INTI JOURNAL | Vol.2024:01
eISSN:2600-7320

Analyzing the Efficacy of Anti-Gravity Treadmill in Enhancing Gait and Balance among Patients with Spastic Cerebral Palsy - A Critical Review

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Abstract

In the pediatric population, cerebral palsy is the most prevalent neurological condition. As the result of prenatal or perinatal events, the cause of this complex physical disability is cast over the congenital fragility. There is often a challenge in gait and balance for individuals with spastic cerebral palsy. Innovative interventions for spastic cerebral palsy such as the anti-gravity treadmill which simulates partial weight-bearing have been sparked in innovative rehabilitation technologies. This study aims to assess published studies on anti-gravity treadmill training, evaluating their strengths and weaknesses, considering study design, sample size, outcomes, and limitations. This critical review will make recommendations for future research and address the limitations identified in the current body of literature. A quantitative research critical review form is used to analyze the eleven studies with different study designs, including 6 Randomized Control Trials, 2 Experimental Study, 1 Prospective Study, 1 Systematic review and meta-analysis and 1 study where not clearly mentioned about their study design. This review includes studies obtained from Google Scholar, PubMed, Cochrane, and ResearchGate databases. Our primary focus revolves around the studies with populations of spastic cerebral palsy and outcomes associated with balance and gait. This critical review concludes that the anti-gravity treadmill enhances gait and balance for children with spastic cerebral palsy. There were positive outcomes despite variations in methodologies and limited studies, including improved gait patterns and enhanced balance. In spite of the necessity for standardized research, anti-gravity treadmills may be an effective way to address the motor challenges of those with spastic cerebral palsy. The long-term efficacy of this intervention needs to be confirmed and compared with alternatives through further robust studies.

Keywords

Spastic Cerebral Palsy, Gait, Posture Balance

Introduction

Cerebral palsy (CP) stands as the foremost prevalent neurological condition within the pediatric population. This intricate physical disability unfurls its origins from prenatal or perinatal events,

Submission: 11 January 2024; **Acceptance:** 19 March 2024

casting its cause over congenital fragility. Individuals who have spastic cerebral palsy often encounter difficulties when it comes to their ability to maintain balance and perform motor functions effectively. These challenges can restrict their engagement in day-to-day tasks and interactions with others (McIntyre et al., 2022). Cerebral palsy appears to be caused by brain damage occurring during preterm birth, infancy, or post-partum asphyxia (Pietrzak, K et.al., 2016).

Children with cerebral palsy experience a wide range of symptoms, ranging from limitations in specific musculoskeletal functions to challenges that impede daily activities and may even be life-threatening. In the case of brain damage that occurs prenatal, perinatal, or postnatal, it affects both the neurological and musculoskeletal systems, leading to muscle contractions, postural changes, and limitations in movement and activity (Sadowska et al., 2020; Paul et al., 2022).

In high income countries, it is estimated that 1.5 cases of cerebral palsy occur per 1000 live births during the pre and perinatal stages, while in low- and middle-income countries, existing data suggests a birth prevalence of CP with rates reaching as high as 3.4 cases per 1000 live births (McIntyre, 2022). NASA originally developed anti-gravity treadmills to help astronauts recover muscle and bone mass after long periods in microgravity environment. As this technology has evolved, it has proven beneficial for those who suffer from neurological conditions. This treadmill creates a setting by reducing the effective weight bearing on the lower limbs through differential pressure (NASA, 2024). Anti-gravity can reduce the weight burden by 80% and it plays a role in maintaining balance while moving. This training program goes beyond exercise, and it follows an intensive approach to locomotor training carried out over an extended period of time and by engaging in this treadmill training, it stimulates neuroplasticity within the brain (Azizi et al., 2017). Indeed, this training programme uses a long-lasting, rigorous approach to locomotor training. Its broad spectrum of applications in many fields is indicative of its adaptability (Thirumalai & Ramalingam, 2024).

While we continue to investigate the long-term effects of anti-gravity treadmills, we are actively involved in pioneering research to better understand the long-term effect. Through this research, we aim to provide insights that can potentially transform how therapists treat and care for people with various physical challenges, resulting in more effective and sustainable strategies.

Table 1. Summary of RCT, Experimental Study, Case Study, Prospective Study

Author	Sample Size & Age	Study Design	Study Description	Outcome Measure	Conclusion
Kurz et al. (2011)	N = 9 Age: 13.8 ± 3 years	Experimental Study (Pre & Post-test type)	9 children with Spastic CP (1 Hemiplegic + 8 Diplegic) ● 7 Childrens were completely received LBPPS Treadmill training. ● They were unable to collect data from a child due to cognitive impairment. ● Intervention Duration - 2 Days per week for 6 weeks.	Walking Speed, Spatiotemporal Kinematics, Lower Extremity Strength, and the BESTest	Children with CP can improve their walking performance, balance, and strength using LBPPS treadmill training.
Emara (2015)	N = 30 Age: 6 to 8 years	RCT	30 spastic diplegic CP Childrens were assigned into 2 groups ● Group A - Specialized Therapeutic Exercise Program. ● Group B - Gait Training using Antigravity Treadmill + Therapeutic Exercise Program.	Biodex Balance System	Children with SDCP could benefit from gait training using antigravity treadmill training in order to improve standing balance.

			• Intervention Duration - 20 minutes per day, 3 sessions per week for 3 months.		
Birgani (2016)	N = 10 Age: Not Mentioned	Not Mentioned	• 1 child with spastic CP has completed the experimental protocol out of over ten recruited. • Alter-G treadmill training was performed 45 minutes per day, 3 sessions per week for 8 weeks.	Romberg's Test, Center-of-Pressure (CoP).	Physical intervention as anti-gravity treadmills can improve gait and postural stability in children with CP.
Rasooli AH (2017)	N = 4 Age: 9.13 ± 3.33 years	RCT	4 spastic CP Childrens were assigned in two groups, • Experimental Group (n = 3) - Antigravity Treadmill Training. • Control Group (n = 1) - Training overground gait training. • Intervention Duration - 45 minutes per day, 3 sessions per week for 8 weeks.	Postural Balance Evaluation (Using standard Romberg based posturography), Diffusion Tensor Imaging (DTI).	Children with spastic CP benefit from AlterG training by improving balance control and improving cerebellum microstructure.
Azizi et.al. (2017)	N = 4 Age: 4 to 15 years	RCT	4 spastic CP hemiplegia patient were randomly assigned into 2 groups, • Experimental Group (n = 3) - Exercised on an Alter-G treadmill. • Control Group (n = 1) - Sessions of occupational therapy were attended. • Intervention Duration - 45 minutes per day, 3 sessions per week for 2 months.	10-minute walking test, Time Up and Go Test (TUG), Diffusion Tensor Imaging (DTI)	Study found that improved walking capacity was concurrent with improved corticospinal tract structure. CP children who undergo AlterG training able to improve their gait permanently.
Parvin et.al. (2017)	N = 4 Age: 10.19 ± 1.19	Experimental Study (Pre & Post-test type)	4 spastic CP hemiplegia Childrens were randomly assigned into 2 groups, • Experimental Group (n = 3) – AlterG Training. • Control Group (n = 1) - Occupational Therapy. • Intervention Duration - 45 minutes per day, 3 days per week for 8 weeks.	H-reflex response, Transcranial Magnetic Stimulation, Sono Elastography.	In children with spastic hemiplegic CP, AlterG training has been shown to promote CST activity, lessen muscular stiffness, and improve reflexes.
Dadashi et.al. (2018)	N = 4 Age: 4 to 14 years	RCT	4 children with spastic CP were randomly assigned into two groups, • Group A (n=2) - AlterG training. • Group B (n=2) - Received Occupational Therapy. • Intervention Duration: 3 times a week for 8 weeks.	VICON MX motion capture system (COP and COM)	AlterG training program offers therapeutic potential for dynamic balance improvements in spastic CP children, compared to typical OT.
Aras et.al., (2019)	N = 30 Age: 6 to 14 years	Prospective Study	30 Childrens with spastic CP were randomly assigned into 3 equal groups, • Group A - Partial body weight-supported treadmill exercise. • Group B - Robotic-assisted treadmill exercise. • Group C - Anti-gravity treadmill exercise. • Intervention Duration - 45 minutes for 5 days a week for 4 weeks.	6-Minutes Walking Test, Gross Motor Functional Measurement, 3D-Gait Analysis, open circle indirect calorimeter.	All three treadmill exercises improve walking, and RATE and ATE can be used more actively in patients with spastic CP.
Ashtiyani (2020)	N = 14 Age: 6 to 11 years	RCT	14 Childrens with spastic hemiplegia CP assigned into 2 groups • Study Group - Antigravity Treadmill Training. • Control Group - Received Occupational Therapy. • Intervention Duration - 45 minutes therapy per day, 3 sessions per week for 8 weeks.	MRI, Timed-Up-and-Go, 10-meter, and 6-minute walk tests	Children with cerebral palsy benefit from AlterG training to improve their gait and balance.

Noroozi et.al. (2020)	N = 18 Age: 4 to 14 years	RCT	18 Childrens with spastic hemiplegia CP randomly assigned into 2 groups and 2 were didn't complete. ● AlterG Group - Antigravity Treadmill Training ● Control Group - Conventional Occupational Therapy ● Intervention Duration - 40 minutes per day, 3 times a week for 8 weeks.	Reflex stiffness gain, Intrinsic stiffness gain.	Findings suggest that AlterG training can be used as a treatment strategy to lessen neuromuscular anomalies and manage spasticity.

Table 2. Summary of Systematic Review and Meta analysis

Author (Year)	Sample Size	Study Design	Included Studies	Outcome Measures	Study Conclusion
Alwhaibi et.al., (2022)	3 studies were included where they have samples of spastic CP Childrens.	Systematic Review and Meta analysis	1. Aras et.al., (2019) 2. El-shamy et.al., (2017) 3. Emara et.al., (2015)	Balance and Risk of Fall, Gait (Cadence, Stride length, Step time, walking speed), open-circle indirect calorimeter, 6-Minutes Walking Test, Biodex Balance System	Antigravity treadmills improve gait and balance in spastic CP children, but limited studies and heterogeneous populations require further trials.

Critical Review Form - Quantitative Research (Law et. al., 1998)

STUDY PURPOSE Did the research purpose and objectives state clear? Did qualitative approach be appropriate for the study?	**OUTCOMES** Were the outcome assessments characterized by reliability? Were the outcome assessments characterized by validity?
STUDY DESIGN Does the study design correspond to the research question and objectives?	**TREATMENT** Was the intervention thoroughly described? Was the prevention of contamination ensured? Was co-intervention avoided?
METHODOLOGY Does the study describe the methods for generating data? Did the method fit the study design?	**RESULT** Did statistical significance play a role in the findings presented? Is the analysis method appropriate? Did clinical significance appear to be indicated? Have attrition rates been documented?
SAMPLE Was the selection of participants justified and did they correspond to the research question? Did the sample have a detailed description? Was informed consent received, and are the reasons for non-participation clear?	**CONCLUSION** Did the study's findings support the conclusions? Did the findings useful for the development of theory or practice in the future?

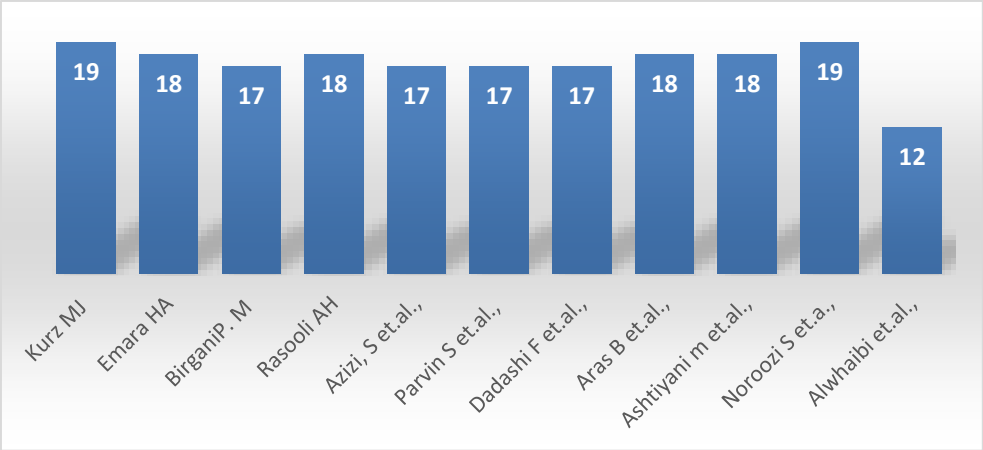

Figure 1. Score for Critical Review Form

Results and Discussion

Eleven articles were retrieved with population of spastic CP. Among these 11 articles 6 were Randomized Control Trial (RCT), 2 Experimental Study, 1 Prospective Study, 1 Systematic review and meta-analysis and 1 study where not clearly mentioned about their study design. The findings of these articles are summarized in Tables 1, 2 and the scores of critical review form is summarized in Figure 1. The included studies focused on anti-gravity treadmill on patients with Spastic CP. The methodological quality and future directions of anti-gravity treadmill interventions for children with spastic CP are conclusive from this critical review.

The question of whether Lower Body Positive Pressure (LBPP) treadmills differ from Anti-Gravity treadmills was examined in a study and it clarified this matter in their introduction by asserting that both treadmill types are essentially similar (Singh & Malhotra, 2018). However, Kurz et al. (2011) study found that 6-week LBPPS treadmill training significantly improved walking speed, kinematics, and lower extremity strength in children with CP. However, the study has limitations such as limited sample size of 9 children, absence of a control group and term follow-up measurements could have impacted the lasting effects of the interventions.

Emara (2015) study aimed to assess the effects of treatments on two different groups. The control group performed therapeutic exercises, while the experimental group received therapeutic exercises with antigravity treadmill as an additional intervention. In this study, the experimental group received more intervention than the control group, and the lack of long-term follow-up on the children involved limits the understanding of the intervention's durability.

The study conducted by Birgani et.al. (2016) at hand has raised some noteworthy concerns. This study heavily depended on one person's experience because nine participants couldn't complete the intervention period, which limited its applicability to a broader audience. The lack of a clear research plan, comparison group, participant details, and potential biases weaken its credibility, and a larger sample size, more stringent controls, and clear participant information is needed to confirm AlterG effectiveness.

Rasooli A.H. et al. (2017) study explores the connection between structural cerebellum changes and functional outcomes using Diffusion Tensor Imaging (DTI) feature to investigate neuroplasticity. The study found an increase in fractional Anisotropy (FA) value in cerebellum after AlterG training, which is believed to correlate with improved functional outcome have an interconnection with the structural change of cerebellum. However, the intervention group comprised 3 participants with a single child in the control group. This could potentially overstate the effectiveness of the antigravity treadmill training.

Azizi et al. (2017) study explores the intricate connection between structural brain changes and functional outcomes. They used Diffusion Tensor Imaging (DTI) and Fractional Anisotropy (FA) to assess neuroplasticity in the corticospinal tract. The study found an increase in FA value within the corticospinal tract after antigravity treadmill training, which is believed to correlate with improved walking capacity. The control group encompasses a long participant aged 4 while in experimental group 3 Childrens aged 9 to 12. The age-based selection bias may significantly confound the observed outcomes, weakening the study's internal validity and broader applicability.

The study by Parvin S et.al. (2017) found that AlterG treadmill training significantly reduced muscular rigidity, reflex hyperactivity, and CST function in children with spastic hemiplegic CP. The training group responded well to transcranial magnetic stimulation (TMS) and Sono Elastography indicating improved neuronal functioning. However, the small sample size necessitates further research with larger populations to confirm and generalize the therapeutic advantages of AlterG treadmill training. Study by Dadashi et al. (2018) examined the effectiveness of AlterG treadmill training in improving balance in children with CP. However, the study's small sample size and lack of long-term follow-up beyond 8 weeks post-treatment raise concerns about its applicability to a larger population.

The study by Aras et al. (2019) examines the effectiveness of three treadmill interventions in individuals with spastic CP. However, the study's short duration of 4 weeks may not be enough to evaluate lasting effects or identify adverse outcomes over an extended follow-up period. Longer intervention periods are needed to understand the complex and time-related effects of these interventions on individuals with CP. Meghdad Ashtiyani et al. (2020) conducted a study on short-term effectiveness of anti-gravity treadmill training in improving brain functional activities and walking capacity in children with spastic CP. However, the study's results may be biased due to the exclusion of information about participants who did not complete the intensive training sessions, which could undermine the study's internal validity.

Study by Noroozi et al. (2020) examined AlterG training's effectiveness in reducing spasticity in children with spastic CP. The study involved children diagnosed with hemiplegic CP and neuromuscular abnormalities supervised using an advanced parallel-cascade system. Result showed that AlterG training reduced abnormalities and managed spasticity but, small sample size and lack of long-term follow-up limit the study. The study by Alwhaibi et. al. (2022) reviews the use of antigravity treadmills to enhance walking abilities in children with CP. Although it acknowledges improvements in speed and balance e, it lacks a clinical assessment and details about the progression and impact on children's capabilities.

Conclusion

According to the analysis of studies carried out to explore whether antigravity treadmill is effective in helping children with spastic CP to recover, positive results have been found and these studies provide a foundation for clinical applications of the anti-gravity treadmill. Antigravity treadmills have been shown to improve gait, balance, cadence, gross motor function, and manage neuromuscular anomalies and spasticity. The use of antigravity treadmills is crucial for the overall well-being of children with CP, since they enable them to manage symptoms and mobilize the children towards excellence. Thus, this critical review suggests that evaluating the practical applicability and effectiveness of Alter-G in improving gait and balance among patients with spastic CP requires extended intervention periods and thorough follow-up evaluations with large sample sizes.

Acknowledgement

The researcher did not receive any funding for this study, and the results have not been published in any other sources.

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