Research Paper

Effects of Whole-body Vibration on Balance in Children With Spastic Diplegic Cerebral Palsy

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ABSTRACT

Objectives: Cerebral palsy (CP) is a group of permanent disorders affecting movement and posture due to non-progressive brain disturbances. Spastic CP, the most common type, primarily affects the lower limbs. Children with spastic diplegic CP experience difficulties with balance and walking. Whole-body vibration (WBV) has shown promise in improving balance in various populations; however, its effects on children with spastic diplegic CP have not been well studied. This study aimed to determine the effects of WBV on balance in children with spastic diplegic CP.

Methods: Twenty children with spastic diplegic CP, aged 6-12 years, were assigned to two groups: Group A and Group B. Group A received WBV combined with therapeutic exercises, while Group B received only therapeutic exercises. Balance was assessed using the Pediatric Balance Scale (PBS) before and after a six-week intervention.

Results: The pre-test PBS scores were 31.63±4.27 for the experimental group and 23.40±2.07 for the control group. Post-test scores were 39.38±4.14 and 26.20±2.30 for the experimental and control groups, respectively. Both groups improved significantly, with the experimental group showing greater post-test balance scores than the control group.

Discussion: WBV combined with therapeutic exercises significantly enhances balance in children with spastic diplegic CP, suggesting its effectiveness as a treatment protocol.

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Highlights

- Children with spastic diplegic CP often have balance issues due to muscle stiffness and motor control difficulties.
- WBV therapy improves balance when added to regular physiotherapy.
- The study showed better performance in functional balance tasks after vibration sessions.
- This approach is safe, simple to apply, and may support progress in pediatric rehabilitation.
- Adding vibration therapy could help children move more confidently in daily life activities.

Plain Language Summary

Children with a condition called spastic diplegic cerebral palsy (CP) often find it hard to keep their balance due to stiffness in their leg muscles. This can make everyday tasks, such as walking, standing, or playing, more difficult. In this study, we examined whether a treatment called whole-body vibration (WBV) could help improve balance in these children. WBV is a therapy delivered using a special machine that gently vibrates the body to help muscles function better. We administered this therapy to a group of children along with regular physiotherapy for six weeks. Another group received only regular therapy. After the treatment, the children who used the vibration machine showed better balance and were quicker in movements than the others. They found it easier to sit, stand, and move around. This result suggests that WBV, when used with regular therapy, can significantly improve balance in children with this condition. It is easy to use, safe, and may help children feel more confident and independent in daily life.

Introduction

Cerebral palsy (CP) refers to a group of permanent, non-progressive disorders of muscle tone, movement, and posture resulting from damage to the developing brain. It is categorized under chronic motor disability in children [1].

According to research findings, the prevalence of CP among children is estimated to range from approximately 15% to 20%, and the incidence rate is reported to be approximately 2 to 3 cases per 1,000 live births. Spastic CP is the most prevalent type of CP, comprising 70-75% of the population, while dyskinetic CP accounts for 10-15%, and ataxic CP less than 5%. Regarding the topographical distribution of CP, diplegia is the most prevalent subtype, representing approximately 30-40% of cases, followed by hemiplegia at 20% to 30%, and quadriplegia at 10-15%. These findings shed light on the distribution patterns of CP subtypes and are crucial for devising appropriate interventions and care strategies for affected individuals [2].

Spastic diplegia, like other forms of CP, results from brain injury that may occur before, during, or shortly after birth. Infants who are born prematurely or have a low birth weight have a higher likelihood of developing spastic diplegic CP [3, 4].

Spastic CP mostly affects balance because of increased muscle tone and stiffness caused by brain damage in the motor control centers. This leads to difficulties in coordinating muscle movements and maintaining stability. Individuals may experience an unsteady gait, making it challenging to maintain an upright posture while standing or walking. Asymmetrical movements due to spasticity can further impact balance. However, the specific impact on balance varies depending on the severity and distribution of spasticity in each case [5, 6]. In the context of children with CP, it is noteworthy that they may exhibit distinct biomechanical deviations while walking. These deviations manifest as a reduced degree of knee flexion during the swing phase of gait, hyperextension of the knee, or excessive flexion (crouch) during the stance phase of gait, limited dorsiflexion, and leg crossing (scissoring). During the swing phase, internal hip rotation and excess hip adduction, in conjunction with challenges in maintaining balance and reduced trunk control, can result in modifications to foot placement and the appropriate alignment of the body's center of mass. Consequently, these deviations lead to decreased stability and an increased risk of falling [7].

Physical therapy (PT) plays a pivotal and significant role in the management of spastic diplegic CP. Its primary emphasis lies in enhancing function, facilitating movement, and maximizing the child's inherent capabilities. By employing physical interventions, PT endeavors to foster, sustain, and reinstate the child's physical, psychological, and social wellbeing. Moreover, physiotherapists actively engage in instructing parents on effective techniques and providing guidance on the appropriate usage of mobility aids. These interventions are intended to optimize the child's overall development and independence, both within clinical settings and in the comfort of their own home [8].

In the realm of PT, a multitude of advanced approaches are employed to meet the specific needs of patients. Among these notable techniques are the Bobath method, sensory integration therapy, proprioceptive neuromuscular facilitation, and the Brunnstrom approach. Therapists adeptly utilize techniques, such as cryotherapy (cold therapy), thermotherapy (heat therapy), strategic positioning, targeted stretching exercises, and the application of orthotic devices. The judicious incorporation of these diverse modalities is geared towards optimizing the outcomes and promoting the well-being of the individuals undergoing treatment [9]. A selection of advanced methodologies implemented approaches, namely, constraints-induced therapy, neuromuscular electrical stimulation, Vojta method, body weight support treadmill training, exercise therapy, hydrotherapy, and conductive education [10].

Whole-body vibration (WBV) is a relatively new intervention that offers a unique way to improve proprioceptive acuity. It specifically applies vibration to improve motor skills, balance, and bone density. Notably, the application of vibration can directly activate muscle spindles and Golgi tendon organs, rendering it a valuable tool for proprioceptive and balance enhancement. This innovative technique holds promising potential for augmenting various aspects of physical function and performance [11, 12].

WBV constitutes a comprehensive approach that engages the entire body in experiencing vibrations through a specialized vibrating platform. This modality elicits a tonic vibration reflex, in which the mechanical stimuli delivered by the vibrating platform are transmitted to the body, resulting in the stimulation of muscle spindles and the activation of alpha motor neurons. This, in turn, triggers reflexive muscle contractions, leading to lengthened muscle activity and strengthened weaker muscles. Consequently, whole body vibration plays a pivotal role in reestablishing balance, ultimately enhancing gait and posture in individuals [13].

To date, only a limited number of studies have investigated the potential impact of WBV on spastic diplegic children concerning various aspects, such as reducing lower extremity spasticity, improving muscle strength, increasing joint mobility, promoting postural stability, enhancing balance ability, and refining gross motor ability and motor performance [14-16]. Several studies have demonstrated that various treatments can improve balance in children with spastic diplegic CP. While some research has investigated WBV for balance enhancement, this approach has not been explored in India, particularly for the middle childhood age group. This study aimed to evaluate the effects of WBV on balance in children with spastic diplegic CP and aligns with the third sustainable development goal of promoting good health and well-being.

Materials and Methods

This experimental study employed a pre-test, post-test design to evaluate the effect of WBV on balance in children with spastic diplegic CP. A total of 20 participants, selected through convenience sampling, were assigned to two groups of 10 children each, designated as Group A and Group B. Participants were randomly allocated to the two groups using a simple randomization method (lottery method) to minimize selection bias and ensure equal distribution. Participants were selected based on strict adherence to the inclusion criteria. Informed consent was obtained from all parents or caregivers.

Sample size calculation

The sample size was determined based on previous studies evaluating WBV in children with spastic diplegic CP. Assuming an effect size of d=1.0, a significance level of α=0.05, and 80% statistical power (β=0.20), a minimum of 8 participants per group was required. To account for potential dropouts, 10 participants were recruited per group, resulting in a total of 20 children. Post hoc power analysis confirmed a study power of >95%, indicating sufficient sample size to detect statistically significant differences in balance outcomes.

Participants

Twenty diagnosed children with spastic diplegic CP, including both boys and girls, were selected from the Pediatric Physiotherapy Department at SRM Medical College Hospital and Research Center, Kattankulathur, and the EXE_SIO Physiotherapy Clinic, Korattur, Chennai. The Children were diagnosed by a pediatric neurologist. Participants were aged between 6 and 12 years and had pediatric balance scale (PBS) scores ranging from 21 to 40.

All children were capable of understanding and following simple instructions. Children were excluded if they had any recent injuries or fractures to the upper or lower limbs, other types of CP, metal implants in the spine or lower limbs, recent surgeries, severe visual or hearing impairments, recent botulinum toxin treatment, or any congenital cardiac or severe respiratory conditions.

Materials

PBS: The PBS is highly valid and reliable for assessing balance in children with CP [17]. It consists of 14 distinct tasks, each scored from 0 (indicating poor performance) to 4 points (indicating excellent performance), with a maximum possible total score of 56 [18]. The scores are interpreted as follows: 41-56 indicates a low fall risk, 21-40 denotes a medium fall risk, and 0-20 reflects a high fall risk.

WBV intervention: WBV was delivered using a Lifelong vibration plate machine (LLM234), which provides side-alternating (pivotal/oscillatory) vibration, where one side of the platform moves upward while the other moves downward, resembling a teeter-totter motion.

Procedure

The Ethics Committee approved the study. Parents or guardians were informed about the study's objectives, benefits, and potential risks, and informed consent was obtained. Demographic data were then collected using assessment forms. Before the intervention began, the children were educated about the exercises, and familiarization was provided, including video demonstrations to aid understanding. Pre-tests were performed using the PBS. Twenty children with spastic diplegic CP, both boys and girls, were conveniently assigned to two groups.

Group A (experimental group)

Ten children were included in Group A. Prior to treatment, the children were made to adopt the WBV for one week. After the familiarization, WBV training was provided for 10 minutes per session (Table 1) along with regular therapeutic exercise physiotherapy (Table 2) for one hour daily, three days per week for six weeks. The duration was selected based on previous studies showing that neuromuscular adaptations and improvements in balance and functional mobility in children with spastic diplegic CP can be achieved within this timeframe, while ensuring participant adherence and practical feasibility.

WBV

The children were made to stand on a vibration platform with footwear, with the support of a therapist behind. The apparatus was turned on with a frequency of 10 Hz, an amplitude of 2 mm, and a duration of 5 minutes. After 5 minutes, the vibration was turned off. The children rested for 1 minute. Then, they were asked to stand on the vibration platform with the same parameters for 5 minutes. Thus, the total time spent for the WBV in each session was 10 minutes. As the child gets adapted and familiarised, the frequency is increased every week (Table 1).

Group B (control group)

Ten children were included in Group B and received regular therapeutic exercise physiotherapy for one hour daily, three days per week for six weeks, which was chosen based on evidence that this duration is sufficient to produce measurable improvements in balance and functional mobility in children with spastic diplegic CP. The therapeutic exercises included a neurodevelopmental approach, strengthening exercises, proprioceptive training, facilitation of righting and equilibrium to improve postural mechanisms and balance, and gait training (Table 2).

After the six-week training session, post-test assessments were conducted for both groups using the PBS. The collected data were tabulated and analyzed using both descriptive and inferential statistics. All parameters were assessed using SPSS software, version 20.

Results

Participants' characteristics

A total of 18 children with spastic diplegic CP completed the study. Group A included four boys and four girls, while Group B included six boys and four girls. The mean age of participants in Group A was 8.88±2.42 years, and in Group B, 8.30±1.95 years. The mean height was 131.63±8.81 cm in Group A and 116.80±22.29 cm in Group B, while the mean weight was 23.04±5.81 kg and 21.00±5.08 kg, respectively. The mean body mass index (BMI) was 13.43±3.30 kg/m² in Group A and 16.22±6.39 kg/m² in Group B.

Demographic characteristics, including age, height, weight, and BMI, were compared between groups using the independent t-test, and gender distribution was analyzed using the chi-square test. No significant differ-

Table 1. WBV treatment parameters

Total Weeks	No. (HZ)	Amplitude (mm)	Duration (min)	Rest Time (min)
1-2	10	2	10	3
3-4	20	2	10	2
5-6	30	2	10	1

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ences were found between groups (P>0.05), indicating that both groups were comparable at baseline (Table 3).

Two participants were excluded from the analysis due to irregular attendance and health issues, which prevented them from completing the intervention. Therefore, data from 18 participants were included in the final evaluation.

Baseline balance comparison

At baseline, the mean PBS score was 31.63±4.27 in Group A and 23.40±2.07 in Group B. An independent t-test revealed a significant difference between the groups (P<0.05), indicating that Group A had higher baseline balance scores. To control for this initial difference, analysis of covariance (ANCOVA) was conducted using pre-test scores as a covariate in the final analysis.

Normality of data

The normality of PBS scores was assessed using the Shapiro–Wilk test. The results showed that the data were normally distributed in both groups (P>0.05), supporting the use of parametric statistical methods.

Within-group comparisons

In Group A (WBV combined with therapeutic exercises), the mean PBS score increased from 31.63±4.27 at pre-test to 39.38±4.14 at post-test. A paired t-test demonstrated a statistically significant improvement in balance within the group (P<0.001, Table 4).

In Group B (therapeutic exercises only), the mean PBS score increased from 23.4±2.07 at pre-test to 26.20±2.30 at post-test. A paired t-test also showed a significant improvement within the group (P<0.001, Table 4).

Between-group comparison (post-test)

After adjusting for baseline differences using ANCOVA, Group A showed significantly higher post-test PBS scores than Group B (adjusted mean: 39.38 vs 26.20, P<0.001, Table 4). This indicates that WBV combined with therapeutic exercises produced significant improvements in balance compared to therapeutic exercises.

Table 2. Therapeutic exercise physiotherapy

Intervention	Methodology	Intensity	Repetations/Sets	Duration (min)
Movements	Active and passive movements for the Upper and lower limbs.	Start with minimal range of movements progress to maximal range of movements	10 repetitions per limb, 2 sets	10
Stretching exercises	Stretching exercise for all groups of Upper and lower limb muscles.	Start with minimal stretch progress to maximal safe stretch	Hold each stretch for 15 seconds, 3 repetitions per muscle group, 2 sets	10
Strengthening exercises	Strengthening exercise for the Upper and lower limb muscles.	start with minimal resistance to progress maximal safe resistance	10 repetitions; hold 15 seconds, relax 5 seconds, 2 sets	20
Balance and gait training	Sitting (Swiss ball or bolster) standing balance (single leg standing, weight shifting) Walking and overcoming obstacle.	Start with minimal support progress to maximal support	10 repetitions per task; 3 sets	20

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Table 3. Demographic variables of group A and group B

Demographic Variables		Mean±SD/No. (%)	
		Group A (n=8)	Group B (n=10)
Age		8.88±2.42	8.30±1.95
Height		131.63±8.81	116.80±22.29
Weight		23.04±5.81	21.00±5.08
BMI		13.43±3.30	16.22±6.39
Gender	Boy	4(50)	6(60)
	Girl	4(50)	4(40)

BMI: Body mass index.

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Discussion

This study aimed to evaluate the effects of a six-week WBV training protocol, combined with therapeutic exercises, on balance in children with spastic diplegic CP. The results indicated a significant improvement in balance for both groups, with Group A (therapeutic exercise and WBV) showing a greater enhancement compared to Group B (therapeutic exercise) (Figure1).

Prior to the intervention, the children received thorough education and familiarization through video demonstrations to ensure they understood and could correctly perform the exercises. Overall adherence was high, with 18 out of 20 participants completing the study, while two children withdrew due to irregular attendance and health issues. This suggests that WBV is generally feasible and well-tolerated in this population. Initial challenges with WBV were overcome through increased supervision and support, which also enhanced participant engagement and enjoyment of the sessions.

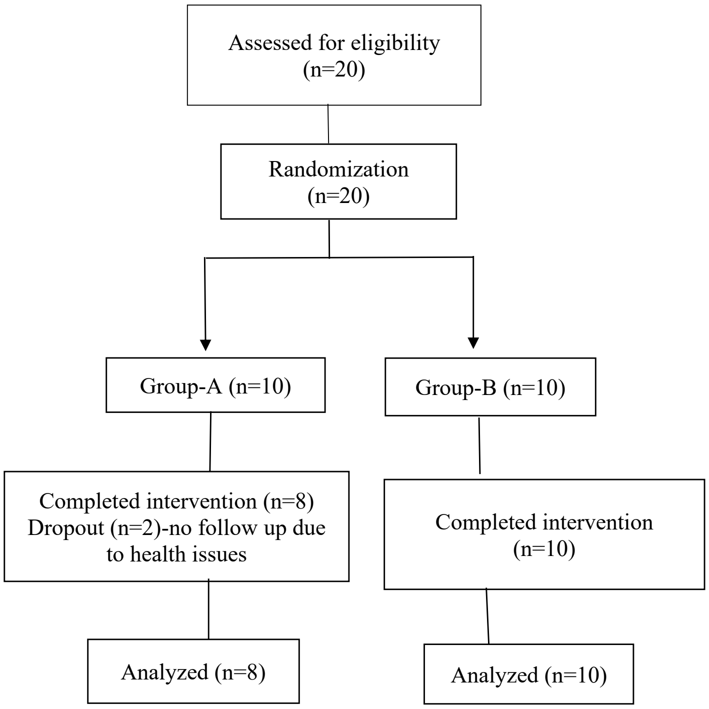

Figure 1. Consort flowchart

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Table 4. PBS: Within and between group comparisons

Group		Test	Mean±SD	MD	t	P*$
Group A		Pre-test	31.63±4.27	-7.75	0.707	0
		Post-test	39.38±4.14			
Group B		Pre-test	23.40±2.07	-2.80	-14.000	0
		Post-test	26.20±2.3			
Between groups	Group A	Pre-test	31.63±4.27	8.23	6.245	0
	Group B		23.40±2.07			
	Group A	Post-test	39.38±4.14	13.18	8.585	0
	Group B		26.20±2.30			

*P<0.05, $Sig. 2 tailed

The improvements in balance observed in this study can be attributed to neuromuscular activation induced by WBV. The vibration stimulus likely activated muscle spindles and reflexive contractions, enhancing muscle tone, coordination, and proprioceptive feedback factors critical for postural control and functional balance. Therapeutic exercises, including techniques from neurodevelopmental therapy (NDT) and neuromuscular stimulation, likely acted synergistically to further improve these outcomes [19]. Repeated WBV exposure may also have enhanced motor control, postural awareness, and proprioceptive feedback, while increased blood circulation contributed to muscle relaxation and reduced spasticity [20].

These findings are consistent with recent studies reporting positive effects of WBV on balance and motor function in children with CP. Hussein et al. (2025) observed significant improvements in muscle tone and sensory-motor function following WBV in children with spastic diplegic CP, [21] while Okur et al. (2025) reported enhancements in gait and balance in a similar population [22]. Earlier research has produced mixed results; for instance, Ibrahim et al. (2014) found that WBV improved muscle strength and reduced spasticity but did not significantly affect walking balance [14]. This highlights the need for further research to optimize WBV protocols and clarify its mechanisms.

The therapeutic exercise program used in this study aligns with the findings of Gbonjubola et al. (2021), who validated various interventions, including NDT, neuromuscular electrical stimulation, and exercise therapy, for managing CP [10]. Additionally, Ko et al. (2016) emphasized that WBV can improve ankle joint perception and gait characteristics, underscoring the importance of long-term follow-up [11]. The current study further supports these observations, demonstrating that WBV combined with therapeutic exercises is safe and effective for enhancing balance in children with spastic diplegic CP.

This study primarily addressed the body functions and structures and activity domains of the international classification of functioning, disability, and health (ICF) in relation to balance. The limitations include the use of a single outcome measure, a small sample size, and a short intervention duration. Consequently, these findings should be interpreted with caution. Future research should include larger samples, extended follow-up periods, and multiple outcome measures to assess the sustainability of WBV therapy. Moreover, incorporating factors related to participation, environmental influences, and personal aspects from the ICF framework would provide a more comprehensive evaluation. Expanding research to include other types of CP, different neurological conditions, various age groups, and diverse WBV parameters could further enhance the understanding and clinical application of this therapeutic approach.

In conclusion, the six-week WBV training protocol combined with therapeutic exercises led to meaningful improvements in balance among children with spastic diplegic CP. These results add to the growing evidence supporting WBV as a valuable adjunctive therapy, while highlighting the need for future studies to refine its protocols and investigate long-term outcomes.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of SRM Medical College and Research Center Potheri, India (Code: SRMIEC-ST0523-670 on July 5, 2023). Additionally, the study is registered with the Clinical Trial Registry-India (Code: CTRI/2024/01/061595).

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Authors' contributions

Methodology: Malathi S; Data collection, visualization and writing the original draft: Malathi S; Supervision: D. Malarvizhi; Conceptualization, Review, editing, software, validation, formal analysis, investigation, resources and project administration: All authors.

Conflict of interest

The authors declared no conflict of interest.

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