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의학석사 학위논문

Effect of Botulinum Toxin  
Injection on Hip Adductor  
Spasticity and Progression of Hip  
Dislocation in Patients with  
Spastic Cerebral Palsy: A Pilot  
Study

경직성 중증 뇌성마비 환자의 고관절 내전근 내  
보툴리눔 독소 주사가 고관절 내전근의 경직 및  
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Spastic Cerebral Palsy: A Pilot  
Study

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# Abstract

## Effect of Botulinum Toxin Injection on Hip Adductor Spasticity and Progression of Hip Dislocation in Patients with Spastic Cerebral Palsy: A Pilot Study

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**Introduction:** Hip adductor spasticity is a contributing factor to hip dislocation in patients with cerebral palsy (CP). We hypothesized that botulinum toxin injected into the hip adductor muscles would reduce spasticity and help prevent hip dislocation.

**Methods:** Twenty patients with bilateral spastic CP aged 2 to 10 years with gross motor function classification system level IV or V were included. Botulinum toxin was injected into the hip adductor muscles at baseline and at 6-month follow-up. Muscle activity was measured with an eight-channel surface electromyography (EMG)

recorder. A hip X-ray was performed, and Reimer's hip migration index (MI) was measured. The Wilcoxon signed-rank test was used to compare the surface EMG values of the hip muscles at baseline and follow-up.

**Results:** The mean root mean square surface EMG value of the hip adductor muscles was significantly reduced at 1, 2, 3, and 7 months after the first injection, up to approximately 53% of the baseline. The 1-year progression of the hip MI was -0.04%.

**Conclusion:** Repeated sessions of botulinum toxin injections at the hip adductor muscles significantly reduced muscle activity and hip displacement. A botulinum toxin injection may be used as an adjunctive treatment in the prevention of hip dislocation.

**Keyword :** Cerebral palsy, hip dislocation, electromyography, botulinum toxin, pathophysiology

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## Chapter 1. Introduction

Factors associated with hip dislocation in patients with spastic cerebral palsy (CP) can be divided into three categories, namely, developmental, protective, and mechanical. Developmental factors include weight bearing and ambulation.<sup>1</sup> In non-ambulatory patients with CP, the lack of physiologic mechanical stress on the hip joint leads to coxa valga, femoral anteversion, and acetabular dysplasia,<sup>1, 2</sup> which increase the risk of hip dislocation. Protective factors are muscles and ligaments. Mechanical factors are hip adductor muscle spasticity and an imbalance in hip muscle tone. Increased adduction forces on the hip joint are thought to create torque on the femoral head, shifting it laterally out of the acetabulum.<sup>3-6</sup>

A botulinum toxin injection is a widely used treatment for hip adductor spasticity.<sup>7</sup> However, its effectiveness in preventing hip dislocation remains unclear.<sup>7, 8</sup> Several studies have reported that a botulinum toxin type A injection into the hip adductor muscles results in stable or improved hip displacement.<sup>9-12</sup> Other studies reported that a botulinum toxin A injection does not significantly improve hip displacement.<sup>13-15</sup> Previous findings are inconsistent with regard to the effectiveness of a botulinum toxin injection into the hip adductor muscles in improving hip displacement.

Multiple factors are associated with hip dislocation; thus, no single treatment may be effective in preventing hip dislocation. However, we hypothesized that a botulinum toxin injection would produce positive effects with regard to the prevention of hip dislocation by causing neurogenic denervation and atrophy of the muscle.<sup>16</sup> We hypothesized that such atrophic changes would lead to a lasting reduction in hip adductor spasticity, an important contributing factor to hip dislocation. We also hypothesized that the reduction in hip adductor spasticity would subsequently decrease hip displacement. Therefore, the aim of this study was to quantitatively evaluate the trajectory of hip adductor muscle spasticity after repeated sessions of botulinum toxin injections and assess its effect on the progression of hip dislocation.

## Chapter 2. Materials and Methods

Patients with spastic CP were included in this prospective observational study conducted between December 2018 and July 2020. They received a botulinum toxin injection into the hip adductor muscles and a repeat injection after 6 months. The patients were followed-up for 1 year. This study was approved by the Institutional Review Board of our hospital (Approval no.: B-1807-478-001). Legal guardians of all the patients provided written informed consent to the research and to the publication of the study results before participation. Patients were recruited from two hospitals.

### 2.1. Participants

To date, no studies have published the changes in surface electromyography (EMG) values after a botulinum toxin injection into the hip adductor muscles. Since this is the first clinical trial, we included 20 consecutive patients in the study. Inclusion criteria were a diagnosis of bilateral spastic CP, <sup>17</sup> aged 2 to 10 years, and gross motor function classification system (GMFCS) level IV or V. Exclusion criteria were as follows: contraindication to botulinum

toxin injection (such as hypersensitive reactions to botulinum toxin), history of a botulinum toxin injection within 6 months prior to study enrollment or scheduled for injection at another institution after study enrollment, history of hip surgery or scheduled for hip surgery after study enrollment, and on drugs that interact with botulinum toxin (such as aminoglycoside, spectinomycin, polymyxin, tetracycline, lincomycin, and tubocurarine muscle relaxant).

## **2.2. Procedures**

Patient demographic data and medical history were collected by the researchers during the screening process. Eligible patients underwent height and weight measurements and initial hip radiographic evaluation. Clinical evaluation and recording of the first hip muscle surface EMG were performed at the initial visit. After the first botulinum toxin injection, the patients were followed up at 1, 2, 3, and 6 months. Following a repeat injection at 6 months, the patients were followed-up at 7 and 12 months after the first botulinum toxin injection (Figure 1a). At each visit, clinical evaluation and surface EMG recording of the hip adductor and abductor muscles were performed. Patients also underwent hip radiographic evaluation at 6- and 12-month follow-up visits. To assess satisfaction levels and the quality of life after a botulinum

toxin injection, the Likert questionnaire and the Caregiver Priorities and Child Health Index of Life with Disabilities (CPCHILD) were administered at each visit (Figure 1b). Twenty patients were enrolled, and fourteen patients completed the 1-year follow-up (Figure 1a).

The injection site of the muscle was initially checked with an ultrasound to mark the injection location. Topical lidocaine cream (EMLA cream 5%) was applied on the muscles prior to the injection. Botulinum toxin was then injected at the motor point under EMG guidance. Ultrasound and EMG-guided injection could not be administered concomitantly due to a lack of cooperation from children. Clostridium botulinum toxin type A (Meditoxin®, 200 units) product was diluted with 4 mL of normal saline to produce a dilution of 50 units/1 mL. Botulinum toxin was injected into the bilateral adductor longus and adductor magnus muscles at a dose of 3 U/kg and into the bilateral adductor brevis and gracilis muscles at a dose of 1 U/kg for a total maximum dose of 16 U/kg of body weight or a maximum dose of 200 units overall. The distribution of the botulinum toxin injection over the different muscles was based on muscle size. For patients receiving 200 units the botulinum toxin dosage was fixed at 100 units at for each side, 12.5 units at the adductor brevis and gracilis muscles, and 37.5 units at the adductor

longus and magnus muscles. Injection was repeated at 6 months.

### 2.3. Outcomes

Clinical evaluation included hip and knee range of motion (ROM) and MAS of hip adductor muscle spasticity. Hip and knee ROM was measured using a goniometer. Hip abduction ROM was measured with the hip and knee in 90 of flexion, and with the hip and knee in neutral position. Knee flexion ROM was measured at the supine position with the hip fully flexed. Knee extension ROM was also measured at the supine position with the hip flexed to 90 (Popliteal angle test).<sup>18</sup> The modified Ashworth scale (MAS) is an ordinal measure of spasticity scored on a 0-4 scale, with a score of 1+ between 1 and 2.<sup>19</sup> A score of 0 denotes no increase in muscle tone, and a score of 4 indicates the affected part was rigid in flexion or extension. Hip adductor spasticity was measured with the knee flexed. Quality of life, comfort, ease of care, and overall health were evaluated with Likert scale questionnaire. A score of 5 indicates very satisfied, and a score of 1 denotes very unsatisfied. The Korean version of the CPCHILD was also administered. The CPCHILD is a measure of caregivers' perspectives on child health, function, and well-being, and has six domains scored on a 0-100 scale and in total. For each of the six domains, standardized scores

from 0 (worst) to 100 (best) were calculated as well as for the total survey.<sup>20</sup>

Hip abductor and adductor muscle activity evaluation was conducted with a wireless S-EMG analysis system (BTS FREEEMG 1000 with EMG-BTS EMG-Analyzer; BTS Bioengineering Co., Garbagnate Milanese, Italy) using electrophysiological quantitative analysis. Surface EMG electrodes were placed on the muscle belly of the bilateral adductor longus, adductor magnus, tensor fascia latae, and gluteus medius muscles. With the patients in the seated position, involuntary background muscle activation was provoked by slow stretch movement. The peak amplitude and root mean square (RMS) values were recorded for 5 s and measured for 1 s at the plateau. Surface EMG RMS values were measured twice, and the mean value was used. Since measurements were taken from both sides, the values were averaged to represent the muscle activity. The surface EMG values of the adductor longus and adductor magnus muscles were added to produce the sum of the adductor muscles. Similarly, the surface EMG values of the tensor fascia lata and gluteus medius muscles were added to produce the sum of the abductor muscles. Surface EMG analysis was performed at baseline and 1, 2, 3, 6, 7, and 12 months.

Plain radiographs of the hip in the supine position were taken at

baseline and at 6- and 12-month follow-up visits. The Reimer's Migration Index (MI) was digitally measured using the Picture Archiving and Communication System (Impax, Agfa, Antwerp, Belgium) by two assessors blind to the timing of the X-ray. Inter-observer correlation coefficient was computed and the mean value was used for analysis. We used the change in Reimer's MI over 1 year as a measure of the progression of hip displacement. The MI of both sides was included.

## 2.4. Statistical Analysis

Statistical analyses were performed using SPSS 25.0 software (SPSS Inc., Chicago, IL, USA). The baseline hip adductor and abductor muscle activity were compared with the hip adductor and abductor muscle activity at 1-, 2-, 3-, 6-, 7-, and 12-month follow-up visits by using the Friedman test and the Wilcoxon signed-rank test. Hip and knee ROM, hip adductor spasticity, and CPCHILD scores at follow-up were also compared with those at baseline using the Wilcoxon signed-rank test. For analysis, hip adductor spasticity MAS grade of 0 was coded as 0, grade of 1 as 1, grade of 1+ as 2, grade of 2 as 3, grade of 3 as 4, and grade of 4 as 5. The Mann-Whitney U test was used to compare the progression of the hip MI over 1 year with that of the historical control data



from a previous study,<sup>3</sup> consisting of 24 patients with cerebral palsy, aged 2 to 10 years, and classified as GMFCS level IV or V (Table 1). The patients were being followed-up every 6 to 9 months at our center according to the hip surveillance guidelines.<sup>21-23</sup> A p value < 0.05 was considered significant. Missing data was addressed by performing complete case analysis.

## Chapter 3. Results

Patient characteristics are presented in Table 1. Twenty patients (fourteen males and six females) were included in the study. The mean age of the patients was 5 years and 1 month (with a standard deviation of 1 year and 10 months). Three and seventeen patients were classified with GMFCS levels IV and V, respectively.

The mean RMS surface EMG values of the hip adductor and abductor muscles by month are shown in Table 2. The Friedman test showed no significant differences in the RMS values between the baseline and follow-up. Post hoc analysis of Wilcoxon signed-rank test was performed. The mean RMS surface EMG values of the sum of the adductor muscles were significantly reduced compared with the baseline at 1, 2, 3, and 7 months (Figure 2a). At 3 months, the mean RMS surface EMG values of the adductors were reduced to approximately 53% of the baseline. The mean RMS surface EMG value at 12 months remained at 70% of the baseline, however it was not statistically significant. The mean RMS surface EMG values of the abductor muscles showed a similar activation pattern to those of the adductor muscles (Figure 2b).

The progression of the hip MI in the study patients after one

year was -0.04% (8.64). This was lower than 3.27% (8.62) of the historical control data of patients with CP recruited at the same center, although this is not statistically significant (Table 3). The hip abduction ROM with a 90 degrees hip flexion had significantly improved from 29.5 (16.54) to 45 (0) by the 12-month follow-up visit. Hip adductor MAS grade was significantly reduced at 12 months compared with the baseline. Satisfaction and quality of life after a botulinum toxin injection, measured using the CPCHILD, significantly improved when compared with the baseline (Table 4).

## Chapter 4. Discussion

A botulinum toxin injection into the hip adductor muscles, followed by repeat injection at 6 months, significantly reduced muscle activity at 1, 2, 3, and 7 months after the first injection.

Our study showed that hip adductor muscle activation was reduced after a botulinum toxin injection. Since spasticity is velocity dependent, our surface EMG recordings were measurements of involuntary background muscle activation and not spasticity.<sup>27</sup> However, both velocity dependent and non-velocity dependent muscle activation are important mechanical factors in hip dislocation. Both spasticity and non-velocity dependent muscle activation share a common pathway of increased muscle tone. Therefore, we considered reduced muscle activation as reflection of concomitant reduction in muscle tone and spasticity.

The hip abductor muscle activity showed a similar activation pattern to the hip adductor muscle activity (Figure 2b). Several explanations seem possible. The hip abductor muscles are antagonists to the hip adductor muscles. Therefore, a similar activation pattern of the abductor muscles can be explained by co-contraction.<sup>28</sup> Reduced hip abductor muscle activity reflects reduced

hip adductor activity after a botulinum toxin injection. Another possible explanation is that the similar activation reflects dystonic features. Spasticity and dystonia frequently coexist, and abnormal movement frequency has been reported to increase with higher GMFCS levels.<sup>29</sup> However, a reduction in hip abductor muscle activity after a botulinum toxin injection into the hip adductor muscles cannot be fully explained by dystonic features.

Hip adductor muscle activity remained below baseline levels at 12 months, although this was not statistically significant. Previous studies using magnetic resonance imaging evaluations have shown that a botulinum toxin injection causes neurogenic muscle atrophy due to chemo-denervation of the muscle.<sup>24–26</sup> The reason that the hip adductor muscle activity did not return to baseline levels at 6- and 12-month follow-up may be attributed to neurogenic atrophy of the muscles. Muscle atrophy is usually considered to be an adverse effect of the botulinum toxin injection. However, in non-ambulatory patients with CP, hip adductor muscle tone has little functional value. Neurogenic muscle atrophy may even be desirable considering its role in reducing spasticity. The progression of the hip MI per year was lower than that of the control group. In a previous study by Terjesen,<sup>30</sup> the hip MI progression per year was 3.9% for patients with CP classified as

GMFCS level IV and 9.5% for patients classified as GMFCS level V. The hip MI progression per year was 3.27% in our control group, which consisted of 24 patients with CP classified as GMFCS levels IV and V. The slightly lower than expected hip MI progression in our control group may be attributed to the inclusion of both hips in the analysis. Terjesen<sup>30</sup> only included the side with the largest hip migration percentage. We included both hips as the bilateral hip adductors were spastic and a botulinum toxin was injected into both sides. In the botulinum toxin injection group, the hip MI progression rate per year was -0.04%, which was lower than the control group, although not statistically significant. Our study results were comparable with those from a previous study by Yang et al.,<sup>12</sup> who compared hip displacement between the botulinum toxin injection group and the surgery group. In low functioning patients (GMFCS levels III, IV, and V), the annual changes in hip MI were 0% and -1.0% for the botulinum toxin injection group and the surgery group, respectively.<sup>12</sup>

Two studies examined the effect of a botulinum toxin injection on hip dislocation, along with abduction bracing.<sup>13, 15</sup> Both studies reported minimal or no significant effect of a botulinum toxin injection on the prevention of hip dislocation. The negative results may be attributed to the inclusion of patients with a

relatively lower risk of hip dislocation (patients classified as GMFCS levels I–III). In our study, we included only patients with CP classified as GMFCS levels IV and V, patients with high risk of hip dislocation. In addition, abduction bracing may have masked the effect of a botulinum toxin injection. Recent studies have reported that abduction bracing can aggravate hip displacement due to leverage effects and length tension relationship.<sup>3, 4</sup> A recent retrospective cohort study by Lin et al.<sup>14</sup> also reported no significant differences in hip dislocation and hip surgery rate in the botulinum toxin injection group and the control group. However, it was a retrospective study; thus, detailed information on the GMFCS levels and the protocols of the botulinum toxin injection administration was lacking. A significantly lower mortality was observed in the botulinum toxin injection group, however the reason for this was unclear.<sup>14</sup> Multiple factors are associated with hip dislocation, and the results of previous studies suggest that a botulinum toxin injection alone may not be sufficient to prevent hip dislocation. Our study results showed that a botulinum toxin injection is effective in reducing hip adductor spasticity, an important factor in hip dislocation, and patients with CP may have additional benefits from the botulinum toxin injection.

The botulinum toxin injection significantly improved quality

of life, as measured using the CPCHILD. In a previous study, the mean CPCHILD scores of children classified as GMFCS levels IV and V were 46.0 (20.1) and 24.3 (18.6), respectively.<sup>20</sup> The CPCHILD score in our study was 25.44 (17.39) at baseline, and it significantly increased to 33.59 (17.64) at 1 month. This remained in the range of 38 to 39 throughout the study period. A previous study also reported a significantly improved CPCHILD score at 16 weeks after a botulinum toxin injection in patients with CP.<sup>31</sup> A botulinum toxin injection can improve the quality of life and ease of care by reducing spasticity. The quality of life and satisfaction measured using the Likert questionnaire were the highest at 1 month after a botulinum toxin injection and the lowest at 12 months.

Our study has several limitations. First, this was a pilot study. Our study was not a confirmatory trial with randomization and calculation of sample size. Correlation between reduced hip adductor spasticity and decreased hip displacement could not be confirmed. Second, 6 patients did not complete the 12-month follow-up and some patients with severe hip displacement were lost in follow-up or received hip surgery. There is a risk of selection bias. Other methods of dealing with missing data such as single value imputation, filling the data with some type of predicted value or carry over value, has the risk of underestimating hip



displacement. Therefore, complete case analysis was performed. However, we still think a botulinum toxin injection may have a role in delaying the progression of hip displacement by reducing hip adductor spasticity, a mechanical factor contributing to hip dislocation, regardless of hip displacement severity. What is unclear is whether patients with severe hip displacement will benefit from a botulinum toxin injection or not, and further studies are needed to elucidate this. Third, the follow-up period was 12 months. The long-term effect of a botulinum toxin injection on hip dislocation was not assessed. Alternatively, we measured the change in Reimer's hip MI over 1 year as a measure of hip displacement progression. We also quantified the change in hip adductor muscle activity, an important contributing factor to hip dislocation, over time. Fourth, the hip adductor muscle tone was not directly measured. Muscle activation was measured using the surface EMG as an indirect measure of muscle tone. Some discrepancies may exist between actual muscle tone and the surface EMG measurements. The strength of this study was the quantitative measurement of muscle activity. Qualitative evaluation of spasticity using MAS has poor reliability in patients with CP.<sup>19</sup> Fifth, surface EMG values were not normalized but expressed with the RMS method. This method does not control for differences between

sessions such as electrode placement and subcutaneous tissues.<sup>32</sup> However normalization methods, such as maximal voluntary contraction, are not clinically possible in children due to problems in cooperation. Sixth, other factors which may affect spasticity such as medication and physical therapy were not controlled. However, these factors were not considered significant since the candidates for a botulinum toxin injection were patients who had spasticity despite medication or physical therapy. Lastly, the GMFCS level of the children was imbalanced, with only 3 children with GMFCS level IV and 17 with GMFCS level V. In contrast, the historical control data consisted of 11 children with GMFCS level IV and 13 children with GMFCS level V. One to one matching of GMFCS level was not possible because there were only 13 children with GMFCS level V in the historical control data. Therefore, we included all children between the ages 2 to 10 for comparison of hip MI progression. Caution is needed in generalizing the results. However, GMFCS level is a significant risk factor for hip dislocation.<sup>33</sup> Our study reported results in the patients with the highest risk.

## Chapter 5. Conclusions

In conclusion, botulinum toxin injection is effective in reducing hip adductor muscle activity and spasticity. Hip adductor spasticity is an important contributing biomechanical factor to hip dislocation, and a botulinum toxin injection may be used in conjunction with other treatments in order to prevent hip dislocation. Future studies with a larger sample size and a longer follow-up period are needed to confirm the effect of a botulinum toxin injection in improving hip dislocation.

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## Tables

**Table 1.** Demographics and clinical characteristics.

Variables	Intervention (N=20)	Control* (N=24)	p-value**
Age (yr)	5.1 (1.86)	6.13 (2.47)	0.13
<b>Age group (yr)</b>			
2-4	9	7	
4-6	5	5	
6-8	6	8	
8-10	0	4	
Sex (M : F)	14:6	13:11	0.29
GMFCS level (IV : V)	3: 17	11:13	< 0.01
Height (cm)	100.6 (12.27)		
Weight (kg)	15.07 (4.41)		
<b>Hip Migration index</b>			
Right	38.19 (22.53)	30.70 (18.94)	0.25
Left	39.14 (29.26)	30.14 (14.77)	0.22
<b>Hip and Knee ROM</b>			
Hip abduction (with hip 90° flexion)	29.5 (16.54)		
Hip abduction (with hip extension)	24.5 (15.64)		
Knee flexion	111 (63.73)		

Knee extension (Popliteal angle)	9.75 (14.19)
<b>Hip Adductor spasticity (MAS)</b>	
< 2	9
≥ 2	11
<b>Orthoses</b>	
Spinal orthoses	0
Postural support	3
Ankle foot orthoses	8
<b>Anti-spasticity medication</b>	7

Data are presented as mean (standard deviation). GMFCS, Gross Motor Function Classification System; ROM, Range of Motion; MAS, Modified Ashworth Scale.

\*Historical control data of patients with CP recruited at the same center.

\*\*Independent-samples t-test for parametric, Mann Whitney U test for nonparametric variables

**Table 2.** Mean RMS S-EMG values ( $\mu V$ ) of the hip adductor, abductor muscles by month. (Available case analysis)

	Baseline	1 month	2 months	3 months	6 months	7 months	12 months
<b>Adductor longus m.</b>	61.62 (56.27)	30.03 (24.18)*	34.14 (32.76)	32.79 (18.49)	43.75 (35.20)	42.18 (46.41)	45.40 (51.67)
<b>Adductor magnus m.</b>	55.90 (49.52)	32.84 (34.65)*	28.86 (23.28)*	29.55 (20.36)*	39.34 (23.56)	23.32 (19.92)*	35.80 (34.36)
<b>Adductor muscles sum</b>	117.52 (102.28)	62.87 (52.37)*	63.00 (53.37)*	62.35 (36.67)*	83.09 (56.63)	65.50 (63.97)*	81.20 (83.87)
<b>Tensor fascia lata m.</b>	78.55 (96.32)	47.63 (39.77)	50.21 (44.82)	53.68 (63.52)	72.64 (69.99)	61.53 (50.36)	69.25 (83.94)
<b>Gluteus medius m.</b>	24.84 (24.37)	27.37 (29.83)	26.01 (32.20)	25.21 (27.08)	36.90 (26.89)	34.17 (33.95)	29.21 (27.05)
<b>Abductor muscles sum</b>	103.39 (112.10)	75.00 (61.93)	76.22 (65.32)	78.89 (87.86)	109.54 (83.55)	95.69 (75.56)	98.46 (103.12)

Values are expressed in as mean (standard deviation). RMS, Root Mean Square; S-EMG, Surface electromyography.

\* P value < 0.05.

**Table 3.** One year progression of the hip migration index (%) compared to control.

	<b>Botox injection (n=14)</b>	<b>ICC<sup>1</sup></b>	<b>Control<sup>2</sup> (n=24)</b>
<b>Hip migration index</b>			
Baseline	31.84 (16.23)	0.98	30.43 (16.85)
6 months	31.95 (13.69)	0.97	
12 months	31.80 (14.27)	0.95	
<b>One year progression rate</b>	-0.04 (8.63)		3.27 (8.62)

Values are expressed as mean (standard deviation). \* P-value < 0.05. <sup>1</sup> ICC, Inter-observer correlation coefficient <sup>2</sup>.

Historical control data of patients with CP recruited at the same center.

**Table 4.** Changes of Hip and knee ROM, Hip adductor spasticity (MAS), CPCHILD and Likert Questionnaire after botulinum toxin injection.

	Baseline	1 month	2 months	3 months	6 months	7 months	12 months
<b>ROM</b>							
Hip abduction (with hip 90° flexion)	29.50 (16.54)	37.37 (12.4)	36.94 (14.87)	41.56 (7.90)*	41.76 (7.06)*	43.67 (3.52)*	45.00 (0.00)*
Hip abduction (with hip extension)	24.50 (15.64)	37.37 (12.84)*	34.17 (14.68)*	40.31 (9.03)*	30.29 (9.43)	42.33 (5.63)*	37.69 (10.33)
Knee flexion	111.00 (63.73)	135.79 (42.86)	133.89 (46.92)	144.06 (23.75)	141.18 (36.38)	150.00 (0.00)	142.31 (27.74)
Knee extension (Popliteal angle)	9.75 (14.19)	0.79 (2.5)*	0.83 (3.54)*	7.50 (21.21)	3.24 (10.15)	0 (0)*	2.31 (8.32)
<b>Hip Adductor spasticity (MAS)</b>							
< 2	9	13	13	14	15	14	12
≥ 2	11	6	5	3	3	2	2
<b>CPCHILD</b>	25.44 (17.39)	33.59 (17.64)*	39.30 (19.94)*	38.93 (20.14)*	39.73 (22.00)*	39.22 (17.5 6*)	39.29 (13.62)*
<b>Questionnaire (Likert scale)</b>							
Quality of life		3.89 (0.81)	3.44 (0.70)	3.71 (0.92)	3.61 (1.14)	3.44 (0.73)	3.14 (0.86)



Comfort	4.05 (0.91)	3.50 (0.71)	3.65 (0.86)	3.56 (1.15)	3.44 (0.73)	3.29 (0.73)
Ease of care	4.05 (0.71)	3.39 (0.70)	3.65 (1.00)	3.50 (1.15)	3.38 (0.72)	3.00 (0.78)
Overall health	3.95 (0.85)	3.44 (0.70)	3.71 (0.92)	3.83 (0.79)	3.25 (0.77)	3.29 (0.47)

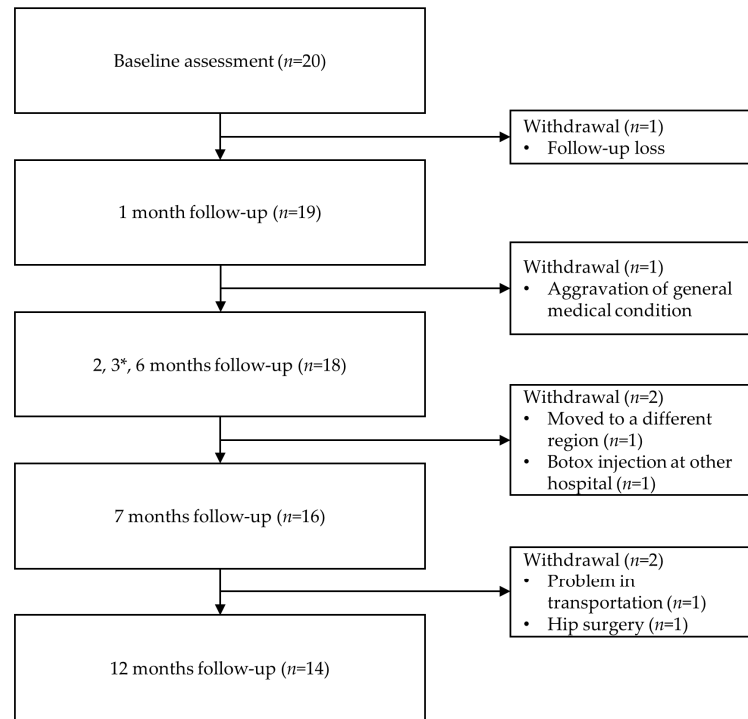
Values are expressed as mean (standard deviation). ROM, Range of Motion; MAS, Modified Ashworth Scale;

CPCHILD, Caregiver Priorities and Child Health Index of Life with Disabilities.

\* P value < 0.05

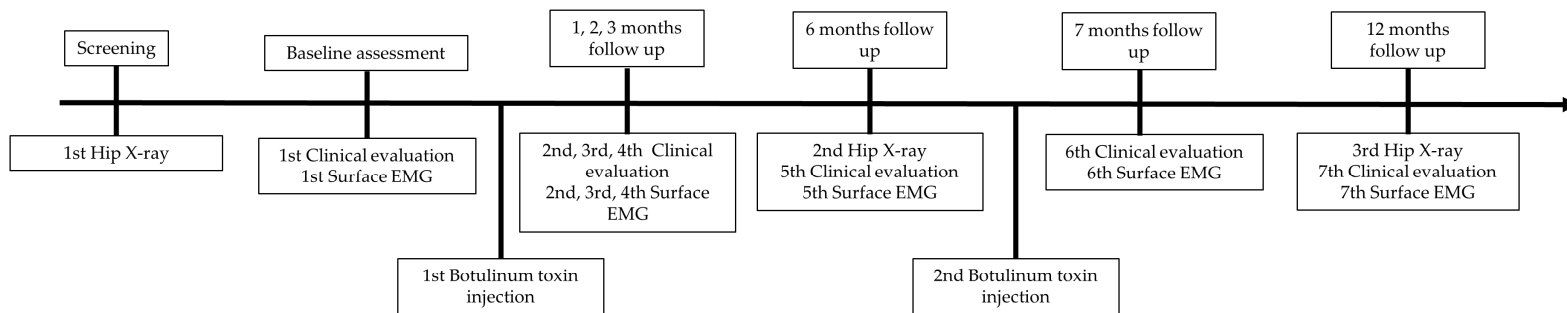
# Figures

Figure 1a. Patient follow-up



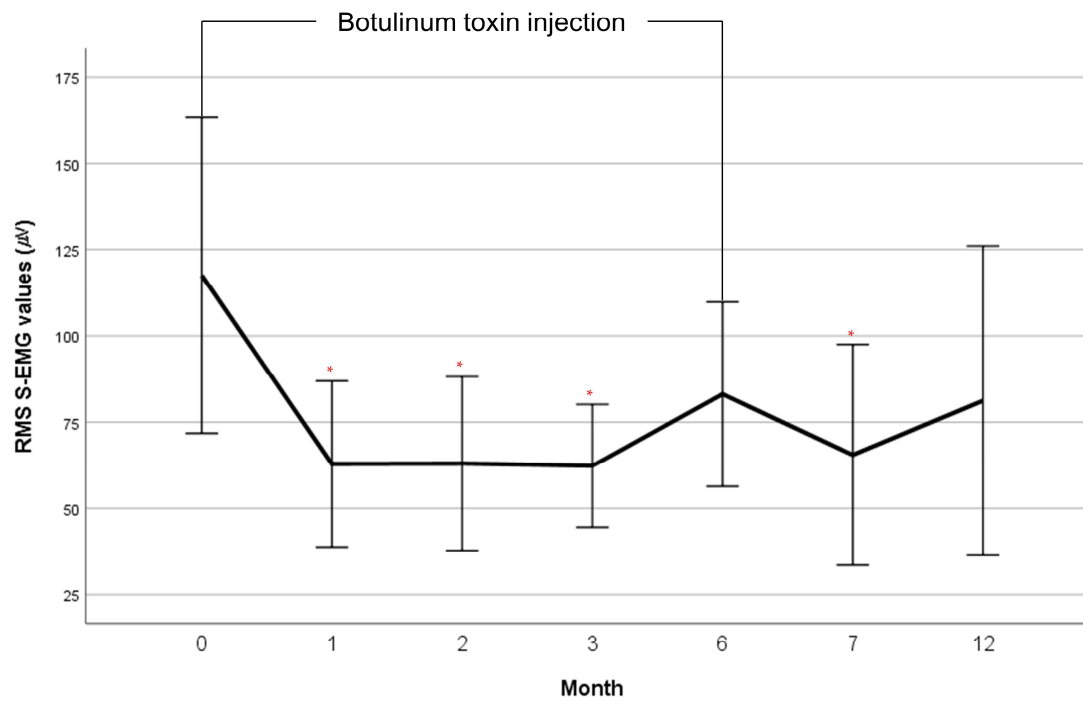
\* n=17, due to missed appointment

Figure 1b. Study flow



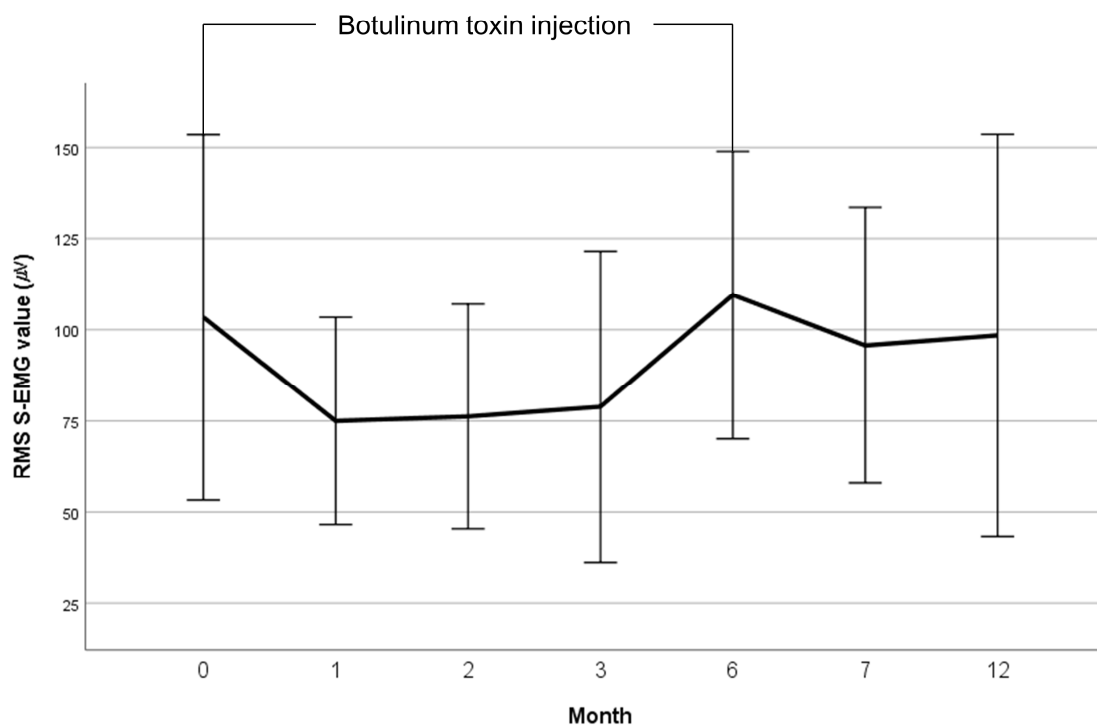
**Figure 2a.** Mean RMS S-EMG value changes of the hip adductor muscles by month.

RMS, Root Mean Square; S-EMG, Surface electromyography; Error bar: Standard error. \* p value < 0.05.



**Figure 2b.** Mean RMS S-EMG value changes of the hip abductor muscles by month.

RMS, Root Mean Square; S-EMG, Surface electromyography; Error bar: Standard error. \* p value < 0.05.



국문 초록

# 경직성 중증 뇌성마비 환자의 고관절 내전근 내 보툴리눔 독소 주사가 고관절 내전근의 경직 및 고관절 탈구에 미치는 영향: 파일럿 임상시험

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## 배경

고관절 내전근 경직은 경직성 뇌성마비 환자에서 고관절 탈구를 일으키는 요인 중 하나다. 본 연구에서는 고관절 내전근에 보툴리눔 독소 주사를 할 경우 경직이 감소하여 고관절 탈구 예방에 도움이 될 것이라는 가설을 세우고 이를 확인하고자 하였다.

## 방법

만 2세에서 10세 사이의 뇌성마비 대운동 기능 분류 시스템 (GMFCS) IV 또는 V에 해당하는 양측성 경직성 뇌성마비 환자 20명을 모집하였다. 고관절 내전근에 보톡스 주사는 첫 방문 시 및 6개월 추적 관찰 시 주입하였다. 근육 긴장도는 8 채널 표면 근전도(Surface EMG)로 측정

하였다. 고관절 탈구 정도는 고관절 엑스레이를 촬영을 하여 라이머의 고관절 이동 지수 (Reimer's MI)로 측정하였다. 윌콕슨 부호 순위 검정을 이용하여 초기 및 추적 관찰 시의 표면 근전도 값을 비교하였다.

## 결과

보톡스 주사 후 고관절 내전근의 표면 근전도 제곱 평균 제곱근 (Root mean square, RMS) 값이 첫 방문과 비교 시 추적관찰 1, 2, 3, 7 개월 때 유의하게 감소하였고 첫 방문 시 측정한 값의 약 53% 정도로 확인되었다. 1년간 고관절 이동 지수의 변화는  $-0.04\%$ 였다.

## 결론

고관절 내전근에 첫 보톡스 주사 후 6개월 시점에 반복 주사를 시행했을 때 근긴장도가 유의하게 감소하였고 고관절 탈구도 감소하는 경향을 보였다. 이에 보툴리눔 독소 주사는 고관절 탈구 예방에 보조적 치료로 사용될 수 있다.

**주요어:** 뇌성마비, 고관절 탈구, 근전도, 보툴리눔 독소, 병태생리

**학번:** 2017-24964