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Original Article

Comparison of the complementary therapeutic effects of Neurodevelopmental Treatment Approach-Bobath and Nintendo Wii Fit Balance-based video games on static balance, functional activities, and game scores in children with cerebral palsy: A case-control study

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ABSTRACT

Objectives: This study aimed to compare the effects of Neurodevelopmental Treatment Approach-Bobath (NDT-B) and Nintendo Wii Fit balance-based video games on balance, motor skills, and functionality in individuals with ambulatory cerebral palsy (CP) and to examine the long-term the effects of Wii Fit balance-based video games and NDT-B.

Patients and methods: A total of 20 individuals with ambulatory CP were included in the randomized-controlled study between June 2018 and September 2019. The participants were randomized into two groups: the Nintendo Wii Fit balance-based video games group (Wii group; 8 males, 2 females; mean age: 13.0±3.3 years; range: 5 to 18 years) and the NDT-B group (control group; 8 males, 2 females; mean age: 9.3±3.9 years; range: 5 to 18 years). Personalized NDT-B was applied to both groups for a total of 12 sessions. Personalized posture and balance activities were applied to the control group, while Nintendo Wii Fit balance-based video games were applied to the Wii group. Motor and functional tests were used for the assessment of functional status and abilities. Balance tests and Nintendo Wii Fit balance assessment were used for balance assessment. The outcomes were recorded before treatment, after treatment, and three months after treatment.

Results: Static balance improved in both groups, with the effect sustained after three months in the control group ($p<0.05$). At the end of the treatment, the decrease in Timed Up and Go test and the increase in Sit-to-Stand test scores were significant in the Wii group, and these improvements were sustained at three months following the treatment ($p<0.05$). There was a significant increase in the game scores for balance, weight shift, and walking speed at the end of the treatment ($p<0.05$).

Conclusion: The current study results suggest that Wii Fit balance-based video games can be used as an additional and complementary therapy to the NDT-B treatment program in the rehabilitation of individuals with CP with sustainable clinical effects in the long-term.

Keywords: Brain damage, child, disabled, rehabilitation outcome, virtual reality.

Cerebral palsy (CP) describes a group of permanent disorders of the development of movement and posture, causing activity limitation, which occur in the developing fetal or infant brain. Cerebral palsy motor disorders often come with sensory, perceptual, cognitive, communicative, and behavioral disturbances, epilepsy, and secondary musculoskeletal problems.[1] Cerebral palsy remains at 2.11 per 1000 live births globally, but in Türkiye, it's 4 per 1000 live births, possibly due to increased survival rates of preterm infants.[2,3]

It is a neurodevelopmental disorder and is the most common cause of physical disability, which begins in childhood and lasts for a lifetime.[4,5] In CP, many problems come together to affect the functional capacity of the individual and complicate their life.

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Problems such as delay in timing of balance reaction response, decrease in its intensity, postural issues occurring in the musculoskeletal system in time, abnormal muscle tone, and coordination disorders cause balance problems in children with CP.[6,7] The current approaches to effective rehabilitation for the mentioned conditions of individuals with CP involves a combination of physical and educational interventions that align with specific rehabilitation goals agreed upon between the patient and the rehabilitation professional. Before implementing a conservative rehabilitation program, a thorough evaluation of motor impairments and the topography of the CP is necessary. This program should include regular in-person meetings with a therapist, as well as a self-management regimen. All sessions should be based on motor learning theory and a functional task-oriented approach. They should include exercises that are specific to a person's individual goals, preferred activities, and activities of daily living.[8] Unfortunately, the general principles for effective rehabilitation interventions are not always applicable due to patient, family, or therapeutic environment conditions and have limitations such as patient participation and motivations.[6,9] Recently, virtual reality (VR) technology and interactive computer games have been used in gamified rehabilitation methods to treat the mentioned conditions.[6,9-12]

Children and young adults of today are known to be familiar with technological tools such as VR as a means of entertainment or socialization.[13] Virtual reality consists of three main elements that activate motor learning, which are repetition, sensory feedback, and motivation.[14,15] Patients can use this treatment method, which enables them to perform the exercises in a voluntary, regular, and systematic manner.[16] Many individuals with CP receive traditional physiotherapy throughout their lifetime. It is important that rehabilitation professionals introduce novel and exciting approaches to treatment that are fun and effective in balance training, such as Nintendo Wii Fit games.[17]

It is a fact that interactive computer play surpasses conventional therapy in enhancing postural control and balance for children who have mild to moderate CP. The effect sizes are of medium to large magnitude, leaving no doubt as to the superiority of this approach. Although neurodevelopmental treatment methods have proven to be effective in assisting with CP rehabilitation, integrating immersive and entertaining tools such as the Nintendo Wii can provide an additional boost to functional progress by encouraging positive motivation and active participation. The games are designed to be enjoyable and motivating, encouraging children to repeat required body movements to achieve high scores without losing interest.[6,9,11,12]

Although there are studies on CP rehabilitation and Nintendo Wii Fit in the literature, there is no consensus on game options, its intensity, and integration into current treatment. There is a limited number of reports relating to the long-term outcomes of Nintendo Wii Fit applications introduced into rehabilitation programs. The primary objective of the current study was to compare the effects of personalized posture-balance activities and video-based Nintendo Wii Fit balance games on balance, motor skills, and functionality, supplementary to a personalized NDT-B approach applied in individuals with ambulatory CP. Our secondary objective was to determine how long the effects of Wii therapy and NDT-B were sustained in the long-term after the interventions.

PATIENTS AND METHODS

This randomized-controlled clinical trial was conducted at the Trakya University Faculty of Medicine, Physical Therapy and Rehabilitation outpatient clinic between June 2018 and September 2019. A total of 20 patients with CP who were admitted to the outpatient clinic and who met the inclusion criteria were included in the study. Inclusion criteria were as follows: aged 5 to 18 years, having a documented diagnosis of CP (diparesis, hemiparesis, or cerebellar involvement), being at Level 5 or 6 as per the Functional Mobility Scale (FMS) in the ambulatory level, being at Level 1 or 2 according to the Gross Motor Function Classification System (GMFCS), having the ability to adapt to the exercises, and their family consenting to the treatment. Exclusion criteria were as follows: having a history of epileptic attack, receiving botulinum toxin injection for spasticity in the lower extremities within the past six months, displaying behavior and compliance disorders during the performance of the tests, and having a medical condition preventing enrollment in the study. Demographic data and clinical characteristics of the participants were recorded. Written informed consent was obtained from each parent and/or legal guardian. The study protocol was approved by the Trakya University

Faculty of Medicine, Scientific Research Ethics Committee (date: 02.04.2018, no: BAEK 2018/126). The study was conducted in accordance with the principles of the Declaration of Helsinki.

A total of 35 children diagnosed with CP were assessed in the study. They were randomized into two groups based on their time of arrival at the outpatient clinic using the random number table. The random number table was produced with the Random Integer Generator procedure (https://www.random.org/). It generated 100 random integers. Afterward, numbered index cards with random assignments were organized and located in envelopes. These children were grouped into two groups by the investigator who opened the envelopes to attribute the interventions: Group 1, the VR (Wii) group (n=10; 8 males, 2 females; mean age: 13.0±3.3 years; range: 5 to 18 years), and Group 2, the personalized Neurodevelopmental Treatment Approach-Bobath (NDT-B) group (n=10; 8 males, 2 females; mean age: 9.3±3.9 years; range: 5 to 18 years). The NDT-B treatment model and Nintendo Wii Fit

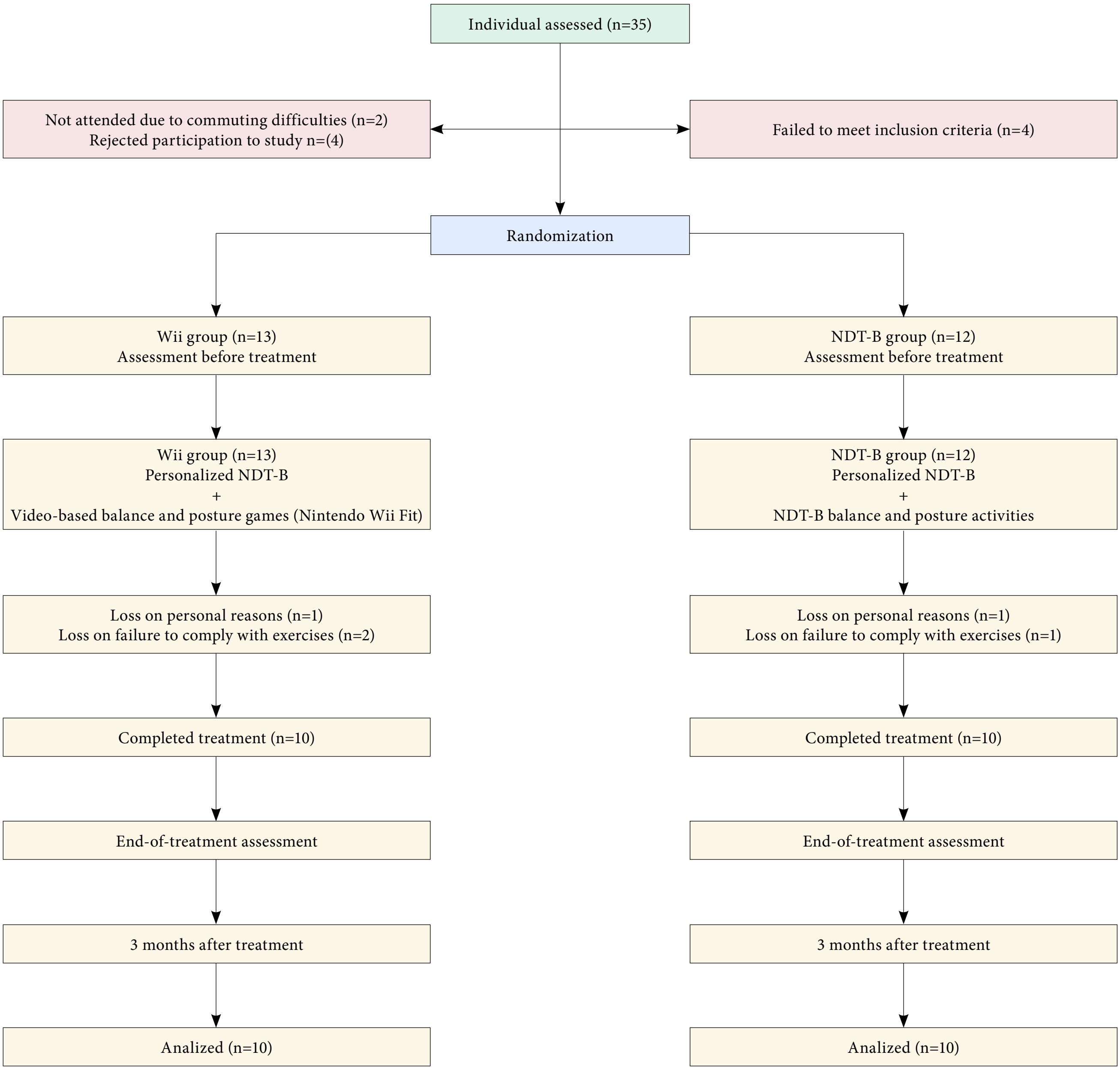

Figure 1. Study flowchart.

NDT-B: Neurodevelopmental treatment approach-bobath.

(Nintendo, Kyoto, Japan) video-based balance games were applied to the Wii group (n=10). The personalized NDT-B treatment model and personalized posture and balance activities were applied to the NDT-B group (n=10). The same researcher performed and recorded a clinical assessment before treatment, after treatment, and three months after treatment. The study flowchart is shown in Figure 1. Each group received interventions and evaluation from the same nonblinded physiotherapist.

The GMFCS is a five-level classification system developed by Palisano et al.[18] and was used to classify the gross motor functions of individuals with CP. The basic objective in the GMFCS is being able to classify the current performance of the individual in daily life, rather than the activities that they can perform the best. Interlevel differences are determined based on the need for functional limitations, wheeled mobility devices, or hand-held assistive tools (walking stick, crutches, or walkers) and, to a lesser extent, the quality of the mobility. General titles of the levels consist of five levels: *(i)* walks without restrictions; *(ii)* walks with restrictions; *(iii)* walks using hand-held mobility devices; *(iv)* self-movement is limited and can use motorized mobility vehicles; *(v)* carried in a wheelchair pushed by hand.[18]

The FMS was used to evaluate walking performance that affects functionality. It is a reliable tool that can be used to assess mobility in children with CP.[19] The FMS assesses the mobility of individuals at six levels: Level 6, can move independently on all surfaces and crowded environments without the need for any walking aid; Level 5, does not need the support of a device or someone else for walking independently on level surfaces but may require banister support on stairs; Level 4, mobile with one or two canes without help from someone else; Level 3, mobile with crutches without help from someone else; Level 2, mobile with walkers without help from someone else; Level 1, uses a wheelchair for mobility or can take a few steps with support from someone else.

The Tandem Stance Test was used to measure the ability to stay in balance by joining the heel of one limb and the toe of the other limb over a straight line on a level surface. The time between the initiation of balance and the moment at which balance was impaired was recorded.[20]

The timed up and go (TUG) is a dynamic test, which includes standing up from a standard chair, walking 3 m at a normal walking pace, as well as turning back and sitting on the chair.[21] The individual was shown a trial walk, and then three real tests were performed, with the average duration recorded in seconds.

During the sit-to-stand test (STST), individuals were asked to sit upright with their feet soles in full contact with the ground and feet open at shoulder level, and to cross their arms in front, on the chest, with their hands touching their opposite shoulders. They were asked to stand upright and sit again without changing the arm position. They were demonstrated how to perform the test and allowed to self-experiment. The number of full stand-ups for 30 sec constituted the individual's score. The measurement was repeated three times, and the average of the three measurements was recorded.[22]

The stair climb test (SCT) was used to evaluate the individual's stair climbing activity, lower limb strength, and dynamic balance. The individuals were asked to climb up and down the nine-step stairs as fast as possible. The time to complete the test was measured with a stopwatch in seconds. The measurement was repeated three times, and the average of the three measurements was recorded.[23]

During the 10-m walk test (10MWT), the individuals were asked to walk at maximum pace in a 10-m corridor. The time to complete the distance was measured in seconds with a stopwatch. The measurement was repeated three times, and the average duration of the three measurements was recorded.[24]

The Berg Balance Scale was used to measure the balance ability of individuals during functional activity including from sitting to standing, placing feet in tandem position, standing on one leg, placing feet together with and without support, and the ability of positional changes. The scale consists of 14 questions with scores ranging from 0 to 4, with 0 indicating being unable to perform the task, and 4 indicating being able to perform the task independently. The maximum possible score is 56.[25]

During the single-leg stance test, individuals were asked to stand on a lower limb independently, and the time they could stand was recorded with a stopwatch.[26] Measurements were made for the right and left lower extremities. Those who could stand for ≥10 sec were considered to have unimpaired balance.

A room was arranged for Nintendo Wii Fit gaming applications. The Nintendo Wii game console and equipment were installed in a fixed place and connected to a fixed television screen. The information of the individual was recorded on the device. The individuals were instructed how to stand on the Wii Fit Balance Board and how to place their foot. They were asked to stand on the balance board without moving and the assessment of the ratio of weight applied on the right and left foot was recorded as a percentage (body center of gravity right - body center of gravity left). The games to be used for each individual and their duration were recorded on the device. The game registration form was created and limb weight ratios, games, levels, and times were recorded.

The treatment of participants in both groups was performed two days a week for a total of six weeks. Duration of each session was set to 45 min. Session content and durations by groups were applied as follows. The Wii group underwent NDT-B (20 min) + video-based game exercises applied with Nintendo Wii Fit (25 min). The NDT-B group underwent NDT-B (20 min) + balance and posture activities included by NDT-B (25 min). A personalized NDT-B program was applied to both groups in line with the limitations and requirements determined based on assessments. The general content of the program was as follows: *(i)* tone regulation exercises; *(ii)* stretching exercises for spastic muscles; *(iii)* muscle strengthening exercises; *(iv)* exercises to support sensory-perception-motor development; *(v)* foot sole sensory stimulation with different materials; *(vi)* training for daily life activities such as eating, dressing, and buttoning; *(vii)* exercises to facilitate normal movements.

In addition to the personalized NDT-B activities, video-based gaming exercises implemented with Nintendo® Wii Fit were applied to participants in the Wii group. Games included reactive balance control, tightrope tension, which is known to be associated with weight-bearing and difficulties in starting walking, balance bubbles, ski jumping, and penguin sliding.[27-30] All these games include balance and coordination training and performance-result feedbacks.[31] All games were played six times, and a 5-min break was implemented between different games. The games and their contents are discussed below.

During tightrope tension, the individual attempted to cross across a virtual rope by transferring weight to the right and left lower limbs on the balance platform. The individual was on a virtual cliff, and they could overcome the moving obstacles they encountered by hip-knee flexion. The foot-ground contact had to be maintained, and balanced weight transfer had to be performed. Tightrope tension is a game that enhances postural control and that improves dynamic balance.[32] Individuals' completion/noncompletion status of the game and completion times was recorded.

During balance bubbles, the individual was inside a virtual bubble. The individual attempted to advance on a virtual river by leaning to the right, left, forward, and backward in a straight and accurate manner. They had to proceed on their way without hitting moving and stationary obstacles. The game ended when the individual hit something or when the time was over. Balance bubbles is a game that enhances postural control and that improves dynamic balance.[33] Individuals' completion/noncompletion status of the game and completion times was recorded.

During ski jump, the individual attempted to keep the center of gravity on the midline in the mini-squat position on the balance platform, accelerated, and jumped from a hill. The transition from the mini-squat position to the full extension of the knees had to be smooth and clear, so that the jump could be done quickly and to a further point. To avoid misbalancing the virtual character after jumping, the individual had to maintain a proper posture during the time spent in the air. Individuals' completion/noncompletion status of the game and jumping distances were recorded.

During penguin slide, the individual attempted to catch the moving fish on a virtual iceberg by sliding their body left and right on the balance platform. Penguin slide is a game that improves the individual's postural control and weight transfer. The number of fish caught when the time was over gave the score.

In addition to the personalized NDT-B activities, participants in the NGT-B group were applied balance and posture activities included by the NDT-B in line with the individual's limitations and needs. Activities and contents were as follows. For an improved body control, balance training on a trampoline (single-leg jumps, double-leg jumps, functional reach, ball throwing and catching exercises, and performing activities with eyes open and closed) was performed. Furthermore, exercises on the balance board (standard type, prickly, air pressurized balance apparatus chosen based on the current condition of the individual with eyes open and closed) were performed. For an improved postural control and balance, exercises on the mat (crawling and activities on knees, unilateral/bilateral/reciprocal resistant and non-resistant activities), weight transfer exercises (mini-squat, stair-step exercises), training on exercise balls, training for walking in various ways (step-taking, tandem walking, sideways walking, forward and backward walking, walking on different grounds and by narrowing the support surface), and balance exercises against the mirror were performed.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 20.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were presented as mean ± standard deviation (SD), median (min-max), or number and percentage. Based on 90% power and %5 error margin considering the change difference in the Berg Balance Scale scores between the groups, at least eight participants in each group were required.[34] The Friedman test was used to compare the first, second, and third measurements of single-leg stance test, tandem stance test, TUG, STST, 10MWT, SCT, and Nintendo Wii Fit parameter values. The Wilcoxon signed-rank test was used to compare game scores of dependent groups. The Mann-Whitney U test was used to compare the significant differences between the groups. The chi-square test was performed to compare categorical variables of GMFCS, FMS, and Berg Balance Scale. A p-value <0.05 was considered statistically significant.

RESULTS

Baseline demographic and clinical characteristics of the participants are shown in Table 1. The comparison of the patients' single-leg stance test and tandem stance test times before (p=0.06) and after (p=0.06) treatment and at three months (p=0.06) is shown in Table 2. There was no statistically significant difference between the groups. In

TABLE 1
Baseline demographic and clinical characteristics of patients

	Wii group (n=10)			NDT-B group (n=10)			
	n	%	Mean±SD	n	%	Mean±SD	*p*
Age (year)			13.0±3.3			9.3±3.9	0.043
Sex							
Female	2			2			
Male	8			8			
Body mass index (kg/m²)			21.84±4.03			19.76±3.94	0.226
CP type							1.000
Hemiplegic	4	40		4	40		
Diplegic	4	40		4	40		
Ataxic	2	20		2	20		
GMFCS							0.302
Level 1	9			6			
Level 2	1			4			
FMS							1.000
Level 5	5			6			
Level 6	5			4			
Berg balance test							
BT							0.456
Score 21-40	0			2			
Score 41-56	10			8			
AT							0.456
Score 21-40	0			2			
Score 41-56	10			8			
3 months AT							0.456
Score 21-40	0			2			
Score 41-56	10			8			

NDT-B: Neurodevelopmental treatment approach-bobath; SD: Standard deviation; CP: Cerebral palsy; GMFCS: Gross motor function classification system; FMS: Functional mobility scale; BT: Before treatment; AT: After treatment.

TABLE 2
The comparison of single-leg stance test and tandem stance test times before and after treatment and at three months and change between groups

		BT	AT	3 months AT		BT-AT	BT-3 months AT	AT-3 months AT	
		Mean±SD	Mean±SD	Mean±SD	*p*	Mean±SD	Mean±SD	Mean±SD	*p*
Single-leg balance	Right (sec)								
	Wii	20.7±17.7	31.6±33.1	29.9±31.1	0.06* 0.06** 0.06***	10.9±19.9	9.2±18.3	1.7±2.8	0.64* 0.9** 0.58***
	NDT-B	16.1±18.6	19.2±20.1	18.8±20	**0.001*** **0.007**** **0.50*****	3.1±2.4	2.7±1.7	0.4±1.17	
	Left (sec)								
	Wii	11.6±12.7	12.9±12.6	12.4±12.7	**0.01*** 0.18** 0.31***	0.5±0.7	0.8±1.2	0.5±0.7	0.65* 0.07** 0.65***
	NDT-B	9±12.1	14.7±12.8	14.2±21.2	**0.01*** **0.01**** 0.91***	0.5±2.7	5.2±11.5	0.5±2.7	
Tandem stance time	Right (sec)								
	Wii	15.8±14.1	21.9±19.5	21.7±20.4	**0.002*** **0.01**** 0.57***	0.2±1.7	5.9±9.9	0.2±1.75	0.26* 0.54** 0.26***
	NDT-B	12.9±12.2	17.9±15.2	16.6±15.8	**0.01*** 0.31** 0.18***	1.3±2.5	3.7±6.9	1.3±2.5	
	Left (sec)								
	Wii	26.9±20.3	31.8±28.2	32±27.4	0.41* 0.41** 0.41***	0.2±2.6	5.1±11.1	0.2±2.6	0.39* 0.96** 0.39***
	NDT-B	13.3±14.2	15.7±18.1	17.1±19.6	0.14* 0.14** 0.14***	1.4±2.2	3.8±7.8	1.4±2.2	

BT: Before treatment; AT: After treatment; SD: Standard deviation; NDT-B: Neurodevelopmental treatment approach-bobath; * BT-AT; ** BT-3 months AT; *** AT-3 months AT, Related-samples friedman's two-way analysis of variance by ranks.

addition, there was no statistically significant difference in the intra- and intergroup comparisons of Berg Balance Scale score before and after treatment and three months after treatment (p=0.456; Table 1).

Comparison of participants' TUG, STST, 10MWT, SCT scores, and Nintendo Wii Fit values before, after treatment, and at three months is shown in Table 3. The TUG and STST scores of the Wii group changed statistically significantly at three months after treatment compared to pretreatment values (p=0.01, p=0.02 and p<0.001, respectively). However, there was no statistically significant change in the functional test scores of the groups between after treatment and at three months (p=0.82). In-group changes of the right foot and left foot weight transfers of the groups before treatment and after treatment were not found statistically significant (p=0.27 and p=0.27 for the Wii group; p=0.11 and p=0.11 for the NDT-B group). Right foot and left foot weight transfer ratios of the NDT-B group before treatment and at three months showed a statistically significant increase (p=0.01 and p=0.01, respectively). However, in-group changes of right foot and left foot weight transfers of the groups after treatment and at three months was not statistically significant (p=0.37 and p=0.37, respectively).

Furthermore, there was a significant difference in the STST scores before and after treatment between the groups in favor of the Wii group (p=0.05). In addition, there was a significant difference in the in-group STST changes before treatment and at three months after treatment in favor of the Wii group (p=0.02).

TABLE 3
Comparison of functional test values and Nintendo Wii Fit parameter values BT, AT, and at three months after treatment by groups

		BT	AT	3 months AT	
		Mean±SD	Mean±SD	Mean±SD	*p*
Functional tests	TUG (sec)				
	Wii group	8.30±2.30	7.40±1.77	7.50±1.95	**0.01*** **0.02**** 0.82***
	NDT-B group	8.80±2.40	8.20±2.30	7.90±2.23	0.11* 0.11** 0.11***
	STST				
	Wii group	12.40±2.50	15.10±1.97	15.30±2.26	**0.001*** **0.001**** 0.82***
	NDT-B group	12.40±4.90	13.50±4.14	13.20±5.49	0.72* 0.72** 0.72***
	10MWT (sec)				
	Wii group	8.50±1.70	8±1.63	8.20±1.81	0.26* 0.26** 0.26***
	NDT-B group	8.70±2	8.20±1.61	8±1.49	0.16* 0.16** 0.16***
	Stair climb test (sec)				
	Wii group	8.10±1.90	7.50±2.95	7.70±1.76	0.15* 0.15** 0.15***
	NDT-B group	19.80±13.40	15.90±8.76	17.50±10.77	0.05* 0.05** 0.05***
Nintendo® Wii Fit parameter values	BCG R				
	Wii group	48.9±9.5	47.6±5.6	45.7±7.6	0.27* 0.27** 0.27***
	NDT-B group	43.6±12.3	47.2±8.9	47.5±8.9	0.11* **0.01**** 0.37***
	BCG L				
	Wii group	50.9±9.5	52.3±5.6	54.2±7.6	0.27* 0.27** 0.27***
	NDT-B group	56.3±12.3	52.7±8.9	52.4±8.9	0.11* **0.01**** 0.37***

BT: Before treatment; AT: After treatment; SD: Standard deviation; TUG: Timed up and go test; NDT-B: Neurodevelopmental treatment approach-bobath; STST: Sit-to-stand test; 10Mwt: 10-meter walk test; BCG R: Body center of gravity right; BCG L: Body center of gravity left; * BT-AT; ** BT-3 months AT; *** AT-3 months AT, Related-samples friedman's two-way analysis of variance by ranks.

TABLE 4
Comparison of Nintendo Wii Fit game values BT, DT, AT, and in-session

		BT	DT	AT	
		Mean±SD	Mean±SD	Mean±SD	*p*
Tightrope tension	All session	15.2±11.4	27.7±8.2	32.4±10.8	0.002* 0.001** 0.911***
	Last 3 games of session	17.1±13.6	26.9±8.65	31.2±8.7	0.74* 0.004** 0.264***
Balance bubbles	All session	349±200.1	476.3±480.9	607.8±414.8	0.074* 0.074** 0.074***
	Last 3 games of session	424.2±271.6	486±436.7	622.3±414.1	0.074* 0.074** 0.074***
Ski jump	All session	32.6±24.9	36.6±20.8	43±22.6	0.118* 0.014** 0.371***
	Last 3 games of session	34.1±21.7	37.6±26.2	45.3±23.7	0.179* 0.179** 0.179***
Penguin slide	All session	51.2 ±12.5	67.6±16.9	71.2±14.6	0.058* 0.004** 0.343***
	Last 3 games of session	56.6±10.3	73.2±14.2	75.2±12.6	0.058* 0.004** 0.343***

BT: Before treatment; DT: During treatment; AT: After treatment; SD: Standard deviation; * BT-DT; ** BT-AT; *** DT-AT.

Comparison of the patients' Nintendo Wii Fit game values before treatment, during treatment, after treatment, and in-session is shown in Table 4. There was a statistically significant change in the tightrope tension and penguin slide game scores during the treatment compared to before treatment ($p=0.002$, $p<0.001$, and $p=0.058$, $p=0.004$, respectively). A statistically significant change was obtained in tightrope tension, ski jump, and penguin slide game scores after treatment compared to before treatment ($p<0.001$, $p=0.014$, and $p=0.004$, respectively). A statistically significant change was also found between the means of all sessions and the last three games before treatment upon review of the comparison of the participants' Nintendo Wii Fit penguin slide game values before treatment, during treatment, and after treatment, as well as change during the session ($p=0.058$ and $p=0.004$, respectively). A significant improvement was obtained in tightrope tension game score during treatment and after treatment ($p=0.002$ and $p<0.001$, respectively). No significant difference was observed between the means of all game scores and the last three games scores in the sessions ($p=0.911$, $p=0.264$ for tightrope tension; $p=0.074$, $p=0.074$ for balance bubbles; $p=0.371$, $p=0.179$ for ski jump; $p=0.343$, $p=0.343$ for penguin slide).

DISCUSSION

The results showed that static balance developed in both groups, with the effect continuing after three months in the NDT-B group. In the Nintendo Wii Fit group, significant improvements were attained in functional activities, which continued following three months after treatment, and a significant increase was obtained in the game scores for end-of-treatment balance, weight transfer, and walking speed. Although there are studies reporting the posttreatment effects of VR in the literature, long-term effects have not been fully examined. Therefore, we believe that the current study contributes to the existing literature by evaluating the effective duration of the application.

However, evidence-based, implementable motor rehabilitation guidelines for individuals with CP have suggested VR therapy and interactive computer play as moderate-importance interventions. The recommendations for VR are graded as B (conditionally recommended) due to scientific presumptions and Level 2 evidence from small randomized controlled trials, well-conducted nonrandomized controlled trials, and cohort studies.[8]

There is variation in the literature regarding the VR games that are best for rehabilitation purposes.[17,29,35-38] The selection of game interventions should be based on a thorough evaluation of motor disorders, the topography of the CP, gross motor skills, and an individual's age, expectations, and preferences. It is necessary to conduct longer follow-up studies to showcase the lasting impacts of rehabilitation practices based on the Wii platform.[8]

It is known that Nintendo Wii games training using the Wii balance platform increases the static standing balance in individuals with CP.[29,39] Tarakçı et al.[38] conducted a randomized-controlled study including mildly-affected 30 individuals with CP and reported that concurrent application of Wii balance games and NDT-B improved static and performance based balance. In another study, Gatica-Rojas et al.[35] reported that, in a series of four CP cases, functional balance was improved with six weeks of Nintendo Wii games training, while no improvement was observed in the static balance. In a randomized-controlled study including 32 individuals with CP by Gatica-Rojas et al.,[29] the Nintendo Wii games training improved standing balance in patients with CP better than standard physiotherapy, although its effect decreased after two to four weeks.

Furthermore, Brien and Sveistrup[40] reported in their study with four ambulatory CP patients that VR training developed functional balance similar to the current study results, and that this change was sustained after one month. The current study found that this gain was maintained after three months. Comparing traditional physiotherapy and Nintendo Wii games training in children with CP, Tarakçı et al.[38] also reported that both groups had shortened TUG time and increased STST scores after treatment and that this change was significant in the Wii group. Likewise, significant improvements were obtained in the current study in the Wii group, and these improvements were sustained after three months. Gatica-Rojas et al.[35] reported in their study that there was a significant shortening in TUG time after applying the Nintendo Wii games training in individuals with CP. The authors concluded that TUG was a dynamic test with similar aspects to games, and therefore, it could demonstrate more improvement compared to static balance tests.

In the current study, an improvement was detected in the walking speed and SCT time of the participants, although the changes were not significant in both groups. Tarakçı et al.[38] found an improvement in the Wii group and conventional therapy group in 10MWT and SCT time, and the improvement in the Wii group was significant. Gorter et al.[41] also reported that, in individuals with ambulatory CP, step climbing improved after functional training, and this development was maintained 11 weeks after treatment. On the other hand, the SCT time did not improve significantly with the application of VR approach, and some cases worsened.[17,40] Jelsma et al.[17] showed that the SCT times obtained two months after VR treatment were better than at the end of treatment, which was explained by the fact that the task-specific training was lacking in the VR approach, and conventional therapy was discontinued during treatment. Therefore, factors such as participants' adherence to intervention protocols and engagement during VR sessions may have significantly influenced the outcomes. In parallel with the study underlining that the therapy providers noted that children with CP showed great enthusiasm and motivation towards playing Wii games, the therapist noted significant interest in playing among the children who received the intervention in the current study.[9]

Clinical reasoning is recommended in the selection of VR games in the rehabilitation of individuals with CP. However, there is no consensus on the choice of games for rehabilitation purposes.[29,35] In the current study, games included reactive balance control, tightrope tension, which is known to be associated with weight-bearing and difficulties in starting walking, balance bubbles, ski jumping, and penguin sliding. A significant increase was observed in all game scores after treatment, except for balance bubbles. Kliem and Wiemeyer[36] also found no significant increase in the balance bubbles game scores.

Similar to the current study, a significant improvement in the game scores of the Wii group at the end of the treatment were reported in previous studies.[17,36-38] Kliem and Wiemeyer[36] defined this development as the therapeutic effect of games. Both exercise and repetitive learning could have been effective on this improvement. Hanneton and Varenne[37] reported that the change in Wii game scores in sessions was significant. However, it is necessary to evaluate game scores before and after treatment to understand whether this change is related to individuals developing cognitive strategies. In the current study, all game scores of the Nintendo Wii group before, during, and after treatment were recorded. Significant improvements were achieved in the tightrope tension balance game scores during and after treatment. No significant difference was found between all game scores in the sessions and the average of the last three games. This finding supports the view that motor recovery is dominant rather than the effect of learning on the developing game scores.

Virtual reality approach, which is expressed as a promising intervention for individuals with CP, is still controversial due to studies with a limited number of participants and insufficient randomized-controlled studies.[11] In terms of applicability, Nintendo Wii games training are a cost-effective, reliable, and easy-to-generalize treatment method for rehabilitation applications (at hospital or at home).[12,29] However, according to the classical physiotherapy method, Nintendo Wii game training is reported to be advantageous in terms of children's participation level, motivation, and satisfaction.[42] Nevertheless, based on the current literature, it is recommended to be used as an additional and complementary method to conventional therapy.[9,17] In parallel with this recommendation, NDT-B, which is one of the conventional approaches, was applied to both groups in the current study.

Based on current research, the clinical implications of the findings suggest that playing Wii games may be a fun and effective way to improve balance, weight distribution, and walking speed in children with CP. These games offer a chance for children to actively engage and control their bodies in a specific activity, which can help them with everyday tasks. In addition, VR technology may be utilized for telerehabilitation in the comfort of one's home during the pandemic. When conducting future research on using Wii for rehabilitation, it is advised to analyze how characteristics of Wii games, such as game difficulty, immersion type, and scenario, impact rehabilitation outcomes. It is also crucial to utilize suitable imaging methods to assess the neuroplastic changes that occur due to rehabilitation with these games. This approach will enable the detection of changes brought about by virtual games and their association with their unique features.

The limitation of the current study was that the clinical types of CP in groups were different and not distributed in a balanced way. However, the number of individuals with CP who have the mobility and cognitive levels necessary to benefit from VR therapy is relatively low. Another limitation of the current study was the fact that we could not perform clinical assessment tests during the treatment week. Therefore, we could not compare the changes in the game scores and clinical tests during treatment. Similarly, long-term follow-ups at narrow intervals with higher frequency will provide clearer information on how long the treatment effectiveness lasts. It is important to note that the study conducted on individuals with CP had a relatively small sample size, with a post hoc analysis indicating a statistical power of 32%. Therefore, the findings may not be entirely indicative of the entire CP population.

In conclusion, the results suggest that the use of VR methods in addition to the neurodevelopmental treatment program in the rehabilitation of individuals with CP may provide sustainable long-term benefits. However, further large-scale, long-term, prospective, randomized-controlled studies are needed to confirm these findings.

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

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