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# The effect of head mounted display - HMD Virtual Reality Games in the Functionality of Children with Cerebral Palsy

Karamolegkos Andreas*, Skordilis Emmanouil

School of Physical Education and Sport Science, National and Kapodistrian University of Athens, Greece.

**Corresponding author:** *Karamolegkos Andreas, School of Physical Education and Sport Science, National and Kapodistrian University of Athens, Greece.

**Abstract**

The present study examined the effect of the head mounted display (HMD) virtual reality games in the functionality of children with cerebral palsy (CP). The intervention program lasted 8 weeks, with a frequency once a week. The participants were 8 children with CP, aging 10 to 11 years old, following the rehabilitation program of a daily center within the wider area of Athens. The participants, randomly assigned to the experimental and control conditions (EG & CG), were ambulatory and classified according to the GMFCS E & R in classes I (N=4), II (N=2) and III (N=2). The EG followed the weekly rehabilitation schedule plus an hour per week exposure to two different HMD virtual reality games chosen by the students. The CG followed the weekly rehabilitation schedule, and both groups declared absence of any organized activities beyond the rehabilitation center during the 8 week intervention. The participants were assessed at the begin and at the end of the intervention program in the functionality measures, according to the ICF.

The statistical analyses revealed significant improvement in the 30sSTS ($F=19.271$, $p=.007$, $\eta^2=.794$) and elbow range of motion ($F=7.089$, $p=.045$, $\eta^2=.586$) and approached significance in walking ability (1 Minute Walking Test) and gross motor function (GMFM D & E). Further, the participants recorded no episodes of dizziness, experienced enjoyment throughout the intervention, while no adverse effects with respect to spasticity were found.

Conclusively, the HMD virtual reality games may improve the functionality of children with CP and they provide a positive experience without any adverse effects. The HMD games therefore may be considered in the future to add in the rehabilitation programs of children with CP.

**Keywords:** Cerebral palsy, virtual reality, functioning

## Introduction

Cerebral palsy (CP) refers to damage to the motor centers of the developing brain leading to motor control deficits and disorders of posture and movement in general. Abnormal reflexes, muscular tone disorders and the absence of coordinated and deliberate movements that affect one's skills and ability to respond to daily activities are the main characteristics of CP (Rosenbaum et al., 2007; Himmelmann et al., 2006), leading to decrements in functionality (ICF) (WHO, 2001).

The goal of interventions in CP is to inhibit pathological reflexes, facilitate physiological reactions, and treat abnormal muscle tone through specific techniques, such as stretching and positioning of the child by the therapist (Barber, 2008). Some of the approaches to achieve the above are Bobath-NDT, PNF, therapeutic swimming, adapted physical activity and exercise programs as well as the use of technology and more specifically Virtual Reality (VR) games (as mentioned in Levitt, 2010).

The VR games have been added recently in the rehabilitation of children with CP. In particular, virtual reality refers to the advanced form of human-computer interaction allowing the user to be part of the virtual environment and interact with the environment in real time through the computer (Sandlund, 2011). The recent VR games are different from the older ones in a way that they require from the user to be moving, being active and not just sitting. Such games are provided through a variety of devices such as the Nintendo Wii, Playstation, Xbox 360 Kinect, Interactive Rehabilitation and Exercise Systems-GestureTek (IREX), and the most up-to-date Head Mounted Displays (HMD) (as reported in Pereira et al., 2014).

Studies have shown the positive effects of rehabilitation programs using VR devices upon individuals with CP. Cho, Hwang, Hwang, and Chung (2016), who examined the effect of a combinational gait training program on the Nintendo Wii device in children with CP, observed that the experimental group improved in dynamic balance, maximal walking distance in 2 minutes, and in walking speed. Luna-Oliva et al. (2013) through the Xbox 360 Kinect applied to children with CP found significant improvements in balance, self-service in daily activities, running, jump and the mobility of the arm. Chen, Fanchiang and Howard (2018) in their systematic review and meta-analysis confirmed the positive effects of VR games as an alternative means of rehabilitation for children with CP.

However, there are few studies leading to conflicting results. The researchers in these studies observed that programs with VR devices are not as effective as traditional approaches used in rehabilitation programs for children and adolescents with CP (Ravi, Kumar, & Singhi, 2017; Robert, Ballaz, & Lemay, 2016). Further investigation therefore seems essential to confirm the effect of VR interventions as an evolving method for the rehabilitation of individuals with CP.

The Head Mounted Display (HMD) devices are considered the "rising power" in VR games (Pereira et al., 2014). The user, through the device that placed on his/ her head, reproduces the game very close to the eyes at a sufficiently high resolution, and feels that he/ she is part of the virtual environment. The participant does not just see a virtual image on a screen, but interacts with the game itself by being part of it and trying to complete the levels set by the game, which motivates him/ her to try harder. A review of literature has revealed a limited number of publications evaluating the impact of HMD devices on the functionality and rehabilitation of children, adolescents and adults with CP or other disorders in general. San Luis, Atienza, and San Luis (2016) for example, who tested the acceptability and efficacy of HMD devices in stroke patients, observed that patients reported no discomfort from the device (e.g. dizziness) and improvement of their balance and ability to walk. Similar results were also observed in the studies of Kim, Darakjian, and Finley (2017) in patients with Parkinson's disease and Shema and colleagues (2015) in elderly with a history of falls and unstable balance.

Overall, the results are usually positive, but sometimes ambiguous about the effectiveness of VR game rehabilitation programs for children and adolescents with CP. These differences may be due to the diversity of devices, the different ways of assessing participants' functional characteristics, the diversity of participants, etc (Pereira et al., 2014). In addition, it has been observed that the effectiveness of HMDs have not yet been sufficiently studied and they may not be regarded as the golden standard of the VR devices in both the entertainment and the rehabilitation of individuals with CP (Pereira et al., 2014).

Based on the above, the present study was designed to examine the effect of a HMD virtual reality games, upon the functionality of children with cerebral palsy (CP).The independent variables were time (pre and post testing) and condition (experimental group and control group). The dependent variables were: a) functionality (primary outcome variables: 30sSTS, TUG, GMFM D & E, 10 meters walking test, 1 minute walking test, b) range of motion (RoM) and spasticity (secondary outcome variables) and c) fatigue, dizziness and enjoyment experienced during the intervention. We anticipated that the intervention program would lead to an improvement in the functionality of CP children. Further, no adverse effects were anticipated, with respect to spasticity, RoM, dizziness and fatigue, and the participants would experience enjoyment throughout their involvement in the program.

## Method

### Participants

A total of 8 children, aging 10 to 11 years, with mild or moderate cerebral palsy (CP), attending the rehabilitation program of a daily physiotherapy center within the wider area of Athens, participated in the present study. The selection criteria were as follows: a) CP diagnosis, b) ability to understand simple instructions and execute commands, c) ability to walk with or without aids (GMFCS E & R I-III), d) absence of any organized activities beyond those in the rehabilitation center, e) absence of epilepsy, f) non-participation in therapeutic approaches such as orthopedic surgery or injection of botulinum toxin A (Botox-A) into the hypertensive muscles during the last 6 months and g)participating in all scheduled sessions with the HMD- in any absence, the session was rescheduled in the following (ninth) week, after the termination of the intervention (Urgen et al., 2016; Luna-Oliva et al., 2013; Cho et al., 2016).

**Measuring Instruments**

The following measures were used in the present study:

Primary Outcome Variables

- Gross motor function

Assessment of gross motor function of children with cerebral palsy (CP) was performed using the gross motor function scale (GMFM). In the present study, only the posture (D) and walking, running, jumping (E) parameters were examined.

- Change of body position

The change in body position was assessed by the sitting-standing test (30 sec Sit to Stand Test–30sSTS).

- Walking

  Walking ability was assessed by the a) 10 Meters Walking Test (10MWT) and b) 1 Minute Walking Test (1MWT).

- Movement

  Movement was assessed by the Time Up and Go test (TUG).

  Secondary Outcome Variables

- Spasticity

  Spasticity in the muscle groups of the upper extremities (elbow and wrist flexors) and lower extremities (hip flexors, knee flexors and extensors, plantar flexors) was assessed using the modified Ashworth scale.

- Passive range of motion

The passive range of motion of the upper and lower extremity joints was assessed with a plastic goniometer. Specifically, the passive range of motion of a) shoulder abduction, b) elbow extension, c) arm extension, d) hip abduction, e) hip flexion, f) knee extension and g) ankle dorsiflexion were assessed.

In addition, an improvised 10-point scale for fatigue, dizziness or nausea and enjoyment experienced during each session was used and assessed orally.

**Procedure**

Power analysis was held for the determination of the appropriate sample size (Grimm, 1993) to detect significant differences in gross motor function. The research study of Urgen et al (2016), with an effect size of 1.74, power of 80%, significance level $\alpha = .05$, and two (2) repeated measures (pre & post test), estimated that the minimum sample size in the present study would be 3 individuals in total, for both groups (experimental and control group).

The assessments were held at 2 separate sessions in a week, just before the initiation and immediately after the termination of the intervention program. The testing order was as follows: a) gross motor function, change of body position, walking and movement tests during the first session and b) spasticity and passive range of motion during the second session. The assessments were counterbalanced within each session. Permission was requested from a daily center for the rehabilitation of children and adolescents with motor impairments in Athens, to conduct the present research study. Upon permission, a signed informed consent was requested from the parents of the children who met the inclusive criteria and were selected to participate. The consent form stated the aims of the research, the content of the intervention program and ensured the anonymity of the participants.

The 8-week intervention program, with a frequency of once a week, was performed as an extra treatment within the weekly schedule. The day of the week and the time of the sessions were fixed for each child, when he/ she had no other planned activities to attend, in a specifically prepared research environment (room). The temperature was held constant (25$^{o}$C) during the sessions which were always held between 10:00 am to 14:00 pm. The frequency of the sessions was set at once/ week by the rehabilitation center, in order to avoid probable conflicts with the ordinary rehabilitation schedule and ensure the cooperation with the staff employed at the rehabilitation center. The primary researcher was the supervisor of the HMD intervention program. The primary researcher and the physiotherapists employed at the rehabilitation center were informed and trained on the implementation of the virtual reality device by a trained technician. The functionality assessments were conducted at the begin and at the end of the program from the employed physiotherapists. The primary researcher trained the physiotherapists and was present during the data collection process.

The primary researcher's training in the use of the virtual reality device was conducted in a field specializing in entertainment through HMD devices. Specifically, the researcher was provided with information concerning the installation of the device in a room, the games that are available and specific instructions of different game options. The researcher pilot tested the HMD device to several colleagues who had never played similar games before, to better familiarize himself, since there is no official certification for HMD use for research purposes, rehabilitation or simply recreation. The HMD games are simply available to everyone who can procure and install them on his/ her own environment.

A stratified random sampling procedure was followed to assign the participants, according to their respective functionality (Classes I, II & III), in the experimental and control conditions. The experimental group (EG) participated in a virtual reality game program with the HMD (HTC Vive) once a week, while continuing the scheduled rehabilitation program at the respective center. The control group (CG) on the other hand continued to follow the center's rehabilitation program.

The virtual reality program included 5 minutes of warm-up with motor skill exercises, 15 minutes of playing the first game with the HMD, 5 minutes of rest and changing the game by the primary researcher, 15 minutes of the second game, and 5 minutes of rest and stretching. The 2 games were selected based on children's preferences, from a list of several games, during their familiarization with the HMD. During the first game, the participants had to hold the controllers, which represented two different colored light swords in the game, to cut in a certain direction with the rhythm of the music different colored cubes (same cube color as the sword) while avoiding walls and bending or stepping right-to-left. The game was provided with increasing difficulty according to the speed, the frequency, the direction and the number of colored cubes the participants needed to cut during the event. During the second game, the participants holding the controllers, which represented two shields in the game, had to hit a ball with the shields to the opposite goal were the "computer-goalkeeper" was in order to defend. At the same time, the "computer" shots had to be repelled with the shields. Both defense and attack required from the participants to a) move in the room and protect their own goal and b) reach the ball and eventually hit it against the "computer-goalkeeper". In addition, through the shields they had the ability to reduce the speed of the ball, allowing them to hit it with more force and proper technique and score easier. The second game was provided with an increasing difficulty, and the participants would level up only if they could beat the "computer" in a previous level.

After the 8 weeks of the virtual reality HMD program, the experimental group continued to follow the physiotherapy program of the rehabilitation center, as did the control group. At the end of the 8 weeks, the functional characteristics were reassessed in both groups to identify possible changes.

**Statistical analysis**

Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS) version 25.0. Separate ANCOVAs examined post test differences, with the effect of pre test partially out. Repeated sample t-tests, with Bonferroni adjustments, examined the effect of the program (pre vs post), separate for each group (EG and CG). The initial level of statistical significance was set at an alpha level of .05.

**Results**

A total of 8 children receiving services at a daily rehabilitation center in Athens participated in the present study. Their ages ranged from 10 to 13 years old and their functionality was grouped according to the GMFCS E & R at levels I (N=4), II (N=2) and III (N=2). They were randomly divided into the experimental conditions (EG=4 and CG=4) and their descriptive statistics are presented in Table 1. The children in the EG attended all eight scheduled sessions of the program with a Head Mounted Display (HMD), and no sessions had to be re-scheduled.

**Table 1.** *Descriptive Statistics*

| Variables | M | SD | N |
|---|---|---|---|
| Age | 10.25 | 0.46 | 8 |
| Gender | | | |
| Males | | | 4 |
| Females | | | 4 |
| Classification GMFCS E & R | | | |
| I | | | 4 |
| II | | | 2 |
| III | | | 2 |

Subsequently, the pre and post assessments for the primary (GMFM (D and E), 10MWT, 1MWT, TUG, and 30sSTS) and secondary (spasticity, ROM) outcome variables, describing the impact of the HMD virtual reality program, are presented in Table 2.

**Table 2.** *Pre and post testing assessments for the primary and secondary outcome variables*

| Variables | M | SD | N |
|---|---|---|---|
| **Primary Outcome Variables** | | | |
| **GMFMD** | | | |
| EG Pre | 79.48 | 26.23 | 4 |
| EG Post | 82.05 | 24.41 | 4 |
| CG Pre | 74.36 | 29.53 | 4 |
| CG Post | 76.92 | 31.61 | 4 |
| **GMFME** | | | |
| EG Pre | 63.89 | 35.76 | 4 |
| EG Post | 67.69 | 34.22 | 4 |
| CG Pre | 66.66 | 37.98 | 4 |
| CG Post | 70.14 | 39.29 | 4 |

| | | | |
|---|---|---|---|
| **10MWT** | | | |
| EG Pre | 16.15 | 16.05 | 4 |
| EG Post | 13.27 | 13.27 | 4 |
| CG Pre | 10.08 | 7.44 | 4 |
| CG Post | 6.95 | 1.79 | 4 |
| **1MWT** | | | |
| EG Pre | 51.75 | 31.67 | 4 |
| EG Post | 60.00 | 33.4 | 4 |
| CG Pre | 59.25 | 27.17 | 4 |
| CG Post | 64.5 | 22.00 | 4 |
| **TUG** | | | |
| EG Pre | 22.98 | 29.48 | 4 |
| EG Post | 17.65 | 22.81 | 4 |
| CG Pre | 78.9 | 144.07 | 4 |
| CG Post | 39.5 | 67.00 | 4 |
| **30secSTS** | | | |
| EG Pre | 13.5 | 5.2 | 4 |
| EG Post | 17.75 | 4.27 | 4 |
| CG Pre | 11.75 | 4.11 | 4 |
| CG Post | 12.5 | 3.7 | 4 |

**Secondary Outcome Variables**

**Spasticity**

| | | | |
|---|---|---|---|
| Wrist flexors left | | | |
| EG Pre | 1.00 | 0.82 | 4 |
| EG Post | 0.5 | 0.58 | 4 |
| CG Pre | 0.25 | 0.5 | 4 |
| CG Post | 0.25 | 0.5 | 4 |
| Wrist flexors right | | | |
| EG Pre | 2.50 | 0.5 | 4 |
| EG Post | 0 | 0 | 4 |
| CG Pre | 0.25 | 0.5 | 4 |
| CG Post | 0.5 | 0.58 | 4 |
| Elbow flexors left | | | |
| EG Pre | 0.75 | 0.5 | 4 |
| EG Post | 0.5 | 0.58 | 4 |
| CG Pre | 0.25 | 0.5 | 4 |
| CG Post | 0.25 | 0.5 | 4 |
| Elbow flexors right | | | |
| EG Pre | 1.00 | 0.82 | 4 |
| EG Post | 0.75 | 0.96 | 4 |
| CG Pre | 1.00 | 1.41 | 4 |
| CG Post | 1.00 | 1.41 | 4 |
| Knee flexors left | | | |
| EG Pre | 2.75 | 1.89 | 4 |
| EG Post | 2.00 | 1.15 | 4 |
| CG Pre | 1.75 | 1.71 | 4 |
| CG Post | 1.75 | 0.96 | 4 |
| Knee flexors right | | | |
| EG Pre | 2.25 | 2.06 | 4 |
| EG Post | 2.00 | 1.83 | 4 |

| | | | |
|---|---|---|---|
| CG Pre | 2.25 | 1.26 | 4 |
| CG Post | 2.00 | 0.82 | 4 |
| Ankle plantar flexors left | | | |
| EG Pre | 2.25 | 0.96 | 4 |
| EG Post | 1.25 | 0.50 | 4 |
| CG Pre | 2.25 | 0.50 | 4 |
| CG Post | 2.00 | 0.82 | 4 |
| Ankle plantar flexors right | | | |
| EG Pre | 2.00 | 1.63 | 4 |
| EG Post | 1.25 | 1.26 | 4 |
| CG Pre | 2.75 | 0.50 | 4 |
| CG Post | 2.25 | 0.96 | 4 |
| Knee extensors left | | | |
| EG Pre | 1.00 | 1.41 | 4 |
| EG Post | 0.50 | 0.58 | 4 |
| CG Pre | 1.00 | 1.15 | 4 |
| CG Post | 1.25 | 1.26 | 4 |
| Knee extensors right | | | |
| EG Pre | 1.25 | 1.50 | 4 |
| EG Post | 1.00 | 1.15 | 4 |
| CG Pre | 1.50 | 1.00 | 4 |
| CG Post | 1.50 | 1.29 | 4 |
| **Range of motion** | | | |
| Shoulder abduction left | | | |
| EG Pre | 133.25 | 10.24 | 4 |
| EG Post | 151.25 | 14.36 | 4 |
| CG Pre | 129.00 | 8.25 | 4 |
| CG Post | 135.50 | 7.72 | 4 |
| Shoulder abduction right | | | |
| EG Pre | 129.75 | 12.12 | 4 |
| EG Post | 148.50 | 16.52 | 4 |
| CG Pre | 131.00 | 6.16 | 4 |
| CG Post | 134.25 | 5.68 | 4 |
| Elbow extension left | | | |

| | | | |
|---|---|---|---|
| EG Pre | 5.75 | 6.75 | 4 |
| EG Post | 7.50 | 11.90 | 4 |
| OG Pre | 4.00 | 5.66 | 4 |
| OG Post | 4.00 | 5.66 | 4 |
| Elbow extension right | | | |
| EG Pre | 6.00 | 9.52 | 4 |
| EG Post | 6.50 | 13.00 | 4 |
| OG Pre | 4.25 | 5.68 | 4 |
| OG Post | 4.25 | 5.68 | 4 |
| Wrist extension left | | | |
| EG Pre | 90.75 | 17.19 | 4 |
| EG Post | 107.50 | 9.57 | 4 |
| OG Pre | 89.25 | 9.91 | 4 |
| OG Post | 98.00 | 8.48 | 4 |
| Wrist extension right | | | |
| EG Pre | 96.25 | 18.30 | 4 |
| EG Post | 104.00 | 11.43 | 4 |
| OG Pre | 88.50 | 9.68 | 4 |
| OG Post | 96.00 | 4.32 | 4 |
| Hip abduction left | | | |
| EG Pre | 40.25 | 11.15 | 4 |
| EG Post | 47.00 | 9.27 | 4 |
| OG Pre | 42.50 | 13.77 | 4 |
| OG Post | 55.25 | 4.99 | 4 |
| Hip abduction right | | | |
| EG Pre | 39.50 | 14.98 | 4 |
| EG Post | 46.75 | 9.29 | 4 |
| OG Pre | 39.75 | 11.84 | 4 |
| OG Post | 55.00 | 7.26 | 4 |
| Hip flexion left | | | |
| EG Pre | 112.75 | 5.50 | 4 |
| EG Post | 112.50 | 5.0 | 4 |
| OG Pre | 114.25 | 13.12 | 4 |
| OG Post | 113.50 | 13.99 | 4 |

| | | | |
|---|---|---|---|
| Hip flexion right | | | |
| EG Pre | 113.25 | 6.99 | 4 |
| EG Post | 117.00 | 4.76 | 4 |
| CG Pre | 111.75 | 11.79 | 4 |
| CG Post | 114.25 | 10.59 | 4 |
| Knee extension left | | | |
| EG Pre | 0.50 | 1.00 | 4 |
| EG Post | 0.00 | 0.00 | 4 |
| CG Pre | 0.50 | 1.00 | 4 |
| CG Post | 0.00 | 0.00 | 4 |
| Knee extension right | | | |
| EG Pre | 0.00 | 0.00 | 4 |
| EG Post | 0.00 | 0.00 | 4 |
| CG Pre | 0.50 | 1.00 | 4 |
| CG Post | 0.00 | 0.00 | 4 |
| Ankle dorsiflexion left | | | |
| EG Pre | 8.00 | 4.00 | 4 |
| EG Post | 11.25 | 4.11 | 4 |
| CG Pre | 8.25 | 7.41 | 4 |
| CG Post | 10.50 | 7.33 | 4 |
| Ankle dorsiflexion right | | | |
| EG Pre | 12.00 | 9.20 | 4 |
| EG Post | 11.25 | 5.61 | 4 |
| CG Pre | 6.50 | 5.51 | 4 |
| CG Post | 7.75 | 5.19 | 4 |

The Intraclass coefficient was used to estimate the reliability. The results are presented in table 3.

**Table 3.** *Intraclass reliability coefficients for the primary and secondary outcome variables*

| Variables | Intraclass Coefficient |
|---|---|
| **Primary** | |
| GMFMD | 0.997 |
| GMFME | 0.998 |
| 10MetersWT | 0.961 |
| 1MinWT | 0.992 |
| TUG | 0.868 |
| 30secSTS | 0.934 |
| **Secondary** | |
| Spasticity | |
| Wrist flexors left | 0.850 |
| Elbow flexors left | 0.873 |
| Elbow flexors right | 0.907 |
| Knee flexors left | 0.789 |
| Knee flexors right | 0.937 |
| Ankle plantar flexors left | 0.644 |
| Ankle flexors right | 0.821 |
| Knee extensors left | 0.744 |
| Knee extensors right | 0.784 |
| Range of Motion | |
| Shoulder abduction left | 0.821 |
| Shoulder abduction right | 0.668 |
| Elbow extension left | 0.799 |
| Elbow extension right | 0.973 |
| Hand extension right | 0.838 |
| Hip abduction right | 0.647 |
| Hip flexion left | 0.968 |
| Hip flexion right | 0.966 |
| Ankle dorsiflexion left | 0.787 |

The ANCOVA results, with respect to the primary outcome variables are presented accordingly. Specifically, the ANCOVA examined the post test differences, excluding the effect of the pre test scores. Repeated sample t-tests, with Bonferroni adjustments were used for post hoc comparisons.

1MWT

The ANCOVA results did not reveal significant post test differences between the two groups (EG & CG), excluding the pre testing effect ($F=0.514$, $p=.506$, $\eta^2=.093$). The post hoc repeated t-tests revealed significant differences across time for the EG ($t=-4.272$, $p=.024$). Examination of the mean scores revealed that the participants in the EG covered significantly wider distance during post testing compared to pretesting. On the contrary, no significant differences were found across time for the CG ($t=-1.830$, $p=.165$). The results are presented in figure 1.

10MWT

The ANCOVA results did not reveal significant post test differences between the two groups (EG & CG), excluding the pre testing effect ($F=0.712$, $p=.437$, $\eta^2=.125$). The post hoc repeated t-tests did not revealed significant differences across time for the EG ($t=1.967$, $p=.144$). In addition, no significant differences were found across time for the CG ($t=1.102$, $p=.351$). The results are presented in figure 2.

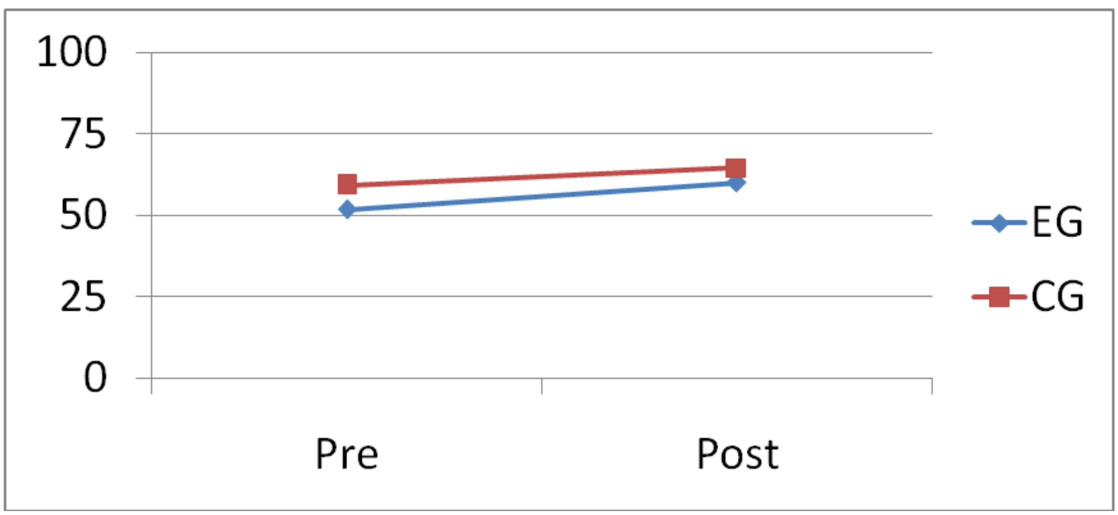


**Figure 1.** *Pre and post test results in the 1MWT for both groups (EG and CG)*

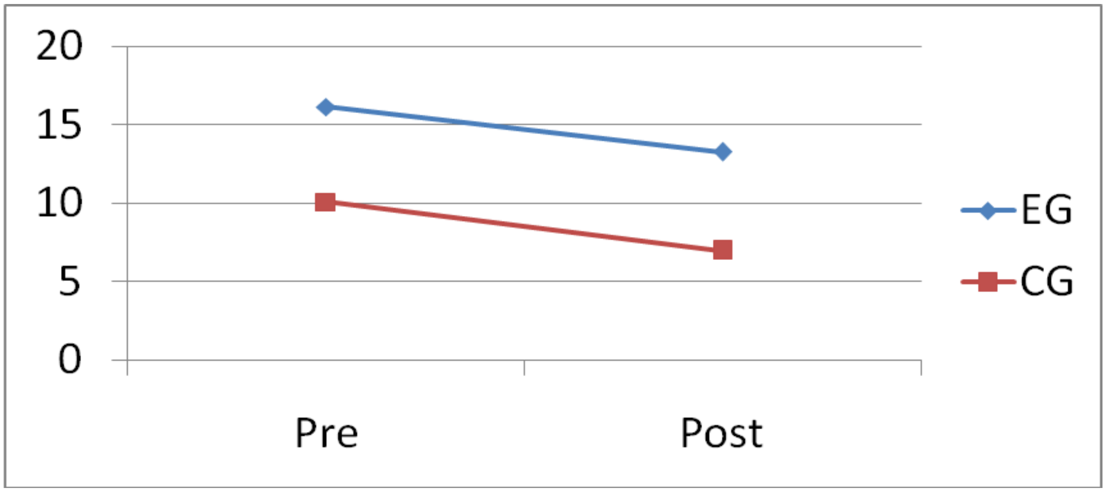


**Figure 2.** *Pre and post test results in the 10MWT for both groups (EG and CG)*

<u>30sSTS</u>

The ANCOVA results were significant, indicating significant post test differences between the two groups (EG & CG), excluding the pre testing effect (F=19.271, p=.007, $\eta^2$=.794). The post hoc repeated t-tests revealed significant differences across time for the EG (t=-6.755, p=.007). Examination of the mean scores revealed that the participants in the EG exhibited more repetitions of sitting and standing in 30 seconds during post testing, compared to pretesting. On the contrary, no significant differences were found across time for the CG (t=-1.000, p=.391). The results are presented in figure 3.

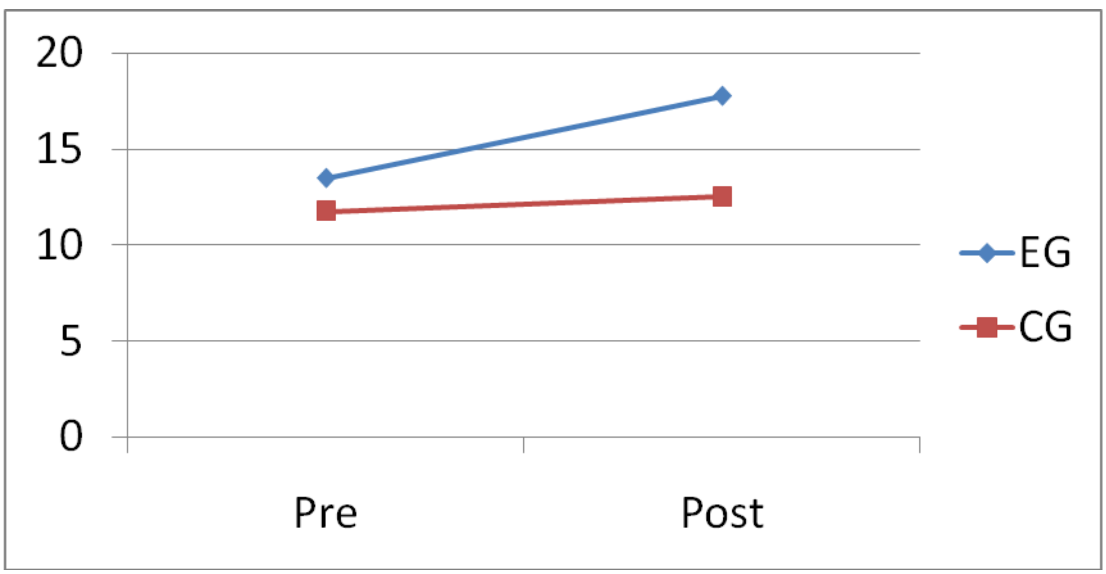


**Figure 3.** *Pre and post test results in the 30sSTS for both groups (EG and CG)*

TUG

The ANCOVA results did not reveal significant post test differences between the two groups (EG & CG), excluding the pre testing effect ($F=0.897$, $p=.387$, $\eta^2=.152$). The post hoc repeated t-tests did not revealed significant differences across time for the EG ($t=1.585$, $p=.211$). In addition, no significant differences were found across time for the CG ($t=1.022$, $p= .382$). The results are presented in figure 4.

GMFMD

The ANCOVA results did not reveal significant post test differences between the two groups (EG & CG), excluding the pre testing effect ($F=0.001$, $p=.991$, $\eta^2=.001$). The post hoc repeated t-tests did not revealed significant differences across time for both the EG ($t=-2.449$, $p=.092$) and the CG ($t=-1.414$, $p=.252$). The results are presented in figure 5.

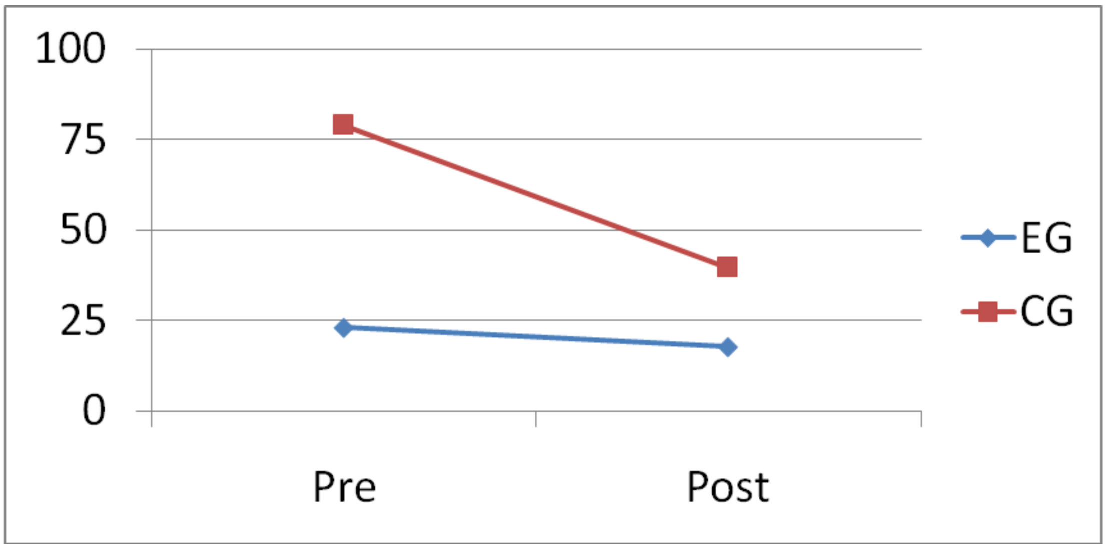


**Figure 4.** *Pre and post test results in the TUG for both groups (EG and CG)*

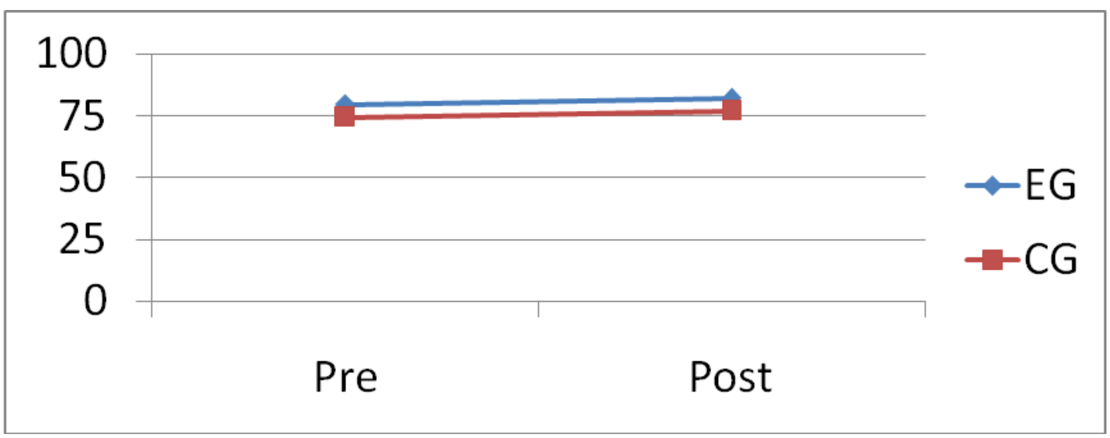


**Figure 5.** *Pre and post test results in the GMFM D for both groups (EG and CG)*

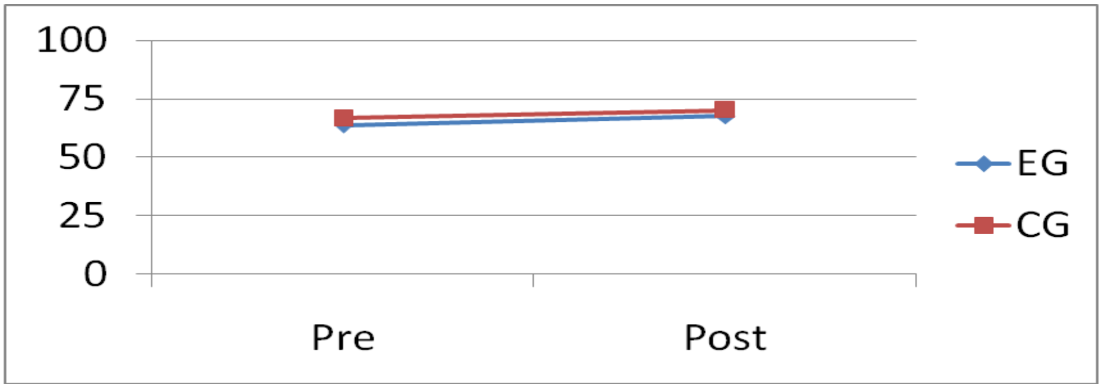


**Figure 6.** *Pre and post test results in the GMFM E for both groups (EG and CG)*

GMFME

The ANCOVA results did not reveal significant post test differences between the two groups (EG & CG), excluding the pre testing effect (F=0.013, p=.915, $\eta^2$=.003). The post hoc repeated t-tests did not revealed significant differences across time for both the EG (t=-2.892, p=.063) and the CG (t=-1.609, p=.206) (figure 6).

Spasticity

In addition, the effect of the program on the secondary outcome variables (spasticity and RoM) was evaluated. Regarding spasticity, both sides (left and right) were evaluated in the pre and post assessments in the elbow flexors, knee flexors, ankle flexors and knee extensors. The differences between the two sides were examined accordingly. The results did not reveal significant differences between the two sides in any of the spasticity variables and were therefore averaged for further statistical analyses (Table 4).

**Table 4.** *Differences in spasticity variables, between right and left side, during pre and post testing*

| Variable (left vs right) | t | p |
|---|---|---|
| Elbow flexors pre | -1.323 | .227 |
| Elbow flexors post | -1.323 | .227 |
| Knee flexors pre | .001 | .999 |
| Knee flexors post | -.552 | .598 |
| Ankle plantar flexors pre | -.424 | .685 |
| Ankle plantar flexors post | -.357 | .732 |
| Knee extensors pre | -1.001 | .351 |
| Knee extensors post | -1.158 | .285 |

The ANCOVAs did not reveal significant post test differences between the two groups (EG & CG), excluding the pre testing effect in elbow flexors (F=0.337, p=.265, $\eta^2$=.239), knee flexors (F=0.155, p=.710, $\eta^2$=.030), ankle plantar flexors (F=2.042, p=.142, $\eta^2$=.378) and knee extensors (F=0.903, p=.386, $\eta^2$=.153).

Range of Motion

With respect to the range of motion (RoM), both sides (left and right) were evaluated during the pre and post assessments in the shoulder abduction, elbow extension, and hip flexion. Differences between the two sides, separately for the pre and post assessments, were examined for each (RoM) variable. The results did not reveal significant differences between sides in any RoM assessment and were therefore averaged for further statistical analyses (Table 5).

The ANCOVA results did not reveal significant post test differences between the two groups (EG & CG), excluding the pre testing effect, in shoulder abduction (F=5.534, p=.065, $\eta^2$=.525) and hip flexion (F=2.313, p=.189, $\eta^2$=.316). The ANCOVA however was significant for the elbow extension (F=7.089, p=.045, $\eta^2$=.586).

**Table 5.** *Differences in the range of motion variables, between right and left side, separately for the pre and post assessments*

| Variable (left vs right) | t | p |
|---|---|---|
| Shoulder abduction pre | .358 | .731 |
| Shoulder abduction post | 1.740 | .125 |
| Elbow extension pre | -.923 | .387 |
| Elbow extension post | .957 | .370 |
| Hip flexion pre | .989 | .640 |
| Hip flexion post | -2.049 | .080 |

## Discussion

The present study was designed to examine the effect of a virtual reality program with a Head Mounted Display (HMD) device on the functionality of children with cerebral palsy (CP). The program lasted 8 weeks, with a frequency once per week, and the children participated in two virtual reality games during each session, while continuing their scheduled physiotherapies at the rehabilitation center. The ICF 'body structures and functions' and 'activities' parameters were evaluated. Specifically, the assessment concerned primary outcome variables: a) gross motor function, b) change of body position, c) walking, and d) movement (activities), and secondary outcome variables: a) spasticity and b) range of motion of certain joints (body structures and functions).

The results showed that the program had positive effects mainly on changing of body position, in a certain range of motion and a limited effect on walking distance and gross motor function. On the contrary, no differences were found in the other outcome variables of the ICF parameters (walking speed, spasticity, movement and range of motion of certain joints).

At the end of the intervention program, the ability to change body position, assessed by the 30sSTS test, was improved. There was an increase in the number of repetitions of the sitting-standing test within 30 seconds in the EG, compared to the CG. The literature review did not provide virtual reality studies evaluating their effect on change of body position in children with CP and the present results therefore could not be matched.

The effect upon the gross motor function is consistent with previous researches who found improvement in GMFM D and E (Cho et al., 2016; Urgen et al., 2016; Luna-Olina et al., 2013). In the present study, however, the improvement for the experimental condition did not exceed the limit of statistical significance. This result is in partially agreement with the above researchers, possibly due to the use of different devices (Nintendo Wii and Xbox 360 Kinect), the frequency, the total duration of the program, and the number of participants who attended the experimental condition.

The effect from the HMD intervention was positive for the one-minute walking test (1MWT) and the children in the EG covered a wider distance at the end of the intervention (approximately 6 meters more). In contrast, the speed, assessed by the 10MWT, showed no effect. These findings are partially in agreement with previous researchers who reported differences in speed and distance covered across time (Cho et al., 2016; Luna-Olina et al., 2013; Brien & Sveistrup, 2011). In addition, no improvement was observed in the TUG test and this result is in contrast with San Luis et al. (2016) who observed an improvement in the TUG test in a monthly game program via HMD device in patients with stroke.

Concerning the secondary outcome variables (spasticity and range of motion), there were no differences between the two groups. The only exception was the range of motion of the elbow extension, which in the EG was greater after the end of the program. It appeared therefore that the intervention had no negative effects and consequently the muscle tone and the joint range of motion did not deteriorate across time. Although the intervention had a minimum frequency of once a week, each session incorporated a tiring program for the children, which, according to older clinical observations, may had increased their muscle tone (Bobath, 1990). The above speculation has appeared in several other studies with particularly difficult intervention programs (Urgen et al., 2016), leading us to conclude that the necessary increase in muscle tone during the program does not necessarily lead to an increment of spasticity. On the other hand, the increase in muscle tone observed due to the recruitment of more muscle groups (Dodd et al., 2002) may consequently influence the performance of children in the present study regarding change of body position, gross motor function and walking ability.

During the intervention, none of the children in the EG reported fatigue, dizziness or nausea during the sessions. The fatigue, dizziness and nausea were evaluated with responses to separate 10-point subjective scales. These scales were similarto those of San Luis et al. (2016), who evaluated the impact of a similar program on adults with stroke. In addition, it should be noted that from the diary kept throughout the two month intervention, the participants in the EG appeared to progress quite a bit, and were able to play at the most difficult levels of the VR games.

Another important aspect was the fact that the children enjoyed themselves very much during the two months intervention. They were all happy when they entered and exit from the playroom during the intervention. In particular, they were always smiling, did not miss any session, and were looking forward to the next session in order to improve themselves and level up. Further, they were tireless, did not want to give up even when the level (difficulty) of the game was particularly difficult for them, wanted to play more often during the week and did not want to finish after 8 weeks because they had fun and experienced improvement in their abilities. Enjoyment in the present study was a) quantitatively assessed with an improvised subjective scale by the students, and b) qualitatively assessed from the primary researcher and staff employed at the rehabilitation center. Even though, this particular evidence is crucial and worthwhile to report.

The present findings are subjected to certain limitations, which do not allow generalization without caution. First, a small number of participants was recruited, approximately of the same age, in a single rehabilitation center in Athens. Second, only ambulatory individuals participated, from classes I, II and III of the GMFCS E & R (walking ability with or without walking aid). Third, the evaluation of dizziness-nausea, fatigue and enjoyment experienced during the program was conducted with an improvised 10-point scale that was used exclusively for the purpose of the study. Fourth, the participants were assessed from the therapists employed at the rehabilitation center, who were not blind for the purposes of the study and had daily contact with them. Fifth, the frequency of the sessions was only once a week, which is not in agreement with similar intervention programs which often recorded frequencies of 2-3 times/ week (Cho et al., 2016; Urgen et al., 2016; Luna-Olina et al., 2013; San Luis et al., 2016).

In the present study, the sample size was initially determined through power analysis, which verified that the number of children who participated was sufficient to confirm the positive effect of the program. Similarly to the present study, the interventions conducted and reported in the literature have mainly used ambulatory individuals with CP. The low frequency however, of once a week, may have affected the present findings. The decision to proceed however was based upon consultation and agreement with the staff employed at the rehabilitation center and was impossible to overcome. Finally, the familiarization process followed with the HMD was essential to prepare the intervention, and was adapted according to the participant's preferences and interest.

The above steps may be seen as an attempt to control the present limitations. In any case, the present findings may not be generalized without caution and replication study is necessary to confirm the findings. Further, the present intervention may not be compared to alternatives, such as Halliwick, therapeutic horseback riding, etc. The virtual realities HMD program needs constant re-evaluation, in CP children of different ages, at different functionality levels (IV & V), with different frequency and duration, with blind assessors and follow up assessments.

In conclusion, the present findings revealed that the virtual reality HMD intervention conducted once a week during the rehabilitation program managed to improve certain functionality variables(ability to change body position, distance covered in a minute, range of elbow extension).It appears therefore that the VR games may have positively affected different areas of functionality. There may have been no significant changes in some variables, but almost all of them improved in a child-friendly environment where the participants spent their time pleasantly looking forward to the next session. Incorporation of the virtual reality games with HMD devices may be considered in the future to add during the classic treatment. The virtual reality HMD interventions are playful, enjoyable, motivate children to participate and provide positive experiences during the rehabilitation programs.

Future researches may examine the effect of VR games through a HMD device to non ambulatory CP children, of different ages, carry out intervention programs that are longer (over two months) with frequency at least twice a week, establish follow-up assessments to examine whether the intervention changes are maintained, assess psychological status with valid instruments and examine, through systematic review and meta analysis, the effect of alternative therapies (including HMD) upon the functionality of children with CP.

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