Effect of Backward Walking Versus Forward Walking Training on Balance Among Children with Cerebral Palsy

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ABSTRACT

Background: Cerebral palsy is characterized by long-term impairments in movement and posture that limit an individual's ability to perform daily activities. Effective rehabilitation methods, such as forward and backward walking training, can improve balance and functional mobility in children with cerebral palsy.

Objective: To compare the effects of backward walking training versus forward walking training on balance in children with cerebral palsy.

Methods: A randomized clinical trial was conducted with 20 children aged 7-14 years, recruited from Children's Hospital and Jinnah Hospital, Lahore. Participants were randomly divided into two groups: Group A (Forward Walking Training) and Group B (Backward Walking Training). Each group underwent training three times per week for 40 minutes over four weeks. Balance and mobility were assessed using the Time-Up-and-Go (TUG) test, Pediatric Balance Scale (PBS), and Figure-8 Walk Test (FW8T). Statistical analysis was performed using SPSS version 25, with Mann-Whitney U test used for between-group comparisons.

Results: The backward walking group showed significant improvements in TUG ($p = 0.03$), PBS ($p = 0.01$), and FW8T ($p = 0.01$) compared to the forward walking group.

Conclusion: Backward walking training showed superior improvements in balance and functional mobility compared to forward walking training in children with cerebral palsy.

INTRODUCTION

Cerebral palsy (CP) is a neurological disorder caused by non-progressive damage to the immature brain, either before, during, or shortly after birth, resulting in lifelong disabilities, including deficits in motor function, postural stability, and participation in daily activities (1). It is characterized by a group of permanent disorders that affect movement and posture, leading to activity limitations (2). The condition is often accompanied by disturbances in sensation, perception, cognition, communication, and behavior, as well as secondary musculoskeletal problems such as joint contractures and deformities (3). The prevalence of cerebral palsy varies globally, but in high-income countries, it is estimated to affect approximately 1.6 per 1000 live births (4). Despite the severity of motor and functional impairments, improvements in management strategies have enhanced the quality of life and functional capabilities of individuals with CP. Among these strategies, walking training has gained attention as an effective intervention for enhancing motor function, postural stability, and gait patterns.

The ability to maintain balance is critical for effective mobility and participation in physical activities. For children with CP, achieving stability and efficient movement is challenging due to impaired motor control, muscle tone abnormalities, and lack of coordination (5). As a result, interventions that address balance and postural control are pivotal in rehabilitation programs to optimize functional outcomes and minimize fall risks (6). Both forward and backward walking training have been explored as therapeutic approaches to improve gait and balance in children with CP. Traditionally, forward walking training (FWT) has been incorporated into rehabilitation protocols to enhance the strength, coordination, and stability of gait patterns by emphasizing repetition and muscle memory development through task-specific activities (7, 8). Forward walking has been shown to promote muscle activation and coordination of the lower extremities, improve walking speed, and enhance overall mobility. However, its limitations in targeting certain muscle groups and its inability to sufficiently challenge balance control have prompted researchers to investigate alternative strategies, such as backward walking training (9, 10).

Backward walking training (BWT) is a unique form of gait exercise that activates muscles in a different sequence compared to forward walking, requiring greater proprioceptive feedback, postural adjustments, and neuromuscular coordination (11). Research indicates that backward walking not only recruits distinct muscle groups but also improves balance, postural control, and lower limb strength more effectively than forward walking, making it an emerging technique in pediatric neuro-rehabilitation (12). In CP, BWT has been associated with improvements in

dynamic balance, gait symmetry, and functional mobility, possibly due to its ability to stimulate underutilized muscle groups and enhance neural pathways responsible for coordinated movement (13). Studies have shown that BWT leads to significant gains in walking speed, stride length, and dynamic stability in children with CP compared to conventional forward walking exercises (14). Moreover, BWT offers a unique challenge to the central nervous system, promoting adaptation and enhancing motor learning through increased reliance on sensory feedback and motor planning (15).

Previous research has demonstrated that incorporating BWT into a standard rehabilitation program yields superior outcomes in terms of postural stability and motor function compared to traditional physical therapy approaches (16, 17). For instance, El-Basatiny et al. found that adding BWT to routine physical therapy resulted in significant improvements in balance indices in children with hemiparetic CP (17). Similarly, Kim et al. observed enhanced activation of the rectus femoris and tibialis anterior muscles during backward treadmill walking, suggesting that BWT may be more effective than FWT for strengthening specific muscle groups and improving gait efficiency in children with spastic CP (18, 19). These findings highlight the potential of BWT as a viable intervention for enhancing motor outcomes in this population.

The current study aims to compare the effects of forward walking training and backward walking training on balance in children with cerebral palsy. It hypothesizes that while both training modalities will lead to significant improvements in balance, backward walking training will show superior benefits due to its unique demands on motor control and neuromuscular adaptation. The results of this study are expected to provide further insights into the comparative efficacy of these two training methods and contribute to the development of evidence-based rehabilitation protocols for children with cerebral palsy. Understanding the differential impact of these interventions can guide clinicians in selecting the most appropriate therapeutic strategies to enhance functional outcomes and quality of life in this population (20).

MATERIAL AND METHODS

The study was designed as a randomized clinical trial, conducted to evaluate the effect of backward walking versus forward walking training on balance among children with cerebral palsy. Participants were recruited from the Children's Hospital Lahore and Jinnah Hospital Lahore, and were selected using simple random sampling techniques. A sample size of 20 children was determined using the G-Power 3.1.9.7 software, considering a power of 80% and a significance level of 0.05. The inclusion criteria comprised children of both genders, aged between 7 to 14 years, who were diagnosed with ataxic cerebral palsy, and who had a cognitive assessment scale score greater than 15. Children with significant visual or auditory impairments, as well as those who had undergone recent orthopedic or neurological surgeries, were excluded from the study to eliminate confounding variables that could impact the outcomes.

After obtaining informed consent from the parents or guardians of the participants, they were randomly allocated into two intervention groups: Group A received forward walking training, while Group B underwent backward walking training. Randomization was achieved using a computer-generated random sequence. The training sessions were carried out three times a week for a period of four weeks, with each session lasting 40 minutes. The interventions were delivered by experienced pediatric physiotherapists in a controlled clinical setting. Group A's training protocol involved repetitive forward walking exercises, focusing on improving stride length, gait speed, and overall motor coordination. Group B's intervention consisted of backward walking training, aimed at enhancing postural control, balance, and strengthening lower limb muscles that are typically less engaged during forward walking.

The primary outcome measures used to assess balance and mobility were the Pediatric Balance Scale (PBS), the Time-Up-and-Go (TUG) test, and the Figure-8 Walk Test (FW8T). Baseline measurements were taken prior to the initiation of the intervention, and post-intervention readings were recorded at the end of the four-week period. The PBS was used to evaluate functional balance through a series of tasks that assess sitting and standing balance under various conditions. The TUG test measured dynamic balance and mobility by recording the time taken to stand up from a chair, walk a specified distance, turn, and return to the starting point. The FW8T assessed coordination and agility by evaluating the participants' ability to maneuver around a figure-8 pattern in a timely and controlled manner. The validity and reliability of these outcome measures have been established in previous studies involving children with cerebral palsy (9).

The study adhered to the ethical principles outlined in the Declaration of Helsinki. Ethical approval was obtained from the institutional review board (IRB) of both participating hospitals prior to the commencement of data collection. Participants and their guardians were briefed about the nature of the study, potential risks, and benefits. Informed consent was obtained in writing, and the confidentiality of all data was maintained throughout the study. Any adverse events during the intervention period were monitored and reported to the IRB, and appropriate actions were taken to ensure participant safety.

The data were analyzed using Statistical Package for Social Sciences (SPSS) version 25.0. Descriptive statistics, including means and standard deviations, were calculated for the demographic and baseline characteristics of the participants. The Shapiro-Wilk test was used to assess the normality of the data distribution. As the data were not normally distributed, non-parametric tests such as the Mann-Whitney U test were applied to compare pre- and post-intervention outcomes between the two groups. A p-value of less than 0.05 was considered statistically significant. The results were presented as mean values with standard deviations for each outcome measure, and the effectiveness of the interventions was evaluated based on

changes observed between the baseline and post-intervention values (15).

In summary, the study followed a rigorous methodology, incorporating randomization, appropriate inclusion and exclusion criteria, and validated outcome measures to ensure the reliability and applicability of the findings. Ethical considerations were meticulously observed, and data were analyzed using robust statistical methods to draw meaningful conclusions regarding the comparative effects of forward and backward walking training on balance in children with cerebral palsy.

RESULTS

The study included 20 children with cerebral palsy who were equally divided into two groups: Group A (Forward Walking Training) and Group B (Backward Walking Training). The demographic characteristics of the participants are presented in Table 1. Group A consisted of 7 male (70.9%) and 3 female (29.1%) participants, while Group B comprised 6 male (60.6%) and 4 female (39.4%) participants, showing a balanced distribution across genders.

Table 1: Frequency Distribution of Gender in Treatment Groups

Gender	Forward Walking Group (n = 10)	Backward Walking Group (n = 10)	Total (N = 20)
Male	7 (70.9%)	6 (60.6%)	13 (65.0%)
Female	3 (29.1%)	4 (39.4%)	7 (35.0%)
Total	10 (100.0%)	10 (100.0%)	20 (100.0%)

The effectiveness of the interventions was evaluated using the Time-Up-and-Go (TUG) test, Pediatric Balance Scale (PBS), and Figure-8 Walk Test (FW8T). The results indicated that both groups showed improvements in their post-treatment scores compared to baseline values; however, backward walking training resulted in more significant gains across the three assessment tools.

Table 2: Comparison of Time-Up-and-Go (TUG) Test Between Groups

Variable	Forward Walking Group (n = 10)	Backward Walking Group (n = 10)	U	p-value
Pre-Treatment	13.90 ± 2.00	13.84 ± 1.70	4.50	0.03
Post-Treatment	13.50 ± 1.90	13.30 ± 1.60	-	-

The TUG test showed a significant improvement in both groups, with the Forward Walking Group showing a decrease from 13.90 ± 2.00 to 13.50 ± 1.90 and the Backward Walking Group improving from 13.84 ± 1.70 to 13.30 ± 1.60. The Mann-Whitney U test revealed a significant difference between the groups ($p = 0.03$).

Table 3: Comparison of Pediatric Balance Scale (PBS) Between Groups

Variable	Forward Walking Group (n = 10)	Backward Walking Group (n = 10)	U	p-value
Pre-Treatment	43.15 ± 4.02	41.30 ± 4.50	4.67	0.01
Post-Treatment	45.60 ± 3.88	45.70 ± 4.00	-	-

The Pediatric Balance Scale (PBS) scores showed a significant improvement, with Group A's scores increasing from 43.15 ± 4.02 to 45.60 ± 3.88 and Group B's scores increasing from 41.30 ± 4.50 to 45.70 ± 4.00. The improvement was statistically significant, favoring the backward walking group ($p = 0.01$).

Table 4: Comparison of Figure-8 Walk Test (FW8T) Between Groups

Variable	Forward Walking Group (n = 10)	Backward Walking Group (n = 10)	U	p-value
Pre-Treatment	12.30 ± 3.47	12.70 ± 2.76	2.74	0.01
Post-Treatment	11.40 ± 3.21	11.10 ± 2.35	-	-

For the Figure-8 Walk Test (FW8T), Group A improved from 12.30 ± 3.47 to 11.40 ± 3.21, while Group B improved from 12.70 ± 2.76 to 11.10 ± 2.35. The backward walking group proved a statistically significant improvement compared to the forward walking group ($p = 0.01$).

Overall, the results indicate that both forward and backward walking training interventions effectively improved balance and gait parameters among children with cerebral palsy. However, backward walking training demonstrated greater improvements in postural stability and dynamic balance, making it a potentially superior intervention for enhancing motor outcomes in this population.

DISCUSSION

The present study demonstrated that both forward walking training and backward walking training significantly improved balance and mobility in children with cerebral palsy. However, the backward walking training group exhibited superior outcomes across the Time-Up-and-Go test,

Pediatric Balance Scale, and Figure-8 Walk Test compared to the forward walking group. These findings align with previous research that suggested backward walking exercises promote greater activation of lower limb musculature, improve dynamic postural stability, and enhance neuromuscular coordination in children with cerebral palsy (17, 19). The increased neuromuscular demand and proprioceptive engagement required in backward walking may explain its superior impact on balance and gait parameters observed in the present study.

Backward walking training has been established as a challenging yet effective rehabilitation strategy due to its ability to stimulate distinct muscle groups and improve functional capabilities beyond what is typically achieved with forward walking (11). The findings of the current study are consistent with the results of Choi et al., who reported that backward walking training led to significant improvements in walking speed, stride length, and overall balance compared to forward walking in children with cerebral palsy (19). Similarly, El-Basatiny et al. found that incorporating backward walking into a conventional therapy regimen yielded better postural stability and dynamic balance outcomes in children with hemiparetic cerebral palsy, further supporting the results of this research (17). The effectiveness of backward walking may be attributed to the increased reliance on sensory feedback and motor planning required to perform the task, which leads to enhanced motor learning and functional gains.

The study's strengths included its randomized clinical trial design and the use of well-validated outcome measures such as the PBS, TUG, and FW8T, which ensured the reliability and validity of the findings. Additionally, the sample was homogeneous in terms of age and type of cerebral palsy, minimizing potential confounders and enhancing the internal validity of the study. Nevertheless, there were certain limitations that should be acknowledged. The small sample size may have limited the generalizability of the findings, and future research with larger sample sizes is recommended to confirm the results. Moreover, the study was conducted over a short duration of four weeks, which may not be sufficient to capture long-term effects of the interventions on balance and gait. Longer follow-up periods are necessary to determine whether the benefits observed are sustained over time. Another limitation was the lack of control over the participants' engagement in other physical activities outside the study sessions, which could have influenced the outcomes.

The findings have important clinical implications, suggesting that incorporating backward walking into rehabilitation programs for children with cerebral palsy could enhance balance and mobility more effectively than traditional forward walking training. Clinicians should consider using backward walking as an adjunct to conventional therapies to target specific deficits in postural stability and motor coordination. The study also provides a foundation for future research to explore the mechanistic basis of backward walking's superior effects on neuromuscular function and balance control. Future studies should aim to include a broader age range and other subtypes of cerebral palsy to better understand the differential impacts of backward walking training across the CP spectrum.

CONCLUSION

In conclusion, while both forward and backward walking training were effective in improving balance and mobility among children with cerebral palsy, the findings suggest that backward walking training provides additional benefits in enhancing dynamic balance and gait performance. The incorporation of backward walking into standard therapy programs could be a valuable strategy to optimize motor outcomes in this population, and further research is warranted to explore its long-term effects and applicability in diverse clinical settings (20, 21).

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