Original Article
Yonsei Med J 2026 Jan;67(1):56-61
https://doi.org/10.3349/ymj.2025.0003
Yonsei Medical Journal
YMJ
pISSN: 0513-5796 · eISSN: 1976-2437

Effect of Botulinum Toxin Injection in Hip Adductor Muscles on Gross Motor Function in Low-Functioning Children with Spastic Cerebral Palsy

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Purpose: Botulinum toxin type A (BoNT-A) injections are used to manage spasticity in children with low-functioning cerebral palsy (CP), particularly in cases involving the hip adductor muscles. Despite their widespread use, research on the impact of BoNT-A injections on gross motor function in children with CP within Gross Motor Function Classification System (GMFCS) levels III–V remains limited, prompting us to evaluate their effectiveness in this population.
Materials and Methods: This retrospective study included 100 preschool children (mean age, 3.9 years) with CP (GMFCS levels III–V) who received BoNT-A injections targeting the adductor muscles at a tertiary hospital (2006–2024). Gross motor function was assessed using the Gross Motor Function Measure (GMFM) within 1 month before injection and between 3 weeks and 4 months post-injection. Subgroup analyses were conducted by GMFCS level and by injection site. Pre- and post-injection assessments were compared using the Wilcoxon signed-rank test.
Results: GMFM scores improved significantly across all GMFCS levels (p<0.05). Children at GMFCS levels III and IV demonstrated improvements across all domains (A–E), whereas those at GMFCS level V showed significant gains in domains A, B, and C (p<0.05). Further analyses showed significant improvements in all three groups: adductors alone, adductors and hamstrings, and adductors and distal muscles (p<0.05).
Conclusion: BoNT-A injections into hip adductor muscles improved gross motor function in children with low-functioning CP, affecting both overall and specific functional domains. This effect was observed in children who received injections into the adductors alone, as well as in combination with injections into the hamstrings or distal muscles.

Key Words: Cerebral palsy, spasticity, botulinum toxin, motor function

INTRODUCTION

Cerebral palsy (CP) is defined as a group of permanent disorders of movement and posture development, attributed to non-progressive disturbances in the developing fetal or infant brain.[1]

Received: March 5, 2025 **Revised:** May 27, 2025
Accepted: June 26, 2025 **Published online:** October 21, 2025
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•The authors have no potential conflicts of interest to disclose.

Spasticity, a common feature of CP, is a form of hypertonia caused by damage to neural pathways within the central nervous system, which severely affects motor control, voluntary movements, and gross motor function. Managing spasticity is essential, as it can significantly influence the gross motor function of children with CP, which is closely linked to Gross Motor Function Classification System (GMFCS) levels.[2-4] Furthermore, since persistent spasticity is a major cause of secondary musculoskeletal disorders, such as hip displacement and scoliosis, the control of spasticity can help prevent such complications.[5,6]

Spasticity can be managed using various approaches, including physical therapy, oral medications, intrathecal baclofen, selective dorsal rhizotomy, and orthopedic surgery.[7-9] Among these, botulinum toxin type A (BoNT-A) injection offers distinct advantages, particularly due to its targeted application, minimal systemic side effects, and ability to complement other mo-

tor-improving therapies.[10] The therapeutic effects of BoNT-A last for approximately 3 months, during which muscle recovery occurs through axonal sprouting and the regeneration of neuromuscular junctions.[11]

However, most studies on BoNT-A have focused on high-functioning children with CP and GMFCS levels I–II, where the primary goal is to improve gait and enhance functional mobility. BoNT-A injections are often targeted at the gastrocnemius muscle to reduce spasticity, improve walking efficiency, and prevent musculoskeletal deformities. Contrastingly, for children with GMFCS levels III, IV, and V, who experience more severe motor impairments, the focus of BoNT-A is often on pain relief and improving ease of care, rather than enhancing functional mobility. These children are more likely to receive injections in the hip adductors to facilitate caregiving, such as improving positioning and hygiene, and preventing secondary musculoskeletal disorders, such as hip subluxation. Despite its widespread use, research on the effects of BoNT-A on gross motor function in this low-functioning population is limited.[12,13]

In low-functioning CP, gross motor functions, such as lying, rolling, and repositioning play a critical role in pressure relief by reducing prolonged pressure on vulnerable areas, which helps prevent pressure ulcer formation.[14] Additionally, impairments in these functions limit compensation for sleep apnea through postural shifting, leading to poorer sleep quality, while restricted daytime activity and limited independent postural adjustment contribute to a higher prevalence of disorders of initiating and maintaining sleep.[15] Meanwhile, enhanced sitting balance reduces respiratory morbidity by improving postural control, facilitating effective airway clearance, and preventing complications, such as aspiration and spinal deformities, which collectively support better lung function and reduce the risk of recurrent respiratory infections.[16] Furthermore, improvements in sitting balance promote greater daily participation by enhancing trunk stability and supporting physical and emotional well-being, collectively boosting independence and quality of life for both children and caregivers.[17]

This study aimed to address this research gap by investigating the effects of BoNT-A injections on gross motor function in children with low-functioning CP (GMFCS levels III, IV, and V). Specifically, we focused on BoNT-A injections administered to the hip adductor muscles, which are commonly targeted for spasticity management in this population.

MATERIALS AND METHODS

Study design

This retrospective observational study was conducted at a tertiary hospital between March 2006 and May 2024. The Institutional Review Board of a university-affiliated hospital in Seoul, South Korea granted ethical approval for this study (4-2024-1311). The inclusion criteria were: 1) preschool children with CP under 84 months of age; 2) low-functioning CP classified as GMFCS levels III, IV, or V; 3) treated with muscular injections including in the hip adductor muscles. The exclusion criteria were: 1) children who did not receive BoNT-A injections in the hip adductor muscles and 2) those who had undergone any BoNT-A injections, nerve blocks, selective posterior rhizotomy, or orthopedic surgery within 1 year prior to the study.

Dosage and injection technique

The dosage was determined based on the weight of the child, the injection site, and the severity of spasticity. Depending on the total dose required, one vial containing either 100 units of onabotulinumtoxinA (BoNT-A; BOTOX®) (AbbVie, North Chicago, IL, USA) or 500 units of abobotulinumtoxinA (BoNT-A; Dysport®) (Ipsen, Basking Ridge, NJ, USA) was mixed with 2 cc of 0.9% sodium chloride solution. All injections were administered under ultrasound guidance to ensure accurate targeting of the muscles; the remaining doses were discarded. Specific muscles injected included the adductor longus, gracilis, and adductor magnus in the hip adductor group; the semimembranosus and semitendinosus in the hamstring group; and the gastrocnemius and soleus in the calf muscle group. The choice of muscles was determined based on clinical findings such as increased tone on the Modified Ashworth Scale and Modified Tardieu Scale, reduced passive range of motion, and impaired posture and movement observed during physical examination.

Outcome measures

Evaluations were conducted using the Gross Motor Function Measure (GMFM), and the study included only children with CP who underwent pre-injection assessments within 1 month before injection and post-injection assessments between 3 weeks and 4 months after injection.[11,18]

Statistical analysis

Statistical analyses were performed using the R software (version 4.1.3; R Foundation for Statistical Computing, Vienna, Austria). Descriptive statistics were used to characterize the study cohort, with continuous variables reported as means and standard deviations (SD). The Shapiro–Wilk test was performed to assess normality. Since the data did not meet the assumption of normality, the Wilcoxon signed-rank test was used to analyze the pre- and post-injection results, including subgroup analyses comparing GMFCS levels III, IV, and V, as well as to evaluate the effects of different injection sites. Statistical significance was determined using a p-value<0.05.

RESULTS

Overall, 100 children with bilateral spastic CP were included in the study (range, 1.5–6.9 years; mean, 3.9 years; 65 males and 35 females) (Fig. 1). According to the GMFCS, there were

34 children in level III, 34 children in level IV, and 32 children in level V (Table 1), and these children were assessed with the GMFM before treatment and again 3 weeks to 4 months after injection. The number of children treated and doses of BoNT were analyzed by muscle group, with further classification based on the specific muscles in each group (Table 2).

In the patient cohort, there was a significant increase in both GMFM-66 and GMFM-88 scores. The GMFM-66 scores increased by a mean of 2.39±3.38, while the GMFM-88 total scores increased by a mean of 3.49±4.03; both were statistically significant (p<0.05) (Fig. 2). Given that the minimum clinically important difference (MCID) for GMFM-66 and GMFM-88 is reported to range between 1.0% and 2.0%, these improvements also exceeded the MCID threshold, suggesting that the observed gains were not only statistically significant but also clinically meaningful.[19]

The GMFM-66 scores demonstrated a statistically significant improvement after BoNT-A injection, with a mean increase of 1.96±2.00 in GMFCS level III, 2.27±2.71 in GMFCS level IV, and 2.96±4.88 in GMFCS level V (p<0.05). Also, GMFM-88 total scores demonstrated statistically significant improvement post-BoNT-A injection, with a mean increase of 4.29±3.38 in GMFCS level III, 3.62±4.74 in GMFCS level IV, and 2.50±3.74 in GMFCS level V (p<0.05) (Fig. 3).

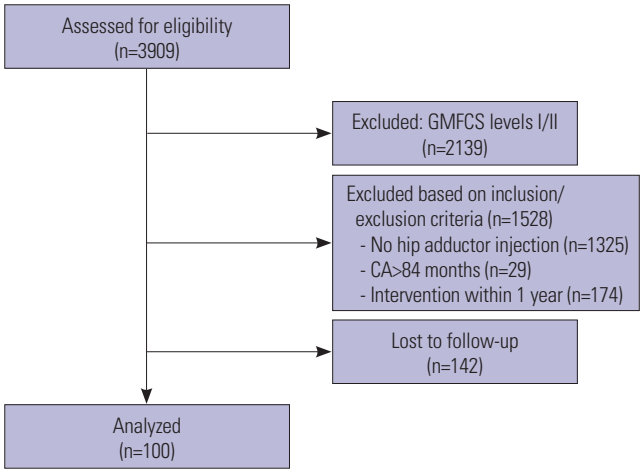

Fig. 1. Patient selection flowchart for study inclusion. Starting from a total of 3909 patients, exclusion criteria were applied sequentially, resulting in a final sample of 100 patients. GMFCS, Gross Motor Function Classification System; CA, chronological age.

Table 1. Demographic and Baseline Clinical Characteristics of the Study Population (n=100)

Characteristic	Value
Sex	
Male	65 (65.0)
Female	35 (35.0)
GMFCS	
III	34 (34.0)
IV	34 (34.0)
V	32 (32.0)
Product name	
BOTOX®	85 (85.0)
Dysport®	15 (15.0)
Age (months)	47.0±16.4 (18–83)
Body weight (kg)	13.8±3.9 (8.1–30.5)
Assessment period (days)	45.4±24.8 (21–150)
Total injection dose (units)	
BOTOX®	174.2±53.5 (70–300)
Dysport®	618.7±136.1 (500–880)
Injection dose per kg (units/kg)	
BOTOX®	12.90±3.53 (4.61–21.82)
Dysport®	50.89±8.22 (41.32–62.61)

GMFCS, Gross Motor Function Classification System.
Values are expressed as mean±SD (range) or number (%). BOTOX® and Dysport® are commercial preparations of botulinum toxin type A.

Table 2. Analysis of Botulinum Toxin Doses by Muscle Group and Specific Muscles

Muscle group	Muscle	Dose (units/kg)
Adductor muscles	Total (n=100)	
	BOTOX® (n=85)	7.41±2.15 (2.55–15.11)
	Dysport® (n=15)	29.76±9.86 (16.67–43.48)
	Adductor magnus (n=7)	
	BOTOX® (n=4)	4.36±0.77 (3.28–5.04)
	Dysport® (n=3)	14.96±0.07 (14.88–15.00)
	Adductor longus (n=90)	
	BOTOX® (n=76)	3.88±0.95 (1.97–6.36)
	Dysport® (n=14)	13.78±3.87 (8.57–22.60)
	Gracilis (n=97)	
	BOTOX® (n=82)	3.87±0.91 (2.46–6.36)
	Dysport® (n=15)	13.93±3.84 (8.57–20.87)
Hamstring muscles	Total (n=26)	
	BOTOX® (n=20)	6.84±1.85 (2.92–10.37)
	Dysport® (n=6)	26.65±2.99 (22.22–30.77)
	Semimembranosus (n=25)	
	BOTOX® (n=19)	6.16±1.28 (2.92–8.33)
	Dysport® (n=6)	26.65±2.99 (22.22–30.77)
	Semitendinosus (n=4)	
	BOTOX® (n=4)	4.95±0.82 (4.26–6.09)
	Dysport® (n=0)	-
Calf muscles	Total (n=48)	
	BOTOX® (n=43)	7.81±1.47 (3.65–10.53)
	Dysport® (n=5)	30.37±7.08 (21.24–36.36)
	Gastrocnemius (n=47)	
	BOTOX® (n=43)	7.73±1.53 (3.65–10.53)
	Dysport® (n=4)	32.66±5.66 (24.27–36.36)
	Soleus (n=2)	
	BOTOX® (n=1)	3.50
	Dysport® (n=1)	21.24

Values are expressed as mean±SD (range). Doses represent injections per muscle on one side, not combined bilateral doses. BOTOX® and Dysport® are commercial preparations of botulinum toxin type A.

https://doi.org/10.3349/ymj.2025.0003

Additionally, as the GMFM-88 consists of five domains—A (lying and rolling), B (sitting), C (crawling and kneeling), D (standing), and E (walking, running, and jumping)—domain-specific analyses were performed, and the results showed that improvements varied according to the GMFCS level. In children with GMFCS levels III and IV, statistically significant improvements were observed across all GMFM domains ($p<0.05$). In children with GMFCS level V, statistically significant improvements were observed in the GMFM domains A, B, and C ($p<0.05$) (Table 3).

Furthermore, a subgroup analysis was performed based on additional muscles that received injections along with the adductor muscles. Statistically significant improvements were observed in all groups: the "Adductor only" group, the "Adductor with hamstring" group, and the "Adductor with distal muscles" group ($p<0.05$) (Table 4).

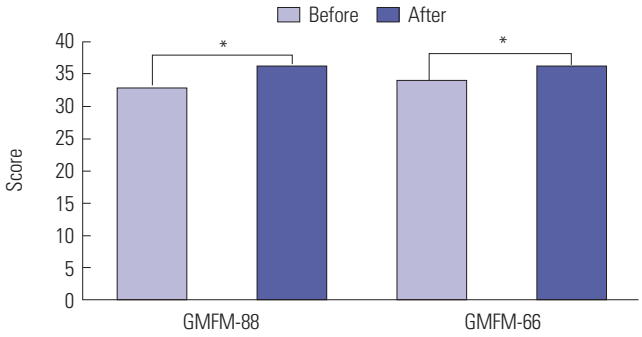

Fig. 2. Comparison of GMFM-88 and GMFM-66 scores before and after injection. *$p<0.05$. GMFM, Gross Motor Function Measure.

DISCUSSION

To our knowledge, this is the first study to evaluate the effect of BoNT-A injections targeting the hip adductor muscles on motor function in children with low-functioning CP, providing a

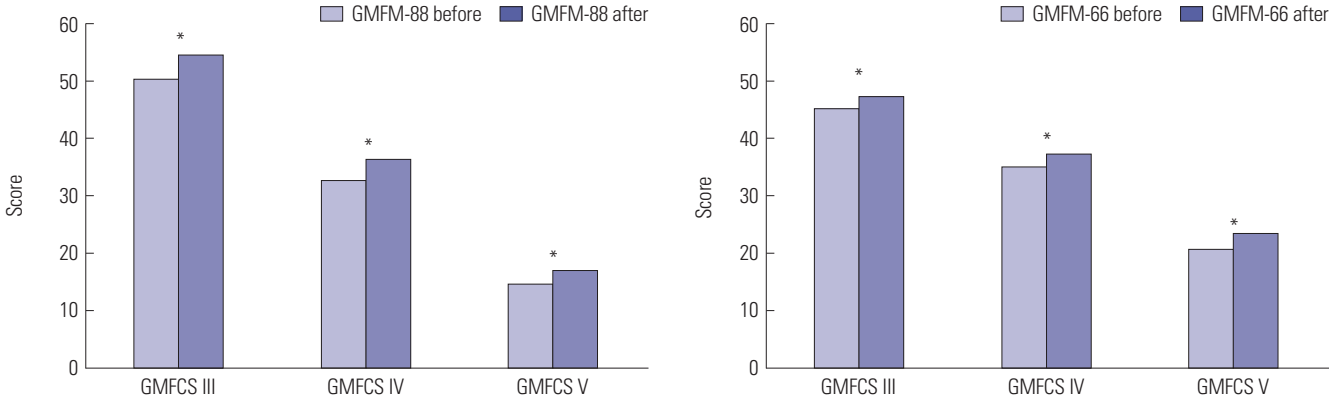

Fig. 3. Comparison of GMFM-88 and GMFM-66 scores before and after injection across GMFCS levels III, IV, and V. *$p<0.05$. GMFM, Gross Motor Function Measure; GMFCS, Gross Motor Function Classification System.

Table 3. Changes in GMFM-88 Domain Scores and GMFM-66 Pre- and Post-Injection by GMFCS Levels

GMFCS level	GMFM-88										GMFM-66	
	Domain A		Domain B		Domain C		Domain D		Domain E			
	Mean±SD	*p*	Mean±SD	*p*	Mean±SD	*p*	Mean±SD	*p*	Mean±SD	*p*	Mean±SD	*p*
III (n=34)	2.19±5.03	0.011*	7.11±9.44	<0.001*	3.99±7.31	0.001*	6.03±6.68	<0.001*	2.12±2.86	<0.001*	1.96±2.00	<0.001*
IV (n=34)	3.29±5.29	0.003*	5.78±10.88	0.001*	4.90±10.12	<0.001*	3.39±7.65	0.004*	0.74±1.85	0.027*	2.27±2.71	<0.001*
V (n=32)	3.92±10.08	0.004*	4.22±7.45	<0.001*	2.53±5.57	0.007*	0.88±2.57	0.068	0.96±3.30	0.109	2.96±4.88	<0.001*
Total (n=100)	3.12±7.08	<0.001*	5.73±9.38	<0.001*	3.83±7.91	<0.001*	3.49±6.39	<0.001*	1.28±2.77	<0.001*	2.39±3.38	<0.001*

GMFCS, Gross Motor Function Classification System; GMFM, Gross Motor Function Measure.
*$p<0.05$.

Table 4. Pre- and Post-Injection GMFM-66 Scores by Injection Site

Injection site	n	Pre (mean±SD)	Post (mean±SD)	*p*
Hip adductor only	26	27.60±17.82	29.61±17.46	0.002*
Hip adductor with hamstring	26	35.26±15.54	37.62±13.08	<0.001*
Hip adductor with calf muscles	48	36.71±10.64	39.32±10.69	<0.001*

GMFM, Gross Motor Function Measure.
No children received injections in all three muscle groups (adductors, hamstrings, and calf muscles).
*$p<0.05$.

comprehensive quantitative GMFM analysis across GMFCS levels, GMFM domains, and additional injection sites. Previous studies have investigated BoNT-A injections in children with CP; however, most have not focused on specific injection sites[20] or level-specific GMFCS analyses.[21] Others have used tools, such as the GMFM; however, they did not conduct detailed, level-specific, or quantitative evaluations.[22,23]

The GMFM-88 was used as the primary outcome measure due to its strong validity and comprehensive assessment of gross motor function changes and was later converted to the GMFM-66 to improve accuracy and sensitivity in monitoring motor function changes over time.[24,25]

The improvements in GMFM-66 and GMFM-88 total scores following BoNT-A injections are consistent with findings from previous studies, which have demonstrated that reducing spasticity leads to significant improvements in gross motor function.[26] Moreover, the statistically significant improvements observed across all GMFCS levels (III, IV, and V) in our study reinforce the notion that BoNT-A can effectively enhance motor function in children with CP, regardless of their GMFCS level, particularly in injections that include the hip adductor muscles.

Our GMFM domain-specific analysis revealed that, at GMFCS levels III and IV, children achieved statistically significant improvements across all GMFM domains. Hip adductor spasticity can interfere with rolling into a side-lying position, as this movement requires the hip to rotate externally while maintaining a near-neutral abduction-adduction angle.[27] Severe spasticity of the hip adductors can also lead to leg crossing, thereby negatively affecting sitting balance.[28,29] Furthermore, spasticity in the hip adductor muscles can disrupt reciprocal leg movements during crawling and hinder leg kicking in the prone position, thereby impairing locomotion.[30] For standing and walking, severe contractures and spasticity in the hip adductors can cause narrow-based scissoring gait and compromise stability.[28] Prior research on hereditary spastic paraplegia has shown that BoNT-A injections, combined with stretching of the hip adductors, lead to improvements in muscle tone, gait width, comfortable gait velocity, and lateral balance.[31]

At GMFCS level V, the children showed significant gains primarily in domains A (lying and rolling), B (sitting), and C (crawling and kneeling), which can be explained by the same factors described for GMFCS levels III and IV. However, domains D (standing) and E (walking, running, and jumping) did not show significant improvement, underscoring the limitations of BoNT-A in addressing motor functions that require substantial strength and coordination, as reducing spasticity alone is insufficient to enable these abilities in severely impaired children.

In the subgroup analysis, all three injection site groups showed statistically significant improvements in the GMFM scores. This suggests that BoNT injections targeting the adductor muscles, either alone or in combination with injections targeting other muscle groups, can significantly improve gross motor function.

This study has several limitations. First, the study was conducted at a single institution, which may limit the generalizability of the findings. Second, although the study included a relatively large sample of children with CP, it focused exclusively on short-term outcomes, assessing changes in gross motor function within a few months post-injection. Third, as this was a retrospective study, there was no control group, which restricted the ability to compare the outcomes with those of a non-intervention cohort. However, considering the mean age of our cohort (3.9 years), the improvements observed likely exceed expected natural progression, as children with GMFCS levels III–V typically reach 90% of their motor function potential by ages 2.7 to 3.7.[32] In addition, although children with GMFCS levels III–V tend to reach motor plateaus earlier, the functional improvements observed in this study exceeded the MCID thresholds, especially in GMFCS level V.[33] This suggests that the gains may reflect a potentially meaningful treatment effect rather than natural development alone, thereby partially mitigating concerns related to the lack of a control group. Fourth, there was no control over additional interventions for spasticity reduction, such as physical therapy or medications that may have been administered before or after the BoNT-A injections, which is an inherent limitation of the retrospective study design.

In conclusion, this study demonstrated that BoNT-A injections targeting the hip adductor muscles can enhance gross motor function in low-functioning children with CP. BoNT-A injections showed functional improvements across the GMFM domains specific to each GMFCS level, highlighting the importance of tailored interventions. The subgroup analysis showed significant improvements across all injection sites, suggesting the effectiveness of targeting the adductor muscles alone or in combination with other muscle groups. These findings suggest an expanded role of BoNT-A in facilitating functional gains in low-functioning children with CP, although further studies are needed to confirm these results and examine their long-term effects.

AUTHOR CONTRIBUTIONS

Conceptualization: Jun Min Cha and Dong-Wook Rha. Data curation: Juntaek Hong and Jeuhee Lee. Formal analysis: Jehyun Yoo. Investigation: Jun Min Cha, Jehyun Yoo, and Jeuhee Lee. Methodology: Jun Min Cha, Jehyun Yoo, Jeuhee Lee, and Yebin Cho. Project administration: Dong-Wook Rha. Resources: Dong-Wook Rha. Supervision: Dong-Wook Rha and Juntaek Hong. Validation: Jun Min Cha. Visualization: Jun Min Cha and Yebin Cho. Writing—original draft: Jun Min Cha. Writing—review & editing: Jun Min Cha, Juntaek Hong, and Dong-Wook Rha. Approval of final manuscript: all authors.

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https://doi.org/10.3349/ymj.2025.0003

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