 to 0.78) | 0.48 (0.39 to 0.78) |
| | Standar-therapy | 0.51 (0.42 to 0.69) | 0.53 (0.42 to 0.65) | 0.50 (0.32 to 0.71) |
| $SD_{AP}$, open-eyes, cm | Wii-therapy | 0.43 (0.39 to 0.67) | 0.61 (0.34 to 0.70) | 0.47 (0.32 to 0.69) |
| | Standar-therapy | 0.48 (0.42 to 0.71) | 0.55 (0.34 to 0.80) | 0.60 (0.48 to 0.70) |
| $SD_{AP}$, closed-eyes, cm | Wii-therapy | 0.45 (0.29 to 0.74) | 0.70 (0.51 to 0.90) | 0.64 (0.39 to 0.72) |
| | Standar-therapy | 0.51 (0.42 to 0.69) | 0.63 (0.46 to 0.88) | 0.60 (0.45 to 0.77) |
| $V_{ML}$, open-eyes, cm/sec | Wii-therapy | 0.85 (0.65 to 1.19) | 1.00 (0.66 to 1.33) | 0.90 (0.66 to 1.24) |
| | Standar-therapy | 0.97 (0.75 to 1.15) | 0.91 (0.60 to 1.21) | 0.94 (0.70 to 1.13) |
| $V_{ML}$, closed-eyes, cm/sec | Wii-therapy | 0.92 (0.77 to 1.28) | 1.15 (0.84 to 1.70) | 1.07 (0.76 to 1.44) |
| | Standar-therapy | 1.05 (0.75 to 1.30) | 1.03 (0.77 to 1.28) | 0.96 (0.62 to 1.37) |
| $V_{AP}$, open-eyes, cm/sec | Wii-therapy | 0.94 (0.85 to 1.50) | 1.00 (0.84 to 1.44) | 0.95 (0.88 to 1.15) |
| | Standar-therapy | 1.10 (0.77 to 1.37) | 0.97 (0.69 to 1.57) | 1.02 (0.74 to 1.37) |
| $V_{AP}$, closed-eyes, cm/sec | Wii-therapy | 1.11 (0.89 to 1.70) | 1.18 (1.09 to 1.79) | 1.13 (1.05 to 1.53) |
| | Standar-therapy | 1.32 (0.95 to 1.59) | 1.14 (0.82 to 1.58) | 1.05 (0.91 to 1.55) |

[a]Missing values from three children at follow-up during the eighth and tenth weeks (Wii-therapy, N.=2; SPT, N.=1); [b]Friedman's one-way ANOVA.
IQR: interquartile range; CoP: centre-of-pressure; $CoP_{Sway}$: area of CoP sway; $SD_{ML}$ and $SD_{AP}$: standard deviation of CoP in the directions medial-lateral and anterior–posterior: both in cm; $V_{ML}$ and $V_{AP}$: CoP velocity in the directions medial-lateral and anterior-posterior.

*Adverse events*

All participants completed each therapy without any adverse effects.

## Discussion

This is the first study aimed to compare the effects of a Nintendo Wii balance board intervention with standard physiotherapy to improve standing balance in children with CP using posturographic measures. This is also the first study determining post-treatment effectiveness of Wii-therapy. Overall, we found that Wii-therapy was better able to improve standing balance than a SPT intervention, especially in SHE, and that these positive effects wane within 2-4 weeks post-intervention.

Two previous randomized controlled trials using Wii have reported significant improvements in the balance of CP children when assessed with clinical tools such as the functional reach [25] and the pediatric balance score.[26] Ramstrand and Lygnegård reported the effects of Wii on balance by using posturographic measures but found no significant changes after the intervention. Nonetheless, it is noteworthy that in the latter study, Wii training was self-guided at home for 5 weeks (minimum 30 minutes each time) with only 66% compliance.[18] Interestingly, that study did not include $CoP_{Sway}$ and standard deviation as outcome measures, which are among the most common in posturography, and this hampers further comparisons with the current findings.

Six weeks of Wii-therapy were more effective than SPT, as it improved standing balance in CP expressed in the reductions in $CoP_{Sway}$ (primary outcome) and $SD_{AP}$ (secondary outcome) only in the EO condition. Children and adolescents with CP improved their standing balance performance because of multisensory kinaesthetic and visual interactions. Most of the games utilized in this study challenge medial-lateral and anterior–posterior balance by eliciting weight-shifting strategies in order to move interactive elements, *i.e.* avatars.[19, 27] This causes the displacement of body weight on the foot and lower limbs, producing a sufficient mechanical stimulation to trigger the proprioceptors at

| End therapy (6 weeks) Median (IQR) | Follow-up (8 weeks) Median (IQR) [a] | Follow-up (10 weeks) Median (IQR) [a] | Difference in medians (95%CI) | P value [b] |
|---|---|---|---|---|
| 2.19 (1.40 to 6.02) | 3.85 (1.92 to 6.89) | 4.05 (2.39 to 8.24) | 1 (-2.92 to 4.92) | 0.004 |
| 4.68 (3.56 to 7.17) | 5.55 (2.70 to 7.46) | 5.30 (3.52 to 6.52) | 1 (-2.92 to 4.92) | 0.656 |
| 4.83 (2.39 to 7.69) | 5.81 (2.88 to 9.23) | 6.42 (3.37 to 8.87) | 1,5 (-2.42 to 5.42) | 0.058 |
| 3.69 (2.66 to 7.51) | 7.16 (5.93 to 9.03) | 5.86 (5.14 to 6.90) | -1 (-4.92 to 2.92) | 0.402 |
| 0.36 (0.28 to 0.55) | 0.38 (0.29 to 0.53) | 0.39 (0.30 to 0.69) | 1 (-2.92 to 4.92) | 0.213 |
| 0.44 (0.34 to 0.58) | 0.46 (0.33 to 0.60) | 0.50 (0.42 to 0.60) | 0 (-3.92 to 3.92) | 0.873 |
| 0.45 (0.39 to 0.52) | 0.51 (0.36 to 0.75) | 0.55 (0.36 to 0.71) | 1 (-2.92 to 4.92) | 0.595 |
| 0.43 (0.33 to 0.68) | 0.66 (0.48 to 0.89) | 0.49 (0.42 to 0.57) | -1 (-4.92 to 2.92) | 0.279 |
| 0.47 (0.29 to 0.67) | 0.54 (0.37 to 0.71) | 0.54 (0.46 to 0.68) | 1 (-2.92 to 4.92) | 0.351 |
| 0.64 (0.55 to 0.90) | 0.59 (0.42 to 0.75) | 0.63 (0.53 to 0.72) | 1 (-2.92 to 4.92) | 0.252 |
| 0.60 (0.35 to 0.77) | 0.65 (0.56 to 0.81) | 0.57 (0.47 to 0.79) | 2 (-1.91 to 5.92) | 0.008 |
| 0.60 (0.46 to 0.90) | 0.66 (0.54 to 0.83) | 0.66 (0.54 to 0.73) | -1.5 (-2.42 to 5.42) | 0.707 |
| 0.84 (0.69 to 1.17) | 1.02 (0.76 to 1.30) | 0.96 (0.84 to 1.18) | 1 (-2.92 to 4.92) | 0.647 |
| 0.88 (0.69 to 1.22) | 0.94 (0.66 to 1.14) | 0.87 (0.69 to 1.09) | -1 (-4.92 to 2.92) | 0.896 |
| 0.96 (0.73 to 1.33) | 1.12 (0.89 to 1.62) | 1.17 (0.94 to 1.49) | 0 (-2.92 to 4.92) | 0.153 |
| 0.91 (0.62 to 1.22) | 1.09 (0.82 to 1.35) | 1.23 (0.92 to 1.26) | -1 (-3.92 to 3.92) | 0.263 |
| 1.00 (0.80 to 1.14) | 1.10 (0.89 to 1.49) | 1.18 (0.88 to 1.40) | 0 (-3.92 to 3.92) | 0.101 |
| 1.06 (0.77 to 1.23) | 1.05 (0.89 to 1.44) | 1.10 (0.91 to 1.37) | 0 (-3.92 to 3.92) | 0.711 |
| 1.22 (0.82 to 1.76) | 1.48 (1.17 to 1.77) | 1.34 (0.99 to 1.61) | 0 (-3.92 to 3.92) | 0.045 |
| 1.15 (0.81 to 1.53) | 1.19 (1.07 to 1.45) | 1.24 (1.01 to 1.40) | -1 (-4.92 to 2.92) | 0.493 |

this level. Furthermore, an advantage of the Nintendo Wii system is the visual feedback that the participants receive during each session. Visual feedback has been postulated to improve balance in participants, as the video game creates the perception that they can perform more complex activities.[28] Also, Wii-therapy generated a virtual reality environment with gesture-based interactions with the patient with CP.[11] In contrast, the SPT did not generate changes in the standing balance under either of the two conditions even after 18 sessions.

The effect over time was observed only for the Wii-therapy group, where the reduction in $CoP_{Sway}$ in EO (from 0 to 6 and 2 to 6 weeks) and $V_{AP}$ in EC (from 2 to 6 weeks) indicated improvements in the standing balance. The following physiological foundations and clinical evidence support these effects: 1) Repetition. Each virtual game involved the successive repetition of exercises in different planes of motion in each session.[11] Repetition is the basis of neuroplasticity. A 4-week intervention using VR therapy caused neural activation and subsequent reorganization in the primary sensorimotor cortex of the affected side in a child with hemiparetic CP, which was associated with an increase in their functional abilities.[29] Neural activation is based on the existence of mirror neurons that were stimulated by observation of the execution of analogous tasks by other people in a mirror-like *effect* created by virtual environments;[30] 2) sensory feedback. Provided by proprioceptive, visual, vestibular and auditory systems when are activated in the performance. Three of them are directly associated with the control of postural balance;[11] 3) individual motivation. This motivation was achieved through various attractive and interesting exercises introduced by the Nintendo Wii balance board.[11]

The reduction of $CoP_{Sway}$, similar to $V_{AP}$, was weakened 2 and 4 weeks after the end of therapy, suggesting that Wii-therapy should be repeated over a period of no longer than this. So, is possible that CP children required an initial 2-week adaptation during Wii-therapy, which was revealed in the $SD_{AP}$ in EC of balance responses.

The SPT had no effect over time. It has previously been reported that patients move more during Wii than SPT sessions, which may have meant that — despite the

SPT sessions habitually were of 40 minutes, that is 10 minutes longer than the Wii sessions — the Wii-therapy was more intense.[8, 23] As previously indicated, repetition of a motor task is fundamental in improving motor control during rehabilitation and it is possible that this is better achieved during Wii sessions due to its continuous weight shifting,[28] which is crucial for upright and walking stability.[31]

The literature broadly describes the differences in motor control impairment between SHE and SDI. The quiet standing balance between these types of CP is different.[4-6] Within these differences, greater standard deviation and displacement have been reported in the AP axis in SHE; however, SDI patients exhibit greater standard deviation and displacement in the ML axis.[5, 6] Furthermore, in SDI has been reported that the rapid ML weight-shifting capacity is affected, which can explain the difficulty in initiating the gait.[31] A matched-pairs design used in our study according to the type of CP and age, controlled the possible bias, an identified limitation in rehabilitation studies of this type.

In this study, significant effects of Wii on posturographic measures of balance were found only for the SHE group. It has been suggested that SHE patients are better able to use proprioceptive and somatosensory information arising from the unaffected limb,[6] which may have been enhanced (sensory up-weighting) by the Wii-therapy. Therefore, the improvement in the balance performance for SHE during EC for both $CoP_{Sway}$ and $SD_{AP}$ may be due to proprioceptive stimuli generated during Wii-therapy. The use of VR games also provides continuous visual feedback, which elicits not only reactive but also proactive balance responses, such as weight shifting, to accomplish a task.[28] During Wii games, visual feedback is predominant and therefore up-weighted, and this would explain a greater improvement in the EO condition. Our results agree with Gatica-Rojas *et al.*'s findings that in a recent study reported spasticity reduction of calf muscles and improved static standing balance after a Nintendo Wii intervention in a population of ten CP patients of which sixty percent had spastic hemiplegia.[32]

Children with SDI did not show an improvement in their standing balance in either Wii-therapy or SPT. In contrast, Deutsch *et al.* reported improvements in postural control during EC, functional mobility, and visual–perceptual processing in an adolescent with SDI after 11 sessions of training using the Wii sports games. The sessions lasted between 60 and 90 minutes, and used four games that involved the use of the hand with the Wii remote, and training in both sitting and standing positions.[34] Previous studies with longer protocols and heterogeneous samples (diplegic, hemiplegic and dyskinetic) were inconclusive.[17, 26]

A drawback of research exploring the benefits of Wii for the treatment of balance in CP children is the non-standardization of interventions. Although it has been suggested that games should be chosen based on clinical reasoning,[16, 35] there is still no consensus for the selection of games for specific rehabilitation aims, *e.g.* reaching or stepping. In our study, we used the Snowboard, Penguin Slide and Super Hula Hoop games that mainly elicit reactive balance control for correct weight shifting,[12, 36] which is known to be highly affected in SHE and SDI children, and has been associated with difficulties initiating the gait.[33] We also selected the deep breathing in the Yoga game as it challenges proactive balance control for maintaining static positions.[12] Since AP balance is more affected in SHE and ML balance in SDI,[4-6] a diagnosis-specific selection of games could be more effective in the rehabilitation of balance, especially for SDI. Further research should explore the balance challenges imposed by each of the games used in rehabilitation in order to better guide their use with different clinical populations.

This is the first study to explore the retention effects of a Wii-therapy intervention, which wane within 4 weeks after the intervention period. Most CP children undergo much longer rehabilitation periods than the 18 sessions (6 weeks) comprehended in this study. Hence, if adopted as part of long-term rehabilitation programs, the effects of Wii-therapy may be sustained for more time, for example including one session every two/four weeks to maintain its positive effect on balance.

Although the sample size of CP patients was adequate for testing the main hypothesis, the sample size reduction when performing the post hoc analysis on CP subtypes (SDI and SHE) was a limitation. The inclusion of children with mild levels and without intellectual disability in this study limits the generalizability of these results to CP populations with severe intellectual disability. There was no blinding and, although trained in different rooms, group contamination may have occurred due to all patients being trained within the same

rehabilitation center. Another limitation of this study is the absence of information concerning the number of repetitions used for the stretching, flexibility, strength and balance exercises for the SPT group. Since other aspects of balance control (*e.g*. dynamic balance) were not assessed, the benefits of SPT and/or Wii-therapy may have been underestimated by only analyzing static posturography. Therefore, it is necessary to consider more dynamic measures of balance, such as tracking tasks. The exercise programs with the Nintendo Wii should also consider children with CP with greater motor disabilities, such as GMFCS/GMFCS-ER levels III, IV and V.

## Conclusions

Wii-therapy over a period of 6 weeks significantly improved standing balance in children and adolescents with CP. These improvements were significantly greater than in SPT, which did not improve balance over a similar period. Further analysis found that significant improvements in balance control only occurred in SHE and that positive effects wane 2-4 weeks after the end of the intervention.

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*Conflicts of interest.*—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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For supplementary materials, please see the online version of this article.

## ONLINE SUPPLEMENTARY MATERIALS

SUPPLEMENTARY TABLE I.—*Description of the treatments applied through Template for Intervention Description and Replication (TIDieR) checklist.*

| |
|---|
| *Brief name* |
| Randomized controlled clinical trial to compare the effect of two therapy programmes, the Nintendo Wii balance board and standard physiotherapy, on the performance of standing balance in children and adolescents with cerebral palsy. |
| *Why* |
| The neural maturity of sensory systems responsible for the control of postural balance is sequential and dependent on age, and fully matures by 15–16 years of age. This is the key reason for providing postural balance rehabilitation programmes during childhood and adolescence, a period in which the CNS exhibits high plasticity in response to multisensory stimulation environments. Nintendo Wii and other commercially available virtual reality (VR) devices offer a relative low-cost, accessible and highly transferable option to CP patients and neurological care centres to perform rehabilitation interventions. Furthermore, providing immediate feedback, VR environments can elicit multisensory interactions that motivate and engage the patient in longer and more intensive sessions. Although there is evidence of the effectiveness of VR systems in improving balance in some clinical populations (*e.g.* post-stroke, Parkinson's disease, older adults and knee replacement), evidence regarding CP patients is scarce. |
| *What* |
| All participants in the standard physiotherapy group received similar therapy sessions, which included stretching, flexibility, strengthening, and balance exercises for 40 minutes in each session. Wii-therapy consisted of training sessions using the Wii Fit Plus with the Nintendo Wii Balance Board for 30 minutes, divided into three series. For the first two series, the Snowboard, Penguin Slide and Super Hula Hoop games were used. Between the first and the second series of exercises, there was a 1-2-minute break, where the children sat on a chair until they had recovered. The third series involved deep breathing in the Yoga game with eyes open and closed. For those participants who were not able to perform the first two series of games, less challenging games, such as the Run Plus and Heading Football, were used. Overall, all games demand continuous weight shifting in the mediolateral (left-to-right), anteroposterior (heel-to-toes) directions, as well as their combinations. Furthermore, these games do challenge the sensorimotor integration by utilising continuous feedback to perform motor tasks as accurately and precisely as possible. |
| *Who provided* |
| For both groups, qualified physiotherapists previously trained in the use of the Wii games delivered the intervention therapies. |
| *How* |
| The interventions were delivered face-to-face individually. |
| *Where* |
| Both interventions were delivered in the aforementioned centre whereas posturography was measured at the Motor Control Laboratory, University of Talca, Chile. |
| *When and how much* |
| Both groups received 18 sessions delivered at a frequency of three times per week over 6 weeks. To avoid interference between the groups, a different room within the rehabilitation centre was assigned to deliver each intervention therapy at a similar time of day. All participants in the SPT group received similar therapy sessions, which included stretching, flexibility, strengthening, and balance exercises for 40 minutes in each session. Wii-therapy consisted of training sessions using the Wii Fit Plus with the Nintendo Wii Balance Board for 30 minutes, divided into three series. |
| *Tailoring* |
| The intervention was planned to be standardized amongst all participants. |
| *Modifications* |
| The intervention was no modified during the course of the study. |
| *How well* |
| All patients comply with the intervention as planned |