Original Article

Effect of Virtual Reality Therapy on Balance and Walking Speed in Children with Spastic Cerebral Palsy: A Randomized Controlled Trial

Minoo Kalantari[1], Maryam Naderi[1], Seyedeh Zeinab Beheshti[2] and Reihaneh Askary Kachoosangy[1,3]*

1. Department of Occupational Therapy, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran
2. Department of Occupational Therapy, School of Rehabilitation, Arak University of Medical Sciences, Arak, Iran
3. Physiotherapy Research Center, School of Rehabilitation, Shahid Beheshti University of Medical Sciences,Tehran, Iran

Abstract

Background: Children with spastic cerebral palsy have some limitations in their functional mobility and also problems with their balance and postural control. The purpose of this study was to examine the effect of virtual reality training on balance and walking speed in children with spastic Cerebral Palsy (CP).

Methods: This is a single blinded randomized controlled trial. According to the preliminary data obtained from the pilot study, the total sample size was determined, and 30 children with spastic CP (5–12 years) were randomly allocated into the intervention (n: 15) and control groups (n: 15). Both groups received the treatment with conventional occupational therapy for 30-*min* sessions three times per week. The intervention group also received supervised therapy using Xbox Kinect games in each session for 6 weeks. Balance by TUG test and Pediatric Balance Scale (PBS), and walking speed by 10-meter walking test were measured in pretest, post-test, and follow-up. Additionally, repeated measures analysis of variance (ANOVA) was used to examine the interaction effects of time and group.

Results: Thirty children with spastic CP (mean age: 8.5 years; Gross Motor Function Classification System: level I, 23.3%, level II,) were analyzed. The results showed that there was a statistically significant difference between the two groups only in the PBS score ($p=0.013$). Additionally, the interaction effect of time and group was significant for both TUG and PBS scores ($p<0.001$).

Conclusion: Using V.R therapy along with routine occupational therapy can be effective for improving balance and walking speed in children with spastic CP.

Keywords: Balance, Spastic cerebral palsy, Virtual reality, Walking speed

*** Corresponding author**
Reihaneh Askary Kachoosangy, PhD
Physiotherapy Research Center, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran
Tel: +98 9122792842
Email: re-askary@sbmu.ac.ir, askary_ot@yahoo.com

Received: 24 Jul 2024
Accepted: 18 Nov 2024

Citation to this article
Kalantari M, Naderi M, Beheshti SZ, Askary Kachoosangy R. Effect of Virtual Reality Therapy on Balance and Walking Speed in Children with Spastic Cerebral Palsy: A Randomized Controlled Trial. *J Iran Med Counc*. 2025;8(4):779-87.

Introduction

Cerebral Palsy (CP) is an unprogressive neurological disorder caused by damage of immature brain, leading to progressive sensory and motor and postural disabilities (1). The prevalence of CP in the world is 2 per 1000 live births and in Iran is 2.06 per 1000 live births (2). Spastic cerebral palsy is the most common type of CP, making up 70 to 80% of all cases (1). The main characteristic of this type of CP is spasticity which affects the balance as a significant component of child's development that appears in the last stage of cortical motor development (3).

Balance disabilities in children with spastic CP can cause problems in their executive function during activity of daily living (4). Frequent falls resulting from postural fluctuations, weakness, and loss of balance are very common among these children (4). Unlike traditional approaches that focus on isolated movement components, correct specific motor deficits in a nonfunctional context such as on a balance beam or exercise ball, and not placing too much emphasis on the child's motor function in natural environment (5), new functionally oriented rehabilitation approaches highlight the interventions delivered in different activities in a functional context. According to the motor learning and motor control theories, motivation, repetition, and special and purposeful target-directed training should be applied in the treatment of children with CP (6).

Virtual Reality (VR) technology is one of these approaches that refers to an interactive artificial experience of reality that induces a sense of presence (7) and it can help children learn and perform their practical skills in a controlled environment by creating immersive experiences as games. Due to the precise adjustment of speed, intensity, and level of training in this technology, these exercises can range from simple to complex tasks (8). In such a situation, a CP child can do his/her activities and explore the environment with no feeling of fear (9). Previous studies have reported that using VR technique has a positive effect on the performance of upper extremity function (10) and balance (11) in children with spastic CP. Also, the results of a systematic review confirmed the positive effect of VR on balance and walking in children with CP to some extent. However, the authors believed that the results should be used with caution for various reasons such as differences in interventions used, the lack of randomized clinical trials, and the relatively small sample sizes of studies (12). Also, authors of other systematic reviews mentioned that considering the limited number of well-conducted RCTs in this field, a large homogeneous samples size is still needed for future RCTs (13,14). In addition, in the present study, standardized assessments for children with CP were used. Thus, the aim of this study was to use validated test for investigating the effect of VR training on balance and walking speed of children with CP.

Materials and Methods

Participants

This single blinded randomized controlled trial (IRCT20200415047094N1) in which assessors were kept unaware of knowledge of group assignment, was conducted at Yekta and Raha occupational therapy clinics, Khorram Abad, Iran. Sample size was calculated with an α-value of 5% and power of 80%. According to the preliminary data obtained from the pilot study, the total sample size was determined 30 that according to the inclusion criteria, 30 children with spastic CP who were receiving routine occupational therapy as outpatients of above clinics were enrolled. After getting informed written consent by the parents and determining the final participants in the study, each of them was assigned a number from 1 to 30, and then using the Kittest program, 15 random numbers were considered for the intervention group and the rest for the control group. The inclusion criteria were as follows: age 5-12 years, Gross Motor Function Classification System (GMFCS) level I-II, no use of sedatives during the intervention, absence of any hearing or visual impairments that cannot be remedied by assistive devices, absence of any intellectual disability, and absence of drug-resistant epilepsy. The exclusion criteria were lack of child cooperation and absence of more than three sessions in therapy sessions.

The ethics committee of Shahid Beheshti University of Medical Sciences approved all the protocols (IR.SBMU.RETECH.REC.1398.206). Also, all the children's parents signed a written sign consent to participate in the study.

Instruments

After completing the demographic questionnaire, children's balance was evaluated by using Time Up and Go test (TUG) and Pediatric Balance Scale (PBS). TUG is a quick and simple test that assesses a person's functional balance by using the time that a person takes to rise from a chair, walk three meters, turn around, walk back to the chair, and sit down (15). The TUG test is a reliable and responsive measure of balance and mobility for children with CP (16). PBS is designed to assess the static and dynamic balance in children with balance disorders and consists of 14 items scored from 0 to 4 points with a maximum score of 56 (17). Kalantari *et al* investigated the psychometric properties of the Persian version of PBS and reported that PBS is appropriate for measuring functional balance in children with spastic cerebral palsy with mild to moderate motor impairment. CVR (1-0.73) and CVI (0.96) were in the acceptable range (18). For the present study, the total score of PBS was considered. The 10-metre walking test is a performance measure used to assess walking speed. In this test, a 14-meter route is determined and marked by a strip. Two meters before and two meters after this route are specified to create and reduce the acceleration of child's movement and he/she would be asked to walk this path once at normal and comfortable speed and once at maximum speed. The movement time in middle 10 meters is recorded by the therapist (19). Previous studies have reported that the 10-metre walking test is valid for evaluating the walking speed of CP children with GMFCS I-III (20,21).

Procedure

All the evaluations were performed two times with a one-week interval before study to check for absence of spontaneous recovery, with no significant difference in the values of two evaluations. Then, all the assessments were repeated at the end of intervention and 3 months later.

All the interventions for both groups were performed in the clinic environment. The control group received 30 *min* conventional occupational therapy (Neuro-developmental treatment) sessions 3 times per week over a 6-week period. The intervention group, in addition to usual occupational therapy, received non-immersive virtual reality. The intervention included 20 to 30-*min* sessions 3 times per week for a total of 6 weeks. In each session, the participants played the selected games. To play the balance games, a Kinect device was used, which was designed and released by Microsoft for using with the Xbox 360 platform. By using depth, image and sound sensors, Kinect allows a person to control the game using only his body. Each session included different games (holahob, skate, basket and ball, football, basketball, dance, motion explosion, and bodybuilding) that facilitated weight shifting in both anteroposterior and mediolateral directions. The time allocation of the selected games in each session was as follows: 5 *min* for weight shifting in the anteroposterior directions, 5 *min* for weight shifting in the mediolateral directions, and 10 *min* for weight shifting in all directions. Selecting the exercises was based on 4 types of games. All the games were presented to each child for weight shifting in each direction and child selected them based on his/her interest. In the treatment sessions, a 5-*min* break between each game was considered in order to prevent possible fatigue in the participants. In addition, the intervention was stopped whenever the child expressed fatigue and needed rest. Therefore, the game did not continue until the fatigue was over.

Data analysis

The resulting data were analyzed by SPSS statistical software for social sciences (version 21, IBM. Corporation, Armonk, NY, USA). To summarize the descriptive statistics, the mean and Standard Deviation (SD) were used for quantitative variables, while the frequency and percentage were used for qualitative variables. For comparing the quantitative demographic variables between the two groups, an independent t-test was used. Meanwhile, the Chi-square test was employed to compare qualitative variables between the two groups. Additionally, repeated measures analysis of variance (ANOVA) was used for the analysis of the statistical data. p values less than 0.05 were considered statistically significant.

Results

Thirty children with spastic CP (aged 5-12 years) were analyzed (Figure 1). Table 1 shows the children's

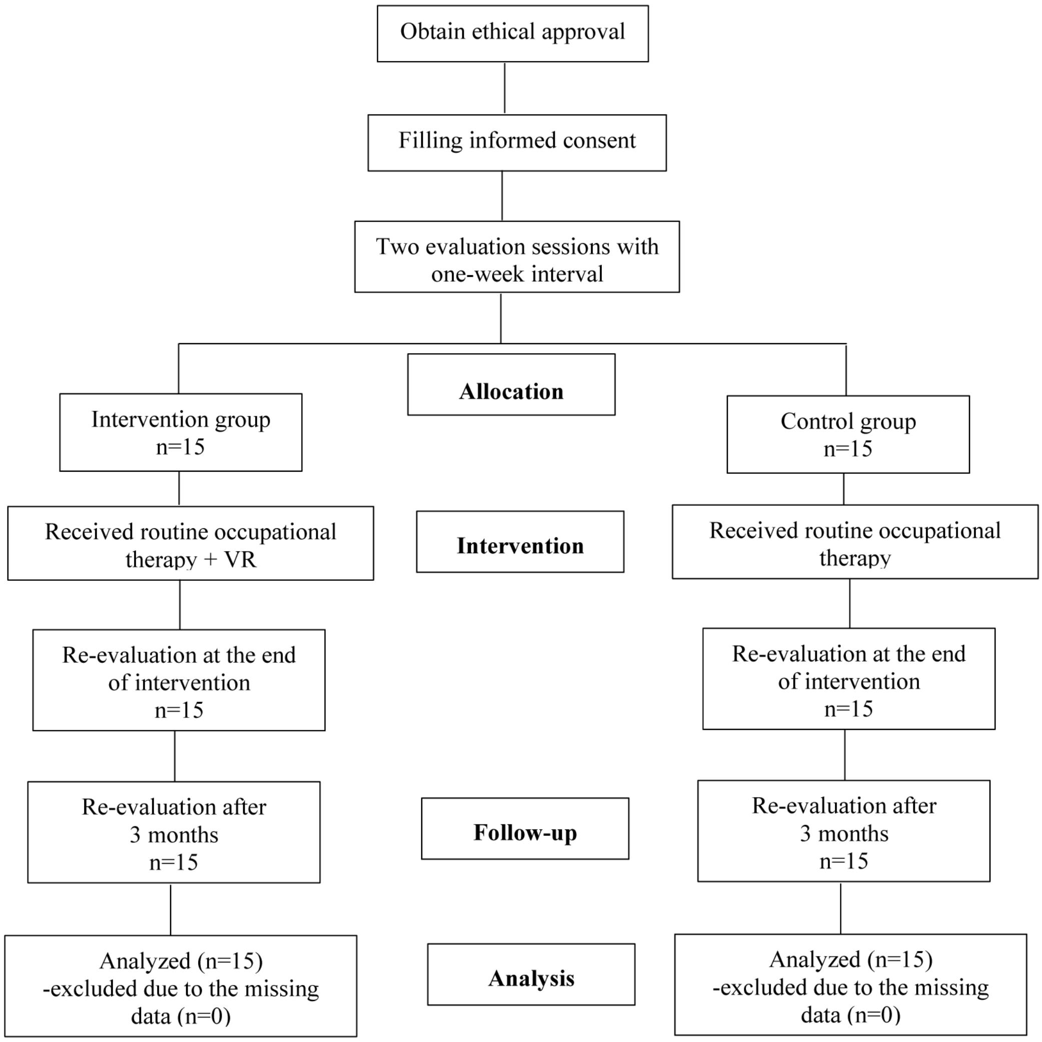

Figure 1. The study process diagram.

Table 1. Participants' demographic data

Characteristics	Subgroup	Group		Frequency (%)	p-value
		Control (%)	Intervention (%)		
Age (years)	-	8.47±2.39	8.53±2.20	-	0.937
Gender	Male	9(60%)	9(60%)	18(60%)	1.00
	Female	6(40%)	6(40%)	12(40%)	
GMFCS Level	Level I	7(46.7%)	2 (13.3%)	9(30%)	0.109
	Level II	8(53.3%)	13(86.7%)	21(70%)	
Spastic Type	Hemiplegic	7(46.7%)	7(46.7%)	14(46.7%)	1.00
	Diplegic	4(26.7%)	4(26.7%)	8(26.7%)	
	Quadriplegic	4(26.7%)	4(26.7%)	8(26.7%)	

demographic information (gender, GMFCS level, and spastic type) in control and intervention groups.

The results of the independent t-test demonstrated no significant difference in the mean age between the intervention and control groups ($p=0.937$). Additionally, the results of the Chi-square test indicated no significant differences between the control and intervention groups in terms of gender ($p=1.00$), GMFCS level ($p=0.109$), and spastic type ($p=1.00$). Descriptive statistics for the research variables, separated by the two groups at the measurement stages, are reported in table 2.

Based on the repeated measures ANOVA analysis, a statistically significant difference was found between the two groups over time in PBS scores ($p=0.013$), while no significant differences were observed in other variables ($p>0.05$). Additionally, the interaction effect of time and group was significant for both TUG and PBS scores ($p<0.001$). The effect of time on TUG and PBS scores was also significant ($p<0.001$). The effect size indicated that this difference is high and acceptable (Table 3).

Furthermore, the repeated measures ANOVA showed no statistically significant difference between the two groups over time in Normal walking speed and Max walking speed scores ($p>0.05$). However, the interaction effect of time and group was significant for normal walking speed and max walking speed scores ($p<0.001$). The effect of time on these scores was also significant ($p<0.001$). The effect size suggests that this difference is high and acceptable (Table 3).

Discussion

The purpose of this study was to investigate the effect

Table 2. Descriptive statistics of the two groups across baseline, immediately after the intervention and follow-up

Parameters	Intervention group			Control group		
	Baseline	Immediately after intervention	Follow-up	Baseline	Immediately after the intervention	Follow- up
Balance						
TUG (*s*)	19.32(3.74)	12.44(2.58)	12.62(1.75)	15.89(1.94)	14.50(1.92)	14.13(2.12)
PBS (score)	35.13(3.02)	45.53(2.50)	46.64(2.34)	34.46(5.06)	39.86(5.6)	40.40(5.53)
Walking speed						
Normal walking speed (*s*)	0.21(0.15)	0.34(0.27)	0.34(0.30)	0.26(0.13)	0.32(0.18)	0.33(0.23)
Max walking speed (*s*)	0.41(0.13)	0.65(0.18)	0.64(0.15)	0.51(0.08)	0.56(0.12)	0.60(0.13)

Pediatric Balance Scale (PBS); Timed Up and Go (TUG).

Table 3. Summaries of two-way repeated-measures ANOVA comparison

Variables	Within-group						Between-group		
	Time			Time × group					
	F	p	η^2	F	p	η^2	F	p	η^2
Balance									
TUG (sec)	74.02	<0.001	0.72	29.01	<0.001	0.50	0.01	0.954	0.00
PBS (score)	259.55	<0.001	0.90	26.38	<0.001	0.49	7.02	0.013	0.21
Walking speed									
Normal walking speed (*s*)	64.40	<0.001	0.69	9.47	0.001	0.25	0.03	0.874	0.01
Max walking speed (*s*)	61.79	<0.001	0.68	18.62	<0.001	0.40	0.06	0.805	0.01

η^2: partial eta squared; Pediatric Balance Scale (PBS); Timed Up and Go (TUG).

of VR training on balance and walking speed of children with spastic CP. The findings revealed that VR exercises could improve balance and walking speed in the intervention group.

Balance and walking speed difficulties are serious problems of children with CP, leading the challenge on performing many their daily activities. VR can help the children perform many activities regardless of environmental barriers. In addition, the recreational nature of the virtual environment diverts children's attention from the number of repetitions and the nature of exercises and increases duration of exercise therapy, thereby can be effective in the process of children's rehabilitation (22). The VR also provides visual feedback related to performance which is critical for motor learning in children with CP (22). Tasks used in this approach should have three features: being challenging, using real activities and objects, and being inherently purposeful. VR technique has all three of these features (8). Also, the principles of the task-oriented approach are client-centered, occupational-based therapy, person-environment interaction, and feedback that these principles are clearly seen in VR training (8,23).

The findings of the present study demonstrated that implementing regular weight-bearing exercises on the legs and shifting the weight between the legs while standing can have a positive effect on improving children's balance with diplegic and hemiplegic CP (24). Hence, it is possible that implementing these exercises with moving the center of gravity on the frontal and sagittal plans could lead to practice balance strategies in the ankle and hip of both legs. On the other hand, combining these exercises with VR technique and providing the playful exercises in the form of video games in fun environment keep children's focus away from repeated movements and increase their motivation and active participation to perform better and more accurate, and the children will able to practice their selected games for a longer period of time and lead to better motor learning (8). Literature review suggested that implementing purposeful exercises with sufficient frequency can facilitate the plasticity of the musculoskeletal system and improve practiced activity (25). Therefore, appropriate features of the virtual environment and doing repeated weight-bearing exercises on different plans can promote the balance strategies of the ankle and hip. This can be considered as the reasons for more improvement of the children's balance in the intervention group. Salem *et al*, in a study aimed at investigating the effects of low-cost virtual reality systems on balance and muscle strength in children with developmental delays, reported that virtual reality can be used as an effective, feasible, and safe therapeutic tool in rehabilitation interventions for children with developmental delays that is consistent with the current study (25-28).

When children with CP have poor postural control, they may fall in walking. Thus, balance control training is effective in reducing the risk of fall (7). By VR exercises, based on the results, the PBS score in the intervention group was significantly increased from 35.13 to 45.53 and after the follow-up period reached to 46.64. According to Kim's study, children who score below 45.5 were more likely to experience falls (29). Therefore, it seems that VR exercises have been able to reduce the risk of falling in the intervention group.

In this study, walking speed was increased in both groups, but it was greater in the intervention group than in the control group. These results are consistent with previous studies that used VR to improve walking speed (25-28). Salem *et al* showed an improvement in the walking speed of the children with developmental delay, but this improvement was not significant in the statistical analysis (25). Jelsma *et al*, in a study aimed at examining the impact of Nintendo Wii Fit on balance control and gross motor function in children with spastic hemiplegia, reported that the effects of these exercises on the studied variables were not statistically significant (26). One possible reason for the inconsistent between the results of their study and the present study could be the selection of exercises type. The selected exercises in the present study were performed in in three directions, forward and backward, up and down and sideways and included all the stages of walking such as lifting one leg and moving it forward. Therefore, it is possible to consider the proportionality of the type of selected exercises with the measured test as one of the effective factors in achieving such a result. It seems that the implementation of weight shifting exercises on the forward and backward, up and down and sideways during playing in VR has been resulted in the difference in the walking speed between the two groups. It has been able to affect the walking cycle (swing and stance phases). Thus, walking speed showed greater improvement in the intervention group compared with the control group even though according to GMFCS, the experimental group had more movement problems (15 people were at level 2).

Ramstrand *et al* suggested that type and duration of the game, as well as the complexity and specificity of the selected exercises, were also an effective factor in the results of using VR. The selected exercises in this study were performed around three directions. Also, these exercises included whole gait cycle. Moreover, all the participants believed that this type of exercises was fun and attractive and it could be a key factor in determining the duration of children's engaging in exercise therapy (23). Therefore, selecting appropriate exercises can be considered as one of the effective factors in achieving desired results.

Finally, all the mentioned active elements resulting from VR assist to change personal and environmental barriers that a child with CP may face. By reduction of these barriers or enhancement of the enablers, a child may gradually decrease impairments of his/her body function and structure and activity limitations and improve participation in communities, school, and society (7).

One of limitations in the present study was that types of CP were included in each group. Therefore, it is recommended that the effect of VR be compared in different types of CP in future studies. Also, comparing non-immersive and immersive virtual reality can be conducted in other studies. Another limitation was the randomization process that had not led to the match between two groups according to the primary outcome measures.

Conclusion

These data provided evidence for the effectiveness of VR exercises in virtual environment on balance and walking speed of children with spastic CP. VR technology could make therapy sessions more attractive and reduce the fatigue of children and therapists. Also, this approach can be used as an effective and efficient clinical tool in rehabilitation clinics, especially occupational therapy along with routine programs.

Funding

There is no funding to report for this study.

Acknowledgement

The ethics committee of Shahid Beheshti University of Medical Sciences approved all the protocols (IR. SBMU.RETECH.REC.1398.206). This study was registered in the Iranian registry of clinical trials (registration number: IRCT20200415047094N1). Also, all the children's parents signed a written sign consent to participate in the study.

The authors would like to thank all the faculty members of the Occupational Therapy Department of Shahid Beheshti who assisted us in this research and would like to acknowledge all the participants who volunteered to participate and helped in conducting this research.

Conflict of Interest

The authors report no conflict of interest.

References

1. Ross SM, MacDonald M, Bigouette JP. Effects of strength training on mobility in adults with cerebral palsy: a systematic review. Disabil Health 2016;9(3):J375-84.

2. Dalvand H, Dehghan L, Hadian MR, Feizy A, Hosseini SA. Relationship between gross motor and intellectual function in children with cerebral palsy: a cross-sectional study. Arch Phys Med Rehabil 2012;93(3):480-4.

3. Novak I, McIntyre S, Morgan C, Campbell L, Dark L, Morton N, et al. A systematic review of interventions for children with cerebral palsy: state of the evidence. Dev Med Child Neurol 2013;55(10):885-910.

4. Zwier JN, van Schie PE, Becher JG, Smits DW, Gorter JW, Dallmeijer AJ. Physical activity in young children with cerebral palsy. Disabil Rehabil 2010;32(18):1501-8.

5. Wilson PN, Foreman N, Stanton D. Virtual reality, disability and rehabilitation. Disabil Rehabil 1997;19(6):213-20.

6. Geerdink Y, Aarts P, Geurts AC. Motor learning curve and long-term effectiveness of modified constraint-induced movement therapy in children with unilateral cerebral palsy: a randomized controlled trial. Res Dev Disabil 2013;34(3):923-31.

7. Fandim JV, Saragiotto BT, Porfírio GJM, Santana RF. Effectiveness of virtual reality in children and young adults with cerebral palsy: a systematic review of randomized controlled trial. Braz J Phys Ther 2021;25(4):369-86.

8. Weiss PL, Rand D, Katz N, Kizony R. Video capture virtual reality as a flexible and effective rehabilitation tool. J Neuroeng Rehabil 2004;1(1):12.

9. Sarasso E, Gardoni A, Tettamanti A, Agosta F, Filippi M, Corbetta D. Virtual reality balance training to improve balance and mobility in Parkinson's disease: a systematic review and meta-analysis. J Neurol 2022:1-16.

10. Do JH, Yoo EY, Jung MY, Park HY. The effects of virtual reality-based bilateral arm training on hemiplegic children's upper limb motor skills. NeuroRehabilitation 2016;38(2):115-27.

11. Brien M, Sveistrup H. An intensive virtual reality program improves functional balance and mobility of adolescents with cerebral palsy. Pediatr Phys Ther 2011;23(3):258-66.

12. Liu W, Hu Y, Li J, Chang J. Effect of virtual reality on balance function in children with cerebral palsy: a systematic review and meta-analysis. Front Public Health 2022;10:865474.

13. Ziab H, Mazbouh R, Saleh S, Talebian S, Sarraj AR, Hadian MR. Efficacy of virtual reality-based rehabilitation interventions to improve balance function in patients with cerebral palsy: a systematic review and meta-analysis of RCTs. Arch Neurosci 2022;9(2).

14. Warnier N, Lambregts S, Port IVD. Effect of virtual reality therapy on balance and walking in children with cerebral palsy: a systematic review. Dev Neurorehabil 2020;23(8):502-18.

15. Nicolini-Panisson RD, Donadio MV. Timed "Up & Go" test in children and adolescents. Rev Paul Pediatr 2013;31(3):377-83.

16. Carey H, Martin K, Combs-Miller S, Heathcock JC. Reliability and responsiveness of the timed up and go test in children with cerebral palsy. Pediatr Phys Ther 2016;28(4):401-8.

17. Hovbrandt P, Carlsson G, Nilsson K, Albin M, Håkansson C. Occupational balance as described by older workers over the age of 65. Scand J Occup Ther 2019;26(1):40-52.

18. Kalantari M, Alimi E, Irani A, Nazeri A, Baghban AA. Content and face validity of pediatric balance scale in children with spastic cerebral palsy. Sci J Rehabil Med 2016;5(3):104-10.

19. Thompson P, Beath T, Bell J, Jacobson G, Phair T, Salbach NM, et al. Test-retest reliability of the 10-metre fast walk test and 6-minute walk test in ambulatory school-aged children with cerebral palsy. Dev Med Child Neurol 2008;50(5):370-6.

20. Chrysagis N, Skordilis EK, Koutsouki D. Validity and clinical utility of functional assessments in children with cerebral palsy. Arch Phys Med Rehabil 2014;95(2):369-74.

21. Anjos DMC. Comparison of reliability between a ten-metre and a one-minute walking test in children and adolescents with cerebral palsy at mean velocity 2017. Phys Med Rehabil Int 2017;4(2):1116.

22. de Oliveira JM, Fernandes RC, Pinto CS, Pinheiro PR, Ribeiro S, de Albuquerque VH. Novel virtual environment for alternative treatment of children with cerebral palsy. Comput Intell Neurosci 2016;2016:8984379.

23. Weiss PL, Bialik P, Kizony R. Virtual reality provides leisure time opportunities for young adults with physical and intellectual disabilities. Cyberpsychol Behav 2003;6(3):335-42.

24. Hartveld A, Hegarty J. Frequent weightshift practice with computerised feedback by cerebral palsied children—four single-case experiments. Physiotherapy 1996;82(10):573-80.

25. Salem Y, Gropack SJ, Coffin D, Godwin EM. Effectiveness of a low-cost virtual reality system for children with developmental delay: a preliminary randomised single-blind controlled trial. Physiotherapy 2012;98(3):189-95.

26. Jelsma J, Pronk M, Ferguson G, Jelsma-Smit D. The effect of the Nintendo Wii Fit on balance control and gross motor function of children with spastic hemiplegic cerebral palsy. Dev Neurorehabil 2013;16(1):27-37.

27. Deutsch JE, Borbely M, Filler J, Huhn K, Guarrera-Bowlby P. Use of a low-cost, commercially available gaming console (Wii) for rehabilitation of an adolescent with cerebral palsy. Phys Ther 2008;88(10):1196-207.

28. Luna-Oliva L, Ortiz-Gutiérrez RM, Cano-de la Cuerda R, Piédrola RM, Alguacil-Diego IM, Sánchez-Camarero C, et al. Kinect Xbox 360 as a therapeutic modality for children with cerebral palsy in a school environment: a preliminary study. NeuroRehabilitation 2013;33(4):513-21.

29. Michalski A, Glazebrook CM, Martin AJ, Wong WW, Kim AJ, Moody KD, et al. Assessment of the postural control strategies used to play two Wii Fit™ videogames. Gait & posture 2012;36(3):449-53.