Complementary Therapies in Clinical Practice 35 (2019) 189–194

Contents lists available at ScienceDirect

Complementary Therapies in Clinical Practice

journal homepage: www.elsevier.com/locate/ctcp

Effects of virtual reality in body oscillation and motor performance of children with cerebral palsy: A preliminary randomized controlled clinical trial☆

Joice Luiza Bruno Arnoni*, Silvia Leticia Pavão, Fernanda Pereira dos Santos Silva, Nelci Adriana Cicuto Ferreira Rocha

Department of Physiotherapy, Neuropediatrics Section, Federal University of São Carlos, Rod. Washington Luis, Km 235, 13565-905, São Carlos, SP, Brazil

A R T I C L E   I N F O

Keywords:
Active video game
Cerebral palsy
Intervention
Rehabilitation
Virtual reality

A B S T R A C T

Background and purpose: Virtual reality is an adjuvant technique to rehabilitation of children with cerebral palsy (CP). It has been gaining prominence in this field because of its accessibility and great levels of motivation it promotes in treatment. However, there is a lack of studies addressing the effects of virtual reality-based therapy on activity levels regarding postural stability, especially considering the level of evidence presented by studies addressing this issue. Therefore, we aim to evaluate the effects of intervention in body sway and gross motor function of children with CP using an active video game.

Materials and methods: In this blind randomized controlled trial, fifteen children with CP, Gross Motor Function Classification System (GMFCS) I-II, regularly attending conventional physical therapy programs, were randomly assigned to an intervention (IG:n = 7) or to a control group (CG:n = 8). In both groups, children remained attending conventional therapy. In addition, IG underwent intervention using an active video game twice a week for 45 min and eight weeks. Standing body sway was assessed using a force plate, and Gross Motor Function Measure (GMFM) dimensions D (Standing) and E (Walking, Running and Jumping) were tested.

Results: Following the virtual reality-based intervention, the IG only showed significant improvements in the GMFM dimensions D ($p = 0.021$) and E ($p = 0.008$). Improvements were clinically significant (D = 10.8%; E = 14.0%). For the CG, no variable analyzed showed differences after eight weeks.

Conclusions: Intervention using an active video game is a promising tool that can improve the gross motor function of children with CP, GMFCS I-II.

1. Introduction

Children with cerebral palsy (CP) have primary impairments in posture and movement [1]. Such impairments limit their functional performance in daily life activities and social participation [2]. In fact, postural control deficits are among the main limiting factors of gross motor function among this population [3,4]. Considering the impacts of these deficits on the daily life of children with CP [2], designing adjuvants rehabilitation techniques that improve postural stability during motor function is relevant [5].

An adjuvant technique that has been noteworthy in rehabilitation of children with CP is therapy based on virtual reality (VR) [6]. It uses active video games and promotes a systematic practice of functional movements and a multisensory feedback. The use of VR-based therapy for rehabilitation promotes perceptual training and accomplishment of tasks in a virtual environment similar to reality, however with higher predictability and activity control levels [7]. In fact, active video games promote functional activities with multisensory demands, active muscle stretching and motor training that challenge postural stability and body alignment. They create propitious therapeutic conditions for rehabilitation of children with neuromotor conditions, such as CP [8].

Previous studies have shown that VR-based therapy provides a visual-perceptual stimulus resulting from dynamic changes of context, which facilitates the performance of controlled exercises and requires attention and several postural adjustments [9–13]. In addition, the playful context promoted by active video games result in high

☆ The study follows the national guidelines and research ethics standards (Resolution 466/2012 of the National Health Council). It was approved by the local Research and Ethics Committee (Case 326–611) and registered in the Brazilian Registry of Clinical Trials (RBR-3zty4w).

* Corresponding author.
E-mail address: joicearnonifisio@gmail.com (J.L.B. Arnoni).

https://doi.org/10.1016/j.ctcp.2019.02.014
Received 28 August 2018; Received in revised form 30 December 2018; Accepted 21 February 2019

motivational levels. Its use as therapy results in greater motor improvements [8]. In this sense, studies have shown that using VR-based therapy improved the functional performance in activities such as reaching [10], squatting [11], standing posture [14], and energy expenditure [15].

Nevertheless, despite positive evidences of VR-based therapy for children with CP [7,8], existing studies addressing this issue do not have a strong design. They miss control groups or randomization of participants, which limits the level of evidence of the VR-based intervention [16]. Moreover, existing studies addressing the effects of VR-based therapy on the motor function of children with CP, by using clinical measurements to evaluate the level of activity of children, rarely use complementary analyses such as kinetic measures by force plate [17]. Evaluation of postural stability using measurements related to center-of-pressure (COP) trajectories provides details on intrinsic mechanisms involved with balance control [16]. In addition, the existing literature addressing this issue does not interpret results in terms of functional gains applied to clinical practice nor perform a detailed analysis of clinically significant changes. This would ensure translating scientific knowledge into clinical practice [7].

Besides our study design and the evaluation tools we adopted in our study, our proposed therapy is based on using a commercially active video game coupled with body scanning as an interface of virtual environment [18]. Considering clinical setting specificities, the use of commercially available video games seem to be a better choice to treat children with CP since they are cost-effective and accessible to professionals involved with rehabilitation. Moreover, body scanning, used as with a virtual environment interface, provides a broader experience within the virtual environment, stimulating the bilateral use of the body [7], which may increase rates of motor learning and retention of trained skills [9]. Nevertheless, there seems to be a lack of studies addressing the effects of VR-based therapy using active video games [9]. The majority of previous studies used commercially available consoles focusing on a real interaction with virtual environment using remote controllers [13,15,19]. Considering that impairment in upper limbs is frequently observed in CP children, the use of remote controllers as interaction tools with the virtual environment may limit the access of children with mild upper limb impairments to this type of therapy [20,21]. Other studies have used software and/or equipment such as specific gloves and hats [7] that might be effective; nevertheless, they are expensive and not accessible.

The aim of this study is to investigate the effects of VR-based therapy using an active video game coupled with body scanning on the postural stability and gross motor function of children with mild CP. Considering the multisensory feedback provided by a broader experience within the virtual environment [7] and the high levels of motivation provided by VR-based therapy [18,22], we expect that this therapy adjuvant may increase motor improvement in children with CP compared to the conventional therapy. Therefore, our initial hypothesis is that the therapeutic training in a virtual environment for eight weeks can improve body stability and gross motor function in children with CP.

2. Materials and methods

2.1. Study design

A randomized, comparative, controlled, single-blind study with a longitudinal design was performed at the Laboratory of Analysis of Child Development in Physical Therapy Department. The local Ethics Committee for Human Research approved the study (case# …). It is in agreement with the Declaration of Helsinki and the resolution no. 466/2012 of the National Health Council. Children were admitted in the study after the parents signed an informed consent.

2.2. Participants

We initially calculated the sample size required to our study by considering the type of statistical analysis we intended to perform (MANOVA: repeated measures, within-between subjects' interaction), the assumed effect size (r = 0.6), and power of statistic tests (80%). The required sample size we found comprised 35 children.

Patients were recruited through posters in rehabilitation centers and posts in social media between October 2013 and October 2014. Children with mild spastic hemiplegic CP (n = 15), levels I and II of the *Gross Motor Function Classification System* (GMFCS), aged between five and 14 years (mean = 10.0 ± 3.0 years), were invited to participate. Potential volunteers were screened, and eligible patients attended an initial screening. Parents/guardians of eligible children signed an informed consent.

The inclusion criteria were a) regularly attending physical therapy programs for more than six months, b) being able to understand simple verbal commands and to interact with the proposed games, and c) GMFCS Level I or II. The exclusion criteria were a) having bone deformities and/or muscle shortening, potentially limiting the intervention, b) having undergone orthopedic surgeries or neurochemical blockages in the last six months, c) sensory deficits (visual and/or hearing) not corrected by auxiliary devices, d) cardiorespiratory limitations of any intensity, such as low exercise tolerance and excessive tiredness, e) children who had continuous contact (home use for entertainment) or usual contact (during physical therapy) with active consoles such as Playstation 3™, Nintendo Wii™ and X-Box™ 360° Kinect (to prevent effects of previous uses of the devices).

2.3. Procedures

The probabilistic sample of children with CP included in the study was randomly assigned to either an intervention group with active video game (IG) or a control group (CG) attending conventional therapy. The allocation of participants into each group was randomly made by drawing lots. The allocation is shown in Fig. 1. Allocation was conducted by a researcher who did not know the objectives and the experimental hypothesis of the study.

2.4. Evaluation of body sway

To evaluate body sway, participants were instructed to stand barefoot on a force platform (Bertec400, sampling frequency 1000 Hz) with their feet parallel to and aligned with the side of their hips. While standing on the platform, the children were asked to stand as steady as possible for 30 s looking at a dot positioned at eye level 1 m in front of them [23,24]. The initial position of the feet was marked on the platform with chalk in order to standardize and ensure a consistent positioning [24]. Participants performed three valid trials with 2 min of rest between each trial [24]. We considered the performed trial as valid if the child was able to stand 30 s on the force platform without intentionally moving the body.

We performed low-pass filter medio-lateral and anteroposterior CoP time series with a fourth-order Butterworth filter and a cut-off frequency of 5 Hz. Force plate data were normalized by the participant's body weight. The following variables were calculated: total CoP displacement (cm), anterior-posterior and medial-lateral displacement (cm), anterior-posterior and medial-lateral amplitude of CoP displacement (cm), area (cm^2) and mean velocity (cm/s) of CoP sway. The mean of the three performed trial was used to conduct the statistical analysis.

2.5. Gross motor function assessment

The participant's gross motor function was assessed using the Gross Motor Function Measure (GMFM) tool. The reliability, validity and responsiveness of GMFM scores have been well documented for

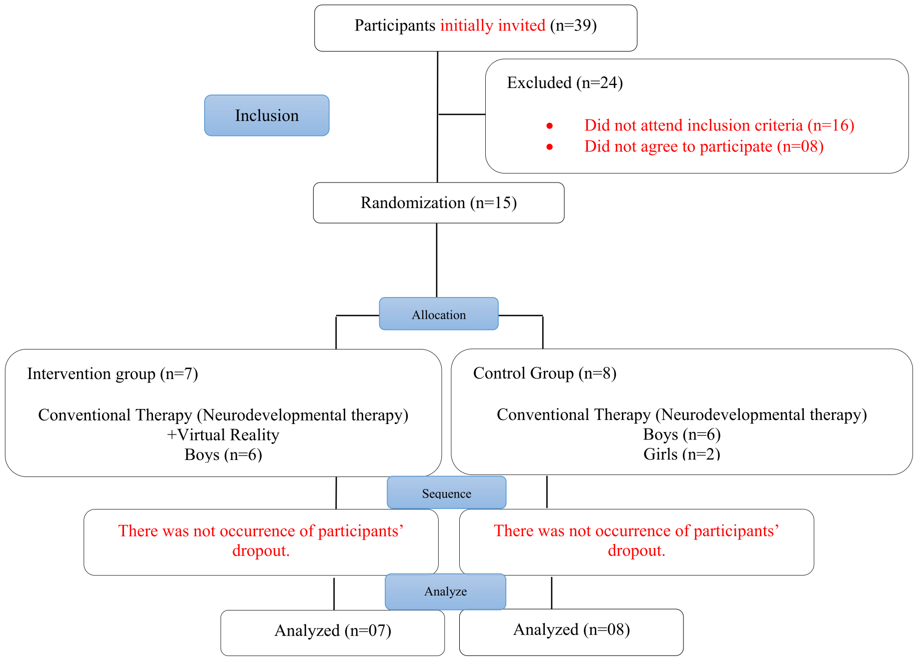

Fig. 1. Flow chart of recruitment and group assignment of children in the study.

children with CP, with excellent test–retest coefficients (intra-class correlation coefficients ranging from 0.76 to 1.00)[25]. The GMFM includes 88 items in five dimensions: (A) lying and rolling, (B) sitting, (C) crawling and kneeling, (D) standing, and (E) walking, running and jumping. This study used the dimensions D and E since they involve actions closer to those performed during the VR intervention. The minimal change considered clinically significant by the instrument is 1% [25,26]. To obtain the clinical significance, the difference between the final GMFM percentage (post-intervention) is subtracted from the initial GMFM percentage (pre-intervention) for each child in the dimensions D and E.

Previously obtained intrarater reliability value was equal to 100% by the equation: [number of agreements/(number of agreements + number of disagreements) * 100]. The order of assessments in each time point was standardized for all children and split into two different days. On the first day, the evaluation of body sway was performed; on the second day, the assessment using the GMFM tool was performed to ensure that the child would not be exhausted during testing.

2.6. Intervention

Immediately after collecting baseline data, the subject received a sealed opaque envelope containing each participant's allocation. Therefore, every participant was allocated into one of the two groups. After baseline assessments, the participants started the VR intervention (IG) or followed conventional physical therapy treatment twice a week, following the parameters of neurodevelopmental therapy with a practical and playful approach (CG) [27]. Each session lasted 50 min and aimed to strengthen and stretch muscles, prevent deformities and biomechanical misalignment, and improve functionality in activities of daily life using supporting equipment such as rollers, wooden benches and therapeutic balls.

The IG, in addition to attending conventional therapy twice a week following the exact same parameters of neurodevelopmental therapy [27], underwent an additional VR intervention twice a week in individual sessions lasting 45 min for eight consecutive weeks [7,18]. The treatment protocol was carried out under the supervision of a physical therapist not involved with the evaluation. The main evaluator did not know the patient's allocation.

The IG was submitted to a VR-based therapy described below. Four commercially available Kinect Adventures games (20,000 Leaks, Space Pop, River Rush and Reflex Ridge) were used. The games were chosen due to their ability to recreate motor skills similar to those tested in GMFM dimensions D and E. In each session, children were exposed to two different games (20 min each game) with 5 min of rest between them. The therapy was conducted using the commercially available X-Box™ 360° console and the Kinect sensor (Microsoft®). The equipment was synchronized to a 32-inch TV. The child was placed in front of the TV screen for calibration and then invited to start the game. For children using orthoses, assistive devices were tested for child positioning, adjusted when necessary and kept during the entire experimental procedure and intervention. The order of the games was randomized by drawing lots to minimize accommodation effects. All games were played in a basic level, and no participant was able to reach a higher level during the intervention. Game details are shown in Table 1. During the games, verbal cues were given by the researcher to correct compensatory movements made by the children seeking to maintain biomechanical alignment.

Participants of both groups were retested one day after the end of the VR intervention or one day following the eight weeks after the initial evaluation. The evaluations were performed by two trained physical therapists with experience on GMFM testing and no knowledge about the study objectives and the group allocation.

An intention-to-treat analysis was made ensuring that all children were assessed and reassessed in the planned times. There was no dropout.

3. Statistical analysis

Descriptive statistics (means, standard deviations) across trials were performed. Data distribution was tested for normality and homoscedasticity using the Kolmogorov-Smirnov and Levene tests, respectively. Nonparametric data were transformed using hyperbolic transformation of first degree ($Xi = 1/xi$). The tests for normality and homoscedasticity were performed again after data transformation. A multivariate analysis of variance (MANOVA) was performed to detect differences among subjects before and after the intervention (two

Table 1
Description of the games adopted during virtual reality-based intervention.

Game	Description of motor activities in each game
Game 1 20.000 Leaks	The avatar is inside a glass box at the bottom of the sea. The goal is to cover the holes made in the glass box by the fish that passed by. The motor tasks performed are: squats. Elbow extension. Wrist and fingers extension. Abduction and adduction of hips and horizontal adduction of shoulders.
Game 2 Reflex Ridge	The avatar is positioned on a moving trailer. The goal is to overcome the obstacles along the route. The motor tasks performed are: lateral displacements of the body. Squats and jumps.
Game 3 River Rush	The avatar is inside a boat that goes down the rapids of a turbulent river with various obstacles. The goal is to overcome the obstacles picking up as many coins as you can. The motor tasks performed are: lateral detachments and weight-bearing on the lower limbs to control the direction of the boat and jump each obstacle so that the boat jumps simultaneously surpassing them.
Game 4 Space Pop	The avatar is in a room that simulates low gravity and from the movement of the upper limbs. It can control how much it floats to reach the bubbles arranged in the environment. The goal is to pop the bubbles that come up everywhere. The motor tasks performed are: steps in lateral and anterior-posterior directions associated with abduction and adduction of the shoulders.

levels: pre- and post-intervention) and differences between groups (two levels: IG vs. CG). The analysis was performed considering all CoP dependent variables (total CoP displacement, anterior-posterior and medial-lateral amplitude of CoP displacement, area and mean velocity of CoP sway). Effect sizes were reported as partial eta squared (n^2p) and were categorized as low (> 0.01), medium (> 0.06) or high (> 0.14) [28].

The Shapiro-Wilks test indicated a non-normal distribution of GMFM scores. Thus, for comparison among subjects (pre- and post-intervention, dimensions D and E), the nonparametric Wilcoxon test was performed. The effect sizes of tests were calculated and reported as (r).

Following the analysis above, we calculated the percent of change (% change) of all variables related to body sway using the formula: ([POST-PRE]/PRE × 100). The tests were performed according to the normality of distribution of variables. The Mann-Whitney test was used for variables with a normal distribution and the independent *t*-test was used for variables with a non-normal distribution. The Cohen's d test was used to investigate the practical relevance of percent change results, where a value of 0.2 was considered a small effect, a value of 0.5 was a medium effect, and a value of 0.8 was a large effect [29]. Statistical analyses were performed using the software SPSS (version 19.0) *(SPSS Inc. Chicago, IL, USA)*. The statistical significance level was $p < 0.05$.

4. Results

We initially invited 34 children with CP to take part in the study. Among the invited children, only 15 met our inclusion criteria. Therefore, after randomization process, seven children were assigned to IG and eight to CG. All children initially tested completed the VR intervention. The description of the allocation process of participants was reported in the flow diagram on Fig. 1.

Table 2 shows the anthropometric and functional characteristics of each participant included in our study.

We conducted comparative tests to ensure that anthropometric and functional characteristics of participants were not different between groups. We did not find differences between groups for none of the analyzed characteristics. The groups were similar for gross motor or function on Dimension D (p = 0.78) and Dimension E (p = 0.78), as well as for age (p = 0.71), weight (p = 0.30) and height (p = 0.65).

We did not observe main effects of group (F (1.5) = 1.127, p = 0.411, n^2p = 0.385), time (F (1.5) = 1.226, p = 0.372, n^2p = 0.405) or interaction group × time (F (1.5) = 0.247, p = 0.931; n^2p = 0.121) for none of the variables of body sway. The statistical power of the analysis was 0.085.

We observed significant time differences for IG (pre- vs. post-intervention) for both dimensions D (Z (1) = −2.310, p = 0.021, r = 0.596) and E (Z (1) = −2.672, p = 0.008, r = 0.690) of the GMFM. We did not observe significant time difference in GMFM for CG.

Clinically significant changes were measured by percentage difference (PD) obtained in GMFM dimensions D (PD_D) and E (PD_E). For the IG, the PD-D was 10.8% and the PD_E was 14.0%, both considered clinically significant. The CG showed values below 1% for both dimensions (PD_D = 0.27% and PD_E = 0.15%), indicating that there was no clinically significant change after eight weeks of conventional therapy.

The percent change (% change) of variables related to CoP displacement are shown in Table 3. Means, confidence intervals (lower bound, upper bound) and values of Cohen's d test are also shown.

5. Discussion

Our study aimed to investigate the effects of a VR-based intervention using an active video game on body stability and gross motor function of children with CP levels I-II of GMFCS. Our initial hypothesis was partially supported by the results. We only found differences in gross motor function (dimensions D and E of the GMFM) for the IG after the tested therapy. We did not find effects of intervention on postural stability. Even considering the percent of change in the variables analyzed, we did not find clinically significant changes in postural sway. In fact, the effect size found for these variables was small.

Contrary to our results, Deutsch et al. (2008) [13] found a reduction in body sway and a better distribution of body weight in lower limbs after [13] VR-based sessions in a 13-year-old child with CP (GMFCS level III). That study was a case report, thus presenting low scientific evidence. Moreover, the authors evaluated a child with moderate motor impairments, different from our sample, which comprised children with levels I-II of GMFCS. It might be possible that children with CP presenting mild motor impairments (levels I-II of GMFCS) would have reached a ceiling effect in postural stability during upright stance, limiting the effects of the proposed intervention on CoP trajectories. Moreover, still considering the aforementioned possibility, the activity used to test postural sway in our study may also explain the absence of effects on postural stability that we found. In fact, children with GMFCS levels I-II are able to keep an upright stance without falling. Thus, the chosen tested posture would not have been sensitive enough to capture stability changes resulting from the intervention since the children did not show previous relevant balance impairments in this posture.

The VR-based therapy involved active games that required unexpected and unpredictable body movements determining postural threats that should be overcome to maintain stability in space. Thus, the choice of functional tasks to be tested, such as gait, postural transitions or reaching, would be suitable to test the effectiveness of the adopted intervention since these movements require greater biomechanical adjustments resulting in different patterns of body sway. This seems to be more in tune with the chosen games for rehabilitation protocol. Accordingly, further studies should address the effects of VR-based therapy on postural stability by testing postural sway during functional tasks.

Different from the main effects on postural stability, the VR-based therapy resulted in gross motor function improvements in the dimensions D and E of GMFM in IG. We chose GMFM to test VR-based therapy

Table 2
Characteristics of participants considering anthropometric and functional data.

Subject	Group	Gender	Weight (Kg)	Height (cm)	Age (month)	CP Topography	GMFCS
1	IG	Ma	26.4	121.0	5	RH	I
2	IG	Fe	22.6	152.0	8	RH	I
3	IG	Ma	21.4	125.5	8	LH	I
4	IG	Ma	35.9	134.5	9	RL	I
5	IG	Ma	31.7	153.5	13	RL	I
6	IG	Ma	54.9	165.5	13	RL	I
7	IG	Ma	50.1	159.5	13	RL	II
			34.71 ± 13.21	144.50 ± 17.39	M = 10.0 SD ± 3.36		
8	CG	Ma	20.2	107.5	5	RH	I
9	CG	Ma	18.4	138.0	7	LH	I
10	CG	Ma	22.8	127.0	8	LH	II
11	CG	Ma	28.6	149.5	10	RH	I
12	CG	Fe	41.9	156.0	10	RH	I
13	CG	Ma	26.0	122.0	11	RH	II
14	CG	Fe	34.5	154.5	12	LH	I
15	CG	Ma	37.2	165.5	13	RH	I
			28.70 ± 8.45	140.00 ± 19.85	M = 9.39 SD ± 2,79		

Legend: (IG) Intervention group. (CG) Control group. (Ma) Male. (Fe) Female. (Kg) Kilogram. (M) Mean. (SD) Standard Deviation for the amounts related to the weight. Stature and Age. (cm) Centimeter. (RH) Right hemiplegia. (LH) Left hemiplegia. GMFCS I: Child can walk indoors and outdoors and climb stairs without using hands for support. Can perform usual activities such as running and jumping. Has decreased speed. Balance and coordination. GMFCS II: Child has the ability to walk indoors and outdoors. And climb stairs with a railing. Has difficulty with uneven surfaces. Inclines or in crowds. Has only minimal ability to run or jump.

Table 3
Variables of body sway for each groups before and after intervention.

Variables	Group	% Change	[min/máx]	Cohen's d
Total displacement [cm]	Intervention	−15.93	[-30.07/27.28]	0,05
	Control	−14.53		
Displacement AP [cm]	Intervention	1.45	[-34.37/41.75]	0,11
	Control	−2.22		
Displacement ML [cm]	Intervention	2.45	[-56.36/66.16]	0,09
	Control	−2.44		
Amplitude AP [cm]	Intervention	−3.66	[-47.28/35.88]	0,04
	Control	2.03		
Amplitude ML [cm]	Intervention	6,23	[-72.84/95.03]	0,15
	Control	−4.85		
Area [cm^2]	Intervention	23.32	[-118,83/	0,09
	Control	13.29	138.89]	
Mean velocity [cm/s]	Intervention	20.22	[-122,79/69.55]	0,32
	Control	46.84		

Abbreviations: AP, antoreposterior; ML, mediolateral; cm, centimeters; s, seconds.

effects because it contains activities similar to those carried out in the virtual environment during our experimental intervention.

The effects of VR-based therapy on gross motor function are conflicting in literature [9,20,26]. Brien and Sveistrup (2011) [20] did not find changes in the dimension E of GMFM after an intensive VR-based intervention after five consecutive days in four teenagers with CP GMFCS level I. Considering the severity of neuromotor deficits observed in children with CP in this previous study [20], the intervention was possibly not long enough to provide functional changes for the participants. Moreover, the study design adopted by the authors [20] had biases, such as absence of control group and absence of probabilistic sample or randomization of participants among groups. Similarly to our results, Luna-Oliva et al. (2013) [9] found positive effects of VR-based therapy on GMFM dimensions D and E of nine children with CP (after a eight-week intervention using an active video game coupled with a body scanner). Nevertheless, the authors' methodological design did not include a control group, which is an important research problem. The main factors for an excellent internal validity in clinical trials include the presence of a control group, a random distribution of participants into groups, intention-to-treat analysis, blind sample and evaluators (whenever possible), and recruiting groups with homogeneous characteristics [30]. Methodology rigor is essential to ensure a proper data interpretation, thus creating a high level of scientific evidence.

Our results suggest that the virtual environment was able to simulate components of the real physical world in a controlled virtual environment and provide functional motor gains. Indeed, following the motor training in virtual environment, the individual's movements could be adjusted based on environment information [31] by exploration and selection of the most appropriate motor action. Together, the use of the multi-sensory feedback (provided by the contact with the virtual environment) and constant therapist hints during the VR-based therapy were possibly the main factors guiding adaptive responses to the virtual environment. The need to accomplish tasks in a virtual environment (by an active video game with body scanning) challenges sensory and neuromotor systems. The visual system is responsible for constantly adjusting the attention required for accomplishment of activities [9]. The vestibular system continuously reacts to gravity and inertial forces to maintain stability. Finally, the somatosensory system frequently captures changes in body position and joint alignment [9]. Therefore, visual, vestibular and somatosensory systems seem to contribute to the selection of the best route of information processing and the emergence of adaptive motor responses [32].

Contrary to CG, which showed insignificant percent changes (lower than 1%) [25], the IG showed clinically significant changes in GMFM with percent changes of 10.8% in the dimension D of GMFM and of 14% in the dimension E. In fact, the calculation of clinically significant changes after VR-based intervention ensures a better description of the clinically feasibility of the tested intervention, which ensures translating scientific knowledge into clinical practice. Only few studies performed this type of analysis, which allows better applying the results of our results to clinical practice. Gordon, Roopchand-Martin, and Gregg (2012) [11] also reported an average change of 7% in GMFM after a six-week VR intervention in six children with CP, between six and 12 years of age. However, the authors did not report the children's levels of GMFCS. The knowledge about gross motor function level is important to interpret the effects of interventions since the capabilities and motor demands change according to the level, requiring distinct therapeutic choices [20]. Therefore, since therapeutic effects of VR may differ according to the child's level of GMFCS, the intervention plan should also consider the functional level.

The changes in gross motor function point out to the feasibility of using VR-based therapy for training gross motor skills in children with CP. Nevertheless, it is worth considering the summation effects of VR-based therapy and conventional intervention. The latter is responsible for training musculoskeletal components such as stretching during functional tasks (to preserve and gain joint mobility) and preparing the body to perform the activities in a virtual environment. On the other hand, VR-based therapy provides multisensory stimuli, accomplishment of functional tasks and energy expenditure. Thus, VR-based therapy is an adjuvant of conventional therapy. Moreover, we believe that the association of both types of intervention is more beneficial to children when compared to its isolated use. Future studies should evaluate the effects of different therapy combinations.

Among the main limitations of our study is the reduced sample size. Although we have taken methodological care to avoid bias, we could not analyze a larger sample. Nevertheless, although we have tested a small sample, we could find significant changes following our VR-based intervention, with medium effect size to results. Moreover, the literature points out the need of preliminary studies to evaluate the feasibility, acceptability and cost of therapy or therapeutic tools preceding studies that are more robust. Such preliminary studies should guide future studies in addressing the investigated issue [33] because they allow elucidating questions about sample size, variables of interest for research and therapy intervals, explore community acceptance and costs, guide researchers and clinicians to develop future research.

Our study is relevant as it points out the potential feasibility of VR-based therapy. There is a need for new controlled studies addressing the issue of intervention in population with CP.

6. Conclusion

VR-based therapy improved gross motor function in children with mild CP, as demonstrated by the gains in the dimensions D and E of GMFM. Nevertheless, the therapy did not increase postural stability during upright stance in the children. Therefore, the addition of VR-based therapy to therapeutic planning of children with mild CP may benefit the rehabilitation process by promoting motor gains. We highlight the need of a correct prescription for this tool to ensure good therapeutic results and solid clinical guidelines.

Acknowledged

The authors declare that the study was financially supported by a grant from Coordenação de Aperfeiçoamento de Pessoal de Nível Superior and FAPESP (2017/11259-6; 2016/10396-7 2013/13380-6).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ctcp.2019.02.014.

References

[1] M. Bax, D.M. Frcp, P. Rosenbaum, et al., Review Proposed Definition and Classification of Cerebral Palsy , April 2005 Executive Committee for the Definition of Cerebral Palsy, (2005), pp. 571–576. April.
[2] A.N. Dos Santos, S.L. Pavão, A.C. De Campos, N.A.C.F. Rocha, International classification of functioning, disability and health in children with cerebral palsy, Disabil. Rehabil. 34 (12) (2012) 1053–1058, https://doi.org/10.3109/09638288.2011.631678.
[3] S.L. Pavão, A.N. dos Santos, M.H. Woollacott, N.A.C.F. Rocha, Assessment of postural control in children with cerebral palsy: a review, Res. Dev. Disabil. 34 (5) (2013) 1367–1375, https://doi.org/10.1016/j.ridd.2013.01.034.
[4] H. Liao, A. Hwang, RELATIONS O F BALANCE FUNCTION AND GROSS MOTOR, (2003), pp. 1173–1184.
[5] D.L. Damiano, (June 2009), Child Neurol. (2013), https://doi.org/10.1177/0883073809337919.
[6] D.E. Levac, J. Galvin, When is virtual reality " therapy "? Arch. Phys. Med. Rehabil. (2013), https://doi.org/10.1016/j.apmr.2012.10.021.
[7] L. Snider, A. Majnemer, V. Darsaklis, (April), Virtual Reality as a Therapeutic Modality for Children with Cerebral Palsy vol. 13, (2010), pp. 120–128, https://doi.org/10.3109/17518420903357753.
[8] S.K. Tatla, K. Sauve, N.V. Liisa, H. Charlene, Evidence for Outcomes of Motivational Rehabilitation Interventions for Children and Adolescents with Cerebral Palsy : an American Academy for Cerebral Palsy and Developmental Medicine Systematic Review, (2013), pp. 593–601, https://doi.org/10.1111/dmcn.12147.
[9] L. Luna-Oliva, R.M. Ortiz-Gutiérrez, R. Cano-de la Cuerda, et al., Kinect Xbox 360 as a therapeutic modality for children with cerebral palsy in a school environment: a preliminary study, NeuroRehabilitation 33 (4) (2013) 513–521, https://doi.org/10.3233/NRE-131001.
[10] K.I. Ustinova, J. Perkins, L. Szostakowski, L.S. Tamkei, W.A. Leonard, Acta Psychologica Effect of viewing angle on arm reaching while standing in a virtual environment : potential for virtual rehabilitation, Acta Psychol. 133 (2) (2010) 180–190, https://doi.org/10.1016/j.actpsy.2009.11.006.
[11] C. Gordon, S. Roopchand-Martin, A. Gregg, Potential of the Nintendo Wii™ as a rehabilitation tool for children with cerebral palsy in a developing country: a pilot study, Physiotherapy 98 (3) (2012) 238–242, https://doi.org/10.1016/j.physio.2012.05.011.
[12] J.E. Deutsch, A. Mirelman, Virtual reality-based approaches to enable walking for people poststroke, Top. Stroke Rehabil. 14 (6) (2007) 45–53, https://doi.org/10.1310/tsr1406-45.
[13] J.E. Deutsch, M. Borbely, J. Filler, K. Huhn, P. Guarrera-bowlby, Case Rep. 88 (10) (2008).
[14] V. Gatica-Rojas, R. Cartes-Velásquez, E. Guzmán-Muñoz, et al., Effectiveness of a Nintendo Wii balance board exercise programme on standing balance of children with cerebral palsy: a randomised clinical trial protocol, Contemp. Clin. Trials Commun. 6 (2017) 17–21, https://doi.org/10.1016/j.conctc.2017.02.008.
[15] L. Foley, R. Maddison, Use of active video games to increase physical activity in children: a (virtual) reality, Pediatr. Exerc. Sci. 9 (2010) 7–20, Accessed date: 24 November 2014.
[16] D.K. Ravi, N. Kumar, P. Singhi, Effectiveness of virtual reality rehabilitation for children and adolescents with cerebral palsy: an updated evidence-based systematic review, Physiotherapy 103 (3) (2017) 245–258, https://doi.org/10.1016/j.physio.2016.08.004.
[17] J.E. Sajan, J.A. John, P. Grace, S.S. Sabu, G. Tharion, Wii-based interactive video games as a supplement to conventional therapy for rehabilitation of children with cerebral palsy: a pilot, randomized controlled trial, Dev. Neurorehabil. 20 (6) (2017) 361–367, https://doi.org/10.1080/17518423.2016.1252970.
[18] J.L.B. Arnoni, B.N. Verdério, A.M.A. Pinto, N.A.C.F. Rocha, Efeito da intervenção com videogame ativo sobre o autoconceito, equilíbrio, desempenho motor e sucesso adaptativo de crianças com paralisia cerebral: estudo preliminar, Fisioterapia Educ. Pesqui. 25 (3) (2018) 294–302, https://doi.org/10.1590/1809-2950/17021825032018.
[19] J. Shin, G. Song, G. Hwangbo, Effects of conventional neurological treatment and a virtual reality training program on eye-hand coordination in children with cerebral palsy, J. Phys. Ther. Sci. 27 (7) (2015) 2151–2154, https://doi.org/10.1589/jpts.27.2151.
[20] M. Brien, H. Sveistrup, An intensive virtual reality program improves functional balance and mobility of adolescents with cerebral palsy, Pediatr. Phys. Ther. 23 (3) (2011) 258–266, https://doi.org/10.1097/PEP.0b013e318227ca0f.
[21] R.N. Boyd, M.E. Morris, H.K. Graham, Management of upper limb dysfunction in children with cerebral palsy: a systematic review, Eur. J. Neurol. 8 (2001) 150–166, https://doi.org/10.1046/j.1468-1331.2001.00048.x.
[22] K. Harris, D. Reid, The influence of virtual reality play on children's motivation, Can. J. Occup. Ther. 1 (2005), http://cjo.sagepub.com/content/72/1/21.short , Accessed date: 24 November 2014.
[23] S.L. Pavão, J.L.B. Arnoni, N.A.C.F. Rocha, Effects of visual manipulation in sit-to-stand movement in children with cerebral palsy, J. Mot. Behav. (2017) 1–6.
[24] J. Rose, D.R. Wolff, V.K. Jones, D.A. Bloch, J.W. Oehlert, J.G. Gamble, Postural balance in children with cerebral palsy, Dev. Med. Child Neurol. 44 (01) (2002) 58, https://doi.org/10.1017/S0012162201001669.
[25] L.M. Avery, P.L. Rosenbaum, S.D. Walter, Improved scaling of the gross motor function measure for children with cerebral palsy: evidence of reliability and validity, Phys. Ther. 80 (9) (2000), https://doi.org/10.1093/ptj/80.9.873.
[26] A.L. Gordon, Pediatric neurology rehabilitation for children after acquired brain Injury : current and emerging approaches, Pediatr. Neurol. 46 (6) (2012) 339–344, https://doi.org/10.1016/j.pediatrneurol.2012.02.029.
[27] J.M. Howle, Neuro-Developmental Treatment Approach: Theoretical Foundations and Principles of Clinical Practice, NeuroDevelopmental Treatment, 2002.
[28] John T.E. Richardson, Eta squared and partial eta squared as measures of effect size in educational research, Educ. Res. Rev. 6 (2011) 135–147, https://doi.org/10.1016/j.edurev.2010.12.001.
[29] J. Cohen, N.L.E.A. Hillsdale (Ed.), Statistical Power Analysis for the Behavioral Sciences, second ed., 1988.
[30] B. Cavalcanti, E. Aranha, How Assess Intensive Care Randomized Trials 21 (11) (2009) 219–225.
[31] B.J. Mohler, W.B. Thompson, S. Creem-Regehr, et al., Visual motion influences locomotion in a treadmill virtual environment, Assoc. Comput. Mach. (2004) 19–22, https://doi.org/10.1145/1012551.1012554.
[32] L. Mochizuki, A.C. Amadio, As informações sensoriais para o controle postural, Fisioterapia em Mov 19 (2) (2006) 11–18.
[33] Peter G. Smith, Richard H. Morrow, DAR, Field Trials of Health Interventions: A Toolbox, third ed., OUP Oxford., Oxford (UK), 2015.