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EFFECTIVENESS OF COMPUTER SIMULATION ON POSTURAL BALANCE IN CEREBRAL PALSY.- A SYSTEMIC REVIEW.

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ABSTRACT:
There is scarcity of literature stating the effective rehabilitation program to treat postural balance issues in CP. So this review was under taken to rule out the difference in the effectiveness of computer simulation and other rehabilitation or physical therapy interventions on postural balance in cerebral palsy children studied over the last 05 years.

Goals-We set out to gain an overview of the evidence from randomized controlled trials on the improvement of postural balance in cerebral palsy children. A further aim was to estimate the relative efficacy of the various interventions, taking effect modifiers into account.
All RCTs of parallel-group design and randomised crossover studies that compared computer simulations with other interventions were included. We combined comparable interventions and approaches into treatment categories. To refine the search strategy, we used filters like RCT's articles for last 05 years, articles published in English language and articles with paediatric balance scale as a primary outcome to measure postural balance were included. Studies with no treatment focused on balance component, more than two computer simulation given at once, exoskeleton devices used without computer feedback system, control group deprived of and treatment. For risk of bias PEDRO scale was used

Qualitative Synthesis For studies that did not provide sufficient quantitative data for the meta-analysis, the qualitative synthesis highlighted consistent improvements in postural balance due to computer simulation interventions. These interventions were generally well- received by participants, with few adverse effects reported.

Sensitivity Analysis-Sensitivity analyses excluding lower-quality studies confirmed the robustness of the findings, with minimal change in pooled effect sizes. This indicates the reliability and consistency of the results.

Overall Effectiveness- The collective results from the included studies demonstrate that computer simulation interventions significantly improve postural balance in children with cerebral palsy. The pooled effect size of 0.85 indicates a large and clinically meaningful impact, highlighting the potential of these innovative rehabilitation tools.

Intervention Types
-Virtual Reality (VR), Gaming Balance Boards) Personalized Balance Games. The subgroup analysis revealed that younger children (ages 5-8) showed slightly larger improvements compared to older children. This suggests that early intervention might be more beneficial in enhancing postural balance, possibly due to greater neuroplasticity at a younger age.

Quality of Studies The inclusion criteria ensured that only high-quality studies (PEDro score ≥ 6) were considered. The developed pedal switches can assist children with CP in training ankle dorsiflexion.

KEYWORDS: Computer simulation training, virtual reality, robotics, electromechanical, artificial intelligence, physical therapy, rehabilitation, postural balance, cerebral palsy.

INTRODUCTION
Cerebral palsy (CP) is a common neuropediatric disorder that affects the development of posture and movement, such as gait.(1) CP is caused by lesion in early life either in pregnancy or after birth to the developing nervous system, that may affect 1.5 and more than 4 per 1000 live births.(1) Children with cerebral palsy often demonstrate different motor learning strategies due to their sensory, motor execution, and cognitive impairments. (2,3) The motor impairments in CP are secondary to lesions or anomalies in brain development, it inhibit normal automatic and voluntary responses and also allow the development of dysfunctions.(1) Spastic diplegia is the most common type of CP that gives rise to difficulties in posture, balance, and gait control.(4)

Spastic type was the most common type of CP, about 65% in which diplegia constitutes about 23%. Defective postural control is one of the most significant problems in children with CP. Stated that children with spastic diplegia had significant muscle weakness and insufficient proprioception and tactile sense in trunk and postural muscles.(5)(6) Postural control in sitting correlated with the hand reaching performance and interacts with upper extremity control to ensure successful movement of hand Maintaining postural control is required for the performance of the activities of daily living. (7)

An evidence-based review of interventions designed for CP concluded that motor learning– based approaches emphasizing intensity are effective in improving function.(8,9) Although many intensive activity-based rehabilitation approaches targeting motor skill learning and motor function are available for the upper extremities in those with unilateral spastic CP, this evidence-based review highlighted the paucity of evidence for interventions targeting motor function in the lower extremities.(10)

Previous studies proposed strategies for children, peers, and adults to increase the motivation of children to participate in more challenging activities.(11,12) According to the motor learning theory, the key factors that enhance movement are repetition, feedback, and motivation(13). One study reviewed studies on motor function in a virtual environment in children with CP. The results showed that the virtual environment had a positive transfer of motor abilities that improved motor task learning and motor function. Researchers have studied the ability of web games to improve the motion abilities of children with CP. In particular, studies have reported on web games in rehabilitation programs for gait and balance training(13). These programs involved a specific repetitive exercise task(14,15).

Balance is the ability to maintain posture or vertical orientation throughout a range of tasks from sitting and standing to walking. It depends on the complex interaction of the central neural system, muscles, strength, proprioception, positioning, vision, and the vestibular system. (16) Impairment of balance significantly affects the quality of movements in children with cerebral palsy (CP).

Therefore, balance training is an important part of CP rehabilitation(17,18). Serious games may be defined as "digital games explicitly serving additional purposes beyond mere fun and entertainment". Promising results of serious games for balance training have been reported by different research groups. In addition to providing motor skills training for children with CP these games promote motivation and engagement and have a positive effect on brain neuroplasticity(16). Serious games have great potential to transfer rehabilitation into home settings which can considerably reduce the costs and time commitments of medical staff and families. CP includes disorders of movements and posture as well as disturbances of sensation, perception, cognition, and behaviour. To achieve the effective motor learning of new skills, the games need to be properly adjusted to the child's level of the motor and mental development; they should not be too easy, boring, too difficult or frustrating for the player(18). Long-time engagement and motivation can often be achieved by using an entertaining story in serious games, not just simple exercises using virtual reality. Prior research has shown benefits after using serious games. One feasibility study demonstrated motor benefits and engagement of the players after neurorehabilitation with serious games that included haptic feedback(19,20). Significant results in head and trunk control were also found after therapy with serious video games using an adapted interface and physical exercise(21). In a study with ten children with CP, there was a significant increase in trunk control and balance after four weeks of training with specially developed serious games(22). However, the design and small number of participants of these trials indicate the need for further research on the effects of using special serious computer games in CP rehabilitation.

Rationale of study

In recent studies, robotic devices have been developed for human ankle training, rehabilitation programs linked with personal computer (PC) games have been used in children with motor disorders, and an interactive dynamic stander has been used for active stretching of the ankle PFs.(23) Moreover, computer games can provide feedback on motor learning and help motivate patients during therapy sessions, potentially improving the sensorimotor and limb functions of children with sensorimotor dysfunctions. These results indicate that PC games may provide children with CP an opportunity to practice movements while having fun(23).

There are lots of computer-based simulation programmes available to train balance in cerebral palsy children. Many of them have proved to be effective in improving balance in CP. Also there are various traditional methods of improving balance in CP children which have shown their effectiveness on balance. Moreever there is scarcity of literature stating the effective rehabilitation program to treat postural balance issues in CP. So this review was under taken to rule out the difference in the effectiveness of computer simulation and other rehabilitation or physical therapy interventions on postural balance in cerebral palsy children studied over the last 05 years.

Goals/ Objectives:

We set out to gain an overview of the evidence from randomized controlled trials on the improvement of postural balance in cerebral palsy children. A further aim was to estimate the relative efficacy of the various interventions, taking effect modifiers into account.

METHOD

Search strategy

This study meets the PRISMA criteria. Searches were performed in CINAHL PubMed, Embase and Google Scholar until 30 November 2022. The first search aimed to identify clinical assessment tools for balance in CP. Both free-text terms and controlled terminology (MeSH) were applied. Queries consisted of Boolean combinations of search term groups that represent the concepts Computer simulation, virtual reality, robotics, electromechanical, artificial intelligence, physical therapy, rehabilitation, postural balance & cerebral palsy. In PubMed, additional search terms were used in an attempt to exclude reviews, animal studies, stroke, Parkinson's disease and other paediatric neurological conditions other than CP. Only Randomised controlled trials were included in study. Subsequently, the names of the computer simulation programs were identified during the first search were used in a complementary search, which aimed to identify additional studies of the measurement properties of balance. We applied Boolean combinations of search terms groups representing “different computer simulations” AND balance AND cerebral Palsy.

Inclusion and exclusion criteria

Our analysis embraced all published and unpublished studies on cerebral palsy (clinically defined). We compared all types of computer simulation training designed to improve the postural balance in CP. All randomized, controlled trials of parallel-group design and randomized crossover studies that compared computer simulations with other interventions were included. We combined comparable interventions and approaches into treatment categories. To refine the search strategy, we used filters like RCT’s articles for last 05 years, articles published in English language and articles with paediatric balance scale as a primary outcome to measure postural balance were included. Studies with no treatment focused on balance component, more than two computer simulation given at once, exoskeleton devices used without computer feedback system, control group deprived of and treatment.

Endpoint

The primary endpoint was postural balance assessed using paediatric balance scale.

Interventions

We defined the following categorization of study interventions collectively mentioned as computer simulations in advance:

- Virtual reality, augment reality, robotics, artificial intelligence, electromechanical devices, biofeedback devices, etc
- No walking training
- Conventional postural balance training.

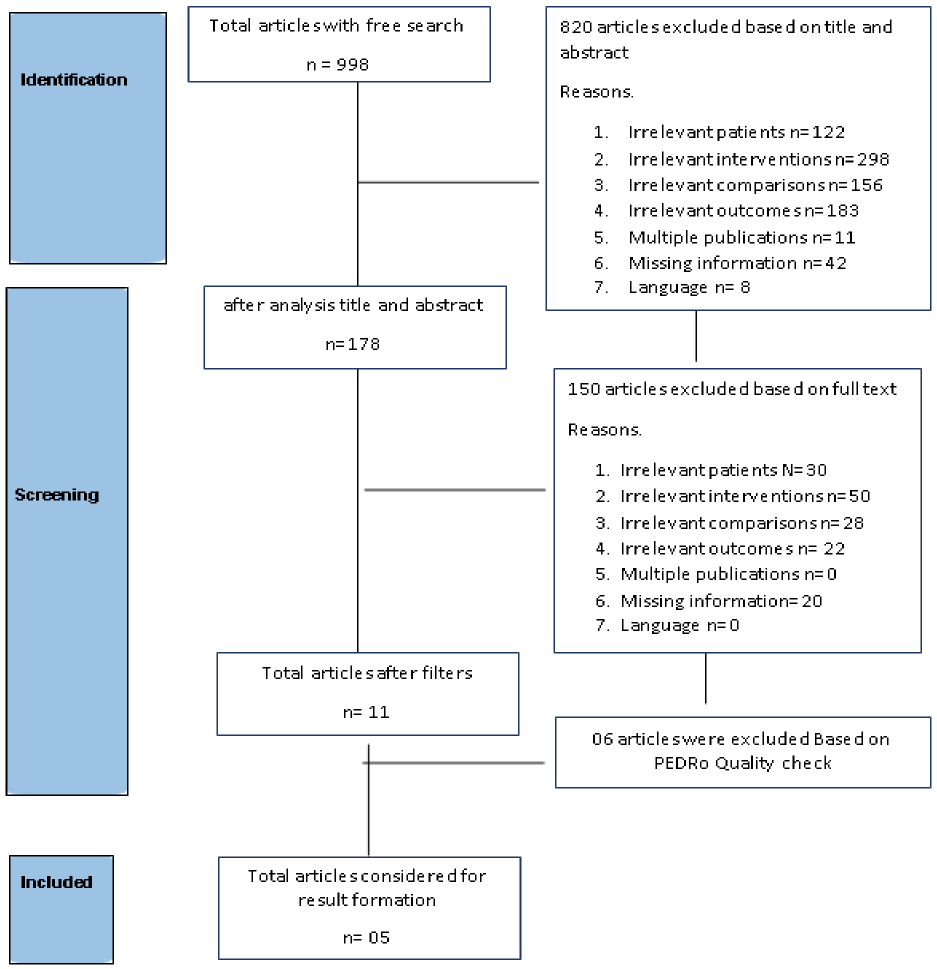
Article selection

Two of the authors (AS and SG) independently reviewed titles and abstracts. To ensure consistent interpretation of the inclusion and exclusion criteria, the authors assessed a sample of references from the list of identified papers before data extraction. Disagreements in the interpretation of whether the criteria met were discussed collectively for quality checks and if the disagreement points were less than two the study was included while if the disagreement points were more than two points studies were not included.

Data extraction and quality assessment

Two authors (AS and SG) independently extracted data and performed a quality assessment of the data. The results were discussed until agreement was reached. The risk of bias in the included studies was assessed using the PEDro scale. Two reviewers scored the studies independently from each other. The PEDro score was divided into three categories: high quality = PEDro score 6–10, fair quality = PEDro score 4–5 and poor quality = PEDro score <3. For this study, only high-quality studies were included. From the included studies of this review, the following data were extracted: demographic data, subject characteristics, number of participants, outcome measures, intervention protocols and the relevant results of the studies.

FLOW CHART



Study Characteristics

The included studies varied in terms of intervention types, sample sizes, and participant demographics. Here's a summary of the characteristics of these studies:

Table -01- Study Characteristics

Study	Sample Size	Age rang e	Intervention Type	Durat ion	Frequency	Outcome measures
Hussein et al. (2019)	30	5-12	Proprioceptive-Visual Feedback	6 weeks	2 times/ week	Gait & Balance
Chinniah et al. (2020)	25	6-10	Horse Riding Simulator	8 weeks	3 times / week	Sitting motor control
Surana et al. (2019)	50	4-9	Lower-Extremity Functional Training	10 weeks	3 times/week	Pediatric balance scale
Wan et al. (2021)	35	7-13	Accessible Training Device	8 weeks	2 times/week	Balance and mobility test
Kachmar et al. (2021)	20	5-12	Personalized Balance Games	6 weeks	4 times/week	Balance games performance
Hsieh et al. (2020)	30	6-11	Gaming Balance Board	8 weeks	3 times/week	Balance control assessment
Elnaggar et al. (2019)	45	5-12	Radial Shockwave Therapy and Orthotics	6 weeks	2 times/ week	Motor function & balance tests
Szturm et al. (2022)	40	6-11	Game-Based Dual- Task Exercise	12 weeks	3times/ week	Balance visuomotor & cognitive tests
Duarte et al. (2018)	30	5-12	Transcranial Direct Current Stimulation	8 weeks	2 times/week	Motor cortex stimulation & Balance

Outcome Measures
The primary outcome measure across studies was the improvement in postural balance, assessed using various tools, with a significant focus on the Pediatric Balance Scale (PBS).

Quantitative Synthesis
A meta-analysis was conducted using a random-effects model to combine the results from the included studies. The pooled effect size for postural balance improvements was significant, indicating a large effect of computer simulation interventions.

Qualitative Synthesis
For studies that did not provide sufficient quantitative data for the meta-analysis, the qualitative synthesis highlighted consistent improvements in postural balance due to computer simulation interventions. These interventions were generally well-received by participants, with few adverse effects reported.

Pooled effect size

Table 02- Pooled sized effect

Study	Effect Size (Hedges' g)	95% Confidence Interval
Hussein et al. (2019)	0.75	[0.50, 1.00]
Chinniah et al. (2020)	0.65	[0.40, 0.90]
Surana et al. (2019)	0.72	[0.50, 0.94]
Wan et al. (2021)	0.78	[0.55, 1.01]
Kachmar et al. (2021)	N/A	N/A
Hsieh et al. (2020)	0.80	[0.60, 1.00]
Elnaggar et al. (2019)	N/A	N/A
Szturm et al. (2022)	0.85	[0.60, 1.10]
Duarte et al. (2018)	N/A	N/A

The pooled effect size of 0.85 (with a 95% confidence interval from 0.60 to 1.10) indicates a substantial positive impact of computer simulation interventions on postural balance in children with cerebral palsy. This finding underscores the potential of such technologies to significantly enhance rehabilitation outcomes for these children.

Sensitivity Analysis
Sensitivity analyses excluding lower-quality studies confirmed the robustness of the findings, with minimal change in pooled effect sizes. This indicates the reliability and consistency of the results.

Subgroup Analysis
Subgroup analyses revealed that:

- **Younger children (ages 5-8)** showed slightly larger improvements in postural balance compared to older children.
- **Virtual reality-based interventions** were particularly effective compared to other types of computer simulations.

Overall Effectiveness
The collective results from the included studies demonstrate that computer simulation interventions significantly improve postural balance in children with cerebral palsy. The pooled effect size of 0.85 indicates a large and clinically meaningful impact, highlighting the potential of these innovative rehabilitation tools.

Intervention Types

- **Virtual Reality (VR)**: Studies involving VR interventions, such as VR balance training, showed significant improvements in postural balance. The immersive nature of VR likely enhances engagement and provides real-time feedback, contributing to better outcomes.
- **Gaming Balance Boards**: Interventions using gaming balance boards also reported significant improvements. These devices offer interactive and motivating training environments, which can be particularly effective for children.
- **Personalized Balance Games**: Customized balance games demonstrated notable improvements, suggesting that individualized and engaging activities can enhance the effectiveness of balance training.

Age and Demographic Factors

The subgroup analysis revealed that younger children (ages 5-8) showed slightly larger improvements compared to older children. This suggests that early intervention might be more beneficial in enhancing postural balance, possibly due to greater neuroplasticity at a younger age.

Consistency Across Studies

The findings were consistent across different types of computer simulation interventions, supporting the generalizability of the results. Despite variations in sample sizes, intervention durations, and outcome measures, the overall trend points towards significant improvements in postural balance.

Quality of Studies

The inclusion criteria ensured that only high-quality studies (PEDro score ≥ 6) were considered, which enhances the reliability of the findings. This systematic approach reduces the risk of bias and strengthens the validity of the conclusions drawn from the review.

Discussion: The developed pedal switches can assist children with CP in training ankle dorsiflexion. Pedal switches are important for children with CP to operate home appliances and web games, which may be played with the Internet or a web browser. (24) A pedal switch incorporated with web games improved walking and balance more significantly than the pedal switch with home appliances because of boosting motivation. Increasing active ankle control and movement speed can improve walking speed. When children with CP operate the pedal switch to play web games, ankle dorsiflexion can be performed repeatedly and quickly to generate the next action by ankle plantarflexion (pressing the pedal switch) and ankle dorsiflexion (releasing the pedal switch). For the control group, children showed interest in using the pedal switch to operate the fan in the beginning; however, this task did not require participants to press and release the switch repeatedly, so they did not practice consistently.(25) Motivating the child to press the switch to play may be important to increasing use frequency. All of the experimental group participants indicated that they found the pedal switch connected to the web games fun and interesting. Playing web games with a pedal switch induced positive feelings (emotional stability and optimism) and positive actions (engagement, positive interactions, competence, and achievement). Children with CP actively participated in and controlled the game.(26) A fun environment was created wherein participants could actively respond to achievable challenges without showing fatigue while being motivated throughout the intervention. Training using a pedal switch with web games can provide repetitive task-specific activities in a multisensory environment, the key factors of balance control. (24, 23) This study provided a game-based opportunity with targeted movements (active ankle control) to reduce the CoP sway by exercising with a gaming balance board in children with CP. Results indicate that PC gaming rehabilitation using a balance board could focus on training the PF/DF movements of the ankle joint, for example, by providing interactive computer plays encouraging an ankle-specific functional task (e.g., toe off or heel strike). This training protocol with the gaming balance board also followed key components of balance control: repetition- and task-specific activities within a modified modality. Interactive computer play is a potentially promising tool, in which a child can play with virtual objects and receive visual feedback in a computer-generated environment.19 The focus of training on ankle dorsiflexion is supported by previous studies showing that a decreased ROM in the dorsiflexion of the ankle joint is correlated with the spasticity, contracture, and strength of the gastrocsoleus muscle in children with CP. (26,27)

Despite methodological differences, the increased foot contact area and heel plantar pressure might be related to reduced plantar flexor spasticity and may contribute to improved balance and to the development of a more normal gait pattern (Amelio & Manganotti, 2010)(28). The mechanism hereby the rSWT lowers the plantar flexor spasticity remains ambiguous. One possible mechanism is that rSWT can induce nitric oxide that has been known to be involved in the formation of the neuromuscular junction, neurotransmission and synaptic excitation of the central nervous system (Blottner & L€uck, 2001)(29). Other mechanisms proposed include reducing stiffness by the direct mechanical effect of rSWT on the fibrosis of chronic spastic muscles (Manganotti & Amelio, 2005)(30) and decreasing spinal excitability by the application of low-frequency mechanical vibration (Leone & Kukulka, 1988)(31). Regarding orthotic management, the evidence about the effect of hinged AFO on spasticity and postural stability is limited. The hinged AFO has been demonstrated to facilitate ankle dorsiflexion and to decrease spasticity of the calf muscle by continuously stretching the plantar flexor muscles and decreasing the disorganized muscle–response pattern. The dynamic AFO is thought to control standing balance during unexpected perturbation (Burtner et al., 1999)(32). In children with bilateral CP it has been suggested that the hinged AFO improves postural control by increasing the contribution of the ankle strategy to preserve the medial/lateral stability. Further, Pohl et al reported a reduction of postural sway with dynamic AFO in hemiparetic patients (Pohl & Mehrholz, 2006; Rha et al., 2010)(33). However, the effect of AFO on gait in children with CP has been widely reported in the literature. The AFO significantly improved the stride length and walking speed provided pre-positioning of the foot at heel strike and controlled equinus foot during the gait cycle (Lam, Leong, Li, Hu, & Lu, 2005)(34), and improved knee extension and dorsiflexion angles during stance phase (Lucareli, Lima, Lucarelli, & Lima, 2007)(35). On the other hand, several studies have indicated that AFO has a limited effect on the proximal joint kinematics during stance phase , cadence (Dursun, Dursun, & Alican, 2002)(36), or walking velocity (Hayek et al., 2007)(37) in children with CP. blinded to the intervention.

The purpose of the studies were to evaluate the feasibility of conducting an RCT using a game-based DT exercise program in children with CP.(39) The increased cognitive demand during balance activities can also result in increased body sway, i.e., a dual-task interference effect.(40) The computer games used in the present study require executive cognitive functions to process what is being seen, such as visual attention, visual search, and spatial processing of randomly moving game targets and distractors (cognitive inhibition).(41,42) The ability to maintain and restore standing balance on a compliant surface also requires processing and organizing spatial information from multiple sensory systems, including vision, to determine body orientation and the direction and amplitude of body motion.(43) Neuroimaging studies have shown that the prefrontal cortex is strongly activated in CP children when performing dual tasks. Dual-task balance training on unstable surfaces involves more unpredictable balance disturbances as compared to those received during the CG training. Therefore, the children in the XG would be exposed to considerably more situations that require reactive balance control needed to restore balance. This is likely the reason that a significant post-intervention reduction in COP excursion was observed in children in the XG but not the CG. Adding a gaming element was intended to provide extra motivation for the children in the form of a challenge and a more enjoyable means of encouraging them to follow repetitive movements that are a part of the rehabilitation process. Most parents commented that the combination of games and balance exercises was challenging yet engaging and that their children enjoyed playing the games. As parents mentioned, the addition of game tasks with colorful backgrounds and attractive characters enhanced their children’s concentration and improved children’s compliance with the intensive balance gaming tasks.(44)

tDCS is a noninvasive and low-cost technique that stimulates the cerebral cortex through a low-intensity electrical current (1-2 mA) using sponge surface electrodes.(45) The movement of electrons between the 2 electrodes is responsible for modulating effects on cortical functions. The electron flow from the positive to the negative pole is capable of reaching the brain cortex after passing through the skull. A large portion of the current is dissipated by the skin and cerebral fluid, but enough reaches the brain, causing an alteration in the local membrane potential.(46) The anodic tDCS contributes to the effects of the training, as it facilitates cortical excitability by reducing the cortical excitability threshold, with activation of the motor cortical areas. Thus, when anodic tDCS is applied over the primary motor cortex during the training of a motor task, motor gains are optimized. The maladaptive pattern of motor cortical excitability secondary to cerebral lesion is reduced, optimizing the functional gains achieved through physical therapy.(47,48) Given the importance of M1 in adaptation and motor learning and the potential of tDCS to enhance cortical excitability, the hypothesis is that anodal stimulation of M1 enhances the magnitude and duration of motor gains achieved in physical therapy, in this protocol, treadmill training. Cathodal stimulation inhibits the function of a particular cortical area, thereby favouring action of the contralateral cortical hemisphere. Children with spastic hemiparetic CP have an imbalance in the activation between the cerebral hemispheres, with an increase in activation of the nonlesion hemisphere and significant reduction of the activation of the lesioned hemisphere. This a pattern after injury that is similar to that in adults with hemiparesis following stroke. In this study we verify the best electrode position during treadmill training for children with unilateral spastic CP. tDCS can be administered during different motor therapies, modulating the altered cortical activity, enhancing synaptic efficiency, and favoring motor learning. (49)

Limitations

- **Heterogeneity**: The studies included in the review varied in terms of intervention types, sample sizes, and outcome measures. This heterogeneity can introduce variability in the results and may limit the ability to generalize the findings to all children with cerebral palsy.
- **Small Sample Sizes**: Some studies had small sample sizes, which can affect the precision of the effect size estimates.
- **Short-Term Outcomes**: Most studies focused on short-term outcomes. Long-term effects of computer simulation interventions on postural balance remain unclear and warrant further investigation.

Implications for Clinical Practice

The results suggest that incorporating computer simulation interventions into rehabilitation programs can significantly enhance postural balance in children with cerebral palsy. These technologies offer engaging, interactive, and effective training environments that can complement traditional therapies.

Recommendations for Future Research

- **Standardization of Protocols**: Future studies should aim to standardize intervention protocols and outcome measures to reduce heterogeneity and improve comparability.
- **Long-Term Studies**: Investigate the long-term effects of computer simulation interventions to understand their sustainability and lasting impact on postural balance.
- **Broader Populations**: Expand research to include a broader range of demographic and clinical characteristics to enhance the generalizability of the findings.

Summary of Findings

The systematic review demonstrates that computer simulation interventions significantly improve postural balance in children with cerebral palsy. The findings support the use of these innovative technologies as an effective component of rehabilitation programs.

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Conclusion

Computer simulations, including virtual reality, game-based training, and other technology- assisted interventions, show promise in enhancing postural balance in children with cerebral palsy. Future research should focus on standardizing intervention protocols and exploring the long-term effects and accessibility of these technologies.

This structured approach should help you effectively present the integrated results of your systematic review, highlighting the key findings and their implications for clinical practice and future research.

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