

Relationships between Gross Motor Capacity and Neuromusculoskeletal Function in Children with Cerebral Palsy after Short-Term Intensive Therapy

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Purpose: To investigate the relationship between gross motor capacity and neuromuscular function in children with cerebral palsy (CP) through a short-term intensive intervention.

Methods: Twenty-four children younger than 6 years of age (17 boys, 7 girls, mean age \pm standard deviation, 42.71 \pm 14.43 months) who were diagnosed with CP underwent short-term intensive treatment for 8 weeks. An evaluation of gross motor function capacity using the gross motor function measure (GMFM-66 and GMFM-88) was performed to measure muscle strength, selective motor control (SMC), and spasticity, factors related to neuromusculoskeletal function. Changes in spasticity, strength, range of motion, selective motor function, and exercise intensity scores were evaluated in terms of the gross motor function classification system (GMFCS) and ages.

Results: The GMFM-88 and GMFM-66 scores significantly increased, by 4.32 \pm 4.04 and 2.41 \pm 1.51%, respectively, following the 8-week intervention. The change in the GMFM-66 score did not reflect a statistically significant difference in the GMFCS level. However, there was a statistically significant difference in the GMFM-88 score change in individuals at GMFCS Level III, the strength and spasticity of subjects at GMFCS Levels I-II did not significantly differ ($p < 0.05$). The changes in the GMFM-66 scores for strength, SMC, range of motion (ROM), and spasticity significantly differed according to age ($p < 0.05$) in children aged 36 months and older. Overall, there was a statistically significant difference in strength, SMC, and spasticity ($p < 0.05$) before and after intensive short-term treatment.

Conclusion: The 8-week short-term intensive care intervention improved the motor function score of study participants, emphasizing the need for early intervention and additional research in this area.

Keywords: Gross motor capacity, Neuromusculoskeletal function, Cerebral palsy, Short-term intensive therapy

INTRODUCTION

Cerebral palsy (CP) is defined as a group of diseases with complex symptoms involving motor function, sensory perception, visual acuity, language, and cognitive impairment.¹ Disease severity depends primarily on the degree of damage to neuropsychiatric functions grounded in brain functioning. Loss or impairment of motor function is the most common problem in children with CP. The goal of CP treatment is to improve the exercise function through physical therapy involving strengthening the muscles, building endurance, and extending the range of motion (ROM).^{2,3} CP is a non-progressive disorder caused by brain lesions; however, the ability to

perform daily activities may be severely limited, affecting the quality of life of individuals with this disease.

Although problems associated with CP vary from child to child, there is a general perception of neuromuscular function impairment, such as spasticity, muscle weakness, ataxia, and loss of selective motor control (SMC).⁴ In general, CP limits the movement of the limbs and trunk via abnormal muscle tension or lack of balance/coordination, this occurs through the shortening of individual muscles or of a group of muscles in relation to the bones or joints, restricting free/voluntary coordinated movement.⁵ Ballaz et al.⁶ suggested that the ROM of the knee during bending, the bending motion, and the ankle joint motion are important kinematic factors

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that determine the gait of children with CP in adolescence. Additionally, McDowell et al.⁷ reported that the reduction in ROM is related to an increase in the activity limitations of children with a higher level of functional classification.

Another major factor is weakness, resulting from the state of constant tension of various muscle complexes. Recent studies have suggested the importance of strength training to improve the functional activity of children with CP.^{8,9} Thompson et al.¹⁰ reported that additional muscular strength in the lower limbs improves walking ability.

SMC is performed by the central nervous system. At the functional level, SMC is one of the most important factors influencing activities involving large movements, such as device control and walking in children with CP.¹¹ Goldberg et al.¹² reported that walking ability is affected by SMC. Ostensjo et al.¹³ showed that loss of SMC strongly affects behavior. Thus, functional activity is influenced by SMC.

Recently, the causal relationships among exercise injuries, activity, and the functional outcomes of children with CP were examined using path analysis, this study¹⁴ showed a direct correlation between muscle strength and motor function in children with spastic CP, with abnormal muscle tone as a secondary factor. There have been numerous studies on SMC and large work function capability with respect to optimizing the range of joint motion. In a bilateral retrospective study, Ross et al.¹⁵ reported on work function ability and strength improvement with spasticity reduction of the hip adductor of children with spastic CP. An understanding the effects of neuromuscular functional impairment on functional performance will be the basis for more effective treatment.

Therapeutic intervention in children with CP focuses on helping children perform tasks in a variety of settings.¹⁶ The rehabilitation regimen of children with CP typically includes physical, neurological developmental, occupational, and speech therapies.¹⁷ The effectiveness of rehabilitation is closely related to treatment concentration. According to a recent meta-analysis,¹⁸ intensive therapy is more effective than non-intensive treatment at the level of functional exercise. However, several short-term studies on the relationship between CP and intensive therapy indicated that this treatment approach is inadequate for improving the operating capacity, spasticity, strength, joint ROM, and neurological musculoskeletal elements of SMC. The purpose of this study was to investigate the relationship between gross motor capacity and neuromuscular function in children with

CP by implementing a short-term intensive intervention.

METHODS

1. Subjects

Twenty-four children younger than 6 years of age diagnosed with CP (17 boys and 7 girls, mean age \pm standard deviation, 42.71 \pm 14.43 months) underwent an 8-week short-term intensive treatment intervention in the day-care treatment facility of Gyeonggi C hospital. Inclusion criteria were as follows: patients with CP caused by central nervous system and/or muscular skeletal disorders; no recent orthopedic surgeries, and no botulinum toxin or baclofen treatments within 6 months prior to study commencement, as children with CP are better able to follow the directions of researchers and caregivers in the absence of these treatments. The parents/guardians of the participants provided informed consent.

2. Experimental method

1) Experimental procedures

The gross motor functional classification system (GMFCS) was used to measure changes in spasticity, strength, ROM, selective motor function, and exercise intensity.¹⁹

All subjects underwent neurodevelopment treatment (NDT) and participated in therapeutic exercises emphasizing normal motion enhancement and suppression of abnormal muscle tone. Physical therapy was provided by an NDT-licensed therapist. NDT was administered 30 minutes, 2 times a day, for 5 days a week, for a total of 8 weeks.

2) Measurement method

(1) Gross motor functional classification system

This classification system uses five levels: GMFSC-Level I, the ability to walk/climb stairs without restriction, Level II, can walk/climb stairs with minimal support (e.g., stair railing) over short distances and use a hand-held or wheeled mobility device for longer distances, Level III, can walk using a handheld mobility device, with a wheeled device required for longer distances and stair climbing with assistance, Level IV, minimal walking, mostly using mobility that requires power or physical assistance, and Level V, transported in a manual wheelchair at all times with structures in place to support the head and trunk and protect/restrain arms and legs.²⁰ The

interrater reliability ranged from 0.76 to 0.81.¹⁹ The Korean version of the GMFCS was used in this study.

(2) Neuromusculoskeletal function

In this study, spasticity, strength, ROM, and SMC were measured on both sides of the body using clinical methods. A modified Ashworth scale was used for spasticity measurements, this scale is based on the six-point scale proposed by Bohannon and Smith,²¹ in which 0 refers to no increase in muscle tone and 5 refers to stiffness (rigidity). The measurements focused on elbow bend. The bipedal hip adductor and plantar flexor of the knee and ankle were not included in these measurements.¹⁵

Strength was tested for the shoulder flexors and extensors, elbow flexors and extensors, wrist flexors and extensors, the hip flexors and extensors, knee extensors and flexors, and ankle dorsiflexors and plantarflexors. Post-evaluation was done by the same measurer, and the mean value was used after 3 repetitions. Strength was measured using the manual muscle test,¹⁴ as reported by Klingels,²² $r = 0.91$ at $r = 0.60$ for the tracking reliability test. The test-retest reliability was $k > 0.78$.

Joint ROM was measured via a manual goniometer in the upper extremities: the shoulder, elbow, and flexion and extension of the wrist. The flexion and extension of the ankle joint were also examined.²³ The hip and knee joints were not included in the joint ROM tests. The manual goniometer was used in the sagittal plane.

SMC measurements were based on the approach outlined by Boyd and Graham.²⁴ The five-point scale to assess the selective dorsiflexion of the ankle: score 0, no movement when asked to dorsiflex the foot; score 1, limited dorsiflexion using mainly extensor hallucis longus and/or extensor digitorum longus, score 2, dorsiflexion using extensor hallucis longus, extensor digitorum longus and some tibialis anterior activity, score 3, dorsiflexion achieved using mainly tibialis anterior activity but accompanied by hip and/or knee flexion, and score 4, isolated selective dorsiflexion achieved, through available range, using a balance of tibialis anterior activity without hip and knee flexion. SMC scale ranges from minimal control (0) to full control (4). Löwing and Carlberg²⁵ reported a test-retest reliability of 0.88-1.00 for SMC evaluation.

(3) Gross motor capacity

The GMFM was developed to determine changes in motor func-

tion in children with CP. The GMFM does not have age limits, and consists of 88 items categorized into five gross motor function dimensions: A (lying and rolling), 17 items, B (sitting), 20 items, C (crawling and kneeling), 14 items, D (standing), 13 items, and E (walking, running, and jumping), 24 items. All 88 items of GMFM-88 are usually scored in reference to what can be achieved with normal motor capacity over 5 years. Each item is scored on a four-point scale, similar to the Likert scale, ranging from 0 (does not initiate) to 3 (completes). In the present study, Korean version of the GMFM-88 (K-GMFM-88) was used. The inter-rater reliability of the K-GMFM-88 was assessed by interclass correlation coefficient (ICC),²⁶⁻²⁸ which ranged from 0.975-0.997.

The GMFM-66 was developed using Rasch analysis of the GMFM-88, whereby 22 of the original 88 items deleted to improve reliability and validity.²⁹ Of the 22 items deleted, 13 were from the lying and rolling dimension, 5 were from the sitting dimension and 4 were from the kneeling and crawling dimension. The GMFM-66 represents the unidimensional construct of gross motor ability according to task difficulty and thus is recommended for research purposes when comparing changes in gross motor function over time in children with CP.³⁰ However, the GMFM-66 is much less useful when scoring children with a severe disability.³¹ Therefore, both the GMFM-66 and GMFM-88 were used to assess gross motor function in this study.

3. Analytical method

Statistical analysis was performed using SPSS 18.0 for Windows (SPSS Inc., Chicago, IL, USA). A paired t-test was used to examine differences in spasticity, strength, ROM, SMC, gross motor function between baseline and follow-up period at 2 months for the day-care patient groups. An independent t-test was performed to examine differences in parameters by the ages. Post-hoc analysis of each group after one-way ANOVA according to GMFCS level. A p-value less than 0.05 was considered statistically significant.

RESULTS

The diagnoses of the study participants are listed in Table 1. Of the 24 study participants (17 boys, 7 girls, average age, 42.71 months) receiving intensive short-term treatment, 14 were diagnosed with CP spastic quadriplegia and 10 with spastic diplegia. The GMFCS levels

Table 1. Characteristics of subjects (N = 24)

Characteristic	Value
Age (mean ± SD, range, mo)	42.71 ± 14.43
Weight (kg)	12.42 ± 2.66
Height (cm)	90.63 ± 7.80
Body mass index(kg/m ²)	14.71 ± 1.82
Gender	
Male	17 (70.8)
Female	7 (29.2)
Number of affected limbs	
Quadriplegia	14 (58.3)
Diplegia	10 (41.7)
GMFCS	
Level I-II	7 (29.2)
Level III	6 (25.0)
Level IV-V	11 (45.8)

Values are presented as mean ± standard deviation or number (%). GMFCS: gross motor function classification system.

Table 2. Changes in Gross Motor Function Measure (GMFM) Scores (N = 24)

Parameters	Pre	Post	Post-Pre	p
GMFM-66 (%)	40.31 ± 16.18	42.73 ± 16.48	2.41 ± 1.51	7.833*
GMFM-88 (%)	42.85 ± 25.24	47.18 ± 26.79	4.32 ± 4.04	5.241*
A (%)	83.49 ± 23.40	87.25 ± 20.38	3.75 ± 5.54	3.321*
B (%)	57.21 ± 36.02	61.17 ± 36.26	3.95 ± 4.52	4.285*
C (%)	42.44 ± 34.87	48.70 ± 39.53	6.25 ± 10.00	3.063*
D (%)	19.22 ± 26.04	24.63 ± 30.28	5.40 ± 9.66	2.740*
E (%)	11.92 ± 18.64	14.10 ± 21.29	2.18 ± 4.25	2.513*

*p < 0.05, significant differences between pre-post intervention.

were as follows: Levels I-II (7 patients), Level III (6 patients), and Levels IV-V (11 patients). Table 2 lists the GMFM-88 and GMFM-66 scores of the study participants and the change in score for each sub-area. GMFM-88 and GMFM-66 scores showed a statistically significant increase of 4.32 ± 4.04 and 2.41 ± 1.51%, respectively, following the 8-week short-term intervention, these differences were also reflected in the sub-regions.

The results of GMFM-66 score, strength, SMC, ROM, and spasticity according to GMFCS level were as follows (Table 3). There was no statistically significant difference in GMFM-66 score according to GMFCS level, but there was a statistically significant difference in GMFM-88 score change in GMFCS level III, The strength, spasticity GMFCS level I-II showed no significant difference in (p < 0.05). The results of changes in GMFM-66 score, strength, SMC, ROM, and spasticity according to age showed a statistically significant difference (p < 0.05) in the strength of children aged 36 months and older (Table 4). There was a statistically significant difference in strength,

Table 3. Changes in the muscle strength, spasticity, ROM, SMC and GMFM-66 score by gross motor function classification measure (GMFCS) level (N = 24)

Parameters	GMFCS	GMFCS	GMFCS
	level I-II	level III	level IV-V
Changes GMFM-66 score (%)	3.01 ± 2.14	2.12 ± 0.97	2.19 ± 1.29
Changes GMFM-88 score (%)	5.40 ± 5.11	6.48 ± 4.73*	2.46 ± 1.82
Changes muscle strength (score)	0.14 ± 0.37*	0.14 ± 0.37	0.63 ± 0.50
Changes spasticity (score)	0.00 ± 1.15*	0.83 ± 0.75	-1.09 ± 0.70
Changes ROM (score)	0.00	0.00	-0.09 ± 0.30
Changes SMC (score)	1.14 ± 1.06	0.33 ± 0.81	1.27 ± 1.00

GMFM: gross motor function measure, ROM: range of motion, SMC: selective motor control. *p < 0.05, Post-hoc analysis of each group after one-way ANOVA according to GMFCS level.

Table 4. Changes in the muscle strength, spasticity, ROM, SMC and GMFM-66 score by ages (yr) (N = 24)

Parameters	≤ 36	> 36
Changes GMFM-66 score (%)	2.30 ± 0.87	2.46 ± 1.72
Changes GMFM-88 score (%)	3.91 ± 3.28	4.50 ± 4.40
Changes muscle	0.85 ± 0.37*	0.35 ± 0.49
Changes spasticity (score)	-0.71 ± 0.75	-0.70 ± 10.4
Changes ROM (score)	0.00	-0.05 ± 0.24
Changes SMC (score)	1.42 ± 0.97	0.82 ± 1.01

GMFM: gross motor function measure, ROM: range of motion, SMC: selective motor control. *p < 0.05, significant change after intervention by independent t-test.

Table 5. Changes in neuromusculoskeletal function (N = 24)

Parameters	Pre	Post	Post-Pre	p
ROM	0.63 ± 1.01	0.58 ± 0.92	-0.04 ± 0.20	-1.000
muscle strength	11.04 ± 2.52	11.54 ± 2.35	0.50 ± 0.10	4.796*
SMC	2.88 ± 2.41	3.88 ± 2.57	1.00 ± 0.20	4.796*
spasticity	3.50 ± 1.86	2.79 ± 1.31	-0.70 ± 0.19	-3.635*

ROM: range of motion, MMT: manual muscle test, SMC: selective motor control. *p < 0.05, significant differences between pre-post intervention.

SMC, and spasticity factors (p < 0.05) between changes in neuromusculoskeletal function before and after intensive short-term treatment (Table 5).

DISCUSSION

The purpose of this study was to investigate the effects of short-term intensive treatment on the motor ability of children with CP in terms of muscle strength, SMC, and spasticity, factors related to neuromusculoskeletal function. Changes in the scores for spasticity, strength, ROM, SMC, and exercise intensity were determined and

further classified in terms of GMFCS level. A statistically significant difference was observed in the GMFM-88 score of individuals at GMFCS Level III, however, there were no statistically significant differences in GMFM-66 scores according to GMFCS level. Our analysis of the posterior changes in nervous musculoskeletal function showed statistically significant differences in strength, SMC, and spasticity after 8 weeks of short-term intensive treatment.

Strength and spasticity in children of and there was a statistically significant difference between the young children (< 36 months) and old children (\geq 36 months). There was no significant difference in the change of the gestational abilities between the two groups divided by 36 months of age. However, there was no significant difference in the cerebral palsy. The effect of muscular strength of neuromusculoskeletal function in CP children was found. Analysis of the pre-and-post changes of the neuromusculoskeletal function through 8-week intervention through short-term intervention treatment revealed statistically significant differences in muscle strength, selective motor control, and spasticity.

The motor function of children with CP who participated in the 8-week short-term intensive intervention significantly improved, supporting the results of previous studies that emphasized early intensive therapy intervention for children with CP.³²⁻³⁵ However, this is not an absolute measure of the success of the treatment. According to GMFM use guidelines, the average change in GMFM-88 scores varies due to differences among individuals with CP as well as due to differences in the person making the assessment. For example, in the original validation research for the development of the GMFM,²⁰ caregivers and therapists observed a 5.2% and a 7.0% improvement in function, respectively. In terms of functionality, parents reported an average improvement of 2.7%, whereas therapists reported no positive change or only a small change of 1.3% on average. Other studies have reported a clinically significant change in GMFM scores of $\alpha \pm 4.0\%$.³⁶ The current study found a clinically significant change in GMFM-88 scores after the intensive intervention.

Depending on the child's GMFCS level, the functional manifestations of CP significantly change between the ages of 3 and 6 years before plateauing at 6-7 years.^{37,38} Future research should examine stagnation in the development of large motor functioning by providing short-term intensive therapy to more study participants. The participants in this study were all relatively young (less than 6 years old), and thus still had the potential for functional motor improve-

ment. In this study, a relatively young child (less than 6 years old) was enrolled in a child with the potential to promote functional exercise. After 36 months, exercise performance was improved in both groups. A systematic review showed that early intervention programs for high risk preterm infants have a position influence on motor outcomes until 3 years of age.³⁹ there is a significant increase in muscle strength improvement in children less than 36 months of age. According to early intervention has become an important topic.

Other studies have examined the effects of neuromuscular function on the performance of children with CP.¹⁵ In particular, Ostensjo et al.¹³ examined the relationships among muscle tone/spasticity, joint ROM, SMC skills, mobility, self-care, and social function, SMC strongly influenced gross motor function. Fowler et al.⁴⁰ investigated the effect of physical exercise and the lack thereof in promoting secondary conditions in children with CP. It should be noted that the exercise tasks may be extremely difficult for individuals with CP, however, exercises that can improve stability by increasing trunk muscle strength should be continued. Givon⁴¹ developed a strength exercise program for children with CP in which strength training was emphasized as the relevant component. This measure will be the focus of our future research into intervention strategies. In general, our results support early intensive therapeutic intervention for children with CP to improve their strength, SMC, spasticity, and neuromusculoskeletal functioning.

This study had several limitations. Although we had intended to examine a 6 year intervention, the study covered an 8 week period. Additionally, we did not include a control group. Future studies should consider age and CP type, among other factors.

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