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Effects of active videogame-based intervention on self-concept, balance, motor performance and adaptive success of children with cerebral palsy: preliminary study

Efeito da intervenção com videogame ativo sobre o autoconceito, equilíbrio, desempenho motor e sucesso adaptativo de crianças com paralisia cerebral: estudo preliminar

El efecto de la intervención con videojuego activo sobre el auto concepto, el equilibrio, el desempeño motor y el éxito adaptativo de niños con parálisis cerebral: el estudio preliminar

Joice Luiza Bruno Arnoni[1], Bruna Nayara Verdério[2], Andressa Miliana Alves Pinto[3], Nelci Adriana Cicuto Ferreira Rocha[4]

ABSTRACT | Children with cerebral palsy (CP) commonly perceive themselves different from their typical peers due to their neuromotor condition, affecting their motivations and activity performance. Virtual reality (VR) seems to be an effective tool to improve motivation and motor performance in rehabilitation. The aim of this study was to verify the effects of VR-based intervention by means of active videogame on self-concept, balance, motor performance and adaptive success in children with CP. Eight children with CP, 10.37 years (±3,29), levels I and II of Gross Motor Function Classification System were submitted to a VR-based intervention, twice a week with sessions of 45 minutes during 8 weeks. The games used in intervention addressed balance, motor coordination, jumps, squats and lateral displacement of the body. Self-concept was tested using Childhood Scale of Self-concept Piers-Harris, balance using Motor Development Scale (MDS) (motor quotient 3), motor performance using MDS (general motor quotient). The games scores were used to test adaptive success on virtual environment. We found significant differences after intervention for all the testes areas. For self-concept scale, the differences appeared in the domains: Anxiety, Intellectual, Popularity, Physical Appearance, Satisfaction and Happiness. It seems that VR-based intervention might interfere with the way children with CP perceive themselves, apart from improve their balance, motor performance and adaptive success. Thus VR-based intervention is a potential tool to assist rehabilitation professionals to improve these aspects of children's health condition.

Keywords | Virtual Reality; Cerebral Palsy.

RESUMO | Crianças com paralisia cerebral (PC) comumente são identificadas como diferentes de seus pares típicos devido à sua condição neuromotora, o que afeta a motivação e consequentemente o desempenho em atividades. A realidade virtual (RV) pode ser uma ferramenta potencial para melhora de aspectos motivacionais e desempenho motor durante a reabilitação. O objetivo deste estudo foi verificar o efeito de um programa de intervenção fundamentado em RV utilizando um videogame ativo no autoconceito, equilíbrio, desempenho motor e sucesso adaptativo de crianças PC. Participaram do estudo oito crianças entre 5 e 14 anos (10,37±3,29), com diagnóstico de PC, níveis I e II no GMFCS. O autoconceito foi avaliado com a Escala Infantil

Study developed in the Child Development Analysis Laboratory, Department of Physical Therapy, Universidade Federal de São Carlos (UFSCar) – São Carlos (SP), Brazil.

[1]Physical Therapist, PhD student in Physical Therapy, Graduate Program, Universidade Federal de São Carlos (UFSCar) – São Carlos (SP), Brazil.

[2]Physical Therapist, graduated from the Faculdade de Taquaritinga (FTGA) – Taquaritinga (SP), Brazil.

[3]Physical Therapist, graduated from the Universidade Federal de São Carlos (UFSCar) – São Carlos (SP), Brazil.

[4]Professor, Physical Therapy Program and Physical Therapy Graduate Program, Universidade Federal de São Carlos (UFSCar) – São Carlos (SP), Brasil.

Corresponding address: Joice Luiza Bruno Arnoni – Rua Dr. Jonas Novaes, 937, Planalto Paraíso – São Carlos (SP), Brasil – Zip Code: 13562-020 – Phone number: +55 (16) 3306-6709 – E-mail: joicearnonifisio@gmail.com – Financing source: Capes (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) – Conflict of interest: Nothing to declare – Presentation: Oct. 16th, 2017 – Accepted for publication: Apr. 4th, 2018 – Approved by the Ethics and Human Research Committee, protocol no. 326,611/2013.

de Autoconceito Piers-Harris, o equilíbrio por meio do domínio quociente motor 3 da Escala de Desenvolvimento Motor. Para avaliação do desempenho motor foi utilizado o quociente motor geral, e as pontuações dos jogos avaliaram o sucesso adaptativo no ambiente virtual. A intervenção aconteceu durante oito semanas, sendo duas sessões semanais de 45 minutos cada. Foram utilizados quatro jogos ativos com demandas de equilíbrio, coordenação motora, saltos, agachamentos e deslocamento lateral do corpo. O teste de Wilcoxon foi usado para verificar as diferenças pré e pós-intervenção. Constatou-se diferença após a intervenção nos domínios: ansiedade, intelectual, popularidade, aparência física, satisfação, felicidade, equilíbrio, desempenho motor, e pontuação dos jogos. Conclui-se que a RV pode influenciar na forma com que essas crianças se enxergam quanto ao autoconceito, equilíbrio, desempenho motor geral e sucesso adaptativo, ajudando os profissionais a desenvolver formas de terapia que possam melhorar tais aspectos.

Descritores | Realidade Virtual; Paralisia Cerebral.

RESUMEN | Niños con parálisis cerebral (PC) comúnmente se identifican como distintos de sus pares típicos debido a su condición neuromotora, lo que afecta la motivación y consecuentemente el desempeño en actividades. La realidad virtual (RV) puede ser una herramienta potencial para la mejora de los aspectos motivacionales y para el desempeño motor durante la rehabilitación. El objetivo de este estudio ha sido certificar el efecto de un programa de intervención basado en RV utilizando un videojuego activo en el auto concepto, en el equilibrio, en el desempeño motor y en el éxito adaptativo de niños PC. Ocho niños entre cinco y 14 años (10,37±3,29), con diagnóstico de PC, niveles I y II en el GMFCS. El auto concepto ha sido evaluado con la Escala Infantil de Auto concepto Piers-Harris y el equilibrio por medio del dominio Cociente Motor 3 de la Escala de Desarrollo Motor. Para la evaluación del desempeño motor ha sido utilizado el Cociente Motor General y las puntuaciones de los juegos han evaluado el éxito adaptativo en el ambiente virtual. La intervención ha ocurrido durante ocho semanas, siendo dos sesiones semanales de 45 minutos cada. Han sido utilizados cuatro juegos activos con demandas de equilibrio, coordinación motora, saltos, sentadillas y desplazamiento lateral del cuerpo. La prueba de Wilcoxon ha sido usada para certificar las diferencias pre y pos intervención. Se ha constado la diferencia después de la intervención en los dominios: Ansiedad, Intelectual, Popularidad, Apariencia Física, Satisfacción, Felicidad, Equilibrio, Desempeño Motor y puntuación de los juegos. Se concluye que la RV puede influenciar la manera con que esos niños se ven cuanto al auto concepto, al equilibrio, al desempeño motor general y al éxito adaptativo, ayudando a los profesionales a desarrollar maneras de terapia que puedan mejorar tales aspectos.

Palabras clave | Realidad Virtual; Parálisis Cerebral.

INTRODUCTION

Children with cerebral palsy (CP) have altered motion and posture[1] recurring from muscle spasticity and weakness[2] that lead to secondary clinical manifestations such as muscle contractures and shortenings[3]. Such deficits are responsible for one of the most relevant clinical signs of CP, balance deficits[4]. Balance deficit causes lower performance in skills such as walking and functional everyday activities, which may result in restrictions in social participation[5].

The difficulties faced by these children in interacting with the physical environment can impact their self-esteem and self- concept[6]. Self-concept is defined as the perception that children have of themselves in different domains[7] and motivation is a psychological force that encourages the individual to achieve a goal that is challenging[8], that is, the reason that leads the individual to action. Motivation is a critical modulator of functional neural plasticity[9] and considered an intrinsic factor that determines the improvement of motor skills of children with CP[8]. Ziebell et al.[10] found that higher level of motor impairment may influence negatively on self-concept and self-esteem in children with spastic diplegia, levels of *Gross Motor Function Classification System* – GMFCS I to III. Thus, maintaining the child motivated during rehabilitation is a preponderant factor for positive results, because these children have a chronic condition that leads them to remain for long in health service[9].

Technological entertainment tools, commercially available as active video games can train important motor aspects in a motivating context[9], because this type of rehabilitation when applied with continuity and repetition, can improve motor skills[11]. Active video games and interactive games are electronic media that use motion sensors, enabling the user to actively control the virtual environment using their gestures and actions[11]. By playing without worrying about failures, the child is able to train movements systematically in an enriched and motivating environment[12], which enables the sense of self-control in the virtual environment[13], in addition to experiencing situations in which they could face restrictions in the physical environment[14]. The motor improvement generated by the use of an active video game is supported by the context of the proposed task, facilitating the transfer of activities from the virtual environment context to functional activities in the real physical environment[15]. Recent studies have shown positive effects of virtual reality (VR) on motor function of children with CP after rehabilitation with active video games, as indicated by the systematic review of Bonnechère et al.[16]

For the domains of motivation, interest and opportunity to participate in activities, only one pilot study was found in the literature researched, conducted with children with CP, and it was found that these domains improve after four weeks of intervention with an active VR system[17]. However, Harris and Reid[12] suggest further investigation about how motivational may be the contact of children with neuromotor disorders during rehabilitation with VR systems.

Thus, it is observed that there are few reports in the literature that highlight the effects of the use of the VR on the specific domains of self-concept in children with CP. Such pieces of information are relevant because they seek to understand the adaptability of this population to changes of context and how motivation can be a modulator of motor performance optimizing therapeutic results.

Considering the above, the aim of this study is to verify the effect of a systematized, RV-based therapeutic intervention program using a low-immersion active video game and commercially available games on the self-concept, balance, motor performance and adaptive success of children with spastic hemiparetic CP.

METHODOLOGY

The present study was longitudinal, applied, with clinical goals. This study included eight children of both sexes (7 boys and 1 girl), aged 5–14 years (M=10.37±3.29), with medical diagnosis of Cerebral Palsy of the spastic hemiparesis type classified between GMFCS levels I and II. Study participants were selected in specific services of special child care in a city in the state of São Paulo. The study was approved by the Ethics and Human Research Committee (CAAE: 15735313.5.0000.5504, protocol no.: 326,611).

We included children with CP able to understand simple verbal commands and interact with the games. The children were within the appropriate height and weight range for the ages[18]. Parents or guardians were informed about the objectives of the study and asked to sign the informed consent (TFCC) to participate in the study, the children verbally consented to participation in the study. The characterization of the sample can be found in Table 1.

Table 1. Characterization of the participants

Individuals	Sex	Mass (kg)	Height (cm)	Age	Topography	GMFCS	Attendance to therapy (%)
1	M	26,4	121,0	5	HD	I	80%
2	F	22,6	152,0	8	HD	I	90%
3	M	21,4	125,5	8	HE	I	80%
4	M	35,9	134,5	9	HD	I	100%
5	M	31,7	153,5	13	HD	I	84%
6	M	54,9	165,5	13	HD	I	73%
7	M	50,1	159,5	13	HD	II	89%
8	M	52,5	156,0	13	HD	II	90%
		36,94(±13,75)	145,93(±16,61)	10,37(± 3,29)			85,7%(±8,7)

kg: kilograms; cm: centimeter; RH: right hemiparesis; LH: left hemiparesis; GMFCS: *Gross Motor Function Classification System*; GMFCS I: Children who can walk in domestic and external environments, go upstairs and downstairs without using hand support. Can perform usual activities, such as running and jumping. Has decreased speed, balance, and coordination; GMFCS II: The child has the ability to walk indoors and outdoors, and climb stairs using rail. Has difficulty with uneven surfaces, slopes or in crowds. Has only the minimum capacity to run or jump. Percentage of attendance to therapy during the period of intervention with Virtual Reality, calculated using the total days of therapy made available.

The study included no children with: (1) bone deformities and/or; (2) muscle shortenings limiting evaluations or intervention; (3) subjected to surgeries in the past year or application of neurochemical blockade for the past six months; (4) sensory deficits (sight and/or hearing) uncorrected with hearing aid or lenses; (5) cardiorespiratory limitations of any intensity informed by the parents/guardians; (6) children who frequently used active video game consoles, such as: Sony PlayStation 3, Nintendo Wii, and Microsoft Xbox 360 with Kinect, thus ensuring the elimination of influences of use of these devices out of the study. All criteria were checked previously according to information collected from the parents/guardians.

Equipment and instruments for evaluation

To evaluate self-concept we used Piers-Harris Children's Self-Concept Scale[19], which evaluates the domains: behavioral aspect (BA), intellectual and school state (IS), physical appearance (PA), anxiety (AN), popularity (PO), satisfaction and happiness (SH). The score can be 1 or 0 for each response, assessing how the child feels about self. We assigned a score of 1 if the answer was positive attitude and 0 in case of a negative attitude. The final score was generated by the sum in each of the domains[19], considering the higher the self-concept the higher the score. The scale was validated in Portuguese by Veiga[19] and presented high internal consistency (Cronbach's Alpha=0.71) indicating high reliability when applied in healthy children[20].

We used the Motor Development Scale (MDS) of Rosa Neto[21], to evaluate balance we used the motor quotient 3 (MQ3) domain, and to evaluate motor performance we used the general motor quotient (GMQ). The scale evaluates motor development in the domains: fine motricity, global motricity, balance, body schema, spatial organization, temporal organization, and laterality. The MDS proposes motor tasks that vary in degree of difficulty, from least complex to most complex, and was used because it can determine the main deviations in development, often affected in children with CP and sensitive to determine the possible effects of the proposed intervention. Each task performed correctly is assigned 1 point, and at end is generated the general motor quotient (GMQ) based on the sum of all points of completed tasks[21].

GMQ values are interpreted as follows: very high (130 points or more), high (120–129), regular high (110–119), regular medium (90–109), regular normal (80–89), low (70–79), very low (79 or less). The scale has good internal consistency of 0.889[22] and is used to determine motor development deviations, such as deficits concerning body balance and general motor performance, which are commonly faced by children with cerebral palsy in their activities.

Adaptive success is a reliable measure of performance in virtual environment,[23] enabling inferences about the success in each game. Thus, game scores were calculated by the video game itself, based on the number of successes and errors of the child and the estimated time for completion of activity. Points obtained in each game were noted in each VR training session and the final value was obtained by averaging the scores of each game at two times: the second week of intervention, when the children were fully familiar with the games, and the last week of intervention, when they had become skilled in the proposed activities in virtual environment. We considered the greater the adaptive success the higher the score obtained.

Intervention

The intervention was carried out using a 32" tv connected to the console and body scan sensor (Xbox 360 Kinect®), properly calibrated. The console was chosen due to not using controllers, because it could make it difficult to use by children with CP, who often have upper limb impairment.[24] During eight consecutive weeks the children trained in virtual environment, two weekly sessions, individual and in alternate days, with duration of 45 minutes.

In each session, two games were used for a period of 20 minutes each (five repetitions) with an interval of 5 minutes of rest. Four commercially available games were used for the intervention and the order of application of the games was randomized. All children used the games at their basic level and further details about the games used are presented in Chart 1.

During the tasks, verbal tips were provided to correct biomechanical alignment during movements, in an attempt to correct the movements so atypical patterns were not reinforced, always by the same physical therapist. In case the child used orthotics, these were evaluated in relation to their position and were adjusted to be maintained during the intervention. All children/parents/guardians were instructed to continue their rehabilitation activities in conventional neurodevelopmental physical therapy normally during this period. We controlled the number of absences during the 16 sessions, period of intervention with virtual reality. Thus, if the children were absent in more than 2 sessions and if it was not possible to replace these sessions, the children were excluded from the study automatically. All children completed 100% of the sessions and attendance was controlled during therapy, seeking to better observe this aspect. However, there was no case that fit the participant exclusion criterion.

Chart 1. Characteristics of the games used in the intervention

Game 1	The child sees his/her avatar in a glass box at the bottom of the sea, when fish approach making holes. The goal is to cover the holes as fast as possible. Squat, movement of extension of elbow, wrist and fingers, abduction and adduction of hips and shoulders are trained. The game calculates a score based on the time the child takes to cover each hole, so the faster, the greater the score.
Game 2	The child sees his/her avatar in a cart that moves on rails, when obstacles appear the child needs to dodge them until reaching the finish line. Each dodge well done is assigned the performance score. The task involves lateral-lateral displacement of the body, squats and jumps.
Game 3	The child sees his/her avatar that is inside a boat that descends the rapids of a river, the goal is to control the boat and avoid the obstacles, picking up as many coins as possible and passing between the flags arranged in the course. For the score, each coin is worth one point in the game. The task involves lateral-lateral displacement of the body and random jumps.
Game 4	The child sees his/her avatar in a room that simulates low gravity, where bubbles appear randomly. The objective of the game is that the child with the movement of the upper limbs (adduction and abduction), lateral-lateral and anteroposterior displacement bursts the bubbles, the more bubbles burst, the higher the score.

Statistical analysis

Nonparametric tests were applied due to the sample size[25]. The Wilcoxon test was used to determine the possible differences in the times before and after the intervention in the variables for "Self-concept," "Adaptive Success," "Balance," and "General Motor Quotient" (motor performance). For all analyses we adopted the 5% significance level with 95% confidence interval, using the statistical package software SPSS (version 17.0).

RESULTS

We found significant difference between the pre- and post-VR intervention times for the domains of Anxiety, Intellectual Aspect, Popularity, Physical Appearance, Satisfaction and Happiness. However, in the domain of Behavioral Aspect no significant difference was observed. There was significant difference also for MQ3, and GMQ, after the intervention with active video game. We observed significant difference for Adaptive Success for all games: 1, 2, 3, and 4. Results are detailed in Table 2.

Table 2. Self-concept, balance, general motor performance and adaptive success before and after the intervention with virtual reality

	Pre intervention	Post intervention	p	Z	f^2
Self-concept					
Behavioral aspect	11,1(±1,3)	11,7(±1,0)	0,059	-1,890	0,670
Anxiety	3,2(±0,4)	4,7(±1,2)	0,016	-2,414	0,853
Intellectual and school domain	6,3(±0,7)	8,8(±1,2)	0,011	-2,539	0,897
Popularity	3,8(±1,8)	5,8(±1,9)	0,017	-2,379	0,841
Physical appearance	3,6(±1,0)	4,5(±0,9)	0,020	-2,333	0,824
Satisfaction and happiness	5,8(±1,1)	6,5(±0,9)	0,025	-2,236	0,790
MDS					
Balance (MQ3)	37,1(±20,4)	43,8(±20,7)	0,036	-2,100	0,742
General motor quotient (GMQ)	43,5(±14,2)	50,3(±19,6)	0,050	-1,960	0,693
Adaptive success					
Game 1	95,7(±18,9)	121,5(±12,5)	0,012	-2,521	0,891
Game 2	76,1(±20,3)	104,8(±18,3)	0,012	-2,521	0,891
Game 3	103,4(±27,0)	133,1(±16,4)	0,017	-2,380	0,841
Game 4	187,0(±31,9)	219,5(±9,2)	0,017	-2,380	0,841

* Statistically significant values p≥0.05; Effect Size Values (Cohen's f - f2); Values pointed to using mean and standard deviation; MDS: Motor Development Scale.

DISCUSSION

Training with active video game was able to modify the domains of self-concept, balance, global motor performance, and adaptive success.

We observed increased number of positive responses for the domains of anxiety, intellectual aspect, popularity, physical appearance, satisfaction and happiness. Studies have found that children with CP have higher levels of anxiety, usually related to the difficulties faced to perform motor skills skillfully[26]. Due to the motivational characteristics of the use of VR in therapy, it is possible that the children worried less about their failures when interacting with the virtual environment, as they have more freedom to make mistakes and to be successful in a relaxed environment[12].

The intellectual aspect improved with the VR practice, observed by the increase in capacities such as answering questions asked by the teacher, increased speed to complete activities, initiative and pro active activity in school environment, reduction in the worry of the child in school testing, reduction in distraction in classroom. Usually, children with neuromotor impairments such as CP may present the intellectual domain reduced in relation to typical children, which may be caused by deficits in processing and modulation of visual and auditory sensory information[6]. Deficits in thalamocortical pathways may affect the sensory processing in this population[27] in addition to interfering the with limbic system responsible for emotional and motivational processes[28], which may influence the proper use of stimuli received by the child. Considering these aspects, the VR possibly favored the integration of sensory information, by specific stimuli that directed the visual and auditory monitoring in games, indirectly influencing the intellectual aspects of children in the present study. In addition, the motivating, dynamic context with targeted goals may encourage dedication towards success in the tasks, promoting greater attention and enhancing intellectual capacities. Thus, VR may be used as a form of aid to traditional learning techniques[15].

Another relevant result was the improvement in the domain of "popularity" after the intervention. Stevens et al.[29] report that children with CP have small groups of friendship, usually consisting of only one friend and often in the school environment and in most cases they are not maintained out of that environment. Rodkin et al.[30] highlight as a factor of attention the low popularity of children, as it is commonly associated with inflexible, antisocial, and even aggressive behaviors. It is believed that the improvement in the domain of popularity may have been influenced by the performance gain in the virtual environment and consequent confidence about their motor skills, leading the child with CP to interact better in the real environment and even with the other children. In addition, it is known that the ability to explore environments in a safer manner may influence the levels of social activity and participation of the population with CP[31].

The domain of "physical appearance" also improved in children with CP, observed in self-physical image issues considering the deficiencies and potentials. According to Soyupek et al.[32], the way children see themselves has great impact on psychosocial well-being. Taleporos and McCabe[33] report how it is still uncommon for children with disabilities to present a fully positive body image; however, the physical appearance conflicts of these children may be related to social factors and environments of which they are part. Thus, seeing oneself by means of an avatar for a virtual reality game may help indirectly in the perception that children have of themselves regarding their disability, since the commercial game does not enhance any disadvantage faced by the child.

Considering the changes of context, motivational and enriched environments are able to remove the focus from the therapy and the motor deficit presented, making children see themselves more actively and positively[34]. Accordingly, intervention with VR using an active video game may promote improvement in the self-image of children, because in visualizing the avatars and seeing themselves without disabilities they can work the self-esteem and confidence along with the motor aspects.

Such aspects may also have influenced the improvement observed in the domain of "satisfaction and happiness," because this domain can affect the quality of life (QOL) of these children[35]. Studies have observed that children with CP have a reduction in the dimensions of QOL and self-concept[32], among them, satisfaction and physical well-being[36]. Children with CP may have a differentiated self-assessment due to their limitations[37] and being pleased and happy generates well-being[36], which in turn moderates the functional capacity, level of participation, and quality of life[37].

It should be noted that only the domain "Behavioral Aspect" was not modified. In this domain is evaluated the child's behavior in school and family environment, such as lack of parental attention, involvement in fights, and the way the child copes with situations involving people in their midst. According to Majnemer et al.[38], although children with motor deficits present some difficulty to integrate and adapt to daily life, which may result in altered behavior, changes in this domain may take a longer time to happen. Thus, it is suggested that future research approach such domain for a longer time of intervention.

Concerning motor development, we found performance improvement for the domains balance and general motor quotient. These results are consistent with the study of

Pavão et al.[4], which observed improvement both in balance and general motor quotient of a child with CP, GMFCS level I, after 12 sessions of intervention with VR. The authors attributed the positive results of VR to the online feedback received by the child through the projection of their avatar on the screen and through the influence of the game score[4]. This score can be used to know the child's performance in the virtual environment[23]. In addition, the possible sensory deficits of this population[39] can be actively worked on considering the multi-sensorial stimulation provided by VR[40]. Active movement of the head during the games may be responsible for stimulating the vestibular system and consequently the antigravity muscles, crucial for the adequate maintenance of standing posture and postural control. Moreover, potential repercussions on proprioception can be inferred, due to increased joint contact provided by constant shifts in weight loads and alignment of body segments during the execution of the tasks directed by the games.

After the intervention period, we found improvement in these children's adaptive success during the performance of tasks in virtual environment and reflected in game scores. The virtual environment is motivating and presents random practices that leverage the motor learning process[41]. Thus, it is believed that systematic practice of skills can achieve better pattern of movement[42], more organized, coordinated and with less energy spent[43], which can justify the improved game scores. Therefore, it is suggested that future study may address the patterns of movement with more accurate analyses, such as kinematics, during periods considered key for intervention, such as the beginning (less skilled movement) and the end (more skilled movement), seeking to answer questions regarding movement strategies used and their relations with motivational factors as self-concept.

One factor that may have contributed to the findings of the present study was the summation of the effects of VR to the effects of conventional neurodevelopmental therapy, since the children of the intervention group continued on conventional therapy. Neurodevelopmental therapy is focused on handlings that work musculoskeletal and neuromotor components, aiming to improve joint mobility, stretching, strengthening and muscular control[44], considered essential for the preparation for functional activities. VR, in turn, can work musculoskeletal, neuromotor, sensory, and motivational components, in a dynamic, active, and contextualized manner, which strengthens the child's involvement with the environment and may have positive influence on self-concept. Thus, it can be inferred that they complement each other during the rehabilitation period. Accordingly, such results suggest that the association of virtual reality can benefit the child in rehabilitation process. However, more studies need to be conducted to verify the effect of different therapeutic associations, which was a limitation of the present study.

The results support the hypothesis that complex tasks carried out in a dynamic and motivating context can help improve the psychosocial function of the studied population. However, more studies should be conducted with a larger sample and using a clinical trial design.

CONCLUSION

VR through an active video game provides improvement in the performance of activities of balance, general motor performance, adaptive success, and in the self-concept of children with spastic hemiparetic CP, GMFCS levels I and II, functioning as a supplementary therapy to conventional physical therapy techniques.

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