IMPACT OF VIRTUAL REALITY TRAINING ON BALANCEIN SPASTIC HEMIPLEGIC CEREBRAL PALSIED CHILDREN

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Abstract

Background: The large majorities of children with cerebral palsy (CP) demonstrate poor balance, that leads to poor gait and reaching movements as the maintenance of stability is critical to all movements. There are various approaches and strategies to improve balance; virtual reality is one of them. Therefore, this study aimed to evaluate the effects of virtual reality training on balance in spastic hemiplegic cerebral palsied children.

Methods: Thirty children who fulfilled the inclusion criteria were randomly allocated into two groups (control and study).Participants in both groups received a selected therapeutic exercise program. The study group additionally received balance training on Nintendo Wii device. Total treatment provided for both groups was 90 min/day, 3 days/week for 4 successive months.Baseline and post-treatment assessment for overall, anteroposterior, andmediolateral stability indices were evaluated by using Biodex balance system.

Results: Children in both groups showed significant improvements in post-treatment mean values of all measured variables when compared to the pre-treatment mean values ($p<0.05$). Significant improvement was observed in favor of the study group when post treatment values of both groups were compared ($p< 0.05$).

Conclusion: Balance training on Nintendo Wii device is a useful tool that can be used in improving balance in children with hemiplegic cerebral palsy.

Keywords: Cerebral palsy, Balance, Virtual Reality.

Introduction

Cerebral palsy (CP) describes a group of motor disorders resulting from prenatal or perinatal damage to brain**[1]** and occursin 2–2.5 per 1000 live births **[2]**. About 33% ofchildren with CP have hemiplegia **[3]**.

Spastic hemiplegia is a form of CP that affects one side of the body. Those children may have combinations of weakness, sensory loss, spasticity and asymmetry between the paretic and the non-paretic sides, with decrease in muscle volume in the paretic side and significant leg length discrepancy**[4]**.

Balance is important for all functional activities**[5].**Hemiplegic cerebral palsied children have poor balance as a result of impaired development of their neural motor control mechanisms combined with secondary musculoskeletal abnormalities such as muscle spasticity, muscle weakness, low proprioception and bone deformations**[6].**

Lack ofpatient motivation is one of the most common reported reasons for patient withdrawal from treatment program **[7]**.Researchers found that integration of rehabilitation program and exercises into video game interfaces has a great role in improving patient compliance to planned exercises and prevent patients demotivation **[8-9].** Commercial video games such as Nintendo Wii Fithave been used as a supplementary treatment for CP children with promising results on balance and motivation **[10].**

The aim of the present study is to find out the effect of virtual reality training on balance inchildren with hemiplegic cerebral palsy.

Materials andprocedures

***Study design*:** Randomized clinical trial.

Participants:For this study, 45 children were identified as potentialparticipants (Figure 1), six participants were excluded because they failed to fulfill the inclusion criteria and three parents refused to participate in the study. therefore, 36 children with hemiplegic CP were included in the study, 18 children in each group. For control group, 3 children didn't continue treatment program

to the final assessment, while for the study group; 2 children didn't continue due to difficulties with Wii usageand one child withdrew as a result of referral for surgery. So 15 children in each group participated in post treatment assessment.

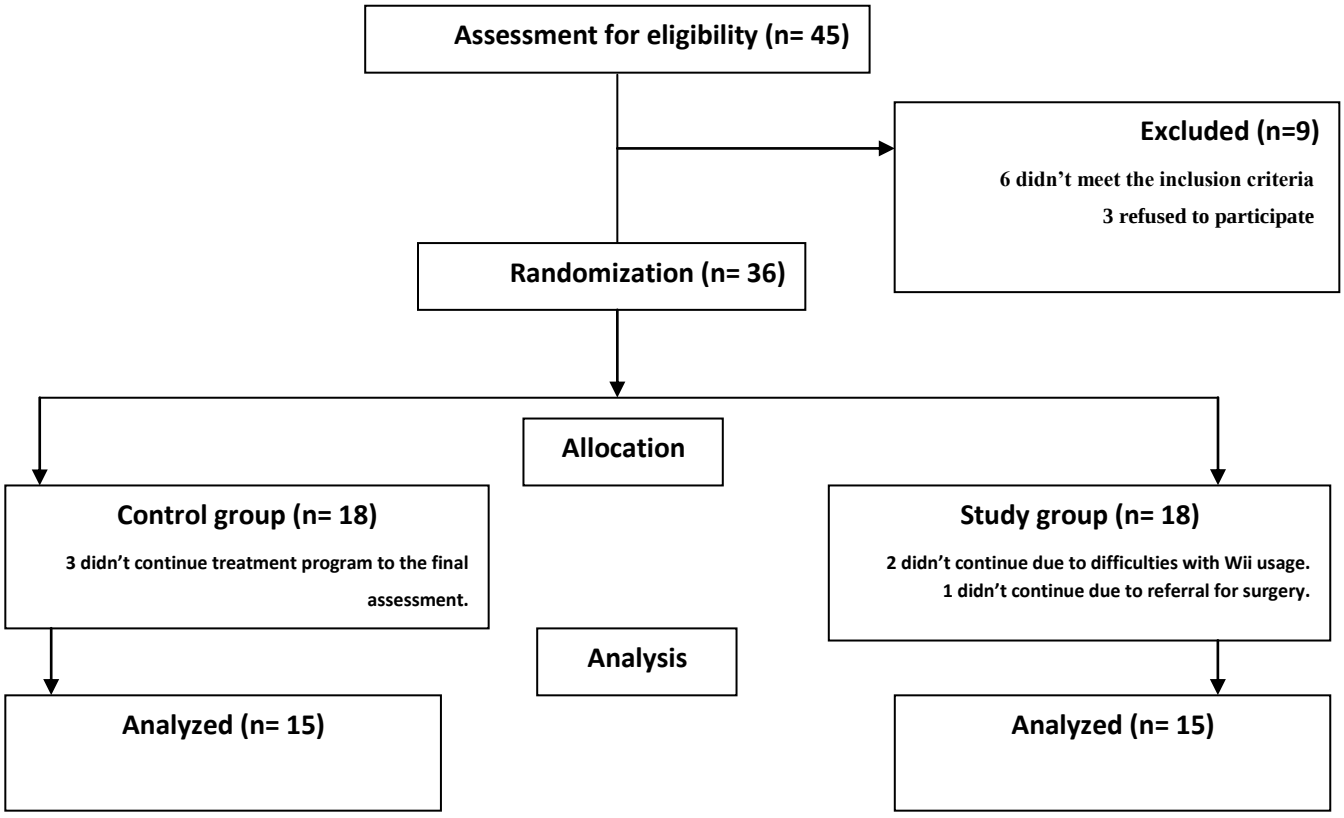

Figure 1. Study flow chart

This study included 30 children from both sexes. They were selected from the out-patient clinic of the Faculty of Physical Therapy, Delta University for Science and Technology and pediatric rehabilitation centers in Al-Mansoura and Damietta. They were initially screened and assessed to determine eligibility of participation in the study. The inclusion criteria were as follows: (1) a diagnosis of spastic hemiplegic cerebral palsy. (2) The age ranged from 5 to 8 years. (3) The degree of spasticity in involved lower extremity according to Modified Ashworth Scale ranged between grade 1 and 1+**[11].**(4) The levels of gross motor function were between level I and II

according to Growth Motor Functional Classification System (GMFCS) for all children **[12]**. (5) Children were able to understand and follow instructions. (6) There were no serious or recurring medical complications.

The exclusion criteria were as follows: (1) any orthopedic conditions or fixed deformities that interfere with balance. (2) Children with visual, auditory, vestibular or perceptual deficits.(3) children with seizures or epilepsy.(4) Children who received Botulinum toxin injections or other spasticity medications. (5) Surgical interventions for the lower extremity musculature during the period of the study.

Materials

1-Modified Ashworth scale was used to measure degree of spasticity **[11].**

2-GMFCS: It was developed to classify severity of functional limitation/disability in children with CP**[12].**

3-Biodex Balance System SD (BBS; Biodex Inc., Shirley, NY) is a valid and reliable balance assessment tool**[13]**. It consists of support handle, platform, display andprinter. It has a static mode and 12 levels of dynamic platform tilt(12 is the most stable and 1 is the least stable). This balance system was used for assessment of the change in reactive postural balance control for the participated children from standing position pre and post-training.

4-Height and weight scale (SH-8024)was used to measure children' heights and weights.

Measurement procedures:

The participants (in both groups) underwent baseline and post-treatment assessments (at the end of four month training period) using the Biodex balance system which was performed at stability levels 8 based on pilot study included 15 children who participated at this study.

At the first, certain parameters were fed to the device including: child's weight, height, age and stability level (platform firmness).Children whose weights were less than 20 kg and length less than 100 cm were excluded.

Each child in both groups was asked to stand on the center of the locked platform within the device with the two legs stance while grasping the handrails. The display screen was adjusted, so he could look straight at it. Then each child was asked to achieve a centered position in a slightly unstable platform by shifting his feet position until it was easy to keep the cursor (representing the center of the platform) centered on the screen grid while standing in comfortable upright position. Once the child was centered, the cursor was in the center of the display target, he was asked to maintain his feet position till stabilizing the platform.

The test began after introducing feet angles and heel coordinates into the Biodex System. The platform advanced to an unstable state, then the child was instructed to focus on the visually feedback screen directly in front of him while both arms at the side of the body without grasping handrails and attempted to maintain the cursor in the middle of the bulls eye on the screen. Duration of the test was 30 s (sec.) for each child and the mean of the three repetitions was determined. The result was displayed on the screen at the end of each test.

Treatment procedures:

Children in both groups received a selected physical therapy program;the control group received that program for 90 min, while the study group received it only for 60 min in addition to thirty minutesofwii fit plus training. Selected physical therapy program was conducted for three days a week on non-consecutive days which include the following items with clear instructions to the children.

(1) Standing with feet together while the therapist sitting behind and manually locking the child knees, and then slowly tilt him to each side, forward and backward.

(2) Step standing with therapist behind the child guiding him to shift his weight forward then backward alternately.

(3) High step standing and try to keep balanced.

(4) Standing with manual locking of the knees then tries actively to stoop and recover.

(5) Equilibrium, righting and protective reactions training.

(6) Closed environment gait training in the form of forward, backward, and sideways walking between the parallel bars. Obstacles including rolls and wedges with different diameters and heights were put inside parallel bars.

(7) Open environment gait training was conducted with obstacles but without parallel bars.

(8) Strengthening exercises for extensors muscles of the back, hip, knee.

(9) Stretching exercises for tight muscles; hip flexors, hamstrings and calf muscles in lower limb and for wrist flexors, pronators and elbow flexors in upper limb**.[14]**

Children in study group received the previous physical therapy program, in addition to virtual reality training using Wii device, for 30 min.The total treatment timewas 90 minfor3 sessions / week.

The following virtual games were used:

(1) Basic Step: the childwas asked to step on and off the Wii Balance Board in response to the on-screen steps.

(2) Soccer Heading: the child tried to head soccer balls by tilting into the path of it.

(3) Obstacle Course: The child was asked to step run through a course and dodges the obstacles.

(4) Tight Rope Walk: The child walked in place to cross the tightrope. Bent and straighten his knees to jump, and instructed to be careful not to fall or be out

(5) Basic Run: The child put the Wii Remote in his/her pocket and run in place, with a trainer in front of him/her, to be followed. The trainers are either a Mii or a dog.

(6) Ski jump: the child jumped off of a Wii balance board and kept balance when return on it. Each session, the previous gameswereperformed for 5 min / game.

Data analysis

The statistical analysis was conducted by using statistical SPSS package program version 25 for Windows (SPSS, Inc., Chicago, IL).Data was not normally distributed by using Shapiro-Wilk test (non-parametric data). Additionally, testing for the homogeneity of variance revealed that there was significant difference ($P<0.05$).Descriptive statistics included the mean and standard deviation for thedemographic data (age, weight, and height), overall stability index, anteroposterior stability index, and mediolateral stability index.Wilcoxon test was used to comparepre- and post-treatment mean values within each group forquantitative variables. Mann-Whitney test was used to compare quantitative variables of both study group and control group. Chi-square test was used to compare qualitative variables for both groups. All statistical analyses were significant at ($P \leq 0.05$).

Results

The statistical analysis revealed that no significant differences ($P>0.05$) in demographic data(age, weight and height) between study and control groups as presented in table (1).

Table 1: Demographic data in study and control groups.

Items		Study group	Control group	P-value	Significance
Age (years)		6.24 ±0.72	6.27 ±0.72	0.603	NS
Weight (kg)		25.17 ±3.38	24.60 ±2.95	0.427	NS
Height (cm)		124.00 ±4.61	123.00 ±4.30	0.901	NS
Gender	Boys	7 (46.67%)	6 (40.00%)	0.713	NS
	Girls	8 (53.33%)	9 (60.00%)		

SD: standard deviation %: percentage P-value: probability value NS: non-significant.

The statistical analysis revealed that there was no significant differences (P>0.05) in pre-treatment of overall stability index, anteroposterior stability index, and mediolateral stability index between study group and controlgroup while there was significant differences (P=0.001; P<0.05) between pre- and post-treatment of overall stability index, anteroposterior stability index, and mediolateral stability index within each group as presented in table (2).

Table 2: Comparison of Overall stability ,anteroposterior stability, and mediolateral stability indicesfor control and studygroups.

Items		**Groups**			
		Study (Mean ± SD)	**Control (Mean ± SD)**	**P-value**	**Significance**
Overall stability index	Pre-treatment	2.32 ±0.12	2.31 ±0.09	0.663	NS
	Post-treatment	1.14 ±0.07	1.59 ±0.11	0.0001	S
	Improvement %	50.86%	31.17%		
	P-value	0.001	0.001		
	Significance	S	S		
Antero posterior stability index	Pre-treatment	2.37 ±0.09	2.41 ±0.08	0.481	NS
	Post-treatment	1.27 ±0.08	1.89 ±0.26	0.0001	S
	Improvement %	46.41%	21.58%		
	P-value	0.001	0.001		
	Significance	S	S		
Medio lateral	Pre-treatment	2.87 ±0.07	2.94 ±0.36	0.418	NS
	Post-treatment	1.35 ±0.21	2.34 ±0.20	0.0001	S
	Improvement %	52.96%	20.41%		

P-value	0.001	0.001
Significance	S	S

SD: standard deviation% percentage P-value: probability S: significant NS: non-significant

Discussion

The present study aims to examine the effect of virtual reality training using Wii Fit Plus training on balance in children with spastic hemiplegic cerebral palsy. The results showed improvement in overall stability, anteroposterior and mediolateral indices for both groups. However, children in the study group had higher improvement in stability indices values compared with the control group.

The post treatment mean values showed improvement in balance in all children. The reported improvement in balance in children of study group could be attributed to the sensory feedback provided by virtual reality interface devices which is provided by the multi-sensory environments generated during Wii training. VR therapy trains the balance in a sequence of exercises and games that requires children to demonstrate continuous weight shifting between feet and from the heel to toes, producing a sufficient mechanical stimulation to trigger the proprioceptors at this level.

Addition of a game-like task into balance training program resulted in larger centre of pressure excursions than seen in a real world reaching situations. It was found that subjects were more motivated to reach further in response to game-like exercising. Virtual reality games encourage children to perform more complex activities, generating kinaesthetic movements, as the proprioceptors in the extremities and the trunk are activated **[15]**.This information ascends to the CNS and descends to spinal cord, performing postural adjustments necessary to keep balance **[16]**.

Most of the games utilized in this study challenge medial-lateral and anterior-posterior balance by eliciting weight shifting strategies in order to move interactive elements **[17,18].** This leads to the shifting of body weight on the foot and lower limbs, producing sufficient mechanical

stimulation to excite the proprioceptors at this level. Furthermore, an advantage of the Nintendo Wii system is the visual feedback that the participants receive during each session. Visual feedback has been postulated to improve balance in participants, as the video game creates the perception that they can perform more complex activities **[19].**

It has been suggested that spastic hemiplegic CP are better able to use proprioceptive and somatosensory information arising from the unaffected limb which may have been enhanced (sensory up-weighting) by the Wii-therapy**[20]**.

Results of the study group come in agreement with the findings of Jelsma et al.,**[10]**who reported an improvement on balance control in fourteen children with spastic hemiplegic CP after engagement in balance training program for (3weeks) using Nintendo Wii device and this improvement was sustained up to 2 months after cessation. The results also agree with the results of a study of 12 weeks of balance training using the Nintendo Wii games which showed improved balance functions in 14 patients with CP including seven diplegic, five hemiplegic, and two dyskinetic.Despite this study didn't have homogeneous sub-groups of CP children , they found that Wii-based training is more fun and provides motivation, and may bea preferable method of treatment for children with CP **[21].**

Improvement of balance in children enrolled in the study group come in accordance with that of Gatica et al.,**[22]** who compared the effects of a Nintendo Wii balance board intervention with the standard physiotherapy on balance using posturographic measures in 32 children with CP (14 diaplegic and 18 hemiplegic) who received three sessions per week over a period of 6 weeks. Their results revealed that Wii-therapy was better able to improve standing balance than the standard physiotherapy intervention. Significant effects of Wii on balance were found only for the spastic hemiplegic CP group.

Our results also come in agreement with the work of Sajan et al.,**[23]**who conducted a randomized controlled trailtargeting to assess the effect of interactive video gaming (IVG) with Nintendo Wii (Wii) supplemented to conventional therapy in rehabilitation of children with CP. This study included 20 CP children. The researchers found significant improvement in balance which ismore reported in the intervention group than in the control group.

AlSaif et al.,**[24]** investigated the effect of training with Nintendo Wii Fit games on motor performance and balance in forty children with cerebral palsy aged 6–10 years for 12 weeks,theystated that there were significant improvements in motor performance and balance favored Nintendo Wii Fit training group.

The improvement obtained in the post treatment results of the control group may be attributed to the effect of conventional physical therapy program (based on neurodevelopmental basis) which was directed toward facilitating normal patterns of postural control (righting and equilibrium reactions) and developing a greater variety of normal movement patterns particularly in the trunk and lower extremities.

The results of the control group comes in agreement with Ottenbacher et al.,**[25]** who conducted a meta-analysis study on the use of neurodevelopmental treatment (NDT) in cerebral palsy children including 37 reviews, and found that children receiving NDT or combination of NDT and other intervention performed better than 62% of subjects receiving other services.

The post-treatment results improvement of control group also agree with the findings of Dodd et al.,**[26]** who found that exercises and rehabilitation programs increase general physical capacity and functional independence for children with cerebral palsy.

On the other hand Ramstrand and Lygnegård**[27]** conducted a cross-over randomized trial, in which children with CP received a 5-week home-based Nintendo Wii Fit-based IVG program, then crossed-over to a 5-week regimen of conventional therapy. Improvement in balance was tested as

one of the outcomes measures. The results of this study showed thatthere is no significant improvement in balance in children who received IVG based therapy.

Conclusion

The results of this study suggested that using Ninetendo Wii Fit Plus is effective in improving balance in children with spastic hemiplegic cerebral palsy.

Acknowledgements

The authors would like to express their appreciation to all children and their parents who participated in this study with cooperation.

Conflict of interest

The authors had no conflict of interest to declare.

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