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Research Paper

The Effect of Virtual Reality Exercises on Dynamic Balance of Children with Developmental Coordination Disorder

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Abstract

Introduction: One of the prominent features of children with developmental coordination disorder is poor postural control. These children are less able to control their balance in variable situations because they respond to balance disorders more slowly than their peers. The purpose of this study was to investigate the effect of virtual reality exercises on the dynamic balance of children with developmental coordination disorder.

Materials and Methods: This research was an experimental study with pre-test, post-test, and control group. Thirty children with developmental coordination disorder were randomly selected and divided into experimental and control groups. The heel-to-toe test was used to assess the dynamic balance. The training protocol consisted of 12 sessions of Wii fit virtual reality training, three sessions per week, and 30 minutes per session. The data obtained from pre-test and post-test were analyzed using covariance analysis at 95% confidence level.

Results: There was a significant difference between the experimental and control groups in the dynamic balance post-test.

Conclusion: Twelve-week of virtual reality game interventions can be effective in improving the dynamic balance of children with developmental coordination disorder.

Keywords: Dynamic Balance; Virtual Reality; Developmental Coordination Disorder; Childhood.

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1. Introduction

Among the many of the motor disorders in children with developmental coordination disorder (DCD), poor postural control is probably the most disturbing because it makes children susceptible to fall (2), affects the development of motor skills, reduces physical activity, increases the risk of obesity, and endangers physical fitness and well-being (4).

Children and adolescents with developmental coordination disorder are reluctant to engage in activities that require physical and motor response, and have a low level of intolerance, frustration, and low self-esteem (5), and they also have difficulties in optimal use of time, completing homework, touching perception, balance, and motor perceptual skills (6).

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It is well known that postural control requirements change with different assignments and situations (7). Therefore, children with DCD need to achieve different types of balance ability, including 1) static balance (static postural control), 2) Balance Response to Static Disorders (reactive postural control), 3) Adjustment of posture control before starting a move (Anticipatory postural control), 4) Changing postural muscle responses on time in response to changing task requirements (Adaptive postural control (7).

73 to 87 percent of children with DCD experience balance problems in their daily activities (8). These children's walking is unbalanced and unstable, indicating that their overall coordination is poor (9). Also,, the inattentive and inaccurate problems of these individuals can impair spatial perception, orientation, correct diagnosis, and so on. Another problem with these children is the lack of coordination in their daily activities.

These children have difficulty performing their movements because they are unable to understand the timing of successive movements and are also unable to coordinate limb movements and maintain balance, they perform their movements with difficulty and often cannot perform the specific movement pattern that requires balance (10), or cannot run or walk in harmony (11). According to Carmeli, Bar-Yossef, Ariav, Levy, Liebermann (2008), children with developmental coordination disorder receive lower scores on balance and cognitive-motor tests than their normal counterparts due to sensory-motor information deficit, and their balance is more unstable than healthy people (12). Poor performances in visual-cognitive and visual-motor skills, tactile sensitivity, visual information organization, deep sense, and vestibular system function have been reported in children with DCD (13).

The vestibular system plays a major role in early motor behaviors (14, 15) with functions such as maintaining balance, controlling posture by changing head movement, and stabilizing the eyes according to the environment (16). Vestibular system dysfunction is common in children with DCD. However, through exercise and therapeutic interventions, motor development and the balance of these children could be improved. For example, Smits-Engelsman, Jelsma, and Ferguson (2017) examined the impact of five-week Wii fit training on functional strength, anaerobic fitness, balance, and agility of DCD children in low-income families. The results indicated that DCD children showed a significant improvement in balance tests (17).

Because computer-games are appealing to children, they seem to be able to help them achieve their motor skills and motivational development for physical activity. Vernadakis (2014) reported that motion-based computer games such as the Xbox Kinect (xbk) may motivate children, increase skill-specific self-efficacy, and increase the likelihood of acquiring skills (18). In addition, Barnett et al. (2011) showed that active physical involvement required by motion-based computer games increases children's learning and play formation. Children in such games do so in terms of successful experience, reinforcing positive feedback on emotional enjoyment, and achievement, which may enhance children's drive to new experiences (19). In general, based on the available evidence on the potential effects of virtual skiing exercises on the infrastructures involved in the dynamic balance skills of children with DCD, identifying more effective methods of these interventions would be useful to rehabilitate these children. Also, regarding the limited knowledge about the effects of virtual reality exercises on the balance skills of these children, the present study aimed to determine the effectiveness of virtual reality exercises on the dynamic balance of children with developmental coordination disorder.

2. Materials and Methods

This study was experimental with pre-test, post-test, and control group. Thirty male children with developmental coordination disorder were randomly selected from 87 children referred to child and adolescent psychiatry centers. They were randomly divided into two groups of 15 matched in virtual reality and control groups. For diagnosing these children, the fourth diagnostic and statistical manual of mental disorders (DSM-IV) was used as the criteria, and basic motor ability test, Coolidge's Neuropsychological and Personality inventory and Raven Intelligence Test were also conducted (20).

Inclusion criteria: no cardiovascular disease, no muscle damage, no neurological disorders, no clear postural abnormalities, no motor problems (walking without assistance), no visual impairment, no orthopedic, cardiovascular and atrial system problems, bodily sensations and parents' consent. The incidence of orthopedic injuries during the intervention, lack of willingness to cooperate by the patient and parents despite the initial agreement, absence in post-test in due time, absence in more than 3 sessions during the exercise protocol implementation were the exclusion criteria. The subjects were homogenized in two groups based on pre-test scores and level of development, age, weight, IQ score and previous experience of physical activity. The virtual reality group performed 12 sessions fitness Wii games for 30-minute each week under the guidance of a therapist. During the first two sessions, verbal cues were provided to the patient to facilitate movements needed to interact with the game and to improve posture. The virtual system used was the Wii Fit, which included balance games (tilting table, penguin sliding, and balance bubble) and aerobics (basic stepping). Wii Fit games were played in the room, and a screen was placed within 3 meters from the person. In each session, the games were played in random order but in equal proportions. The game changed after every 3 minutes. In between game-changing, the patient would rest. To collect data, the heel-to-toe test was used to measure dynamic balance. Details of this measurement are as follows:

Dynamic Balance Measurement: walking heel to toe test was used to assess dynamic balance. This test assesses the subject's ability to walk in a straight path. The subject is asked to walk about 15 steps in a straight path from heel to toe. The maximum score on this test is 15. If the subject deviates from the path before completing the 15 steps, the test is stopped and the number of steps is noted as the subject's record. This test is performed twice and the best score is noted as the record (21). The data collected were classified and described by calculating the mean and standard deviation and drawing the table. Covariance analysis was used to analyze the data and the research hypotheses by using SPSS software version 22.

3. Findings

The mean and standard deviation of the pre-test and post-test scores of the research variables of the two experimental and control groups are presented in Table 1. The results of the Kolmogorov-Smirnov test (K-S Z) are also presented in this table for checking the normal distribution of variables in groups. According to this table, the Z-statistic of the Kolmogorov-Smirnov test is not significant for all variables. Therefore, it can be concluded that the distribution of these variables is normal.

Table 1. Descriptive indices of pretest-posttest scores in two experimental and control groups (n = 30)

Variable	Status	group	mean	Sd.	K-S Z	p
Dynamic balance	Pre-test	**Experimental**	5.78	0.52	1.15	0.23
		Control	5.95	0.58	1.12	1.14
	Post-test	**Experimental**	7.62	0.61	1.24	0.12
		Control	6.1	0.63	1.17	0.17

Table 2. Results of univariate analysis of covariance for examining differences between the experimental and control group

Variable	Source of change	Sum of squares	df	Mean squares	F value	p	Effect size
Dynamic balance	Pre-test	3.345	1	3.345	9.74	0.0 01	0.276
	Group membership	12.773	1	12.773	27.84	0.0 01	0.592
	Error	8.788	27	0.325			

One-way analysis of covariance was used to investigate the effect of virtual reality exercises on children's dynamic balance. Pre-test and post-test homogeneity regression slope test results showed that the regression slope was equal in both groups for dynamic balance (F = 1,26 = 3.17, p<0.08). Levine's test results for investigating the homogeneity of dependent variable variance in groups showed that dynamic balance variance ($F_{1,28}$ = 2.47, p<0.151) was equal in groups. The results of the univariate analysis of variance for examining the dynamic balance differences between pretest and posttest of the experimental and control group is reported in Table 2.

According to Table 2, the F value of the dynamic balance in the post-test was 27.84, which is significant at the 0.001 level, indicating that there is a significant difference between the dynamic balances of the two groups. The effect size of 0.47 also indicates that this difference is large in population. The F value of the dynamic balance pre-test is 9.74, which is significant at the 0.001 level. This indicates that the pre-test has a significant effect on the post-test scores. The results of the analysis of covariance showed that the corrected mean of dynamic balance in the experimental group is 7.62 and in the mean of the control group is 6.1, which is significant at 0.001 level according to F value. Based on this finding, it can be said that virtual reality exercises increase dynamic balance in children with developmental coordination disorder.

4. Discussion and Conclusion

The purpose of this study was to investigate the effect of virtual reality exercises on the dynamic balance of children with developmental coordination disorder. The findings showed that twenty-four sessions of virtual reality training had a significant effect on improving dynamic balance function in children with developmental coordination disorder. These findings are in line with the results of previous studies showing that virtual reality exercises are effective in improving balance. For example, Bainbridge et al. conducted a six-week program on elderly people with balance deficits, which included a 30-minute Wii exercise twice a week. Although no significant difference was observed in the variables studied, there was a growing trend in the balance of 4 out of 6 patients (22). Recovery trends were also reported by Thornton et al., in a sample of TBI patients over a 6-week program that included a 50-minute session per week (23).

Similar results have been obtained in the researches of Yatar and Yildirim, Garcia et al. On the other hand, the results of some research indicated that the use of virtual reality combined with traditional therapies in comparison to traditional physiotherapy results in the improved dynamic balance after brain injury (24, 25). For example, in the research of Cho et al., the dynamic balance of the virtual reality group was improved (because in addition to traditional physiotherapy, had 30-minutes of virtual reality training three times a week) (24). Therefore, the overall duration of intervention in the virtual reality group was longer than the control group, indicating that the effect of training volume was greater than the type of rehabilitation provided. The same situation can be observed in the study of Kim et al., in which the virtual reality group (which in addition to traditional physiotherapy had 30-minutes of virtual practice per session) was better in dynamic balance than the traditional physiotherapy group (26).

Some researchers have shown that taekwondo training improves the unilateral standing balance (one leg) and the impaired vestibular function in children with DCD (27). The analysis of taekwondo techniques shows that taekwondo protocols cover many of the movements performed in vestibular exercises such as rotation, jumping, which are conducted in Sensory Integration Therapy. Sensory Integration Therapy is an effective treatment for sensory deficits and enhances the development of motor skills in children with DCD, in which rotational kicking, back, and side kicking techniques, as well as rapid rotations (rotation of head and body) and vertical movements, can similarly stimulate vestibular and sensory functions. During taekwondo exercises, these kicks are repeated to stimulate the vestibular apparatus and increase the balance of standing on one foot in these children (28). The virtual reality protocols used in the present study are similar to the exercises used in taekwondo. Therefore, improvement in the dynamic balance performance of the subjects can be attributed to improved sensory integration of children as a result of this type of exercise.

To integrate the visual, vestibular, and body sensory inputs, brain mechanisms may be greatly enhanced by long-term exercise and cause less body swing in a standing position (29). Different exercises stimulate different sensory systems and increase postural control of the body (30). Numerous studies have been conducted on the different sensory and motor adaptations that result from continued participation in various sports activities. Every sport requires different levels of sensory-motor processes to execute skills and maintain the neuromuscular system (33-31).

Since balance exercises effectively reduce weakness in the vestibular system, changes in white matter can be introduced as a neural mechanism for this rehabilitation (34). Hanggi et al. (2011) found significant reductions in FA (Fractional Anisotropy) as well as changes in gray and white matter in professional ballet dancers (35). Probably balance exercises, performed after weakness in the vestibular system, affect white matter plasticity, which may help to coordinate different sensory systems for balance and stature, and thus may be introduced as a physiological mechanism for balance exercises as a method of rehabilitation (34).

Virtual reality balance exercises were used in the present study. The nature of these exercises is the involvement of the visual, vestibular, and bodily sense systems that appear to have enhanced balance systems by being strengthened. Generally, the findings showed that virtual reality exercises could be considered as an intervention method to improve the balance status of the children with DCD.

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