

Role of virtual reality and active video games in motor and executive functions in cerebral palsy: A systematic review

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Abstract

Objective: To explore current evidence on the role of virtual reality and active video games in motor and executive functions compared to conventional physical therapies in cerebral palsy patients.

Method: The systematic review was conducted at the University Institute of Physical Therapy, Lahore, Pakistan, and comprised search on MEDLINE via PubMed, Pedro and Cochrane Central related to randomised and clinical controlled trials published from 2005 to 2020. For critical appraisal of the studies, the Pedro tool was used, while methodological quality assessment was done using the Cochrane risk of bias tool.

Results: Of the 15 articles reviewed, 14(93.3%) reported significant effect of virtual reality and active video games on motor functions. Critical appraisal found the quality of the studies from fair to high. Low risk was found in 4(26.7%) articles in terms of selection, 3(20%) allocation, 6(40%) detection, and 8(53.3%) had attrition bias. Unclear risk was reported in the performance and reporting bias domain in all the 15(100%) articles.

Conclusion: Virtual reality games cannot be used as a substitute for therapy, but along with the conventional physical therapy, they are very effective and produce significant changes in motor functions in cerebral palsy patients. As for executive functions, more research needs to be done to determine the impact of these games at a higher level of brain.

Keywords: Virtual reality therapy, Active video games, Motor rehabilitation, Executive functions.

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Introduction

Neurological disorders are the most prevalent, complicated and expensive diagnoses affecting children health, wellness, growth and development throughout their lifespan promoting childhood disability.¹

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Cerebral palsy (CP) is defined as an umbrella term covering a group of non-progressive, but often changing motor impairment syndromes secondary to lesions or anomalies of the brain arising in the early stages of its development.² CP has a great influence on the everyday life of the young, and children struggle at different levels throughout their life with CP, like struggling to flourish at the academic level, having trouble in socialising, coming across less job opportunities etc. Therefore, the primary objective of interventions should be to foster self-sufficiency and health of CP children by incorporating suitable measures.³

In addition to conventional care and rehabilitation of CP patients, new interventions have been applied recently, precisely the use of games within the intervention.³ In actual fact, these games provide constructive, situational and experiential learning opportunities in addition to active game exploration.³ Studies highlighted the probability of entertaining games as an appealing and exciting approach to develop and enhance valuable skills.³ Therefore, new categories of games are emerging that can be used as rehabilitation tools.

Among these games, two applications, active video or exergames, and virtual reality (VR) games, are described in greater detail. Interactive simulations in VR applications are sensitive to user's movements, which enable a child to perform and learn functional activities while interacting in a virtual environment that appear to be and feel similar to real-world objects and events.⁴ Some researchers have learned that attention, memory and executive functions, in general, can be improved by playing video games, meaning games played on computers or gaming platforms, like Nintendo, Sony PlayStation etc.^{3,5}

VR games and applications produce an exercise environment for children with the feasibility to modify duration, intensity and frequency of practice. VR games can create an environment-friendly space that is similar to the real world in which the children can perform task-specific practices.⁴ Task challenges can be easily modified in a VR environment to provide a child with ample difficulty while playing.

There are no clear recommendations and guidelines about active videogames and VR as motor intervention available to assist clinicians, families and other

stakeholders in making decisions about the use of these games. The current systematic review as planned to gather sufficient evidence about VR and active video games available that have been used in CP, the role of these games in motor functions of upper and lower extremities, executive functions, transferal of learning of these skills to real-world environment, and to assess the strength of the available evidence, achievement of outcomes and impact on quality of life (QOL).

Materials and Methods

The systematic review was conducted at the University Institute of Physical Therapy, Lahore, Pakistan, and comprised search on MEDLINE via PubMed, Pedro and Cochrane Central databases related to randomised controlled trials (RCTs) and clinical controlled trials (CCTs) published from 2005 to 2020. The key words used alone with Boolean operators were CP, Cerebral Palsy, Athetoid Cerebral Palsy OR Dyskinetic Cerebral Palsy OR Atonic Cerebral Palsy OR Hypotonic Cerebral Palsy OR Diplegic Infantile Cerebral Palsy OR Spastic Cerebral Palsy OR Spastic Diplegia OR Monoplegic Cerebral Palsy OR Virtual reality OR virtual reality exposure therapy OR computer game(s) OR Kinect videogame(s) OR PlayStation OR active game(s) OR serious game(s) OR exergame OR computer simulation OR Nintendo OR Sony OR GestureTek OR NeuroVR OR Microsoft or Xbox OR Hocoma OR Motek OR HapticMaster OR Virtual Reality OR Immersion Therapy Physical therapy OR standard rehabilitation exercises OR standard therapeutic exercises OR exercise therapy OR conventional physical therapy OR Motor functions OR motor performance OR Fine motor OR Gross motor OR Movement OR strength OR range of motion OR upper extremity OR upper limb OR Arm OR lower limb OR lower extremity OR leg OR Executive functions.

The RCTs and CCTs included were published in peer-reviewed, professional or scientific journals which used any form of VR or active video games on CP patients, had a standardised assessment tool, and outcomes related to motor and executive functions. Feasibility studies, pilot studies, editorials, commentaries or case series were excluded. The methodological quality assessment of the studies was done using the Cochrane risk of bias (ROB 2) tool and the studies were critically appraised using the Pedro scale.^{6,7} Data was synthesised using

the vote counting method which also concluded the effect of the studies. Meta-analysis was not feasible due to heterogeneity between the included studies.

Results

Of the 166 articles found relevant to the topic, 15(9%) were analysed in detail; 13(87%) RCTs and 2(13%) CCTs (Figure-1). Characteristics of all the included studies were tabulated (Table). Overall, 14(93.3%) studies reported significant effect of VR and active video games on motor functions.

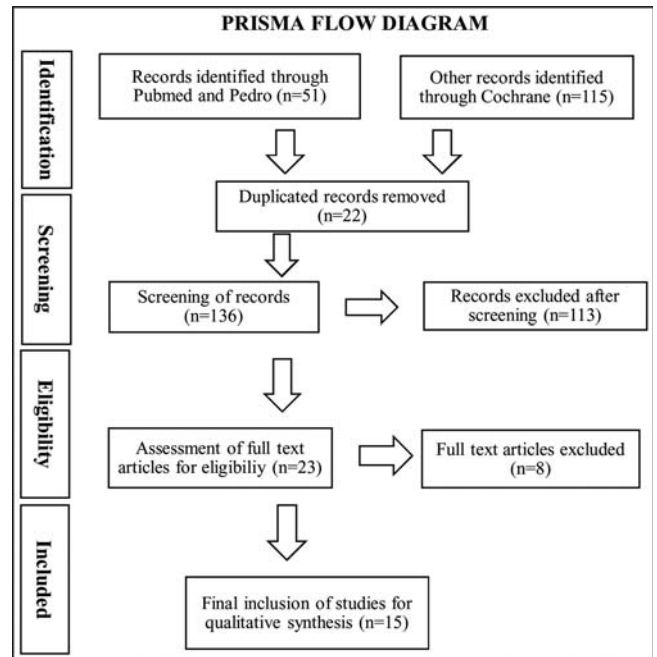


Figure-1: Preferred Reporting Item for Systematic Review and Meta Analysis (PRISMA) flow-chart.

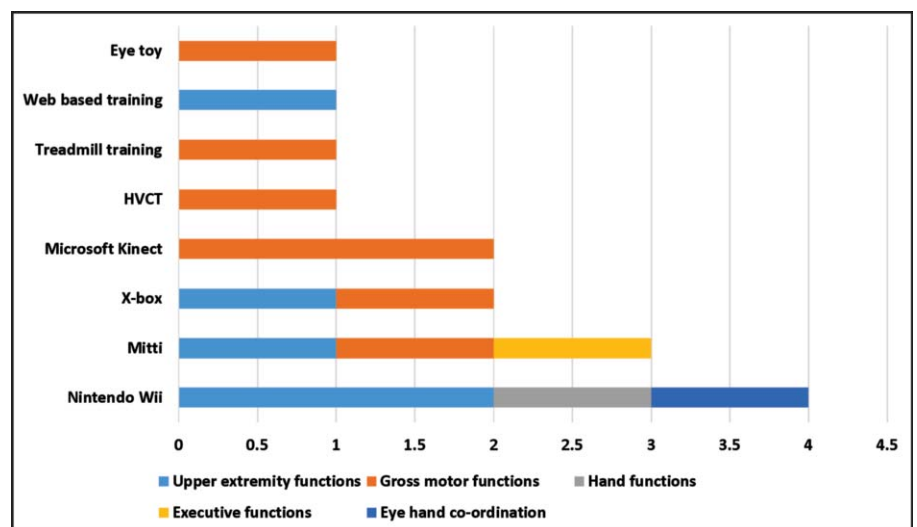


Figure-2: Virtual reality (VR) games in different motor and executive functions.

Table: Characteristics of the included studies.

Study	Total no. of participants	Age	CP type	VR type	Dosage	Training focus	Comparison therapy	Results
Adina M. Piovesana(2016) ⁹	I = 51 C = 51	18-Aug years.	Hemiplegia	Move-it-to-improve-it (MitiiTM), a multi-modal web-based program	20–30 min, six days per week	Executive functions	Care as usual, regular OT/PT	No significant improvement in executive functions
Chia-Ling Chen (2012) ¹⁴	I = 13 C = 15	12-Jun years.	Spastic diplegia Spastic hemiplegia	Home-based virtual cycling training	40 min/day 3 times per week	Gross motor functions, muscle strength	General physical activity	Significant improvement in muscle strength than motor functions
Gönül Acar -2015 ⁶	I = 15 C = 15	15-Jun years.	Spastic hemiparesis	Nintendo® Wii games	45 minutes per session, twice a week, for 6 weeks.	Upper extremity, Functional independence	Neurodevelopmental therapy	Significant difference was not found but affective as combination therapy
Shamekh Mohamed El-Shamy (2018) ¹⁷	I = 20 C = 20	12-Aug years.	Hemiplegia	Nintendo Wii	40 minutes, three times a week for 12 weeks	Hand function	Usual care	Significant improvement in hand function
Eren Avcil -2020 ¹⁸	I = 15 C = 15		Spastic Hemiplegic Diaplegia Dyskinetic	Nintendo® Wii and leap motion controller (LMC) games	1-h sessions 3 times a week for 8 weeks.	Upper extremity functions	NDT-based upper extremity rehabilitation	Significant improvement in upper extremity functions
Sarah James -2015 ¹⁰	I = 51 C = 51	18-Aug years.	Spastic hemiplegia	Move-it to-improve-it (MitiiTM)	20-30 minutes, 6 days/ week for 20 weeks	Occupational performance, upper limb function, and visual perception.	Standard care	No differences between groups on upper extremity functions but improvement in other outcomes
Burcu Metin Ökmen (2019) ¹⁹	I = 23 C = 20	15-May years.	Spastic Dyskinetic Athetoid Diplegia Quadriplegia Triplegia Hemiplegia	EyeToy Game System	An hour three Days a week for four weeks	Motor functions, Functional development	Conventional physiotherapy, occupational therapy	Significant improvements in motor functions
Louise e Mitchell -2016 ¹¹	I = 51 C = 50	17-Aug years.	Hemiplegia	Web-based training	30 minutes, 6 days per week for 20 weeks.	Activity capacity and performance	Usual care	Significant improvement in functional strength and walking endurance
Hamid Reza Rostami (2012) ²⁰	I = 8 C = 8 CIMT = 8 VR+CIMT=8	12-Jun years.	Spastic Hemiparetic	E-Link Evaluation and Exercise System (Version 6 software)	1.5 hours/day 3 times per week for 4 weeks	Upper limb functions	mCIMT, conventional rehabilitation techniques	Significant improvement in upper limb functions
Hsiu-Ching Chiu (2014) ²¹	I = 32 C = 30	13-Jun years.	Hemiplegia	Wii Sports Resort training	40 minutes/day three times a week for six weeks	Coordination strength, hand function, and carers' perception of hand function	Usual physiotherapy	Insignificant differences were found between groups.
Ji-won Shin (2015) ²²	I = 8 C = 8	—	Spastic Diplegia	Nintendo Wii	45 minutes/day, twice a week for 8 weeks	Eye-hand coordination	Conventional neurological physical therapy	Significant improvement in eye-hand co-ordination
Sedef Sxahin -2019 ¹⁵	I = 30 C = 30	16-Jul years.	Hemiplegia	VR Training	45 minutes/day Twice a week, for 8 week	Gross and fine motor functions and independence in daily living activities	Traditional occupational therapy	Significant improvement in gross and fine motor functions

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Study	Total no. of participants	Age	CP type	VR type	Dosage	Training focus	Comparison therapy	Results
Chunhee Cho -2016 ¹⁶	I = 9 C = 9	16-Apr years.	Spastic	Treadmill gait training connected to a videogame-assisted program	30 minutes /day 3 times per week for a total of 8 weeks	Gross motor function, Muscle strength, balance, gait endurance	Treadmill training	Significant improvement in gross motor functions, muscle strength, balance and gait endurance
Joice Luiza Bruno Arnoni (2019) ¹²	I = 7 C = 8	15-May years.	Spastic Hemiplegia	Kinect Adventures games	45 min twice a week for 8 weeks	Evaluation of body sway, Gross motor function assessment	Conventional Physical therapy programs	Significant improvement in gross motor functions.
Rania Bedair -2016 ²³	I = 20 C = 20	10-May years.	Spastic hemiplegia	X-BOX system	30 minutes/session, 3 sessions /week	Upper extremity function	Upper extremity therapeutic program	Significant improvement in upper extremity functions

CP: Cerebral palsy, VR: Virtual reality, OT: occupational therapy, PT: Physiotherapy, NDT: Neurodevelopmental therapy, mCIMT: modified constraint induced movement therapy.

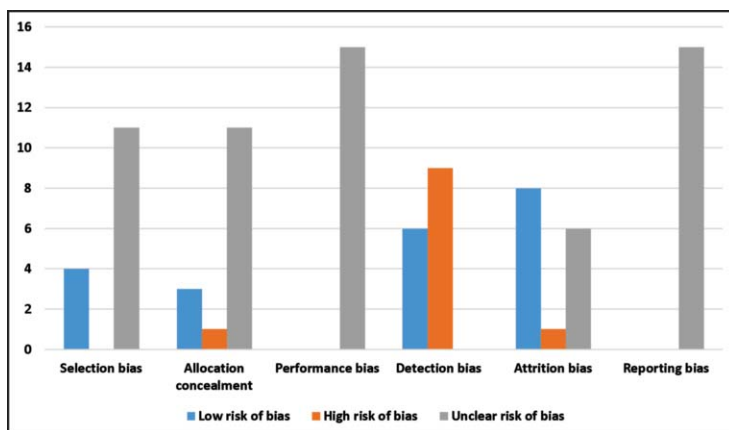


Figure-3: Risk of bias assessment using Cochrane risk of bias (ROB-2) tool.

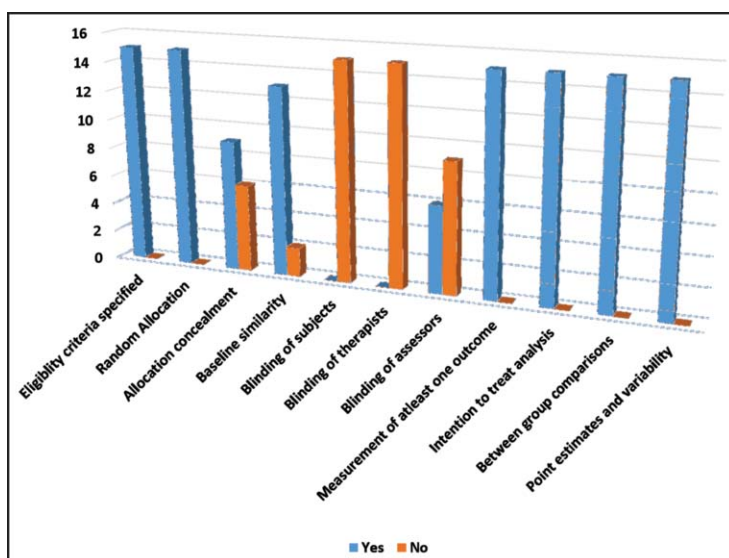


Figure-4: Pedro assessment of the studies reviewed.

Different outcomes and outcome measures were categorised into motor and executive functions. Most researches utilised Nintendo Wii games as a therapy along with conventional physical therapy in their sessions. Other VR games used in these trials were Mitti, Xbox, Microsoft Kinect and Eye Toy for different motor functions (Figure-2). Duration of each session varied from 20 to 90 minutes and 2-6 times per week were required to produce constructive outcomes. Low risk was found in 4(26.7%) articles in terms of selection, 3(20%) allocation, 6(40%) detection, and 8(53.3%) had attrition bias. Unclear risk was reported in the performance and reporting bias domain in all the 15(100%) articles (Figure-3).

Critical appraisal showed 13(87%) studies had high quality with score range 7-9, and 2(13%) had fair quality with score range 5-6 (Figure-4).

Discussion

The current systematic review gathered evidence on the role of different active video and VR games in motor control and executive functions. Both are considered separate applications and have been in use for quite some time for different neurological disorders. These technologies differ in both type and technical complexity. There are a variety of technologies that can be used to implement virtual environments.

Nintendo Wii was found to be used in most of the trials reviewed and significant differences were found in motor functions. In two of these studies, neurodevelopmental therapy was used along with Nintendo Wii games to determine the effect in CP

patients specifically, upper extremity functions.^{8,9} One of the research concluded that neurodevelopmental treatment is effective for improving hand function, but Nintendo Wii games used in addition to the therapy provide enjoyable, motivational and effective rehabilitation programme.¹⁰ According to different studies, Nintendo Wii can be used in rehabilitation to engage children and make activities fun.^{8,10}

Another research determined the effect of conventional neurological treatment and VR training programme, Nintendo Wii games, on eye-hand coordination and visual motor speed, and found significant differences in the VR group compared to conventional neurological physical therapy.¹¹ All the above-mentioned studies found both kind of results on Nintendo Wii games and suggest more well-designed studies on motor functions.

Mitti, Xbox and MS Kinect had also been used in several RCTs. Mitti was used in three of these trials, and two of them determined the effect on upper extremity functions, visual perception, activity capacity and occupational performance, while one focussed on executive functions.¹²⁻¹⁴ The study on executive functions concluded that due to large RCT, Mitii did not lead to significant improvements on measures of EF (executive functions) or parent ratings of EF performance in children with UCP (unilateral cerebral palsy).¹² However, in an appropriately-powered RCT, Mitii led to substantial improvements in daily activities, motor and processing skills, occupational performance, goal attainment and visual processing in UCP children. There were no differences between groups on measures of impaired upper limb function, but Mitii has the potential to be a beneficial component of the therapy for UCP children.¹³

In two RCTs, Xbox and MS Kinect was used to determine the effect of VR games on body oscillation, motor functions, upper extremity functions and activities of daily living (ADLs). These studies concluded that interventions using VR games are a promising tool that can improve gross motor functions, increase active participation of children with motor deficits in majority of upper limb activities through simulating environment and enhance their participation through self-competing activities.^{15,16} RCT utilising novel home-based virtual cycling training (hVCT) programme stated that the programme did not improve gross motor function, but it enhanced knee muscle strength in children with CP.¹⁷

Four RCTs found substantial improvement in gross motor functions after using different VR games and applications.^{15,17-19} Overall, on the basis of current research, as described above, VR and active video games

along with standard physical therapy are very efficient and effective treatment for improving gross and fine motor skills in CP patients. However, more research needs to be done on the effect of these games in executive functions.

Going through all the trials, it was observed that all VR games had different duration in their therapy sessions and did not have a standard dosage or duration. But minimum duration was 30 minutes, 2 times per week for 12 weeks. According to Pedro scoring, many of these RCTs and CCTs were of high quality and described the efficacy of these games along with conventional physical therapy. But ROB 2 reported unclear and high risk of biasness in its different domains in different studies.

Conclusion

The systematic review found that different VR and active video games were utilised in various studies, but mostly Nintendo Wii was used as a therapeutic programme in the VR sessions. Significant improvement in different motor functions was observed, but not many studies were found or major changes were reported related to the executive functions. VR games cannot be used as substitute to the conventional therapy, but when used along with conventional physical therapy, it can be very effective in producing significant changes in motor functions. More well-designed studies are needed to determine the effect of these games on executive functions.

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Conflict of Interest: None.

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