






Nintendo Wii Balance Board therapy for postural control in children with cerebral palsy: a systematic review and meta-analysis

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ABBREVIATIONS

CPT	Conventional physical therapy
NWT	Nintendo Wii therapy
OLST	One Leg Stance Test
PBS	Pediatric Balance Scale
RCT	Randomized controlled trial
SMD	Standardized mean difference
TGUGT	Timed Get Up and Go Test

AIM To analyse the efficacy of Nintendo Wii therapy (NWT) on functional balance in children with cerebral palsy (CP).

METHOD A systematic review with meta-analysis (PROSPERO identification number CRD42020169510) was performed using randomized controlled trials (RCTs) that examined the effect of NWT on functional, dynamic, and static balance in children with CP, assessed with the Pediatric Balance Scale, the Timed Get Up and Go Test, and the One Leg Stance Test respectively. The pooled effect was calculated using the Cohen's standardized mean difference (SMD).

RESULTS Eleven RCTs with 270 children (when sex was reported: 43% females, 57% males) with CP (mean age [SD] 10y 1mo [1y 1mo], range 5–16y) were included. On functional balance, we found very low-quality evidence with a large effect of NWT compared with no intervention (SMD 0.95, 95% confidence interval [CI] 0.02–1.89) and moderate-quality evidence for using NWT plus conventional physical therapy (CPT) versus CPT (SMD 0.78, 95% CI 0.20–1.35) in sessions of approximately 30 minutes (SMD 0.86, 95% CI 0.20–1.52) and interventions lasting longer than 3 weeks (SMD 1.03, 95% CI 0.58–1.47). For dynamic balance, very low-quality evidence for a medium effect for using NWT plus CPT versus CPT (SMD 0.70, 95% CI 0.12–1.29) was found.

INTERPRETATION NWT can be considered an effective treatment for improving functional and dynamic balance in children with CP, especially when combined with CPT in 30-minute sessions with interventions lasting longer than 3 weeks.

Cerebral palsy (CP) describes a group of permanent disorders in the development of movement and posture, causing activity limitations that are attributed to non-progressive disturbances occurring in the developing fetal or infant brain.^{1,2} Currently, CP is one of the major causes of disability and decreased functional capacity in children, representing a large public health problem in childhood with important socioeconomic-associated costs.³ CP produces pathological changes in muscle tissue,⁴ such as spasticity, stiffness, muscle weakness, decreased strength, or muscle pain,⁵ and in the neurological system, primarily affecting the motor cortex, the primary pathway of the descending white matter, and the corticospinal tract in the spinal cord.⁶ These changes limit the gross motor skills required for postural balance⁷ and gait,⁸ increasing the risk of falls and fear of falling.⁹ In addition, deficits in the visual, somatosensory, and vestibular systems,¹⁰ needed to guarantee postural control, have been observed in children with CP, causing distorted balance, producing a reduction in anticipatory and reactive postural adjustments,¹¹ and

causing difficulties in maintaining balance during activities of daily living¹² and restricting participation in social life domains, such as education, entertainment, and social relationships.^{12,13} Owing to these balance alterations, adequate patterns of stability and balance are not acquired in children with CP, resulting in a need for retraining altered postural balance.

Conventional physical therapy (CPT) is one of the most commonly used therapies to train balance in CP.¹⁴ CPT uses passive and active movements and strengthening, stretching, flexibility, and balance exercises. In fact, the therapies involved in CPT have been effective in training balance and other motor disorders in children with CP.¹⁵ In recent years, the development of new technologies with therapeutic applications, such as virtual reality, has gained considerable weight in research and clinical practice for balance and gait training in children with CP.¹⁶ Virtual reality allows the patient to be integrated into an environment similar to the real environment and to interact with this virtual environment through use of a computer.¹⁷

Nintendo Wii therapy (NWT) is one of the most widely used non-immersive virtual reality devices in the neurorehabilitation of children with CP and requires more active participation and movement than other conventional video game systems, such as PlayStation or Xbox.^{18–21} The Nintendo Wii allows participants to interact with a virtual environment projected on a screen using a handled controller or joystick with or without a force platform called the Wii Balance Board.^{22,23} NWT is an accessible low-cost tool^{24,25} that combines physical, functional, and cognitive functions within a safe environment, such as the home,¹⁷ and incorporates motivation and fun into the proposed exercises, increasing the active participation of children with CP in the prescribed rehabilitation.²¹ In addition, NWT has also been used in neurological disorders, such as Parkinson disease, multiple sclerosis, and stroke.²⁶

To date, several studies have evaluated the use of NWT in children with CP to train balance, with interesting findings.^{27–30} As a result, some systematic reviews have analysed the effect of non-immersive virtual reality devices to train balance in children with CP with unclear results due to the heterogeneous battery of balance tests used, variability in the protocols of Nintendo Wii games (with or without a Wii Balance Board), and the absence of an adequate statistical approach.³¹ According to this, some systematic reviews, such as Ravi et al.,³² Chen et al.,³³ and Wu et al.,³⁴ analysed the effect of virtual reality devices on postural balance in children with CP, but they included a low number of randomized controlled trials (RCTs), did not perform a specific analysis according to balance condition, and did not establish a global analysis on the effect of NWT. A recent systematic review included only RCTs that assessed the efficacy of NWT in postural balance in children with CP, although the number of studies included was low, and it did not provide a meta-analysis.³⁵

To improve knowledge about the use of NWT in CP neurorehabilitation, we performed this systematic review with a meta-analysis including the latest evidence on the efficacy of NWT for postural balance in children with CP compared with other active therapies or minimal interventions. Second, we delved into the specific aspects that can improve the effect of NWT in children with CP, characterizing the NWT protocol in terms of duration of the treatment period in weeks, the number of sessions in each week, and the length of each session in minutes. In addition, other aspects, such as the use of this therapy alone or in combination with other treatments, were analysed.

METHOD

A systematic review with meta-analysis was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.³⁶ The methodological protocol of this systematic review was registered in PROSPERO International Prospective Register of Systematic Reviews (identification number CRD42020169510).

What this paper adds

- Moderate-quality evidence with a large effect of Nintendo Wii therapy (NWT) on functional balance, compared with conventional physical therapy (CPT).
- Moderate-quality evidence with medium effect of NWT plus CPT on functional and dynamic balance, compared with CPT.
- Appropriate NWT sessions should be equal to or slightly less than 30 minutes.
- NWT interventions must be longer than 3 weeks.

Search strategy

Two authors (DM-C and IC-P) independently conducted a literature search in the PubMed MEDLINE, Scopus, Web of Science, PEDro (Physiotherapy Evidence Database), and SciELO databases between March and April 2020 (Table S1, online supporting information). Doubts related to the inclusion of key terms, synonyms in the search strategy, and their application in the different databases were resolved by a third author with expertise in the search strategy (EO-G). In addition, authors examined the reference lists from retrieved full-text studies, guidelines, expert papers, and previously published reviews. The Population, Intervention, Comparison, Outcomes, and Study Design (PICOS) search tool proposed by the Cochrane Library³⁷ was used to identify potential studies in the search: population (CP), intervention (NWT), comparison (CPT and/or no intervention), outcomes (postural balance), and study design (RCTs). Keywords used in our bibliographic search strategy, in accordance with Medical Subject Headings, were ‘Nintendo Wii’, ‘postural balance’, and ‘cerebral palsy’. According to each database, a specific keyword combination was used with the appropriate tags and the Boolean operators ‘and’/‘or’. No publication data or language filters were used. Duplicated articles were removed.

Study design

Two blinded reviewers (NZ-A and MCO-P) independently screened the titles and abstracts of all references collected through the search strategy to identify potentially eligible studies. If at least one of the authors selected an article during the inclusion phase on the basis of the title or abstract, it was examined in detail. Disagreements arising during full-text screening were resolved by referral to a third reviewer (RL-V).

A study was only included in the review when it met all inclusion criteria: (1) experimental studies, including RCT and RCT pilot studies; (2) studies including participants with CP between the age of 2 and 18 years old; (3) studies where the intervention group received NWT; (4) studies with a comparison group that received other active therapies or minimal interventions; (5) studies that assessed postural balance as an outcome measure; and (6) studies with quantitative data (mean or standard deviation) to perform the meta-analysis. In the event that the standard deviation of the balance assessment was not available in the selected study, we estimated the standard deviation from other statistics, such as standard error, range, or interquartile

range, for inclusion in the meta-analysis.^{37,38} The exclusion criteria were as follows: (1) RCT studies with intervention and comparison groups that were not exclusively composed of patients with CP and (2) RCT studies that did not provide sufficient data for inclusion in the quantitative synthesis of this review.

Data extraction

Two independent reviewers (DM-C and IC-P) collected data from the included studies using a standardized Microsoft Excel data collection form. Issues were resolved by the participation of a third author (EO-G). From each selected study, the characteristics collected were the authorship and publication date, study design, sample characteristics of the intervention and comparison groups (sample size of each group, age, sex ratio, and CP characteristics), intervention used in experimental and comparison groups (type of intervention, number of sessions, frequency of sessions, duration of the therapy or follow-up period), and outcomes (postural balance). The intervention therapy (NWT) and its comparison were classified into three categories: (1) NWT versus no intervention; (2) NWT versus CPT; and (3) NWT plus CPT versus CPT.

Outcome measures

The outcome assessed was postural balance in children with CP after receiving therapy based on the use of Nintendo Wii or Nintendo Wii combined with CPT (treatment) compared with CPT or no intervention (control). However, we performed different meta-analyses according to the different postural balance domains found in the studies included in the review. So, we identified functional balance (assessed using the Pediatric Balance Scale [PBS]), dynamic balance (assessed using the Timed Get Up and Go Test [TGUGT]), monopodal static balance (assessed using the One Leg Stance Test [OLST]), and static balance assessed with posturographic parameters, such as velocity of the centre of pressure; one meta-analysis was made for each postural balance domain. Outcomes included in our meta-analyses were: (1) continuous, such as the TGUGT, the OLST, and the velocity of the centre of pressure (all assessed in seconds) and (2) numerical scales obtained by adding ordinal items, such as the PBS that is composed of 14 items with scores that vary from 0 (worst balance) to 56 (excellent balance).³⁹ In the TGUGT, the participant has to rise from a chair, walk 3 metres, turn around, return to the chair, and sit down; researchers record the time in seconds (a longer test indicates worse dynamic balance).⁴⁰ In the OLST, the time in which a participant remains in monopodal support without falling is counted (more time without falling indicates better static balance).⁴¹

Quality assessment of included studies

The overall quality of the evidence was evaluated using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system.⁴² The risk of bias in

individual studies, inconsistency, indirectness, imprecision, and risk of publication bias were assessed with the GRADE system. All of these items, except the first, were evaluated according to the GRADE checklist by Meader et al.⁴³ Inconsistency was evaluated through determining the heterogeneity of individual studies,⁴⁴ and imprecision was assessed through the mean number of participants per study (high, >300 participants; medium, 100–300 participants; low, <100 participants), as well as the number of included studies (large, >10 studies; moderate, 5–10 studies; small, <5 studies).⁴²

To assess the risk of bias in the individual included studies, the Cochrane Collaboration Risk of Bias Tool was used. This instrument is a scale composed of six domains (selection, performance, detection, attrition, reporting, and other bias) with seven items (random sequence generation, concealment of randomization sequence, blinding of participants, blinding of outcome assessors, incomplete outcome data, selective reporting, and anything else, ideally prespecified) that are labelled low risk, uncertain risk (when studies did not provide detailed information or description), and high risk of bias.⁴⁵

Two reviewers (EO-G and RL-V) independently judged the overall quality of each meta-analysis, which was downgraded from high quality by one level for each factor that we found. In the case of the presence of several limitations, the overall quality level was downgraded by two levels. Finally, the level of evidence in each meta-analysis was categorized as follows: (1) high (the findings are robust); (2) moderate (it is possible that new research may change our results); (3) low (the level of confidence in our pooled effect is very slight); or (4) very low (any estimate of effect is very uncertain).

Statistical analysis

Comprehensive Meta-Analysis 3.3.070 (Biostat, Englewood, NJ, USA) was used to perform the meta-analysis by two authors (EO-G and RL-V). On the basis of the recommendations of Cooper et al.,⁴⁶ the DerSimonian and Laird random-effects models were used to estimate the pooled effect and its 95% confidence interval (CI) to improve the generalizability of the study findings in children with CP.⁴⁷ The pooled effect was calculated using Cohen's standardized mean difference (SMD),⁴⁸ which may be interpreted at three effect strength levels: small (SMD=0.2), moderate (SMD=0.5), or large (SMD>0.8).⁴⁹ Forest plots were used to display our findings.⁵⁰ In addition, we calculated the mean difference in a random-effects model with the aim of comparing our results to the minimal clinically important difference for each assessed outcome. Minimal clinically important difference is a useful tool that allows clinicians to correctly use and interpret measurement scales and the effects of interventions measured in clinical studies.^{51,52} The Q test and the degree of inconsistency (I^2) from Higgins et al. were used for heterogeneity analysis (small, <25%; moderate, 25–50%; large, >50%), and a *p*-value calculation indicated high

heterogeneity when $p < 0.1$.^{44,53} The risk of publication bias was analysed by asymmetry in the funnel plot⁵⁴ using Egger's test (where, if $p < 0.1$, there exists a risk of publication bias),⁵⁵ and the adjusted pooled effect was estimated using the trim and fill method (taking into account any possible publication bias).⁵⁶ With respect to publication bias, the quality level of evidence was not downgraded if the adjusted pooled effect, according to the trim and fill method, varied less than 10% with respect to the original and raw pooled effect, although the funnel plot was slightly asymmetrical.

Sensitivity analysis

The leave-one-out method (or one study removed) was used in the sensitivity analysis. The leave-one-out method involves performing a meta-analysis on each subset of the studies obtained by leaving out exactly one study.⁴⁶ It shows how each individual study affects the overall estimate of the rest of the studies assessing the contribution of each study to the pooled effect in each meta-analysis.⁴⁶

Subgroup analyses

Subgroup analyses were conducted to assess possible differences in the NWT effect between studies that compared NWT versus other therapies or no therapy, or NWT plus other treatments compared with this treatment only. In addition, the total weeks of NWT intervention and minutes of NWT exposition were evaluated in subgroup analyses.

RESULTS

Search results

Initially, 100 references were retrieved from the databases and six studies from other resources. After duplicate studies were removed ($n=41$), 65 references were screened by title/abstract. Nineteen studies were excluded for not being relevant and 35 references for not meeting the inclusion criteria ($n=27$ for not being an RCT; $n=3$ for not including a comparison or comparison group; $n=1$ for not assessing postural balance in a childhood population; $n=1$ for not presenting statistical data to be included in the meta-analysis; and $n=3$ for not using NWT as the intervention therapy). The excluded studies are shown in Appendix S1 (online supporting information). Finally, 11 studies^{57–67} were included in this review. Figure S1 (online supporting information) shows the PRISMA flow chart, depicting the bibliographic search reports and the study selection process.

Characteristics of studies included in this review

Eighteen independent comparisons were reported from the 11 RCTs included in the review. The studies were performed in the following countries: Saudi Arabia (one study);⁵⁷ Chile (two studies);^{58,63} Turkey (three studies);^{59,60,67} England (one study);⁶² Republic of Korea (two studies);^{61,64} and India (two studies).^{65,66} Only two of the studies included in this review received external funding to perform the research (AlSaif et al.⁵⁷ was funded by the

Deanship of Scientific Research of the King Abdulaziz University in Jeddah, and Farr et al.⁶² was funded by National Institute for Health Research, Research for Patient Benefit Programme). The included studies reported data on 270 children with a mean age (SD) of 10 years 1 month (1y 1mo), of whom approximately 43% of participants were female and 57% were male. Participants included in the studies were diagnosed with spastic unilateral or bilateral CP,^{57–65,67} and one study included patients with CP postsurgery.⁶⁶ According to the Gross Motor Function Classification System, six studies^{60–65} reported patients in level I; eight studies^{59–65,67} in level II; three studies^{57,61,65} in level III in three comparisons; level IV in one study;⁶⁵ and two studies^{58,66} did not report Gross Motor Function Classification System levels. One hundred and thirty-five participants composed the intervention group (mean age [SD] 9y 11mo [11mo]), 135 participants formed the comparison group (10y 3mo [1y 3mo]), and, in both groups, the percentage of females was 40% to 47%. Seven studies^{59–61,64–67} compared NWT plus CPT versus CPT; three studies^{57,58,62} compared NWT versus no intervention; and one study⁶³ compared NWT versus CPT. The duration of therapy was 3 weeks or less in two studies^{65,66} and more than 3 weeks in nine studies.^{57–64,67} Finally, seven studies^{57,58,60–64} established an NWT exposure of 30 minutes or less; three studies^{59,65,67} included sessions lasting more than 30 minutes; and one study⁶⁶ did not report this information. All included studies provided balance assessment data at the end of the intervention. The included studies did not provide data to estimate the effect of NWT in the medium or long term. Eight studies^{57–61,64–66} provided data on functional balance assessed using the PBS; three studies^{59,62,67} assessed dynamic balance using the TGUGT; another three studies^{58,59,67} assessed monopodal static balance with the OLST; and finally, only two studies^{63,65} assessed balance using posturographical parameters, such as velocity of the centre of pressure. Table 1 shows the primary characteristics of the studies included in this review.

Risk of bias assessment

Evaluation of the methodological quality and risk of bias of the studies included in the meta-analysis is shown in Table 2. A high risk of selection bias was observed in eight studies.^{57,59,61,63–67} No study blinded the NWT intervention to participants with CP. Seven studies^{57,58,60,63,65–67} did not blind the assessors after the treatment, increasing the risk of detection bias. Three studies can be considered higher quality than the others.^{60–62} In general, the overall quality of the included studies was moderate owing to the possible presence of selection, performance, and detection bias.

Functional balance

Effects of NWT on PBS

Eight studies^{57–61,64–66} with eight independent comparisons reported data on 187 participants to estimate the effect of

Table 1: Characteristics of studies included in the review

Reference	Experimental group										Comparison group						
	Country	Design	K	N	N _e	Age, y: mo, range or mean (SD)	% Female	Type of CP	GMFCS level	Type	Experimental intervention characteristics			Sample characteristics			
											Duration (wks)	Sessions per week	Session (min)	N _c	Age, y: mo, range or mean (SD)	% Female	Type of control intervention
AlSaif et al. ⁵⁷	Saudi Arabia	RCT	1	40	20	6–10	NR	Spastic bilateral	III	NWT	12	7	20	20	6–10	NR	NI
Arenas et al. ⁵⁸	Chile	RCT	2	21	11	10:11 (2:1)	36	Hemiparesis	NR	NWT	4–6	NR	30	10	10:10 (1:11)	30	NI
Atasavun-Uysal et al. ⁶⁰	Turkey	RCT	1	24	12	9:2 (2:7)	33	Spastic unilateral	I/II	NWT+CPT	12	2	30	12	NR	83	CPT
Cho et al. ⁶¹	Republic of Korea	RCT	1	18	9	10:2 (3:5)	NR	Spastic unilateral	I/II/III	NWT+CPT	8	3	30	9	NR	NR	CPT
Farr et al. ⁶²	England	RCT	1	21	10	5–16	20	Unilateral or bilateral	I/II	NWT	12	3	30	11	5–16	33	NI
Gatica-Rojas et al. ⁶³	Chile	RCT	2	32	16	10:2 (3:1)	37	Spastic unilateral or bilateral	I/II	NWT	6	3	30	16	11:2 (3:7)	43	CPT
Han et al. ⁶⁴	Republic of Korea	RCT	1	20	10	9:6 (2:6)	50	Spastic unilateral	I/II	NWT+CPT	12	3	30	10	8:11 (2:4)	50	CPT
Sajan et al. ⁶⁵	India	RCT	3	18	9	10:7 (3:9)	40	Spastic bilateral	I/II/III/IV	NWT+CPT	3	6	45	9	12:5 (4:11)	50	CPT
Sharan et al. ⁶⁶	India	RCT	1	16	8	8:11 (3:3)	NR	Postsurgery	NR	NWT+CPT	3	3	NR	8	10:5 (4:5)	NR	CPT
Tarakci et al. ⁶⁷	Turkey	RCT	2	30	15	10:6 (2:8)	40	Spastic unilateral, bilateral, or dyskinesia	II	NWT+CPT	12	2	50	15	10:6 (2:9)	33	CPT
Ürgen et al. ⁶⁹	Turkey	RCT	3	30	15	11:1 (2:4)	53	Spastic unilateral	II	NWT+CPT	9	2	45	15	11:4 (2:2)	53	CPT

CP, cerebral palsy; CPT, conventional physical therapy; GMFCS, Gross Motor Function Classification System; K, number of comparisons; N, number of participants in study; N_c, number of participants in comparison group; N_e, number of participants in experimental group; NI, no intervention; NR, not reported; NWT, Nintendo Wii therapy; RCT, randomized controlled trial; SD, standard deviation.

Table 2: Analysis of the methodological quality of the included studies

Reference	Selection bias		Performance bias Blinding of participants	Detection bias Blinding of outcomes assessors	Attrition bias Incomplete outcome data	Reporting bias Selective reporting	Other bias Anything else, ideally prespecified
	Random sequence generation	Concealment of randomization sequence					
AlSaif et al. ⁵⁷	–	+	+	+	?	–	–
Arenas et al. ⁵⁸	–	–	+	+	–	–	–
Atasavun-Uysal et al. ⁶⁰	–	–	+	+	–	–	–
Cho et al. ⁶¹	–	+	+	–	?	–	–
Farr et al. ⁶²	–	–	+	–	–	–	–
Gatica-Rojas et al. ⁶³	–	+	+	+	–	–	–
Han et al. ⁶⁴	–	+	+	–	?	–	–
Sajan et al. ⁶⁵	–	+	+	–	–	–	–
Sharan et al. ⁶⁶	–	+	+	+	?	–	–
Tarakci et al. ⁶⁷	–	+	+	+	–	–	–
Urgen et al. ⁵⁹	–	+	+	+	?	–	–

'+', High risk of bias; '–', low risk of bias; '?', inadequate data for the evaluation.

NWT on functional balance, assessed using PBS. The pooled effect (SMD 0.83; 95% CI 0.38–1.28) showed moderate-quality evidence for a large effect of NWT alone or NWT plus CPT on functional balance in children with CP, compared with CPT or no intervention respectively (Fig. 1 and Table 3). In addition, mean difference estimation in PBS was 3.16 (95% CI 1.66–4.65; Table S2, online supporting information), favouring NWT alone or NWT plus CPT versus no intervention or CPT respectively. Heterogeneity was not present ($I^2=3\%$). The funnel plot seemed

symmetrical (Fig. S2, online supporting information), and Egger's test showed a small risk of publication bias ($p=0.23$). The pooled estimate in the case of publication bias, calculated using the trim and fill method, did not show variation compared with the original pooled estimate (Fig. S2). The level of precision was low owing to the number of participants per study (mean 23.75). The sensitivity analysis (leave-one-out method) yielded pooled estimates that varied by 20% with respect to the original pooled estimate when the study by Sajan et al.⁶⁵ was excluded.

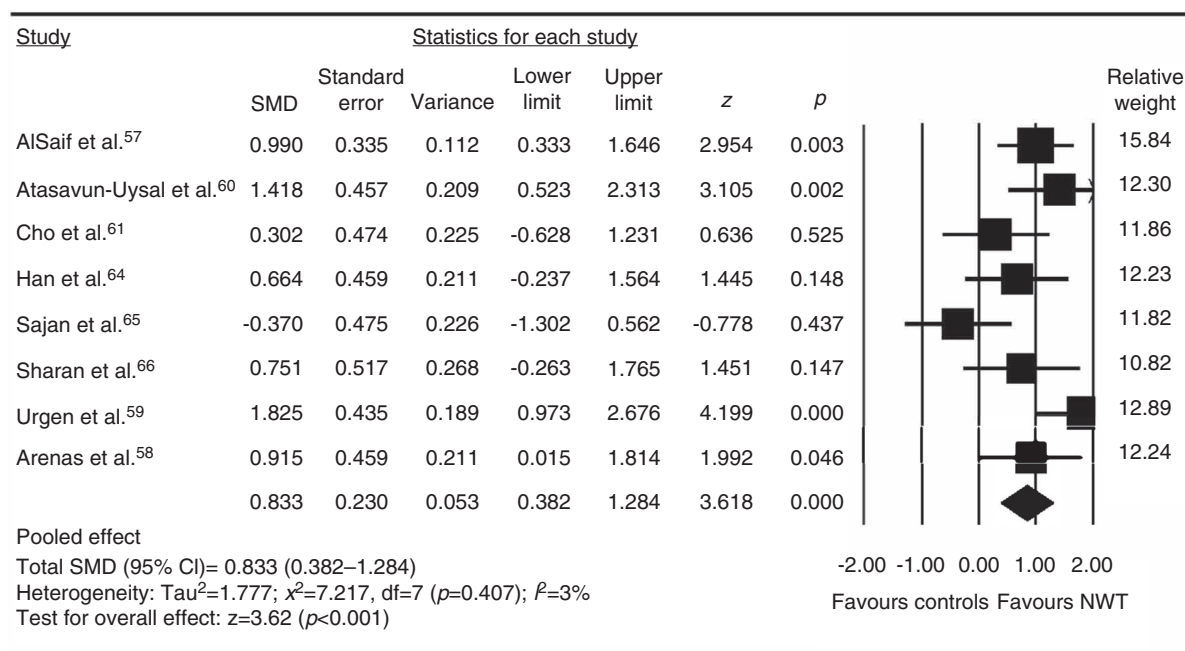


Figure 1: Forest plot of the effect of Nintendo Wii therapy (NWT) on functional balance assessed with the Pediatric Balance Scale. Squares represent the point estimate and the effect size of the individual study result. SMD, Cohen's standardized mean difference; CI, confidence interval; df, degrees of freedom; I^2 , Higgins' degree of inconsistency.

Three subgroup analyses were performed to assess the effect of NWT on functional balance depending on the characteristics of the intervention.

Type of comparison

Six studies^{59–61,64–66} reported data on 136 participants to assess functional balance and compared the effect of NWT plus CPT versus CPT on functional balance, showing moderate-quality evidence with a medium effect (SMD 0.78; 95% CI 0.20–1.35). Two studies^{57,58} with 61 participants compared NWT versus no intervention providing very low-quality evidence in a large pooled effect (SMD 0.95; 95% CI 0.02–1.89), both favouring NWT groups (Fig. 2 and Table 3). Our results showed that mean differences were 3.18 (95% CI 1.13–5.23) and 3.4 (95% CI 1.27–5.52), favouring NWT plus CPT versus CPT and NWT versus no intervention respectively (Table S2). Heterogeneity was not present in the two subgroups, and a possible risk of publication bias appeared in the NWT plus CPT versus CPT subgroup (trim and fill variation of 26%) (Fig. S3, online supporting information). When the study by Sajan et al.⁶⁵ was excluded, the pooled effect varied by 28% in the NWT plus CPT subgroup and by 4.2% in the NWT versus no intervention subgroup.

Duration intervention (weeks)

Two studies^{65,66} with 34 participants who received NWT for 3 weeks did not show statistically significant differences (SMD 0.15; 95% CI –0.67 to 0.99) and had very low-quality evidence with moderate heterogeneity ($I^2=41.79\%$) on functional balance, compared with CPT and/or no intervention. Six studies^{57–61,64} with 153 participants who received NWT intervention for more than 3 weeks showed moderate-quality evidence for a large effect favouring NWT intervention (SMD 1.03; 95% CI 0.58–1.47) without heterogeneity (Fig. S4, online supporting information and Table 3). Our results showed a mean difference in PBS of 3.14 (95% CI 1.65–4.62), favouring NWT with a duration longer than 3 weeks but was not statistically significant when NWT duration was less than 3 weeks (mean difference 2.27; CI 95% –12.53 to 17.07) (Table S2). The risk of publication bias was not present in subgroups of NWT interventions greater than 3 weeks (Fig. S5, online supporting information). The sensitivity analysis estimated that the pooled effect only varied by 14% in the subgroup with an NWT duration of longer than 3 weeks.

Duration session (minutes)

Five studies^{57,58,60,61,64} with 123 participants showed moderate-quality evidence for a large effect of NWT, compared with CPT and/or no intervention in sessions of a duration equal to or slightly less than 30 minutes (SMD 0.866; 95% CI 0.209–1.523). However, two studies^{59,65} with 66 participants did not show any effects of NWT with very low-quality evidence (SMD 0.763; 95% CI –0.292 to 1.817) when sessions lasted longer than 30 minutes (Fig. S6, online supporting information, and Table 3).

Our results showed a mean difference on PBS of 2.15 (95% CI 1.25–3.04), favouring NWT sessions with a duration longer than 30 minutes but was not statistically significant when the NWT duration was less than 30 minutes (mean difference 2.054; 95% CI –6.86 to 10.96) (Table S2). Heterogeneity was relevant in the greater than 30-minute subgroup ($I^2=75\%$). No risk of publication bias was found in the first subgroup (Fig. S7, online supporting information). The precision level was very low in both subgroups. The sensitivity analysis estimated that the pooled effect varied by 12% in the subgroup of sessions with a duration equal to or slightly less than 30 minutes.

Dynamic balance

Effects of NWT on TGUGT

Three studies^{59,62,67} reported data from 81 participants to assess the effect of NWT on dynamic balance evaluated using the TGUGT. The pooled effect (SMD 0.54; 95% CI 0.04–1.03) showed moderate-quality evidence for a medium effect favouring the NWT intervention on dynamic balance (Fig. 3 and Table 3), compared with CPT and/or no intervention. No heterogeneity was found ($I^2=0.7\%$), and the level of precision was very small owing to the small number of participants per study ($n=27$). Regarding the risk of publication bias, the funnel plot was symmetrical, and the adjusted pooled effect, calculated using the trim and fill method, did not vary with respect to the original SMD (Fig. S8, online supporting information). Finally, the sensitivity analysis estimated an important variation of 44% with respect to the original pooled effect when the study by Tarakci et al.⁶⁷ was removed.

A subgroup analysis was performed to allow specific comparisons.

Type of comparison

Two studies^{59,67} included data from 60 participants to compare the effect on dynamic balance of NWT plus CPT versus CPT, showing very low-quality evidence for a medium effect favouring NWT plus CPT (SMD 0.70; 95% CI 0.12–1.29). One study⁶² (21 participants) did not show significant differences between NWT versus no intervention (SMD 0.12; 95% CI –0.73 to 0.97) with very low-quality evidence (Fig. 3 and Table 3). Heterogeneity was not present in either subgroup, and the risk of publication bias could not be assessed. The precision level in both subgroups was very low. The pooled effect estimated varied 42% with respect to the original when the study by Urgen et al.⁵⁹ was removed.

Effects of NWT on OLST

Three studies^{58,59,67} reported data on 81 patients to assess static balance using the OLST, showing low-quality evidence for no effect of NWT (SMD 0.97; 95% CI –0.47 to 2.36) (Fig. S9, online supporting information, and Table 3) compared with CPT or no intervention. Heterogeneity was not serious ($I^2=12\%$), and the precision level of the findings was very low (27 participants per study).

Table 3: Primary findings in meta-analyses

Summary of findings															
Pooled effect heterogeneity															
Publication bias															
Trim and fill															
Quality of evidence (GRADE)															
Imprecision															
Publication bias															
Quality															
	K	N	N _s	SMD	95% CI	I ²	Funnel plot (Egger test <i>p</i>)	Adjusted SMD	% Change	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Quality
Functional balance (PBS)															
Overall	8	187	24.9	0.83	0.38–1.28	3%	Sym. 0.23	0.83	0	Medium	No	No	Yes	Unlikely	Moderate
Specific subgroups	6	136	21	0.78	0.20–1.35	17%	Sym. 0.12	1	26	Medium-High	Not relevant	No	Yes	Low likely	Moderate
NWT															
NWT+CPT versus CPT	2	61	30.5	0.95	0.02–1.89	0%	—	—	—	Medium	No	No	Yes	Likely	Very low
NWT vs NI	2	34	17	0.15	-0.67 to 0.99	42%	—	—	—	High	Medium	No	Yes	Likely	Very low
Duration intervention (wks) subgroups	6	155	25.5	1.03	0.58–1.47	0%	Sym. 0.4	1.03	0	Medium-High	No	No	Yes	Unlikely	Moderate
<3															
>3															
Duration session (min) subgroups	5	123	24.6	0.86	0.20–1.52	0%	Sym. 0.23	0.86	0	Medium	No	No	Yes	Unlikely	Moderate
<30															
>30	2	66	22	0.76	-0.29 to 1.81	75%	—	—	—	High	Yes	No	Yes	Likely	Very low
Dynamic balance (TGUGT)															
Overall	3	81	27	0.54	0.04–1.03	0.7%	Sym. 0.34	0.54	0	Medium	No	No	Yes	Unlikely	Low
Specific subgroups	2	60	30	0.70	0.12–1.29	0%	—	—	—	High	No	No	Yes	Likely	Very low
NWT															
NWT+CPT vs CPT	1	21	21	0.12	-0.73 to 0.97	0%	—	—	—	Low	No	No	Yes	Likely	Very low
NWT vs NI															
Monopodal static balance (OLST)															
Overall	3	81	27	0.97	-0.47 to 2.36	12%	Sym. 0.22	0.94	0	High	No	No	Yes	Unlikely	Low
Static balance (centre of pressure velocity)															
Overall open eyes	2	50	25	0.24	-0.31 to 0.80	0%	—	-	—	High	No	No	Yes	Likely	Very low
Overall closed eyes	2	50	25	-0.12	-0.67 to 0.43	0%	—	-	—	High	No	No	Yes	Likely	Very low

CI, confidence interval; CPT, conventional physical therapy; GRADE, Grading of Recommendations Assessment Development and Evaluation; I², Higgins' degree of inconsistency; K, number of studies; N, number of participants in each meta-analysis; NI, no intervention; N_s, mean of participants per study; NWT, Nintendo Wii therapy; OLST, One Leg Stance Test; PBS, Pediatric Balance Scale; SMD, Cohen's standardized mean difference; Sym., symmetric; TGUGT, Timed Get Up and Go Test.

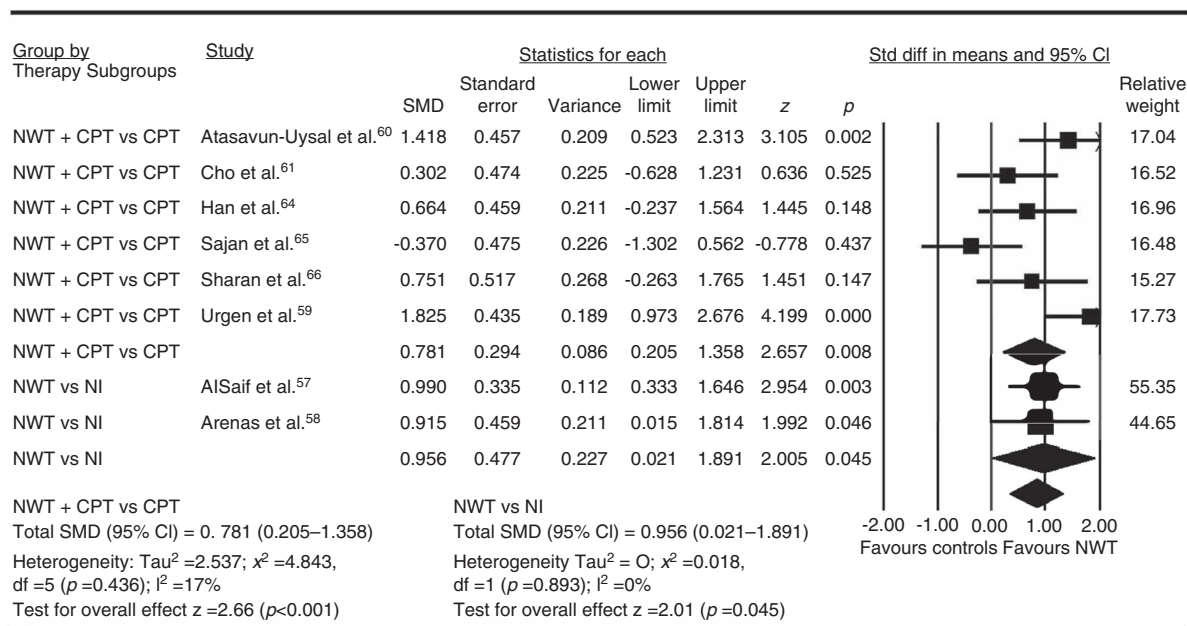


Figure 2: Subgroup analysis of the effect of specific Nintendo Wii therapy (NWT) on functional balance assessed with the Pediatric Balance Scale. Squares represent the point estimate and the effect size of the individual study result. CPT, conventional physical therapy; NI, no intervention; SMD, Cohen’s standardized mean difference; CI, confidence interval; df, degrees of freedom; I^2 , Higgins’ degree of inconsistency.

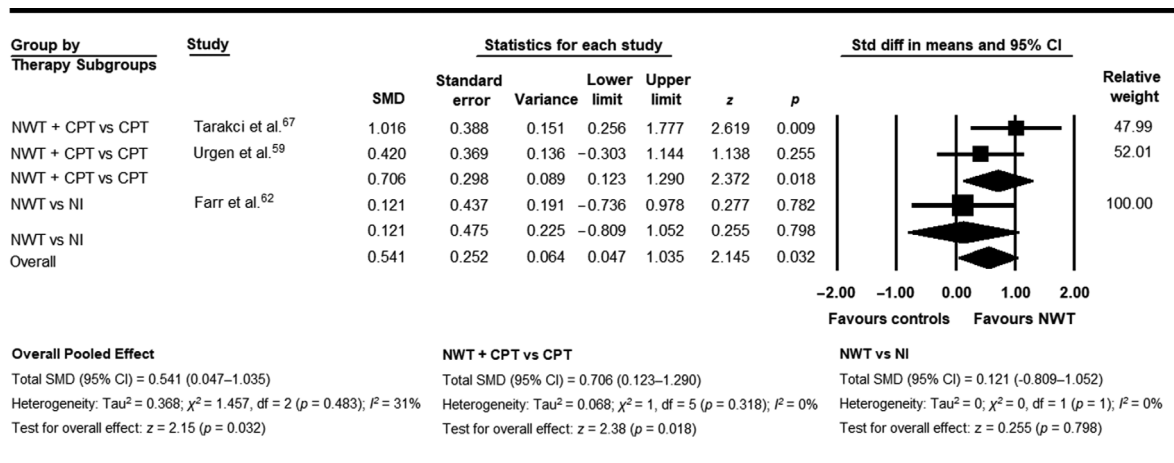


Figure 3: Forest plot of the effect of Nintendo Wii therapy (NWT) on dynamic balance assessed with the Timed Get Up and Go Test. Squares represent the point estimate and the effect size of the individual study result. CPT, conventional physical therapy; NI, no intervention; SMD, Cohen’s standardized mean difference; CI, confidence interval; df, degrees of freedom; I^2 , Higgins’ degree of inconsistency.

The funnel plot was symmetrical, publication bias was not present (Egger test p = 0.22), and no variation was found after applying the trim and fill method (Fig. S10, online supporting information). Finally, sensitivity analysis revealed a variation of 55% with respect to the original pooled effect when the study by Urgen et al.⁵⁹ was removed.

Effects of NWT on velocity of centre of pressure

The analysis of posturographic parameters was performed with two studies^{63,65} that reported data on 50 patients about the velocity of centre of pressure. The analysis showed very low-quality evidence that there was no effect of NWT in open eye conditions (SMD 0.24; 95% CI -0.31 to 0.80) or closed eye conditions (SMD -0.12; 95%

CI -0.67 to 0.43) (Fig. S11, online supporting information, and Table 3) compared with CPT. Heterogeneity was not present in either comparison, and the risk of publication bias could not be assessed. The number of participants per study was 25, yielding results with a very low level of precision. Finally, sensitivity analysis showed a variation of 45% (removing the study by Sajan et al.⁶⁵) in the open eye conditions and 58% (excluding Sajan et al.⁶⁵) in the closed eye conditions.

DISCUSSION

Our review set out to analyse evidence on the effect of NWT on balance in children with CP. We identified a significant number of RCT studies, and we analysed the quality of the existing evidence not only for the analysis of the main effect but also for the effects on the essential aspects of therapy, such as the duration of the sessions or treatment. Effects were calculated not only for functional balance but also for dynamic balance and to a lesser extent for static balance. In addition, our review offers an analytical examination of the efficacy of NWT, alone or in combination with CPT, in each balance condition. These findings are crucially important to make recommendations for clinical practice.

Our systematic review and meta-analysis suggests that NWT seems to be effective for balance in children with CP, with a greater effect on functional and dynamic balance when NWT is used in addition to CPT. The results obtained seem to be in line with findings reported by Chen et al.,³³ Warnier et al.,¹⁶ and Wu et al.³⁴ in their respective studies stating that the use of virtual reality seems to have a positive effect on patients with CP.

The studies included in our review used different tests to evaluate balance, such as PBS, TGUGT, OLST, and velocity of centre of pressure in static posturography. Moderate-quality evidence for a large effect on functional balance in children with CP favours NWT compared with CPT or no intervention. In addition, we performed a subgroup analysis according to the type of Nintendo Wii treatment received, and the results showed moderate-quality evidence for a medium to large effect of adding NWT with CPT on functional balance over the use of NWT alone. We also observed low-quality evidence for a large effect of NWT on functional balance when intervention lasted longer than 3 weeks, establishing a minimal duration of the NWT of 3 weeks compared with other therapies. Furthermore, our results revealed a statistically significant mean difference for functional balance (evaluated with PBS) that was favourable for the NWT group alone or NWT plus CPT in children with CP, compared with CPT or no intervention respectively, and favourable in type of comparison subgroups, such as NWT plus CPT versus CPT and NWT versus no intervention. Although this mean difference did not exceed the minimal clinically important difference reported in the scientific literature on PBS (5.83 points),³⁹ Cohen's SMD showed a large effect of NWT on functional balance between comparison

subgroups in each meta-analysis. It is important to remark that the minimal clinically important difference could be interpreted as a 'clinically important' change in patient function that is perceived as beneficial.⁶⁸ Our results align with the findings of Elliot et al.⁶⁹ and Erickson et al.,⁷⁰ who declare that large interventions (6–12mo) are able to produce changes in the brain cortex, facilitating the establishment of brain maps through motor behaviour acquired with the therapy. Another important aspect to our review is that it provides an adequate amount of time for each session, with moderate-quality evidence showing a large effect for NWT sessions equal to or slightly less than 30 minutes compared with other therapies, which coincides with results reported by Warnier et al.,¹⁶ where short sessions have more effect, although this result should be interpreted with caution owing to the absence of meta-analysis. Therefore, it should be considered that the time per session plays a determining role in the results of the therapy.⁷¹

When dynamic balance was assessed with TGUGT, our results showed low-quality evidence of a medium effect of the NWT on dynamic balance. Specifically, our results showed low-quality evidence of a medium to large effect for NWT combined with CPT versus NWT alone on dynamic balance. Some studies have shown that the use of virtual reality tools applied to neurorehabilitation may have more effect when they are used in combination with CPT.⁷² Our findings suggest that the best option available on dynamic balance is the combination of NWT and CPT, as shown by the results of the subgroup analysis. The isolated use of NWT had no effect on dynamic balance compared with no intervention.

Finally, for the assessment of monopodal balance and static posturography, our meta-analysis showed very low-quality evidence indicating that there is no effect of NWT with or without CPT. It should be noted that these results may be influenced by the presence of a small number of studies that use these balance assessment tools. It would be interesting to perform additional experimental studies that incorporate these assessment tools for a greater number of participants to determine whether our results are confirmed.

We suggest that the benefits NWT produces in the brain cortex are due to the principles of neuroplasticity and motor learning, although mirror neurons play an important role due to multisensory stimulation received from the NWT. Several neuroimaging studies have suggested that the use of virtual reality tools applied to neurorehabilitation can induce brain plasticity and cortical reorganization in CP.⁷³ NWT might be able to induce activity-dependent brain plasticity on the basis of the specific tasks, repetitions, intensity, and multisensory interactions that NWT facilitates.⁶⁹ In line with the principles of neuroplasticity and motor learning, the exercises available in the different games of the NWT may comply with the fundamental principles mentioned above. Several studies have analysed the influence of physical activity on patients with neurological disorders, and many of them conclude

that exercises that are performed repetitively and that resemble activities of daily living typical in a child facilitate motor-evoked potentials, exerting a positive influence on corticospinal interactions⁷⁴ and improving the required balance for gross motor skills. However, other authors, such as Barela et al., suggest that children with CP respond to sensory stimuli and alterations to a lesser extent, indicating that they would need very long interventions or very strong sensory stimuli to produce changes.⁷⁵ Our results indicated that sessions of approximately 30 minutes might be so intense for children that they favour the neuroplasticity process, while sessions longer than 30 minutes do not result in much more benefit.

Virtual reality-based rehabilitation is characterized by the active and interactive participation of the patient, which seems to produce a greater motor improvement than CPT owing to multisensory stimulation that favours the use of different systems that participate in perception, memory, and learning in children with CP.^{76,77} Active training that combines repetitive tasks and multisensory stimulation helps to reorganize the neural networks in charge of controlling trained movements by adding new synaptic connections through a process that contributes to brain plasticity.⁷⁸ After virtual reality therapy, such as NWT, activation of the cerebral cortex involved in movement increases and shows that the learning of new skills leads to the formation of new neuronal connections in the motor cortex, observable both at anatomical and physiological levels.^{79,80} The combination of virtual reality-based therapy and CPT seems to generate a greater reduction in disabling motor symptoms, such as spasticity, and an increase in postural balance,⁸¹ which can be explained by greater inhibitory control and a decrease in the reflex on alpha motor neurons, allowing improved motor control in children with CP.

To maintain correct balance, it is necessary to integrate vestibular, visual, and somatosensory information into the central nervous system.⁸² Somatosensory,¹⁰ vestibular,⁸³ and visual⁸⁴ impairments are present in children with CP. This implies that it is necessary to use multisensory treatments, such as NWT, which offer multisensory exposition and feedback capable of activating the mirror neuron system and the mechanisms of action observation.⁸⁵ The most commonly used feedback in virtual reality therapy is visual feedback,⁷⁴ which allows the patient to generate an illusion about the active execution of a movement,^{86,87} promoting reorganization of sensorimotor circuits⁷⁴ with improved postural balance²³ and motor function. At the vestibular level, researchers, such as Mao et al.,⁸⁰ have suggested that virtual reality induces adaptations in the vestibulo-ocular reflex, increasing its adaptation rate and improving balance. In addition, NWT allows the participant to perform multisensory active exercise while standing that requires constant muscle contraction of both the lower and upper limbs and the erector muscles of the spine, which implies the activation of muscle and joint proprioceptors.⁸⁸ Finally, the standing exercises proposed with NWT may stimulate the plantar pressure receptors that send the exteroceptive

information necessary to maintain balance, together with vestibular and visual information, to the brain.⁸⁹

The effect on balance experienced after a virtual reality intervention might be related to an increase in the functional capacity to perform activities of daily living and personal autonomy.¹⁷ In addition, it seems that the use of virtual reality in neurorehabilitation increases the child's motivation for therapy and favours the practice of active exercises in a safe environment.¹⁷ This may be related to greater adherence to treatment when virtual reality video game-based therapy is used instead of other less playful and active therapies.

The results of this review suggest that NWT may be a useful tool that can be included in neurorehabilitation physiotherapy protocols to improve balance in children with CP. In addition, another advantage of NWT is that it can be performed at home at a low cost, favouring the continuous practice of exercise with prior instructions from a physiotherapist. Sessions of approximately 30 minutes could prevent fatigue, increasing the adherence and attractiveness of NWT. Finally, it must be borne in mind that NWT must have a minimum duration of 3 weeks, which favours this therapy being used in the long term together with CPT. The union of both therapies favours the creation of active, playful, and highly adherent neurorehabilitation protocols in children with CP.

Our study includes some limitations. First, the generalizability of our findings might be affected by the low number of studies included in the review. Second, it is important to note the high risk of selection and performance bias that appeared in the individual studies because of the small sample size and the difficulty of blinding participants and assessors. Third, it is important to consider the possible risk of publication bias and the impossibility of analysing it in certain subgroups with fewer than three independent comparisons. The trim and fill variation may have increased the effect of the NWT plus CPT on functional balance. A limitation of the trim and fill method is that it can underestimate the true positive effect when there is no publication bias or when there is heterogeneity between studies. However, compared with other methods to assess the publication bias, when publication bias is present, trim and fill can give estimates that are less biased than the usual meta-analysis model. Another limitation is the low number of participants per study, which decreases the precision of our findings, although sample size is normally low in studies of this type. After performing the sensitivity analysis, a variation in the original pooled effect higher than 20% can affect the quality of our findings. However, all studies responsible for these variations were identified. Finally, our review demonstrates the effect of NWT in the short term because the included studies assessed balance immediately after finishing therapy. Future research must increase the sample size of studies, analyse the effect on balance in response to different types of virtual reality video game-based therapy in CP, and assess balance in the long term with the aim of identifying an effective therapy to improve balance in children with CP.

CONCLUSIONS

Our results indicate that NWT represents an effective treatment on functional and dynamic balance in children with CP. Moderate-quality evidence for a large effect of NWT on functional balance was found. Subgroup analyses revealed moderate-quality evidence for a medium effect of the use of NWT plus CPT versus CPT alone on functional balance. Moderate-quality evidence for a high effect was found for sessions equal to or slightly less than 30 minutes and for interventions longer than 3 weeks on functional balance. For dynamic balance, we found moderate-quality evidence for a medium effect favouring the NWT intervention, and, specifically, very low-quality evidence was shown for a medium effect favouring NWT plus CPT. In addition, this research clarifies important aspects of balance treatment in children with CP, such as the ideal duration of the sessions and the minimum intervention period. More research is required to assess the effect of NWT in other balance conditions, such as static balance.

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The authors have stated that they had no interests that might be perceived as posing conflict or bias.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

The following additional material may be found online:

Table S1: Bibliographic search strategy in each database

Table S2: Comparison between mean difference and the minimal clinically important difference in the PBS

Appendix S1: Full-text articles excluded with reasons.

Figure S1: PRISMA flow chart for the systematic literature search and study selection process.

Figure S2: Funnel plot of the effect of NWT on the PBS.

Figure S3: Funnel plot of the effect of NWT plus conventional physical therapy on the PBS.

Figure S4: Subgroup analysis of the effect of weeks of NWT on functional balance assessed with the PBS.

Figure S5: Funnel plot of the effect of NWT on PBS in interventions longer than 3 weeks.

Figure S6: Subgroup analysis of the effect of minute duration of each session of NWT on functional balance assessed with the PBS.

Figure S7: Funnel plot of the effect of NWT sessions of 30 minutes or less on PBS.

Figure S8: Funnel plot of the effect of NWT on TGUGT.

Figure S9: Forest plot of the effect of NWT on static balance assessed with the OLST.

Figure S10: Funnel plot of the effect of NWT on the OLST.

Figure S11: Forest plot of the effect of NWT on static balance assessed with static posturography through velocity of center of pressure.

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TERAPIA CON PLATAFORMA DE EQUILIBRIO WII DE NINTENDO PARA EL CONTROL POSTURAL EN NIÑOS CON PARÁLISIS CEREBRAL: REVISIÓN SISTEMÁTICA Y METANÁLISIS

OBJETIVO

Analizar la eficacia de la terapia con la Wii de Nintendo (NWT) para el equilibrio funcional en niños con parálisis cerebral (PC).

MÉTODO

Se realizó una revisión sistemática con metanálisis (número de identificación PROSPERO CRD42020169510) utilizando ensayos controlados aleatorios (RCTs) que examinaron el efecto de la NWT sobre el equilibrio funcional, dinámico y estático en niños con PC, evaluado con la Escala de Pediátrica de Equilibrio, la Prueba Cronometrada de Levantarse y Caminar y la Prueba de Postura de una Pierna. El efecto combinado se calculó utilizando la diferencia de medias estandarizada de Cohen (DME).

RESULTADOS

Se incluyeron 11 RCTs con 270 niños (en aquellos RCTs que reportaron el sexo de los participantes: 43% mujeres, 57% varones) con PC (edad media [DE] 10 años 1 mes [1 año 1 mes], rango 5–16 años). Sobre el equilibrio funcional, se encontraron pruebas de muy baja calidad con un gran efecto del NWT en comparación con ninguna intervención (SMD 0,95; intervalo de confianza [IC] del 95%: 0,02 a 1,89) y pruebas de calidad moderada para el uso de NWT más fisioterapia convencional (CPT) versus CPT (DME 0,78, IC del 95%: 0,20–1,35) en sesiones de aproximadamente 30 minutos (SMD 0,86, IC del 95%: 0,20–1,52) e intervenciones que duraron más de 3 semanas (SMD 1,03, IC del 95%: 0,58–1,47). Para el equilibrio dinámico, se encontraron pruebas de muy baja calidad de un efecto medio del uso de NWT más CPT versus CPT (SMD 0,70; IC del 95%: 0,12 a 1,29).

INTERPRETACIÓN

NWT puede considerarse un tratamiento eficaz para mejorar el equilibrio funcional y dinámico en niños con parálisis cerebral, especialmente cuando se combina con CPT en sesiones de 30 minutos con intervenciones que duran más de 3 semanas.

TERAPIA COM NINTENDO WII BALANCE BOARD PARA CONTROLE POSTURAL EM CRIANÇAS COM PARALISIA CEREBRAL: UMA REVISÃO SISTEMÁTICA E METANÁLISE

OBJETIVO

Analisar a eficácia da terapia com o Nintendo Wii therapy (TNW) sobre o equilíbrio funcional de crianças com paralisia cerebral (CP).

MÉTODO

Uma revisão sistemática com metanálise (número de identificação PROSPERO CRD42020169510) foi realizada usando estudos randomizados controlados (ECRs) que examinaram o efeito da TNW sobre o equilíbrio funcional, dinâmico e estático em crianças com PC, avaliado com a Escala de Equilíbrio Pediátrica, Teste Timed Get Up and Go Test, e Teste do Apoio Unipodal respectivamente. O efeito agrupado foi calculado usando a diferença média padronizada (DMP) de Cohen.

RESULTADOS

Onze ECRs com 270 crianças (quando o sexo foi reportado: 43% do sexo feminino, 57% do sexo masculino) com PC (média de idade [DP] 10a 1m [1a 1m], variação 5–16a) foram incluídos. Sobre o equilíbrio funcional, encontramos evidência de muito baixa qualidade de efeito grande da TNW comparada a nenhuma intervenção (DMP 0,95, intervalo de confiança a 95% [IC] 0,02–1,89) e evidência de qualidade moderada para o uso da TNW mais fisioterapia convencional (FTC) (DMP 0,78, IC 95% 0,20–1,35) em sessões de aproximadamente 30 minutos (DMP 0,86, IC 95% 0,20–1,52) e intervenções com duração maior do que 3 semanas (DMP 1,03, IC 95% 0,58–1,47). Para o equilíbrio dinâmico, evidência de qualidade muito baixa para efeito moderado do uso da TNW mais FTC versus FTC (DMP 0,70, IC 95% 0,12–1,29) foi encontrada.

INTERPRETAÇÃO

A TNW pode ser considerada um tratamento efetivo para melhorar o equilíbrio funcional e dinâmico em crianças com PC, especialmente quando combinada com FTC em sessões de 30 minutos com intervenções que durem mais do que 3 semanas.