

Efficacy of Virtual Reality-Based Therapy on Balance in Children with Down Syndrome

Samia Abdel Rahman Abdel Rahman

Department of Physical Therapy for Disturbances of Growth and Development in Children and its Surgery, Faculty of Physical Therapy, Cairo University, Egypt

Abstract: Virtual reality-based therapy is one of the most innovative and promising recent developments in rehabilitation technology. Virtual reality is the use of interactive simulations created with computer hardware and software to present users with opportunities to engage in environments that appear to be and feel similar to real world objects and events. Wii-Fit is considered as one of the virtual reality-based therapy. Children with Down syndrome have lower scores on balance and agility tasks than do children with other mental impairments. The purpose of this study was to examine the effect of Wii-Fit on balance in children with Down syndrome. Balance was measured by Bruininks-Oseretsky Test of Motor Proficiency for 30 children with Down syndrome. The subjects were randomly divided into two groups of equal size (control and study). They ranged in age from 10 to 13 years old and they were selected from both genders. The control group received the traditional physical therapy program. A program of three Wii-Fit games was conducted for the study group in addition to the traditional physical therapy program. The program for both groups continued for six weeks. The results revealed high significant improvement of balance in the study group ($p=0.000$) when compared with that of the control group indicating that Wii-Fit games as a virtual reality-based therapy could improve balance for children with Down syndrome.

Key words: Virtual reality % Wii-Fit % Balance % Bruininks-Oseretsky Test of Motor Proficiency % Down syndrome

INTRODUCTION

Two major goals of rehabilitation are the enhancement of functional ability and the realization of greater participation in community life. These goals are achieved by intensive intervention to improve sensory, motor and cognitive functions on the one hand and practice in everyday activities and occupations to increase participation on the other hand. Intervention is based primarily on the performance of exercises and/or different types of purposeful activities and occupations [1,2]. For many injuries and disabilities, the rehabilitation process is long and clinicians face the challenge of identifying a variety of meaningful and motivating intervention tasks that may be adapted and graded to facilitate this process [3].

Virtual reality (VR) is a computer technology that simulates real-life learning and allows for

increased intensity of training while providing augmented three-dimensional and direct sensorial feedback. It is a novel technology that allows users to interact with a computer-generated scenario (a virtual world) making corrections while performing a task. There has been limited research involving the inclusion of VR gaming systems in neuro-rehabilitation and there is an identified need for researches to establish the value of VR in the populations with neurological disorders [4].

Virtual reality-based therapy is one of the most innovative and promising recent developments in rehabilitation technology in which users interact with displayed images, move and manipulate virtual objects and perform other actions in a way that attempts to "immerse" them within the simulated environment, thereby engendering a feeling of presence in the virtual world [5,6].

Nintendo Wii is an interactive video game that is played with a hand-held, wireless remote that senses motion and requires the participant to mimic the actions of their on-screen character. Wii-Fit is a video game released for Nintendo Wii that is played using a special Wii balance board in order to perform activities like yoga, jogging and aerobics [7]. Wiihab is an abbreviation for "Wii habilitation" a new idea that came about after the introduction of the Nintendo Wii to use the console for habilitation and rehabilitation. Nintendo's Wii changed the way video games were viewed because it actively involved the gamer in the playing of the game [8].

Hospitals have also embraced the Wii because of its ability to help rehabilitate patients who have damaged their motor system. The Nintendo Wii also appears to be more physiologically challenging than a sedentary video game in adults, adolescents and children [9-12]. Pang [13] conducted a study on a patient with cerebral palsy and found that after four weeks of using the basic Wii system, the patient had better visual perception, posture and could stand for longer periods of time.

Down syndrome (DS) is one of the most common genetic causes of the developmental disabilities. Individuals with DS have three number 21 chromosomes in some or all cells. They have unique physical, neurological, musculoskeletal, sensorimotor and learning and communication characteristics that can impact each other as well as the individuals' ability to develop age appropriate skills. Individuals with DS have ligamentous laxity, decreased strength, hypotonia, excessive hip abduction and external rotation, shoulder girdle instability and difficulty initiating movement, all of which are thought to contribute to delays in motor development. They have difficulty with equilibrium, balance, protective response and graded muscle movement leading to wide base of support in sitting and standing and delay in postural control and locomotion. Most children with DS walk independently between the ages of 2 and 3 years [14-16]. Slow postural responses to loss of balance lead to inefficiencies in maintaining stability. Such balance problems may result from higher-level postural control mechanisms such as delayed cerebellar maturation and a relatively small cerebellum and brainstem [17,18].

The purpose of this study was to examine the effect of Wii-Fit on balance in children with DS. I hypothesized that VR using Wii gaming technology is effective in enhancing balance when it is given in conjunction with the traditional physical therapy among Down syndrome children receiving standard rehabilitation as implemented in Saudi Arabia.

MATERIAL AND METHODS

Subjects: Thirty children with DS were divided into two equal groups (control and study). The inclusion criteria were: 1. children with DS with mild to moderate mental retardation (IQ from 36:67 according to Stanford Binet intelligence scale), 2. age ranging from 10 to 13 years and 3. children who were able to stand and walk independently. Exclusion criteria were: 1. uncontrolled cardiovascular disease and 2. orthopedic limitation to exercise such as hip, knee, foot or spinal deformities. All children were selected from Down syndrome Charitable Association (DSCA) in Riyadh, Kingdom of Saudi Arabia. Ethical approval was obtained from DSCA authority. Children's parents were informed of all aspects of the study and were given their consents. The subjects' distribution is shown in Table 1.

Materials: There were both evaluative and intervention materials. The evaluative material was the balance subtest of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP). The following materials were used to assess balance in the BOTMP: a balance beam, a stopwatch, an adhesive tape past on floor to make a straight line, a stick and a piece of texture to close the eyes. In addition, a small ball was used to determine the preferred leg. The BOTMP has been widely used to assess motor proficiency for children with mental retardation [19]. It is a standardized test for children aged from 4.5 to 14.5 years to assess the developmental age [20]. The BOTMP was also reported as being technically dependable and as presenting favorable construct validity [21].

Table 1: General characteristics of the study groups

Groups	Age (Year)				Gender		Place of Collection*
	Mean	SD	Min.	Max.	Boys	Girls	
Control (15)	11.56	±0.44	11	13	7	8	DSCA
Study (15)	10.92	±1.16	10	12	6	9	DSCA

*This association is located in Riyadh, Kingdom of Saudi Arabia.

The intervention material was the Wii-fit device. Nintendo Wii introduced a new style of VR in 2005 by using a wireless controller that interacts with the player through a motion detection system and its avatar representation in the video. The controllers use embedded acceleration sensors that can respond to changes in direction, speed and acceleration to enable participants to interact with the games. A sensor, mounted on top of a TV, captures and reproduces on the screen the movement from the controller as performed by the participants. The feedback provided by the TV screen generates a positive reinforcement, thus facilitating training and task improvement [22].

The Wii-Fit device used in the present study was a videogame consisting of games using the Wii Balance Board. It mainly consists of Wii balance, Wii console, Wii remote and Wii nunchuk. It has different balance games and three of them were selected including foot ball heading (known as Soccer Heading), the tight rope walk and the Penguin slide game.

The balance board input device is a sturdy plastic panel that rests on four feet, which each contain a pressure sensor. The pressure values measured by the board are communicated to a host computer via Bluetooth™. The four pressure sensors give the balance board four degrees of freedom. In practice, however, the balance board is an isometric input device and one cannot accurately control the individual degrees of freedom separately. During normal use, the balance board supports the user's weight and the user cannot increase the pressure on one sensor without also decreasing the pressure on other sensors [23].

Procedures: The subjects underwent IQ examination before participating in the study. Each child was asked to kick a ball twice to determine the preferred leg. For assessing balance, each child was asked to do the following tests with both hands on the hips: (1) Standing on the preferred foot on a line drawn on the floor while looking at a target on the wall. (2) Standing on the preferred foot on a balance beam while looking at a target on the wall. (3) Standing as in item 2, except with eyes closed. (4) Walking forward on a line on the floor using a normal stride. (5) Walking forward on a balance beam using a normal stride. (6) Walking forward on a line on the floor with a heel-to-toe gait. (7) Walking forward on a balance beam with a heel-to-toe gait. (8) Stepping over response speed stick on balance beam, in which the child walked on a balance beam using a normal stride and then

stepped over a wand held by the examiner above the beam at a height just below the knee. In 1 to 3 items, the free leg was flexed at the knee, the trial was stopped after 10 seconds and the time was then recorded. The trial was stopped before 10 seconds if the child touched the free leg to the floor, hooked the free leg behind the supporting leg or shifted the supporting leg out of place. Items 4 and 5 were scored with a maximum of six steps. If the child placed one foot or both feet completely off the line or beam prior to six steps, the test was stopped and the number of the successful steps was recorded. Items 6 and 7 were scored with a maximum of six correct steps. A step was incorrect if one foot or both feet were placed completely off the line or beam, the heel of the front foot failed to touch the toe of the rear foot, or the toe of the rear foot was moved forward to touch the heel of the front foot. The trial in item 8 was recorded as a failure if the child touched the stick firmly, swung the leg around the stick, or stepped off the beam.

Subjects were tested individually and they wore sneakers. All directions were explained to each child via total communication, involving speech, body language, facial expression and demonstration. To ensure that the instructions were understood, each child was permitted to practice a trial for each item. This test was administered before intervention and after 6 weeks of intervention for each child in both groups.

Each child in the control group received the traditional physical therapy program that was applied by the physical therapists in DSCA for one hour as follows: Approximation and strengthening exercises for 20 minutes followed by rest for 5 minutes. In addition, walking on an even surface in the treatment room and climbing stairs were provided for 35 minutes (15 minutes each with 5 minutes rest in-between). Each child in the study group received the same program received by the control group in addition to the Wii games as follows: Approximation and strengthening exercises for 15 minutes followed by rest for 5 minutes. Walking on an even surface in the treatment room and climbing stairs were provided for another 15 minutes (5 minutes each with 5 minutes rest in-between). In addition, each Wii game was practiced for 5 minutes with 5 minutes rest in-between in the following order; foot ball heading game (Figure 1A), the tight rope walk game (Figure 1B) and finally the Penguin slide game (Figure 1C). The program for the two groups was applied two times per week for 6 weeks.



Fig. 1: Soccer heading game (A), Tight rope walk game (B) and Penguin slide game (C).

Data Analysis: The first three items of the BOTMP was determined by the number of seconds, up to a maximum of 10 seconds, the subject could perform in each of the three items. In items 4 through 7, balance was determined by counting the number of steps, up to a maximum of six steps, taken during each item. Item 8 was rated as pass or fail. Raw scores were converted to point scores. According to the BOTMP manual, the eight items measure balance with a total point score of 32. The total point score of balance for each child was the summation of the point score of the eight tested items of the balance subtest.

The collected data were statistically analyzed to show the means and standard deviations of the balance scores for each group before and after 6 weeks of intervention. Then, a comparative study was conducted between the mean differences in the two tested groups for balance score before as well as after 6 weeks of intervention by using the independent samples t-test to show the statistical difference at 0.05. Last, a comparative study was conducted between the mean differences of the pre-intervention measures and post-intervention measures for balance for each group by using paired samples t-test to show the statistical difference at 0.05.

RESULTS

The statistical analysis was conducted on 30 children with Down syndrome. The children were 13 boys and 17 girls; their ages were ranged from 10 to 13 years. The collected data were statistically analyzed to show the means and standard deviations of the balance scores for each group before and after 6 weeks of intervention. When comparing the pre-intervention mean values of balance for the control group with that for the study group by using the independent samples t-test, the results revealed a non-significant difference ($p= 0.466$). On the other hand, when comparing the post-intervention mean values of balance for the control group with that for the study group by using the independent samples t-test, the results revealed a high significant difference ($p= 0.000$) (Table 2 and Figure 2).

Paired samples t-test showed a significant difference of balance when comparing pre-intervention mean values with that of the post-intervention for the control group as well as for the study group. The results revealed a significant difference ($p=0.017$) for the control group and a high significant difference ($p=0.000$) for the study group (Tables 3 and Figure 3).

Table 2: Comparison between the control and the study groups for balance

Time of Measure	Groups	Mean±SD	Minimum	Maximum	t-value	p-value
Pre-intervention	Control	8.87±5.53	0	17	0.74	0.466
	Study	10.27±4.83	4	18		
Post-intervention	Control	10.40±4.93	1	18	4.53	0.000*
	Study	17.47±3.50	11	21		

SD: Standard deviation. *: Significant.

Table 3: Comparison between pre and post-measures of balance for both the control and the study groups

Groups	Time of Measure	Mean±SD	Minimum	Maximum	t-value	p-value
Control	Pre.	8.87±5.53	0	17	2.70	0.017*
	Post.	10.40±4.93	1	18		
Study	Pre.	10.27±4.83	4	18	6.90	0.000*
	Post.	17.47±3.50	11	21		

Pre.: Pre-intervention. Post.: Post-intervention. SD: Standard deviation. *: Significant.

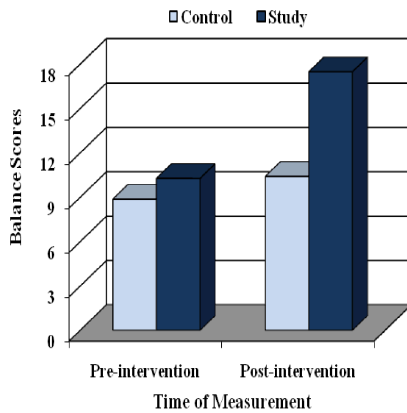


Fig. 2: Balance measures before and after six weeks of intervention between the control and the study groups

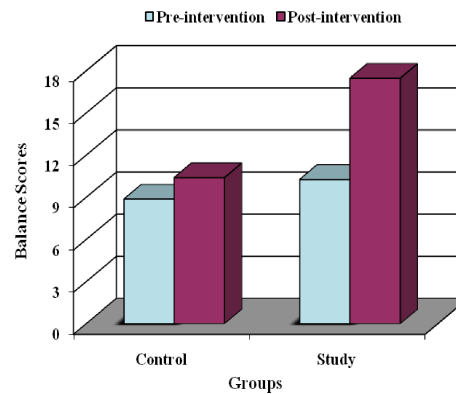


Fig. 3: Balance measures between before and after six weeks of intervention for both the control and the study groups

DISCUSSION

The results of the present study revealed a non-significant difference between the control and the study groups for the pre-intervention mean values of balance ($p=0.466$). On the other hand, when comparing between both groups for the post-intervention mean values of balance, the results revealed a high significant difference ($p=0.000$). When comparing the pre-intervention with that of the post-intervention mean values of balance for the control group, the results showed a significant difference ($p=0.017$). However, the results revealed a high significant difference between the pre-intervention and the post-intervention mean values of balance for the study group ($p=0.000$). These results indicate that the VR-based therapy in the form of Wii-Fit for 6 weeks could improve balance ability of the children with Down syndrome who are ranging in age from 10 to 13 years.

Importantly, the loss of selective motor control may interfere with overall level of functioning even when other impairments are treated since the underlying strength and coordination may be limited [24]. There are no specific modalities to treat selective motor control but physical and occupational therapy in conjunction with a home program may improve selective motor control enough to affect functioning. Thus repetitive activities guided by a therapist or as in this case, a virtual environment and a continuation of repetitive activities in daily functioning may improve gross motor skills [25].

Several studies have examined the use of VR for balance training for nondisabled individuals. In a study using VR for balance training of individuals who are

sitting on a stationary bicycle, there was an improvement in cycling velocity and a decrease in the deviation from the path after virtual cycling training. It was also found that the visual feedback regarding the user's weight shift in real time helped to improve postural balance [26]. Lott *et al.* [27] showed significant differences between functional lateral reach performed in a real versus a virtual environment (VE) in 18 adults. They reported that the participants reached significantly farther when virtual objects were presented within the VE using a video capture VR system than when they were asked to touch the hand of a person who was standing at their sides. They suggested that embedding the reaching task in a game shifts individuals' attention from the possibility of losing balance and thus encourages them to extend their reach beyond what would have otherwise been assumed to be possible.

Cunningham and Krishack [28] reported greater improvement in dynamic standing tolerance following a VR therapy than following a standard occupational therapy. Moreover, there was a significant improvement in balance and functional mobility in community-living older adults following a VR exercise program. The strength, range of motion, fractionation and speed improved following VR-based training and these changes appeared to transfer to changes in function [29].

When comparing between virtual reality-delivered therapy and conventional therapy on 14 individuals who suffered from post-traumatic brain injury for 24 sessions, it was found that both exercise programs resulted in improvement of patients' balance. However, additional benefits were identified for the VR group, including

greater enthusiasm for the VR-delivered therapy program, increased enjoyment while doing the exercises, improved confidence while walking and fewer incidents of falling [30].

Virtual reality-based therapy could be used to direct a client's motor response to be either specific or global making it possible to train diverse motor abilities such as the range of motion of different limbs and whole body balance training [3]. In such way, patients with paraplegic spinal cord injury showed an improvement in their static balance ability following the use of a video-capture VR system [31]. These findings are consistent with work by Lorie [32] who reported an improvement in muscle strength, coordination and physical fitness as well as a reduction in the risk of falls for people with Parkinsonism after an intensive program of Nintendo Wii.

Deutsch *et al.* [33] stated that postural control was improved after the use of Wii training with a neurological impaired adolescent for 11 training sessions. The decrease in sway that was observed after training can be interpreted as a sign of increased stance stability. This finding is consistent with work by Shumway-Cook *et al.* [34] where massed balance training produced a decrease in center of pressure sway in children with CP. The training provided in this case combined massed practice of balance with vision and attention directed at the game rather than maintaining balance, which in turn stimulated the proprioceptive-vestibular system.

It has been found that the Wii-Fit's balance board can improve people's balance and confidence. Moreover, Mackeegan [35] stated that Nintendo Wii-Fit could aid people who have lost limbs. The games helped them regain their stability. Walker *et al.* [36] reported that the use of a VR system in conjunction with partial body weight-supported treadmill training was effective in improving the walking and balance abilities of patients poststroke.

The factor contributing to the learning of the movements may be the specificity and frequency of the feedback provided to the patients by the system regarding both the knowledge of their performance and the knowledge of the results of their actions. Augmented feedback in the form of either knowledge of performance or knowledge of results is known to enhance motor skill learning [37]. Feedback provides information about the success of the action, it informs the learner about movement errors and it is known to motivate the learner by providing information about what has been done correctly [38].

There are a variety of explanations for why our patients improved after training with the gaming system. One explanation may be that the training was task driven and required problem solving. These features of training have been shown to promote behavioral changes [39] as well as neural plasticity in children [40]. Finally the multisensory feedback provided by the system may explain improvements in performance as well as learning [41]. Snider *et al.* [42] stated that VR has potential benefits for children with neurological disorders and could positively affect the brain reorganization/plasticity, motor capacity, visual-perceptual skills, social participation and personal factors.

CONCLUSION

Results of this study showed that improvement in postural stability of children with DS, aged 10 to 13 years, was possible through the use of VR-based therapy in the form of Wii-Fit. To the author's knowledge, this is the first published study on using this particular VR-based therapy for the habilitation of children with DS.

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