Original Article

Effects of Nintendo Wii-Fit® video games on balance in children with mild cerebral palsy

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Abstract   **Background:** This study compared the effects of Nintendo Wii-Fit® balance-based video games and conventional balance training in children with mild cerebral palsy (CP).
Methods: This randomized controlled trial involved 30 ambulatory pediatric patients (aged 5–18 years) with CP. Participants were randomized to either conventional balance training (control group) or to Wii-Fit balance-based video games training (Wii group). Both group received neuro-developmental treatment (NDT) during 24 sessions. In addition, while the control group received conventional balance training in each session, the Wii group played Nintendo Wii Fit games such as ski slalom, tightrope walk and soccer heading on balance board. Primary outcomes were Functional Reach Test (forward and sideways), Sit-to-Stand Test and Timed Get up and Go Test. Nintendo Wii Fit balance, age and game scores, 10 m walk test, 10-step climbing test and Wee-Functional Independence Measure (Wee FIM) were secondary outcomes.
Results: After the treatment, changes in balance scores and independence level in activities of daily living were significant ($P < 0.05$) in both groups. Statistically significant improvements were found in the Wii-based game group compared with the control group in all balance tests and total Wee FIM score ($P < 0.05$).
Conclusion: Wii-fit balance-based video games are better at improving both static and performance-related balance parameters when combined with NDT treatment in children with mild CP.

Key words   cerebral palsy, mobility, postural control, video game, virtual reality therapy.

Impaired postural control is one of the important reasons for difficulty in walking or reaching to hold something in children diagnosed with cerebral palsy (CP).[1,2] Therefore, improved control in static and reactive balance is one of the most important goals in rehabilitation programs for children with CP.[3]

Treatment of CP children is a challenging task for clinicians. Lack of motivation and progress monitoring are two important factors that clinicians need to deal with. Optimal use of function, achieving selective movement and fulfillment of children's motor and cognitive potential are important goals of CP rehabilitation, particularly in the treatment of balance disorders. The neuro-developmental treatment (NDT) approach is the most common method used in CP rehabilitation worldwide. The purpose of this approach is to optimize function by improving postural control and to facilitate the selective movement.[4] In recent years also many interventions such as reactive balance training, treadmill training, and interactive computer play (ICP) have been identified to enhance balance and postural control in CP children.[5]

Interactive computer play allows a person to interact with virtual objects in a computergenerated environment. Over the

past 15 years, interactive computer games have begun to be used as a therapeutic tool because they have the potential to improve physical fitness and postural control.[6] The effect of video games on balance parameters in healthy subjects was first examined and proved by Brumels *et al.*[7] In a recent review, it has been addressed that ICP led to improved gross motor function in individuals with CP. Also it appears to have the potential to produce gross motor improvements in terms of strength, balance, coordination, and gait for individuals with CP.[8] Most of the requirements of motor learning seem to be fulfilled by ICP.9 It provides an opportunity for increased duration, intensity and/or frequency of practice.[10,11] Also, task specificity is provided by realword tasks or movements that are performed during the game,9 and there are many opportunities to be able to organize the individualized treatment programs according to the user's needs: such as the amount and extent of visual and/or auditory feedback or duration of game or task trials.[10] Giving visual and/or auditory feedback via the computer, within the ICP intervention, with regard to task performance, promoting user problem-solving through task, and increasing cortical activity are other reasons why ICP interventions may work for CP rehabilitation.[11–13]

After Nintendo (Nintendo, Kyoto, Japan) launched the Wii game console and Wii balance board an ICP system, many benefits of this system were noted.[14] It is a relatively low-cost system and

provides an opportunity for people with disability to train their balance in an enjoyable way. It has also been suggested in some studies that clinicians can feel comfortable prescribing video game-based balance activities as a way to improve physical performance and patient compliance when balance improvement is the clinical treatment goal.[14,15]

Some utilities of the system have also been proved in many studies on different diseases, but there is still a need to demonstrate the effectiveness of Wii games in children with CP. A review of the use of virtual video games in children with CP indicated the need for high-level randomized trials with a large sample size in order to draw a definitive conclusion, given that many studies have provided limited evidence.[16,17]

Therefore, the aim of the present study was to compare the effects of Wii-Fit balance-based video games and conventional balance training, in addition to an individualized NDT approach, on children with CP.

Methods

This randomized controlled trial included patients with ambulatory CP. The CP patients were recruited from the pediatric neurology outpatient clinic of the Department of Pediatric Neurology, Faculty of Medicine of Istanbul University. The trial was conducted between February 2011 and February 2013.

Inclusion criteria were: diagnosis of CP (diplegic, hemiplegic, dyskinetic type); age 5–18 years of age; Gross Motor Function Classification System (GMFCS) level 1, level 2 or level 3; no history of epilepsy; no botulinum toxin A treatment for the lower extremities in the previous 6 months; no excessive spasticity in any joint (score > 2 on the Modified Ashworth Scale); and confirmed mental ability to be able adapt to exercise.

A total of 43 patients were assessed for eligibility, 38 of whom met the inclusion criteria and were enrolled prospectively in this study. Participants were randomized to either conventional balance training (control group; CG) or Wii-Fit balance-based video game training (Wii group; WiiG) using the function of Microsoft Office Excel. First treatment and random number columns were created. In the treatment column, the conventional balance training group was indicated as "1" and the Wii-Fit balance-based video game group was indicated as "2". Microsoft Excel random number generator then assigned a random number between 0 and 1 to each treatment row. The sort and filter menu was used to sort the random number row from smallest to largest so that groups were randomly ordered.

Each group completed a 12 week exercise program. All measurements were performed before and after the 12 weeks. Interventions were applied to each group by two different physiotherapists. Assessment was performed by the same physiotherapists not blinded to the allocation.

This trial was approved by the Istanbul Faculty of Medicine, Clinical Research Ethics Committee at the meeting dated 7 January 2011 and also was carried out according to the principles of the Declaration of Helsinki. The trial was explained to the parents and written informed consent was obtained.

Outcome measures

Primary outcome measures

The Functional Forward Reach Test (FFRT) is the maximum distance one can reach forward beyond arm's length while maintaining a fixed base of support in the standing position. It is a method for testing the dynamic standing balance.

In the Functional Sideways Reach Test (FSRT), the patient stands with their back to the wall; while his/her arm is in 90° abduction, and tries to reach sideway beyond arm's length while maintaining a fixed base of support in the standing position. The maximum distance that the subject can then extend their arm forward/sideways is measured. The test was repeated for both the right and left side.[18] Liu *et al.* found the FFRT, a useful measurement to assess balance in children with CP.[19]

In the Timed Get Up and Go Test (TGGT) the subject is asked to get up from a chair, walk 3 m at normal speed and rhythm then turn around, walk back, and sit down. The time of this process is recorded in seconds.[20,21]

The Sit-To-Stand Test (STST) was used to assess the muscle strength of the knee extensors. The patient was asked to stand up straight from a chair and then return to the initial position without getting support from the arms. The score is the number of full stands that the patient performed during 30 s. Measurements were repeated three times and the average of the three measurements determined the final score.[22]

Secondary outcome measures

Nintendo Wii-Fit[®] Balance and Game Scores: Wii-Fit balance evaluation was implemented in a completely dark and isolated room specially prepared for this treatment and evaluation. With the mechanisms installed in the room, Wii-Fit images were projected onto a wall. Patient demographic information was recorded into the system according to the orientation of device. The patient was asked to stand still on the balance board and then the weight distribution over the left and right feet was evaluated (body center of gravity; BCG). As a result, the percentage of weight over each foot was recorded. After that, the patient was asked to stand on the right and left foot, respectively, and the time of one leg standing was recorded by the device (Wii Balance). Wii Fit Age, which is a routine test of the device, was used to determine age using information such as demographic factors, body mass index and weight distribution over each foot. If the resulting age is older than the actual age, this indicates insufficiency in exercise and balance compared with the actual age. Also score or duration of each balance game were recorded by the device for each patient and these data used as outcome measures.

The 10 m walk test (10mWT) was used to assess the duration of walking time in a 10 m corridor.[23] The 10mWT has test–retest reliability and is used to assess walking performance in children with neurologic disorders.[24]

During the 10 Steps Climbing Test (10SCT), subjects were asked to climb 10 steps (14 × 28 × 120 cm) as fast as possible. Duration of stepping was measured in seconds with a stopwatch.[21]

The Functional Independence Measure for Children (Wee-FIM) consists of six areas with 18 items: self-care, sphincter control, transfers, locomotion, communication and social cognition.[25] Validity and reliability of the Turkish version of Wee-FIM were confirmed by Tur *et al.*[26]

Intervention

Children who met the research inclusion criteria were trained at the Rehabilitation Unit of Istanbul University, Faculty of Health Sciences, Division of Physiotherapy and Rehabilitation. At the beginning of the study, children participated in assessment for primary and secondary outcome measures (one session). Immediately after the initial assessment, patients in both groups were given a treatment schedule that consisted of 2 days per week (50 min per session) for a total of 12 weeks. While the individual NDT approach was used for each patient in both groups (30 min), a conventional balance training program (20 min) was applied in the CG, and a Wii-Fit balance-based video game program was used in the WiiG (20 min).

After the patient assessment, targets were set in the individualized NDT program. Current Bobath concept principles were considered while applying this program. The program included the following: activities for regulating tone, work that supports sense-perception-motor development, activities that facilitate regular movement, stretching and strengthening exercises for musculoskeletal disorders, functional skills training for upper extremity, and training in daily living activities such as dressing and eating.

Conventional balance training used in the CG is given in Appendix 1. In the WiiG, Nintendo Wii Fit gaming console was used for training. Images from the gaming console were projected onto a screen using an Acer XD1150 projector (San Jose, CA, United States) in a darkened room. A physiotherapist prescribed the Wii Fit activities, and supervised and supported the patients during the therapy. The exercise program included balance exercises on the Wii balance board. In each session the patients played four games. A brief explanation of the purpose of each game is given in Appendix 2.

After final intervention all outcome measures were re-assessed (one session).

Statistical analysis

SPSS version 20.0 (IBM Corporation, Armonk, NY, USA) was used for statistical analysis, and $P < 0.05$ was accepted as statistically significant.

Shapiro–Wilk test was used to determine normality of data distribution in the two groups. Given that the data distribution was not normal, non-parametric tests were preferred.

Two-way analysis of variance was used to compare the baseline characteristics between the two randomized groups. Wilcoxon signed-rank test was used to determine the difference within each group before and after treatment. Differences in intervention efficiency between the groups were compared again using two-way analysis of variance. Partial eta-squared (ηp^2) was estimated to establish effect size.[27]

Results

A total of 38 eligible patients with CP were included in this trial. The number of patients selected at the beginning of study, reasons for leaving the study, randomization and groups are shown in the flow chart (Fig. 1). Four patients dropped out from the CG and four patients dropped-out from the WiiG; a total of 30 patients completed the study. The patients consisted of 12 diplegic type CP, 14 patients with hemiplegic type CP, and four patients with dyskinetic type CP. The demographic and clinical features are listed in Table 1. Significant difference was not detected for mean age and GMFCS score between the two groups ($P > 0.05$). Also there were no statistically significant differences in either primary and secondary outcome measures between the two groups at initial assessment. The changes in outcome measures within and between the two groups at the end of the exercise program are given in Tables 2 and 3. Wee FIM Transfers subscores did not change statistically significantly after treatment in both groups. The changes in all other primary and secondary outcome measures were significant, in favor of the WiiG.

Discussion

Significant improvements were obtained in balance function and independence level in the activities of daily life after Wii Fit balance-based video games compared with conventional balance training. Given that postural control is essential for independence in activities of daily living, balance and walking activities are indispensable in CP rehabilitation.[28,29] Motivation is very important in the CP rehabilitation process because it often takes a long time to reach the desired functional level. Conventional balance training sometimes makes children bored when carried out for a long period of time. Developing interactive computer game technology also provides the chance for clinicians to motivate patients due to the nature of the games, and also objective and sensitive data can be collected during the rehabilitation process. Although force platform systems are reliable in assessing standing balance, the high cost and difficulty in installation and handling make it difficult to use in the clinical setting. Wii balance board has been found to be valid and reliable for assessing standing balance parameters (force distribution, center of gravity deviations etc.) and suitable for clinical practice with its low cost and ease of use.[30] In light of this knowledge, we used Wii Fit Balance parameters and balance game scores as outcome measures in the present study. There were statistically significant improvements on Wii Balance, Wii Age parameters and balance game scores in WiiG compared with CG. Kliem and Wiemeyer, who investigated ski slalom and ball catching games in their study, obtained similar results to the present study.[31] As in the present study, game scores and Wii parameters were improved in a statistically significant manner in WiiG compared with conventional balance activities.

Other studies on the efficacy of Wii games involved patients with multiple sclerosis, intellectual disability and Parkinson disease.[32–35] The effect of virtual video games on children with CP has been demonstrated in some trials with small sample sizes.
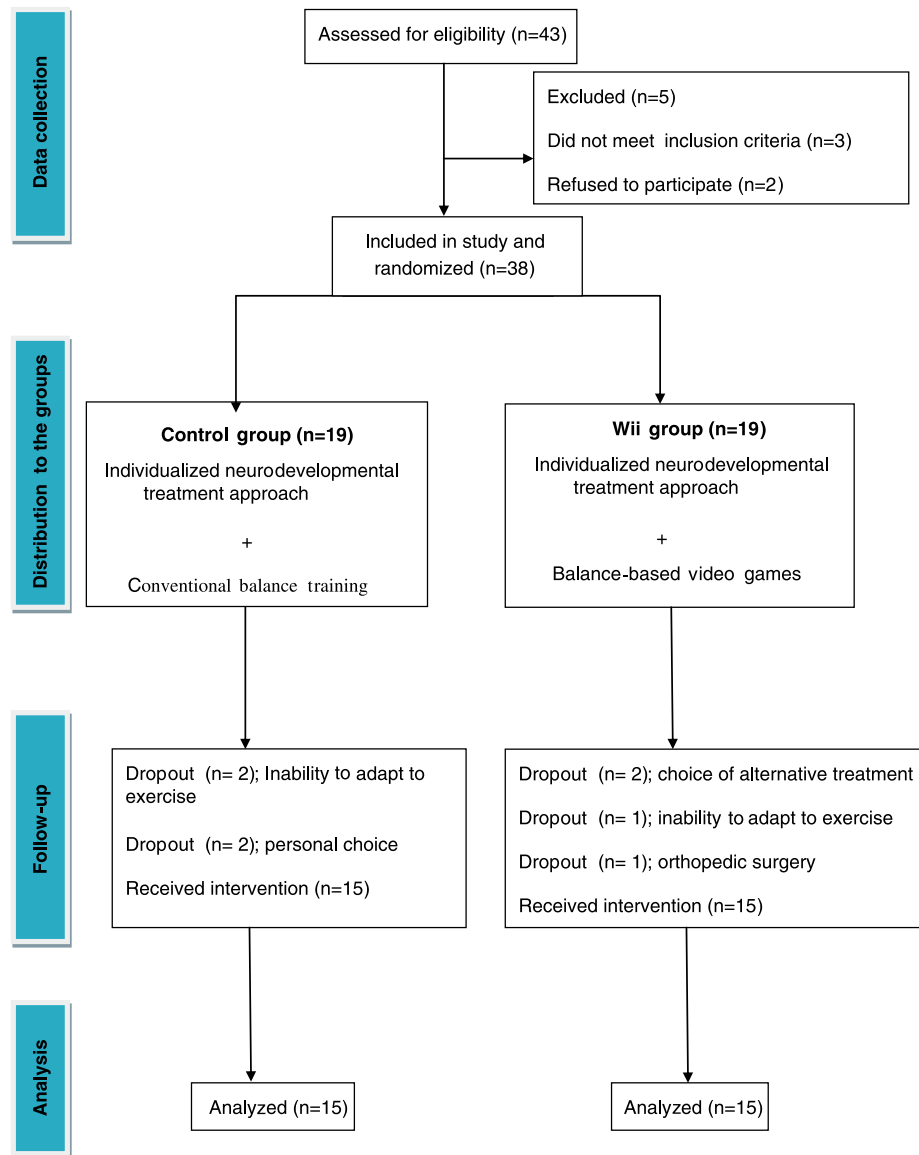
Fig. 1   Study flow chart.

Table 1   Subject demographic and clinical characteristics

	Control group n (%) or mean ± SD	Wii group n (%) or mean ± SD	P-value
Sex (F/M)	6/9	5/10	
Age (year)	10.53 ± 2.79	10.46 ± 2.69	0.94
Type of CP			
Hemiplegic	7 (47)	7 (47)	
Diplegic	5 (33)	7 (47)	
Dyskinetic	3 (20)	1 (7)	
GMFCS			
Median (min–max)	2 (1–3)	2 (1–2)	0.07
Assistive devices			
Yes	3 (20)	0 (0)	
No	12 (80)	15 (100)	
Orthesis			
Yes	10 (67)	9 (60)	
No	5 (33)	6 (40)	

CP, cerebral palsy; GMFCS, Gross Motor Function Classification System.

Table 2 Change in performance after training

	Control group			Wii group			Difference between groups		Effect size (ηp^2)
	Before Mean ± SD	After Mean ± SD	$P^{\dagger}$	Before Mean ± SD	After Mean ± SD	$P^{\dagger}$	Before P	After P	
Wii balance (second)	1.16 ± 0.71	1.25 ± 0.72	0.061	1.59 ± 0.31	2.73 ± 0.41	0.001	0.359	<0.001	0.77
Wii age (year)	48.60 ± 6.24	47.40 ± 6.15	0.006	47.80 ± 7.51	41.53 ± 8.25	0.001	0.753	<0.001	0.65
Ski Slalom (score)	14.06 ± 3.30	14.40 ± 3.81	0.357	9.73 ± 1.70	15.46 ± 2.61	0.001	<0.001	<0.001	0.76
Soccer heading (score)	15.46 ± 5.56	17.26 ± 5.25	0.003	14.53 ± 3.94	23.93 ± 6.41	0.001	0.600	<0.001	0.63
Tilt table (score)	12.20 ± 5.11	15.40 ± 6.56	0.008	14.13 ± 6.19	28.33 ± 11.44	0.001	0.04	<0.001	0.56
Walking a tightrope (m)	1.41 ± 0.53	1.65 ± 0.75	0.012	1.33 ± 0.22	2.35 ± 0.34	0.001	0.607	<0.001	0.60

†Baseline vs after treatment.

Table 3 Changes in outcome measures

	Control group			Wii group			Difference between groups		Effect size (ηp^2)
	Before Mean ± SD	After Mean ± SD	$P^{\dagger}$	Before Mean ± SD	After Mean ± SD	$P^{\dagger}$	Before P	After P	
FRT (cm)									
Forward reach	18 ± 8.29	19.20 ± 8.53	0.002	20.33 ± 5.89	24.60 ± 6.83	0.001	0.382	<0.001	0.65
Leftward reach	15.46 ± 4.08	16.13 ± 4.12	0.020	15.26 ± 6.01	18.46 ± 6.78	0.001	0.916	<0.001	0.36
Rightward reach	15.26 ± 5.45	16.20 ± 5.21	0.015	16.06 ± 4.75	19.66 ± 5.80	0.001	0.672	0.01	0.32
STS (s)	5.60 ± 1.50	6.13 ± 1.68	0.005	6.13 ± 1.55	8.73 ± 2.08	0.001	0.347	<0.001	0.70
TUG (s)	15.77 ± 4.52	14.67 ± 4.54	0.001	12.96 ± 3.65	10.62 ± 3.30	0.001	0.07	<0.001	0.48
10mWT (s)	13.77 ± 4.72	12.96 ± 4.64	0.003	13.25 ± 3.56	11.04 ± 3.46	0.001	0.736	<0.001	0.34
10SCT (s)	12.03 ± 4.91	11.12 ± 4.27	0.004	10.32 ± 3.81	8.42 ± 3.57	0.001	0.296	<0.001	0.19
Wee-FIM									
Total	94.40 ± 10.70	95.50 ± 10.47	0.011	95.73 ± 10.10	100.26 ± 8.75	0.001	0.728	<0.001	0.51
Self-care	30.53 ± 6.85	30.93 ± 6.81	0.063	31.46 ± 4.29	32.60 ± 3.73	0.004	0.658	0.02	0.17
Transfers	16.60 ± 2.84	16.66 ± 2.82	0.317	16.06 ± 2.96	16.46 ± 2.77	0.157	0.619	0.245	0.04
Locomotion	9.33 ± 1.83	10 ± 1.77	0.046	9.66 ± 1.34	11.60 ± 0.73	0.001	0.575	0.01	0.21

†Baseline vs after treatment. 10mWT, 10 m walking test; 10SCT, 10 stair climbing test; FRT, Functional Reach Test; STST, Sit-To-Stand Test; TUG, Timed Up and Go Test; Wee-FIM, Pediatric Functional Independence Measure; cm, centimeter; s, second.

Gordon *et al.* investigated the possibility of using Wii to improve gross motor function for children with CP.[35] Six participants completed the study and it was concluded that Wii had the potential for use as a rehabilitation tool in the management of CP. Jelsma *et al.* trained 14 hemiplegic CP children with Wii Fit and concluded that although most children preferred interactive video games, it should not be used in place of conventional therapy.[36] It could be used as adjunct to therapy. Nintendo was used as an adjunct therapy in the present study, and the results were better compared with the Jelsma *et al.* study, especially with regard to performance measurements.

A review on the use of video games for children with CP indicated that high-level randomized trials with large sample size were needed in order to draw a definitive conclusion.[16] Ramstrand and Lygnegård evaluated the balance-related measures for home Wii Fit use in children with CP.[37] To our knowledge, this is the only randomized cross-over trial in the literature on the effect of the system, and it found that Wii Fit was not effective as a balance training tool when used for 5 days per week with 30 min sessions for 5 weeks. It is possible that lack of supervision may lead to these results because children with CP need feedback to achieve good postural control and selective movement.

Similar to the literature, in the present study one of the balance measurements that was associated with performance was STST. After treatment, there were significant improvements in each group but, in WiiG, the improvement was statistically significant compared with CG. This might be related to the development of postural control and selective movement. TGGT is another performance-based balance test used in the present study. Similar to STST, after treatment there was a significant decrease in completion time in the two groups but, compared with CG, the decrement was significant in WiiG. The ski slalom and tightrope walking Wii games may have caused this content improvement in mobility.

In the present study, in 10mWT and in 10SCT, there were also significant decreases in completion time in the two groups, but, compared with CG, the decrement was significant in WiiG. This is not surprising because it is important to be able to control the center of gravity in order to avoid finishing the games with a low score in video-based games. It is similar to walking and climbing stairs, and the WiiG children had more opportunity to try to keep their center of gravity within the limits of stability, due to the different types of games.

Zaino *et al.* found that children with CP rated as GMFCS level 1 or 2 had FFRT mean distance between 22.8 and 29 cm.[38] In the

present study, this value was between 18 and 21 cm. This difference may be explained by the different ethnicity and by the inclusion of GMFCS level 3 to levels 1 and 2 in the present study. Although there were significant improvements in the two groups after treatment in the present study, increase in WiiG was statistically significant compared with CG. We considered that this improvement might be related to the positive effects of Wii games, which require repetitive and active participation with weight bearing in all directions.

There were some strengths of the present study. To our knowledge this is the first randomized controlled trial to investigate the effects of supervised Wii Fit balance-based video games in CP children in a clinical setting. Given that this trial obtained the effect size for all outcome measurements, these findings may be used as a reference for calculating the power needed for an extensive clinical trial. In addition, the present results provide a new perspective for the physical therapists working with CP patients. Given that CP rehabilitation is a long-term process, this system provides a good alternative for CP evaluation and treatment planning.

There were some limitations to the present study. First, assessors were not blind to the intervention. Second, long-term results are needed in order to determine the length of time for which the effect of Wii training is maintained. Another limitation of the present study refers to the heterogeneity of groups. Children with different types of CP comprised the WiiG and CG, as in the previous studies. In contrast, Wii Fit game scores were used as an outcome measure, but motor learning could be promoted much more in the WiiG than in the CG. Because of this, Wii Fit game scores were used as the secondary outcomes. While the mean of the initial ski-slalom score was better in the CG before treatment, the difference between the mean tilt-table score was near significance in favor of the WiiG at initial assessment. We did not apply advanced statistical analysis, again, because those scores were used only as secondary outcomes.

In conclusion, Wii-Fit balance-based video games are important components of CP rehabilitation because they generate improvement on balance parameters and independence level in activities of daily life. Moreover, given that this training provides motivation and fun, it may be a preferable method for children and their families. Also, adding new technological initiatives to rehabilitation sessions is another factor that increases satisfaction among children and families. For these reasons, we suggest Wii-Fit balance-based video games as an approach which may be integrated into the rehabilitation programs of CP children by the physiotherapists. Further studies are needed to compare the effects of different systems to improve postural balance.

Disclosure

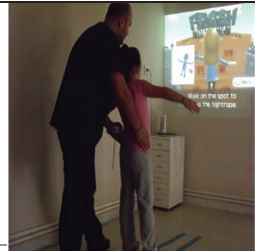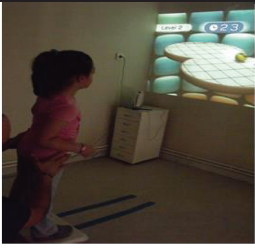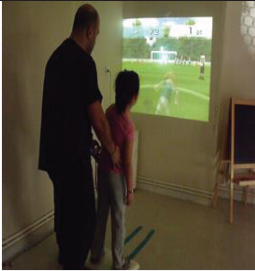The authors declare no conflicts of interest.

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Appendix 1. Conventional balance training program.

Activity type	Description of activity	Therapeutic aim
 Exercises on balance boards with different surfaces	Training on different balance boards, which are changed according to the child's functional capacity on two feet or on one foot.	Trunk control
 Mat activities	Training balance exercise on mat with some game activities in crawling and kneeling positions.	Postural control and proximal stabilization.
 Activities on trampoline	Reaching to different points on trampoline, standing and jumping with two feet or one foot on the trampoline.	Trunk control on unstabilized surface and dynamic balance
 Weight- shifting exercises (mini squat, exercises on step)	Mini squat exercise in standing position, weight shifting to the right and left lower extremity when the knees are semi-flexed, stepping on and down without support.	Equal weight transfer on both lower extremities without disturbing the postural control
 Walking activities	Stepping exercise, walking backward and laterally, tandem walking.	Postural control and proper weight bearing during walking

Appendix 2. Nintendo Wii balance-based video games.

Activity type	Description of activity	Therapeutic aim
 Slalom skiing	Individuals tries not to hit the obstacles while doing slaloms to the right and left and complete the game in the indicated direction.	Trunk control, weight transfer to the left and right, hip-knee-ankle control
 Walking on rope	Child stands on the board and walk on the rope with weight bearing on the right and left side and aims to cross to forward as soon as possible. When there is an obstacle, child tries to pass it with hip and knee flexion.	Postural control, dynamic balance and weight bearing
 Tilt table-balance board	While child stand on the board, tries to guide the balls into the holes with weight bearing.	Trunk control on unstabilized surface and dynamic balance
 Heading (hit the ball with the head)	The child tries to hit the ball with the head, while at the same time escaping from oncoming objects.	Trunk control, weight transfer to the left and right, body awareness and visual perception