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# EFFECTS OF BOBATH EXERCISES COMBINED WITH GASOTRANSMITTER ON SPASTIC DIPLEGIC CP

*Original Research*

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## ABSTRACT

**Background:** Spastic diplegic cerebral palsy (CP) is a neurological disorder primarily affecting lower limb movement due to impaired motor control and increased muscle tone. Gasotransmitters such as nitric oxide (NO) and hydrogen sulfide ($H_2S$) have shown potential neuromodulatory benefits in various neurological conditions. Although Bobath exercises are widely used for CP management, the adjunct use of gasotransmitter therapy remains underexplored. This study aimed to evaluate the effects of combining Bobath exercises with gasotransmitter therapy on motor function, spasticity, and balance in children with spastic diplegic CP.

**Objective:** To assess the impact of adjunct gasotransmitter therapy with Bobath exercises on motor function, spasticity reduction, and balance improvement in children with spastic diplegic CP.

**Methods:** A randomized controlled trial was conducted on 48 children aged 6–18 years diagnosed with spastic diplegic CP. Participants were randomly allocated into three groups: Group A (Bobath exercises only), Group B (gasotransmitter therapy only), and Group C (Bobath exercises with gasotransmitter therapy). Motor function was assessed using the Gross Motor Function Measure (GMFM), spasticity was evaluated via the Modified Ashworth Scale (MAS), and balance was measured using the Pediatric Balance Scale (PBS). Statistical analysis was performed using the Wilcoxon signed-rank test and Kruskal-Wallis test, with a significance level of $p < 0.05$.

**Results:** Group C demonstrated the most significant improvements in GMFM scores, increasing from 48.25 ± 7.04 to 65.69 ± 7.50 ($p < 0.001$). MAS scores showed a reduction from 3.06 ± 0.85 to 1.06 ± 0.85 ($p = 0.003$), indicating decreased spasticity. PBS scores improved significantly from 15.19 ± 3.54 to 25.25 ± 3.66 ($p < 0.001$), highlighting better postural control and balance compared to Groups A and B.

**Conclusion:** Bobath exercises combined with gasotransmitter therapy resulted in greater improvements in motor function, spasticity reduction, and balance enhancement than Bobath exercises alone. These findings support the integration of gasotransmitter therapy as a complementary intervention for optimizing rehabilitation outcomes in children with spastic diplegic CP.

**Keywords:** Balance, Bobath Therapy, Cerebral Palsy, Gasotransmitter, Motor Function, Neuromodulation, Spasticity.

## INTRODUCTION

Cerebral palsy (CP) is one of the most prevalent developmental disorders, primarily affecting motor function due to damage to the developing brain. Initially described by William John Little in 1843 and historically referred to as Little's disease, CP has since been recognized as a group of permanent movement and posture disorders that cause activity limitations due to nonprogressive disturbances occurring in the fetal or infant brain. The condition results from neurological and musculoskeletal impairments, manifesting as abnormal muscle contractions, postural changes, and restricted movement. Additionally, individuals with CP often experience sensory disturbances, perceptual deficits, cognitive impairment, communication difficulties, behavioral challenges, epilepsy, and secondary musculoskeletal complications (1). The epidemiology of CP has evolved over time, with an estimated incidence ranging from 1.5 to 3.0 cases per 1000 live births, varying based on risk factors such as prematurity, birth asphyxia, and perinatal brain injury (2). Physical therapy plays a crucial role in managing CP, aiming to promote, maintain, and restore physical function while improving overall well-being. Physiotherapists employ various treatment strategies, including task-oriented training, which enhances motor skills, stability, and balance in children with CP (3). Due to deficits in postural control and balance, children with CP experience significant difficulties in daily functional activities, particularly those with hemiplegic CP, who struggle with bilateral coordination (4). Among the therapeutic approaches available, the Bobath concept—also known as neurodevelopmental treatment (NDT)—is widely used in pediatric physiotherapy. Developed by Karel Bobath, this approach focuses on facilitation, therapeutic handling, and control techniques to improve muscle tone and postural alignment while promoting functional skill acquisition (5,6). By applying principles of motor learning, Bobath therapy helps children with CP achieve better postural control, balance, and muscle tone regulation, ultimately improving their mobility and quality of life (7). This method is grounded in three key principles: facilitation, stimulation, and inhibition, with individualized therapeutic goals tailored to each child's functional capabilities (8).

In recent years, research has explored the potential of gasotransmitters such as hydrogen sulfide (H2S), carbon monoxide (CO), and nitric oxide (NO) in managing spasticity in CP. Gasotransmitters are small gaseous molecules that function as neurotransmitters, playing a significant role in synaptic plasticity, neuromodulation, and overall neural communication. Unlike conventional neurotransmitters, these molecules are not stored in vesicles but synthesized on demand, exerting their effects by diffusing freely across cell membranes and modulating second-messenger systems (8). Synaptic plasticity is critical for maintaining proper neuronal function, and its disruption can contribute to spasticity by impairing the adaptability of neural circuits, resulting in exaggerated muscle contractions (9). Although traditionally regarded as toxic gases, H2S, CO, and NO have been recognized for their crucial roles in oxidative stress regulation, cardiovascular tone modulation, and immune response (10). Given their ability to influence neuromuscular function, these gasotransmitters offer promising therapeutic potential for managing spasticity in CP. Spastic diplegic CP is characterized by increased muscle tone, leading to motor impairments and restricted mobility. A combined approach incorporating Bobath exercises and gasotransmitters such as hydrogen sulfide may offer synergistic benefits in managing spasticity. Bobath therapy emphasizes postural control, muscle tone regulation, and functional skill development, while gasotransmitters may facilitate muscle relaxation and improve neuromuscular function. Together, these interventions may reduce spasticity, enhance postural stability, improve mobility, and promote motor learning. Given the limited research on integrating these two treatment modalities, this study aims to investigate their combined effects on motor function and overall well-being in individuals with spastic diplegic CP. Understanding the potential benefits of this approach could pave the way for improved therapeutic strategies in CP management.

## METHODS

The study was designed as a randomized clinical trial (NCT06739538) and conducted at Elaj Hospital, Gujranwala, within the Department of Pediatric Rehabilitation in Physical Therapy and Rehabilitation. Ethical approval was obtained from the Institutional Review Board (IRB) under the reference number IRB/FAHS/REHAB/10/24/MS/RS-3446, ensuring compliance with ethical guidelines for human research. Informed consent was obtained from the legal guardians of all participants, and in cases where participants had reached legal age, direct consent was acquired before enrollment in the study. A total sample size of 47 participants was determined using G*Power 3.1.9.7, employing a Wilcoxon signed-rank test for matched pairs. The sample size calculation was based on a one-tailed test with an effect size (dz) of 0.5, an alpha error probability of 0.05, and a power of 0.95. The analysis indicated a non-centrality

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parameter of 3.3496901, a critical t-value of 1.6803274, and a final sample size of 47 participants, ensuring an actual power of 0.9507851. The analysis incorporated predefined mean values and standard deviations for the groups (Group 1: Mean = 105, SD = 38.7; Group 2: Mean = 170, SD = 52.6), with a correlation coefficient of 0.5, resulting in an effect size (dz) of 1.376813 (11).

Participants were recruited using non-probability convenience sampling and had to meet specific inclusion criteria, including a confirmed diagnosis of spastic diplegic cerebral palsy, an age range of 6 to 18 years, moderate to severe spasticity in the lower limbs as measured by the Modified Ashworth Scale, the ability to follow simple instructions, and the capacity to engage in stretching exercises. Additionally, participants had to maintain a stable medication and therapy regimen for at least three months before the study. Exclusion criteria included the presence of other neurological conditions, a history of major orthopedic surgery within the past year or a scheduled surgery during the study period, prior botulinum toxin injections in the lower limbs within six months, severe joint contractures restricting participation in therapeutic exercises, and medical conditions such as uncontrolled epilepsy, severe cardiovascular disorders, or acute infections. Participants who demonstrated non-compliance with the study protocol were also excluded. Randomization was performed using a lottery method, ensuring equal distribution of participants across three intervention groups. Although both physiotherapists and participants were aware of their respective group assignments, the assessor remained blinded to reduce bias during evaluations. Data collection tools included the Modified Ashworth Scale (MAS) for assessing spasticity, the Gross Motor Function Measure (GMFM) for evaluating motor function, and the Pediatric Balance Scale (PBS) for assessing postural stability and functional mobility.

Participants were assigned to one of three groups: Group 1 received only Bobath exercises, Group 2 received only gasotransmitter therapy, and Group 3 received a combination of Bobath exercises and gasotransmitter therapy. In Group 1, Bobath therapy was administered twice a week for eight weeks, with each session lasting 60 minutes. The program targeted key developmental milestones, including sitting, crawling, standing, squatting, and walking, with progressive difficulty across the intervention period. Exercises included postural control training, weight shifting, proprioceptive activities, and muscle strengthening to enhance motor function and balance. Each phase focused on specific functional tasks, such as sitting with weight shifts, supported kneeling, standing balance exercises, and walking on uneven surfaces. In Group 2, gasotransmitter therapy involved the topical application of a compound containing nitric oxide (NO), hydrogen sulfide ($H_2S$), and carbon monoxide (CO) to manage spasticity and muscle stiffness. A preparation was formulated by mixing one drop of a 20 mL NO, $H_2S$, and CO precursor substance in 100 mL of olive oil to achieve homogeneity. Before administration, a patch test was conducted on the forearm to rule out allergic reactions. Upon validation, the mixture was applied twice weekly to the affected regions, including the arms, legs, neck, or back, targeting areas with muscle rigidity. Participants were monitored for potential adverse effects, including skin irritation, dizziness, or hypotension, with safety evaluations conducted regularly (12-14).

In Group 3, combined Bobath exercise and gasotransmitter therapy were implemented following the same protocols as the individual intervention groups. Gasotransmitter therapy was applied first to facilitate muscle relaxation and reduce spasticity before initiating Bobath exercises. This combination aimed to optimize neuromuscular function and enhance therapeutic outcomes. Statistical analysis was conducted using SPSS software, version 25. Descriptive statistics were used to summarize participant demographics, with continuous variables expressed as mean ± standard deviation and categorical variables presented in bar charts. Normality testing was performed, and given a p-value $< 0.05$, the Wilcoxon signed-rank test was applied for within-group comparisons of Ashworth Scale of Wrist Distal (ASWD) scores, while the Mann-Whitney U test was used to compare ASWD scores between groups. A significance level of $p < 0.05$ was considered statistically significant.

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**Table 1: Exercise Protocol and Progression**

| Weeks | Exercise Type | Exercise | Reps/Sets |
|---|---|---|---|
| 1-2 Siting | ROM | Sitting Weight Shifting (Shift weight side-to-side with support.) | 10 reps |
| | Strengthening | Seated Proximal Stabilization (On exercise ball with arms crossed, eyes open.) | 15-20 sec x 3 |
| | Balance | Balance Board Sitting (Eyes open and closed.) | 10-15 sec x 3 |
| | Proprioception | Mirror Balance (One-Leg Standing) | 5 sec x 5 |
| | Functional | Functional Reach (Sitting) (Reach in different directions for objects) | 10 reps |
| | Stretching | Hamstring and Hip Flexor Stretch | 10-15 sec x 3 |
| 3-4 Crawling | Strengthening | Crawling Forward and Backward | 10 reps x 2 |
| | Balance | Dynamic Balance on Exercise Ball (Kneeling) | 10-15 sec x 3 |
| | Proprioception | Balance Board Standing (Eyes open, then closed) | 5 sec x 5 |
| | Functional | Ball Throwing and Catching (Sitting Focus on stability during catch/release.) | 10 reps x 2 |
| | Weight Bearing | Supported Kneeling with Weight Shifts (Shift weight with hands on the surface for support.) | 10 reps x 2 |
| | Stretching | Calf Stretch (Use the wall for bilateral support.) | 15 sec x 3 |
| 5-6 Squat to Stand | Strengthening | Squat to Stand with a Supported chair | 10 reps x 2 |
| | Balance | Standing on Trampoline (Progress to eyes closed.) | 10-15 sec x 3 |
| | Proprioception | Mirror Standing Balance (One Leg) | 5-10 sec x 3 |
| | Functional | Functional Reaching in Standing (Reach-in various directions for objects.) | 10 reps x 2 |
| | Weight Bearing | Equal Weight Distribution in Standing (Practice weight shifting without holding.) | 10 reps x 2 |
| | ROM | Hip Flexor and Quadriceps Stretch | 15 sec x 3 |
| 7 Standing with Balance | Strengthening | Forward Lunges with Support (Use hand support initially) | 10 reps x 2 |
| | Balance | Standing Balance with Eyes Closed (Mirror) | 5-10 sec x 3 |
| | Proprioception | Balance Board Weight Shifting (Progress to single-leg if stable) | 10 reps x 2 |
| | Functional | Ball Throwing in Standing (Increase throw distance for challenge) | 10 reps x 2 |
| | Weight Bearing | Stepping in Different Directions (Step forward, backward, and side-to-side.) | 10 reps x 2 |
| | ROM | Adductor Stretch | 15 sec x 3 |

| Weeks | Exercise Type | Exercise | Reps/Sets |
|---|---|---|---|
| 8 Walking | Strengthening | Single-Leg Standing Squats | 5 reps x 2 |
| | Balance | Heel-to-Toe Walking (Practice along a control line.) | 5-10 steps x 2 |
| | Proprioception | Standing March on Trampoline (Aim for controlled steps) | 10 reps x 2 |
| | Functional | Functional Reaching and Catching in Motion (Move in different directions for throws.) | 10 reps x 2 |
| | Walking | Walking on Uneven Surface (Progress to incline or gravel for challenge.) | 5-10 steps x 2 |
| | ROM | Full Body Stretch Routine (Include significant muscle groups) | 15-20 sec x 3 |

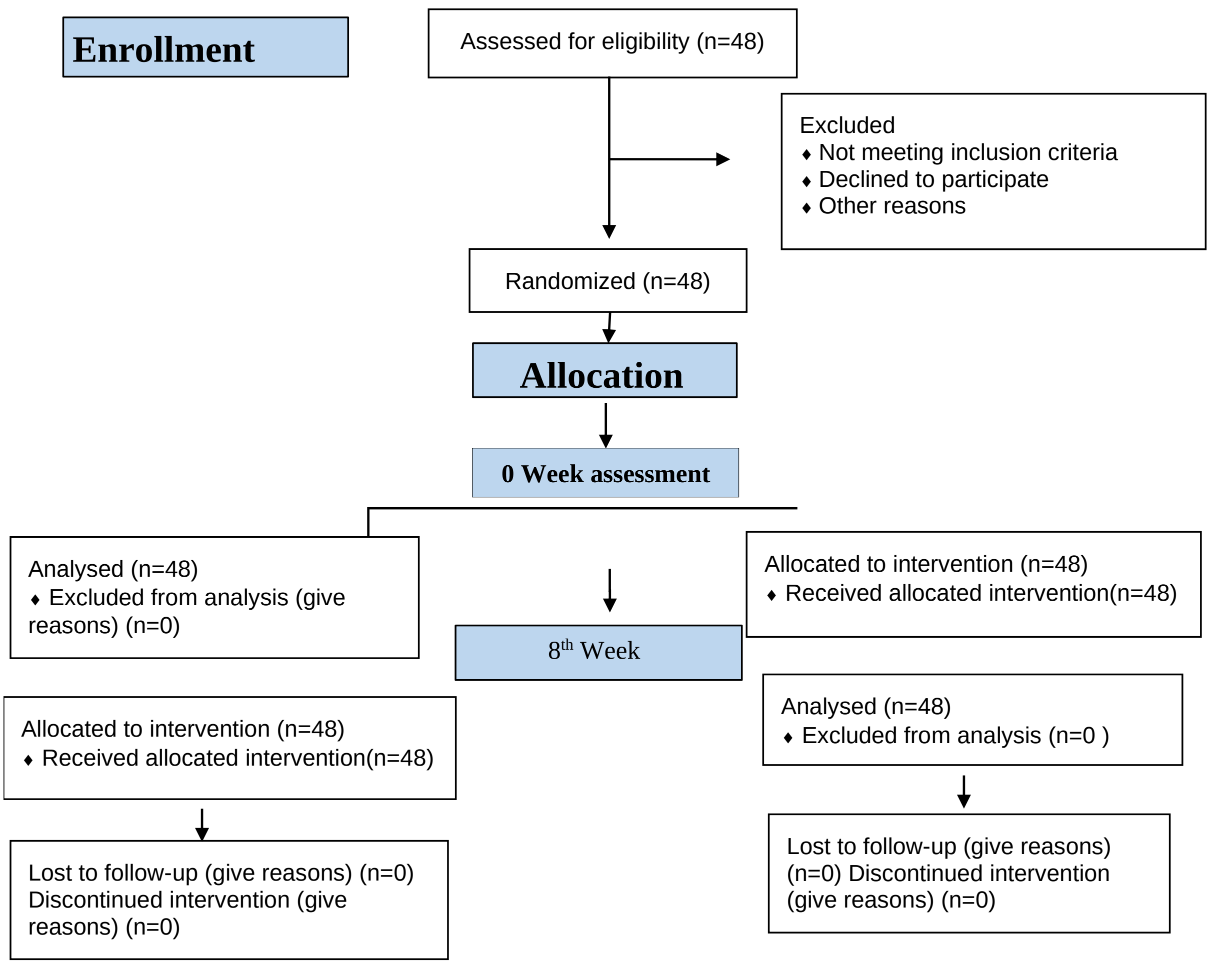


**Figure 1 Consort Diagram**

## RESULTS

The demographic characteristics of participants across the three intervention groups were relatively balanced. The mean age of participants in Group A was 10.06 ± 4.04 years, in Group B was 9.19 ± 3.02 years, and in Group C was 10.50 ± 3.71 years. Height and weight distributions were comparable, with Group A participants having an average height of 124.81 ± 12.80 cm and weight of 26.56 ± 7.99 kg, Group B participants averaging 126.37 ± 11.48 cm in height and 27.62 ± 6.87 kg in weight, and Group C participants averaging 129.56 ± 13.91 cm in height and 29.68 ± 8.59 kg in weight. Gender distribution was relatively equal, with a slight predominance of female participants in two of the groups. The similarity in baseline demographic characteristics ensured comparability of outcomes across all intervention groups. Baseline assessment of the Modified Ashworth Scale (MAS), Gross Motor Function Measure (GMFM), and Pediatric Balance Scale (PBS) showed no statistically significant differences among the three groups, confirming a homogenous starting point. The mean MAS scores before intervention were 2.75 ± 0.86 in Group A, 3.44 ± 0.81 in Group B, and 3.06 ± 0.85 in Group C. After eight weeks of intervention, the MAS scores improved significantly across all groups, with Group A reducing to 1.75 ± 0.86, Group B to 2.43 ± 0.81, and Group C to 1.06 ± 0.85. The greatest reduction in spasticity was observed in Group C, which received both Bobath exercises and gasotransmitter therapy, demonstrating a statistically significant difference ($p = 0.003$).

Motor function improvements were assessed using GMFM scores. The baseline GMFM scores were 47.88 ± 6.42 in Group A, 48.63 ± 6.16 in Group B, and 48.25 ± 7.04 in Group C. Post-intervention, the scores increased to 55.13 ± 6.54 in Group A, 55.50 ± 6.29 in Group B, and 65.69 ± 7.50 in Group C. The most substantial improvement was observed in Group C, where participants showed a marked increase in motor function, with a statistically significant difference ($p = 0.001$). Postural stability and balance improvements were evaluated using the PBS. The baseline scores were 13.94 ± 2.84 in Group A, 13.88 ± 2.75 in Group B, and 15.19 ± 3.54 in Group C. After eight weeks, scores increased to 18.13 ± 2.50 in Group A, 17.81 ± 3.29 in Group B, and 25.25 ± 3.66 in Group C. The improvement in Group C was statistically significant ($p < 0.001$), reflecting the effectiveness of combining Bobath therapy with gasotransmitter application in enhancing balance and functional mobility.

Within-group comparisons using the Wilcoxon Signed Rank Test indicated significant improvements across all variables. The MAS scores showed a statistically significant decrease post-intervention ($z = -3.2$, $p = 0.001$), GMFM scores demonstrated notable improvement ($z = -4.1$, $p = 0.027$), and PBS scores reflected enhanced balance and coordination ($z = -3.85$, $p = 0.043$). Between-group comparisons using the Kruskal-Wallis test further supported the superior efficacy of the combined intervention. MAS reductions were significantly greater in Group C ($p = 0.021$ at baseline, $p = 0.003$ post-intervention). GMFM scores were significantly higher in Group C after eight weeks compared to the other groups ($p = 0.001$). Similarly, PBS scores showed the most substantial improvement in Group C ($p < 0.001$), reinforcing the effectiveness of integrating gasotransmitter therapy with Bobath exercises for managing spastic diplegic cerebral palsy.

**Table 2: Descriptive Statistics of Quantitative Demographic Variable**

| Variable | Group A | | Group B | | Group C | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** | **Mean** | **SD** |
| Age | 10.06 | 4.041 | 9.19 | 3.016 | 10.50 | 3.706 |
| Height | 124.8125 | 12.80218 | 126.3750 | 11.48260 | 129.5625 | 13.90908 |
| Weight | 26.5625 | 7.99140 | 27.6250 | 6.87871 | 29.6875 | 8.59239 |

 

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**Table 3: Descriptive Statistics of Modified Ashworth Scale (MAS), Gross Motor Function Measure (GMFM), and Pediatric Balance Scale (PBS)**

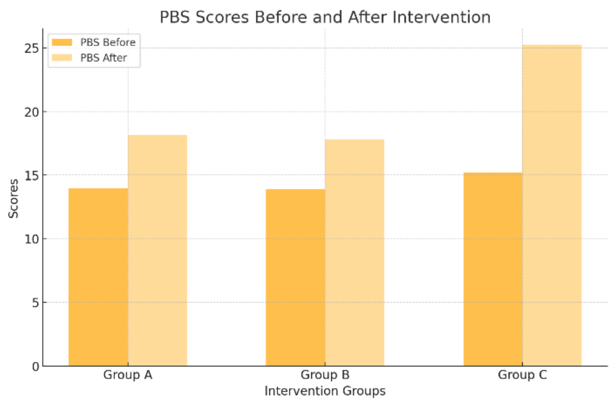
| Variable | Group A | | Group B | | Group C | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** | **Mean** | **SD** |
| MAS at Baseline | 2.7500 | .85635 | 3.4375 | .81394 | 3.0625 | .85391 |
| MAS at 8th Week | 1.7500 | .85635 | 2.4375 | .81394 | 1.0625 | .85391 |
| GMFM at Baseline | 47.8750 | 6.41742 | 48.6250 | 6.16306 | 48.2500 | 7.03799 |
| GMFM at 8th Week | 55.1250 | 6.54090 | 55.5000 | 6.29285 | 65.6875 | 7.49861 |
| PBS at Baseline | 13.9375 | 2.83945 | 13.8750 | 2.75379 | 15.1875 | 3.54436 |
| PBS at the 8th Week | 18.1250 | 2.50000 | 17.8125 | 3.29077 | 25.2500 | 3.66060 |

**Table 4: Wilcoxon Signed Rank Test (Within Group Analysis)**

| Variable | | Mean Rank | Sum of Ranks | z value | p-value |
|---|---|---|---|---|---|
| MAS (baseline - 8th weeks) | Negative Ranks | 6 | 42 | -3.2 | 0.001 |
| | Positive Ranks | 20 | 140 | | |
| GMFM (baseline - 8th weeks) | Negative Ranks | 5.5 | 33 | -4.1 | 0.027 |
| | Positive Ranks | 22.5 | 157.5 | | |
| PBS (baseline - 8th weeks) | Negative Ranks | 6.5 | 39 | -3.85 | 0.043 |
| | Positive Ranks | 21.5 | 150.5 | | |

**Table 5: Kruskal-Walli's test (Between Group Analysis)**

| Variable | Group A Median (Q1–Q3) | Group B Median (Q1–Q3) | Group C Median (Q1–Q3) | F | Sig. (p-value) |
|---|---|---|---|---|---|
| MAS at Baseline | 2.75 (2.0–3.5) | 3.44 (3.0–4.0) | 3.06 (2.5–3.5) | 4.12 | 0.021 |
| MAS at 8th Week | 1.75 (1.0–2.5) | 2.43 (2.0–3.0) | 1.06 (0.5–2.0) | 6.87 | 0.003 |
| GMFM at Baseline | 47.88 (42.0–52.0) | 48.63 (44.0–53.0) | 48.25 (43.0–54.0) | 2.75 | 0.068 |
| GMFM at 8th Week | 55.13 (50.0–60.0) | 55.50 (51.0–60.0) | 65.69 (60.0–70.0) | 10.45 | 0.001 |
| PBS at Baseline | 13.94 (12.0–15.0) | 13.88 (12.0–15.0) | 15.19 (14.0–16.5) | 3.22 | 0.048 |
| PBS on 8th Week | 18.13 (16.0–20.0) | 17.81 (16.0–20.0) | 25.25 (23.0–27.0) | 15.76 | 0.000 |



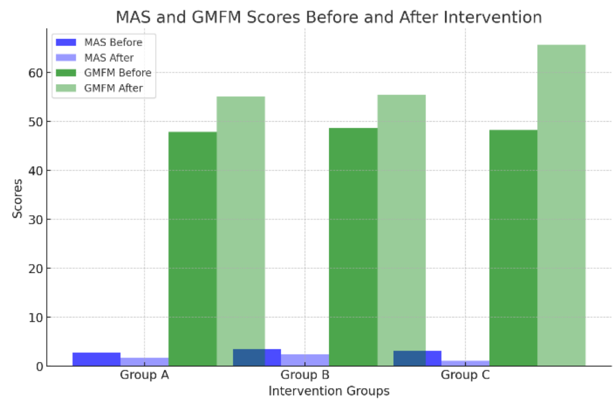
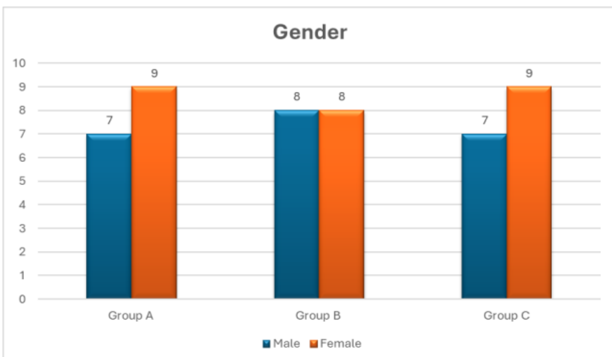




Figure 1 Gender of Group A




## DISCUSSION

The findings of the present study revealed a well-balanced distribution of demographic characteristics across the three intervention groups, with a mean age ranging from 9.19 to 10.50 years. These values align with those reported by Patel et al., who studied children with cerebral palsy aged 5 to 15 years, with a mean age of 10.2 ± 4.3 years and a female composition of 53% (15). However, Whitney et al. found a higher proportion of male participants (63%) and a slightly older mean age of 9.5 years, indicating that gender distribution may vary across different samples (16). The relatively equal gender distribution in the current study strengthens the generalizability of findings, as participants were randomly allocated. The height and weight parameters were also comparable with those reported in similar studies on children with cerebral palsy. The mean height and weight across groups were within a similar range to the findings of Egenolf et al., who documented an average height of 125.2 ± 14.3 cm and weight of 27.8 ± 7.2 kg, confirming that children with CP exhibit growth patterns comparable to typically developing peers (17). Rapson et al. reported slightly lower values, suggesting minor growth delays in children with CP (18). However, the present study aligns with most existing literature, demonstrating no significant variations in these measures. A significant reduction in spasticity was observed across all groups, with the most pronounced improvement in Group C, where the MAS score decreased from 3.06 ± 0.85 to 1.06 ± 0.85 ($p = 0.003$). This aligns with the findings of Saeedi et al., who demonstrated a significant reduction in MAS scores following a combined neurodevelopmental therapy and strengthening exercise intervention ($p = 0.002$) (19). The findings further support the growing consensus that multimodal therapeutic approaches are more effective in managing spasticity than single-modality treatments. In contrast, Simon et al. reported a comparatively smaller reduction in MAS scores ($p < 0.05$), likely due to variations in therapy duration and the nature of interventions applied (20). This highlights the importance of intervention intensity and the synergy between different therapeutic modalities in achieving optimal outcomes.

Motor function, as assessed by GMFM, showed a significant improvement in Group C, with scores increasing from 48.25 ± 7.04 to 65.69 ± 7.50 ($p < 0.001$). This is consistent with findings by Reyad et al., who reported significant gains in GMFM scores following an 8-week intervention in children with CP ($p = 0.0001$) (21). Similarly, Ren et al. demonstrated significant improvements in motor function ($p = 0.002$) when motor skill learning was combined with functional training, reinforcing the effectiveness of integrated therapeutic strategies (22). However, studies that utilized single-modality interventions, such as strength-focused exercises or isolated neurodevelopmental techniques, reported lower gains in GMFM scores. Frederico et al. found a more modest increase ($p = 0.04$), indicating that intervention breadth plays a critical role in optimizing functional outcomes (23). The present findings strongly support the superiority of combined interventions in enhancing motor function, emphasizing the need for holistic therapeutic approaches in children with CP. Postural stability and balance, measured using PBS, improved significantly, particularly in Group C, where scores increased from 15.19 ± 3.54 to 25.25 ± 3.66 ($p < 0.001$). These findings are in line with de Araújo et al., who demonstrated improved balance outcomes following combined physiotherapy interventions ($p = 0.001$) (24). Similarly, Gupta et al. reported significant enhancements in PBS scores with combined treatment strategies ($p = 0.003$), reinforcing the effectiveness of multimodal rehabilitation approaches (24). In contrast, Abd et al. observed a relatively smaller improvement ($p = 0.03$) with conventional physiotherapy alone, suggesting that a targeted, multi-component intervention yields superior balance outcomes in children with CP (25). The present study corroborates the notion that rehabilitation programs should incorporate multiple intervention strategies to achieve optimal functional improvements in this population.

The strengths of the current study lie in its randomized design, the use of validated assessment tools, and the inclusion of a multimodal intervention approach that reflects contemporary rehabilitation strategies for CP. However, the study's generalizability was limited by a small sample size, which may have influenced the statistical power of the findings. Additionally, the short intervention duration did not allow for the assessment of long-term therapeutic effects, raising questions about the sustainability of the observed improvements. The absence of strict control over predictor variables, such as baseline spasticity severity and prior therapeutic exposure, may have introduced variability in treatment response. Moreover, challenges in evaluating motor skills and spasticity in children with varying degrees of cerebral palsy should be considered when interpreting the results. Future research should focus on larger, multicenter trials to validate these findings and enhance generalizability. Longitudinal studies are needed to assess the long-term impact of combined Bobath exercises and gasotransmitter therapy on spasticity, motor function, and balance. Optimization of gasotransmitter dosage should be explored, with preliminary evidence suggesting that three drops per application may yield more effective outcomes. Further investigation into the application of gasotransmitters in other neurological disorders could provide broader insights into their therapeutic potential. Comparative studies evaluating combined therapy against other standard interventions, such as botulinum toxin injections and conventional physiotherapy, would also be valuable in establishing the most effective rehabilitation strategies for children with spastic diplegic cerebral palsy.

## CONCLUSION

The findings of this study highlight the significant therapeutic benefits of combining Bobath exercises with gasotransmitter therapy in managing spastic diplegic cerebral palsy. This integrated approach proved more effective than conventional interventions, demonstrating notable improvements in sensory-motor function, balance, and mobility while significantly reducing spasticity. By addressing both neuromuscular and postural control deficits, this combination therapy offers a promising avenue for enhancing functional independence in children with cerebral palsy. These results emphasize the need for multidimensional rehabilitation strategies that incorporate both physiotherapeutic and neuromodulatory interventions to optimize clinical outcomes and improve the quality of life for affected individuals.

**Author Contribution**

| Author | Contribution |
|---|---|
| Hafsa Abid | Substantial Contribution to study design, analysis, acquisition of Data<br>Manuscript Writing<br>Has given Final Approval of the version to be published |
| Saleh Shah | Substantial Contribution to study design, acquisition and interpretation of Data<br>Critical Review and Manuscript Writing<br>Has given Final Approval of the version to be published |
| Muhammad Naveed Babur | Substantial Contribution to acquisition and interpretation of Data<br>Has given Final Approval of the version to be published |
| Iqra Ikram* | Contributed to Data Collection and Analysis<br>Has given Final Approval of the version to be published |

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