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Review Article

Spontaneous Decrease of Gastrocnemius Spasticity after Correction of Knee Flexion Gait in Cerebral Palsy Children

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Abstract

Purpose: Synergistic neuro-excitability in the lower extremities may be related to gait disorders. This study reported spontaneous changes after correcting knee flexion gait and discussed the underlying mechanisms.

Methods: A prospective study of 23 children with cerebral palsy was conducted to assess postoperative changes in gross motor function, joint range of motion (ROM), and spasticity. Characteristics of children/limbs with spontaneous decrease in gastrocnemius spasticity were assessed.

Results: In 10 patients (19 limbs) without gastrocnemius release, Modified Ashworth scores in the gastrocnemius decreased in 6 limbs after 3 months and in 10 limbs after 6 months. Those limbs had worse preoperative knee flexion contracture than limbs without spasticity changes (knee ROM limitation score 5.4 vs. 3.7, p=0.026).

Conclusions: Patients with knee flexion contracture recruited greater plantar flexion-knee extension couple and enhanced synergistic neuro-excitability. Careful surgical decision-making by neuro-excitability, which is susceptible to other co-existing disorders, is important.

Keywords: Spasticity; Gastrocnemius; Hamstrings; Cerebral palsy

Abbreviations

CP: Cerebral Palsy; ROM: Range of Motion; ICC: Intra-Class Correlation Coefficients; MAS: Modified Ashworth Scale; GMFM: Gross Motor Function Measure; GMFCS: Gross Motor Function Classification System

Level of Evidence

Case-control study, Therapeutic; Level III.

What this Adds to the Evidence

Synergy between different muscles affects motor control and gait function in patients with cerebral palsy. We found enhanced synergy between the hamstrings and gastrocnemius in children with more severe knee flexion contracture. When the hamstrings were released surgically, spasticity in the gastrocnemius was reduced spontaneously.

Introduction

Cerebral palsy (CP) is a disease caused by non-progressive injury to the immature brain. Spasticity, muscle contracture, and subsequent limited range of motion (ROM) are common disorders that cause dysfunctions in gait and posture [1,2]. A common pathologic gait pattern in children with CP is knee flexion gait, which is characterized by increased knee flexion throughout the stance phase of the gait cycle. Knee flexion gait incurs more energy for walking and can be classified as jump knee gait, apparent equinus gait, and crouch gait by different biomechanics in the ankle [3]. Multilevel surgical correction is recommended for treating knee flexion gait to prevent decline in ambulatory ability [4].

Synergistic movement is a common neuropathological sign in patients with stroke and encephalopathy [5]. The primitive movement pattern interferes with coordinated voluntary movements. For example, patients with flexion synergy in the upper limbs show scapular retraction, shoulder adduction, elbow flexion, and wrist and finger flexion at the same time. Patients lose independent control of selected muscle groups, resulting in coupled joint movements known as abnormal synergy that is often inappropriate for the desired task [5]. Synergistic movement also occurs in the lower extremities as shown in hip flexion-adduction, knee flexion, and ankle plantar flexion.

When the hamstrings and gastrocnemius are regarded as one synergistic muscle group, the two muscles relate to each other. When one muscle is changed, the other muscles in one synergistic group may also be affected. Since surgical release is a strong perturbation for a muscle, we speculate that releasing the hamstrings may affect the gastrocnemius, and vice versa. In a clinical scenario where hamstrings are released for knee flexion gait, the gastrocnemius may be inoperable to preserve the plantarflexion power. It offers a chance to investigate how the non-operated gastrocnemius responds to surgical interventions if the hamstrings and gastrocnemius belong to one synergistic group. In this study, we aimed to show spontaneous changes in the length and spasticity of the gastrocnemius when surgery is performed in the hamstrings and to investigate the characteristics

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Table 1: Baseline data of 23 study participants.

No	Age	Sex	BMI	CP	GMFCS	GMFM	Side	ROM scores			Spasticity scales			Surgery Muscle
								Hip	Knee	Ankle	H	Q	G	
1	3.5	M	15.5	Qua	IV	21.78	R	9	4	2	4	1	4	PAH
							L	9	4	2	4	1	4	PAH
2	4.6	M	14.1	Qua	IV	46.47	R	10	5	1	2	3	3	PAH
							L	10	5	1	2	4	4	PH
3	5.1	M	13.6	Di	III	50.64	R	10	4	3	2	1	3	PAHG
							L	9	4	2	2	1	3	PAHG
4	5.9	M	18.3	Qua	III	67.28	R	10	6	2	3	2	4	PAHG
							L	10	6	1	3	1	5	PAHG
5	6.2	M	14	Qua	IV	44.93	R	9	4	4	4	3	4	PQHG
							L	9	4	4	4	2	5	PQHG
6	6.2	M	17.7	Qua	III	71.14	R	9	4	3	2	3	4	PQH
							L	9	4	3	2	3	4	PQH
7	6.9	M	18.2	Di	III	59.91	R	10	5	5	3	1	4	AHG
							L	11	6	5	3	2	5	AHG
8	7.4	M	19.1	Qua	IV	40.69	R	14	8	5	4	3	4	PAH
							L	14	8	5	4	4	4	PAH
9	7.5	M	19.5	Di	II	95.03	R	9	2	2	3	2	4	PAHG
							L	9	2	2	3	2	4	PAHG
10	8.1	F	13.6	Tri	III	70.58	R	11	6	3	2	2	4	HG
							L	12	7	3	2	2	4	HG
11	8.5	M	13.9	Tri	III	64.81	R	11	7	4	3	2	4	PAHG
							L	11	7	4	3	2	4	PAHG
12	8.9	M	15.9	Tri	II	78.68	R	9	5	4	2	2	4	AQHG
							L	9	5	4	2	1	4	AQHG
13	8.9	M	16.2	Di	II	93.27	R	8	4	3	2	1	4	PAQH
							L	8	3	2	2	1	3	PAQH
14	9.2	M	19.7	Di	II	83.55	R	8	2	3	2	2	4	PQH
							L	7	3	3	2	2	4	PQH
15	9.3	M	14	Di	II	95.17	R	8	3	4	3	1	4	PAQHG
							L	8	3	4	4	2	5	HG
16	9.7	M	15.9	Di	II	83.22	R	8	4	3	4	3	4	PAQHG
							L	9	5	3	4	2	4	PAQHG
17	10.3	M	19.8	Qua	III	64.82	R	11	7	3	4	2	4	PAHG
							L	11	7	3	4	2	4	PAHG
18	10.55	F	15.4	Qua	III	41.04	R	11	8	5	4	4	3	AHG
							L	11	8	4	3	3	2	AHG
19	10.8	F	17	Di	III	58.52	R	9	3	4	3	3	3	PAH
							L	9	2	4	3	3	3	PAH
20	11.6	M	16.9	Di	II	85.1	R	7	5	2	3	1	4	PAQH
							L	9	6	3	4	1	4	PAQH
21	11.8	M	14.9	Di	II	94.57	R	10	7	2	4	3	4	AQH
							L	8	5	4	4	3	5	AQH
22	11.8	M	14.8	Di	II	90.5	R	12	5	4	1	1	3	AH
							L	14	7	6	3	1	3	AHG
23	12.81	F	15.2	Di	III	58.94	R	11	8	6	4	3	4	AHG
							L	14	8	6	4	2	4	AHG

BMI: Body Mass Index; GMFCS: Gross Motor Function Classification System; GMFM: Gross Motor Function Measure; ROM: Range Of Motion Scores; Qua: Quadriplegia; Tri: Triplegia; Di: Diplegia; P: Psoas; A: Adductor; Q: Quadriceps; H: Hamstrings; G: Gastrocnemius.

of the patients or the limbs with spontaneous change.

Materials and Methods

After approval from the Institutional Review Board of our institution, a prospective study of surgical outcomes after myofascial release was conducted in 25 children with CP between 2010 and 2013. The children participated in the study, with a mean age of 8.5 years (3.5 to 12.8) before multilevel surgery for spastic knee flexion gait. Signed consent forms were obtained from all the participants' parents. There were 17 boys and 8 girls. Their gross motor function was level II in 9 patients, level III in 11 patients, and level IV in 5 patients by the Gross Motor Function Classification System (GMFCS) [6].

Single-event multilevel myofascial releases of both lower extremities were performed in all patients. The surgery involved the muscles at the knees, hips, and ankles based on clinical judgment by gait characteristics and physical examination [7]. Surgical procedures performed around the hips were release of the adductor longus and gracilis for scissoring and/or the psoas for hip flexion contracture greater than 20° by the Thomas test. Surgical procedures around the knees were performed for the myofascial release of the semimembranosus and semitendinosus muscles for patients with knee flexion gait and the popliteal angle greater than 70°. Knee flexion gait was defined by knee flexion angle greater than 30° throughout the entire stance phase. Surgical procedures performed around the ankles included release of the gastrocnemius for static equinus at knee extension with positive Silfverskiold test. Patients who underwent osteotomies were not included in this study. After surgery, long-leg splints were applied for 2 weeks to facilitate training of standing with full extension of the knees. Non-articulated or ground reaction ankle-foot orthoses were applied for gait training. Postoperative physical therapy was conducted by two certified pediatric physical therapists.

Muscle length was assessed by joint motion using a goniometer. The Spinal Alignment and Range of Motion Measure was an ordinal score to measure limitations of ROM [8]. The hip was assessed according to 6 items including extension, flexion, abduction, adduction, external rotation, and internal rotation. ROM limitation of the knee was assessed by 2 items, namely, the knee extension and the hamstrings. Knee extension was assessed by the maximal angle of passive knee extension at hip extension and was classified as follows: 10° or greater; 20° to -10°; 3, -10 to -20°; and 4, more than -20°. The hamstrings were assessed by maximal angle of passive knee extension at hip flexion 90°. They were classified as follows: 1, less than 20°; 2, 20 to 45°; 3, 45 to 60°; and 4, more than 60°. ROM limitation of the ankle was assessed by 2 items, namely, dorsiflexion and plantarflexion, that were assessed at knee extension. ROM limitation of ankle dorsiflexion was a measure of gastrocnemius length and classified as follows: 1, more than 15°; 2, 5 to 15°; 3, -10 to 5°; and 4, more than -10°. The Spinal Alignment and Range of Motion Measure that was performed at 2-week interval had good test–retest reliability (intra-class correlation coefficients (ICC) 0.95-0.97) and good interrater reliability between the two physical therapists (ICC 0.89).

Muscle spasticity was measured using the Modified Ashworth Scale (MAS) [9]. This 5-point scale was scored as follows: 1, normal tone; 2, mild spasticity with catching in limb movement or minimal resistance throughout the remainder (<50%) of the ROM; 3, moderate spasticity with increased tone throughout most of the ROM; 4, severe spasticity with difficulty in passive motion; and 5, extreme spasticity with rigidity in flexion and extension. Spasticity was assessed at the hamstrings and gastrocnemius. The MAS scores were regarded as an ordinal variable. The MAS that was validated before the study showed good test–retest reliability (ICC 0.76–0.79) and interrater reliability (ICC, 0.86).

Gross motor function was evaluated using the Gross Motor Function Measure (GMFM), which is a standard measure to quantify gross motor ability in children with CP [10,11]. In this study, the GMFM-66, which was a modified scale to improve the interpretability of changes following the interventions, was used [12]. Higher scores indicated better gross motor function. The GMFM scores were regarded as continuous variables in this study. The test–retest reliability and interrater reliability were excellent (ICC, 0.997 and 0.998, respectively).

Each patient underwent assessments at the week prior to surgery and post-operative 3 months and 6 months. Outcome measures included the MAS, ROM, and GMFM. All these measures were performed by two pediatric physical therapists. The surgical effects for all three outcome measures were compared before and after the surgery using a paired t-test. The characteristics of patients with spontaneous change at the gastrocnemius were compared with those of patients without change using t-tests for continuous variables (age, body mass index, ROM scores, GMFM-66 scores), Mann-Whitney test for ordinal variables (MAS scales), or chi-square test for categorical variables (GMFCS, surgery). The possibility of a positive significant factor to be associated with spontaneous change was further analyzed using an odds ratio and 95% confidence interval. A threshold for significance was set a priori at $p<0.05$. All analyses were conducted using SPSS version 21.0.

Results

Twenty-five children with spastic diplegic or quadriplegic CP received bilateral multilevel myofascial release. Two of these children (2 girls, one GMFCS level III and one level IV) did not complete the post-operative assessments, and the other 23 children with 46 limbs were the study participants. All the limbs had myofascial release in two or more muscle groups (Table 1).

General effects from surgery were improvements in the GMFM scores from a mean of 55.9 to 57.5 ($p=0.005$). The ROM limitation scores of the 43 operated hips improved from a mean of 9.8 to 8.5 ($p<0.001$). The ROM limitation scores of the 46 operated knees improved from a mean of 5.1 to 3.7 ($p<0.001$). The ROM limitation scores of the 27 operated ankles were not significantly change (from a mean of 3.6 to 3.7, $p=0.648$), because only the gastrocnemius was released. The MAS of the hamstring in the 46 operated limbs decreased from a median of 3 to a median of 2 ($p<0.001$). The MAS of the gastrocnemius in the 27 operated limbs decreased from a median of 4 to a median of 3 ($p=0.001$).

The ROM scores were unchanged for the 3 hip joints and 19 ankle joints that did not undergo surgery. However, in the 19 limbs without surgery at the gastrocnemius, the MAS of the gastrocnemius decreased from a median of 4 (interquartile range 3–4) to a median of 3 (interquartile range 2–4) ($p=0.006$). Among the 19 limbs, 6 limbs in 3 patients had a spontaneous decrease in spasticity by one MAS scale in 3 months, and the phenomenon was noted in 10 limbs (5 patients) in 6 months. The other 9 limbs (5 patients) remained in the pre-operative status. Between the two groups with different responses in terms of gastrocnemius spasticity to the surgeries at the knees and hips, no significant differences were found in the patients' age, body mass index, GMFCS level, GMFM scores, surgical procedures, and limbs' MAS scales. Only the pre-operative ROM limitation of the knee was significantly different between the two groups of limbs with different responses (mean ROM limitation scores 5.4 in the limbs with change vs. 3.7 in the limbs without change, $p=0.026$). The limbs with pre-operative knee flexion contracture (knee extension score of 2 or more) were more likely to have spontaneous changes in spasticity

Table 2: Comparison between patients/limbs with and without spontaneous decrease of spasticity in the gastrocnemius.

Patients	Decrease of spasticity (-)	Decrease of spasticity (+)	P value
	N=5	N=5	
Age^a	7.9(3.2)	8.9(2.8)	0.5
BMI^a	17.2(1.7)	16.2(1.8)	0.26
GMFCS (II:III:IV)^c	3:00:02	2:02:01	0.282
GMFM^a	62.7(26)	71.6(24.4)	0.453
Limbs	N=9	N=10	
ROM limitation of the hip^a	8.8(0.8)	10.0(2.5)	0.187
ROM limitation of the knee^a *	3.7(1.5)	5.4(1.6)	0.026
Knee extension score^{a*}	0.8(1.0)	1.9(1.2)	0.04
Hamstrings score^a	2.9(0.6)	3.5(0.7)	0.06
ROM limitation of the ankle^a	2.9(0.8)	3.0(1.5)	0.844
Ankle dorsiflexion score^a	2.9(0.8)	2.8(1.0)	0.837
Ankle plantar flexion score^a	0.7(0.5)	0.6(0.8)	0.839
Spasticity hamstrings^b	2.5(2-4)	3(2-4)	0.905
Spasticity gastrocnemius^b	4(3-4)	4(3-4)	1

BMI: Body Mass Index; GMFCS: Gross Motor Function Classification System; GMFM: Gross Motor Function Measure; ROM: Range Of Motion Scores.
Statistic methods: ^{a}independent *t* test; ^{b}Mann-Whitney test; ^{c}chi-square test
Mean (standard deviation) for age, BMI, ROM scores, and GMFM scores. Median (interquartile range) for spasticity scales.

(odds ratio=8.00, 95% confidence interval 1.05-60.99) compared with the limbs with full passive knee extension (knee extension score of 1) (Table 2).

Discussion

A unique phenomenon of spontaneous decrease in spasticity of the gastrocnemius in 50% of patients with CP who received hamstring release for knee flexion gait was found in this study. The gastrocnemius muscle tone decreased by one MAS scale without surgical intervention. Myofascial release of the hamstrings and other muscles could change the underlying synergistic neuro-excitability in the lower extremities and result in decreased spasticity of the gastrocnemius.

The only predictor for the phenomenon was preoperative knee flexion contracture. A possible biomechanical pathway is that patients with existing knee flexion contracture recruit more gastrocnemius-soleus muscle to produce plantar flexion-knee extension couple to stabilize the knee joint during knee flexion gait [3,13]. More gastrocnemius-soleus muscle fibers are employed to control the advancement of the tibia over the foot as well as the orientation of the ground reaction vector with respect to the knee [14]. Chronic and excessive recruitment of the gastrocnemius-soleus may lead to an increase in muscle tone. The coping response in the gastrocnemius muscle tone returns to its original level after surgical correction. This information raises concerns about the accuracy of the preoperative assessment of spasticity and electromyography. The neuro-excitability may be enhanced from original neural morbidity to a higher level by adding responses to musculoskeletal disorders.

No cast was applied to immobilize the ankle in the 19 patients who did not receive ankle surgery. Therefore, immobilization was not the cause of decreasing spasticity in the gastrocnemius. Improvement of dynamic ROM of the knee joint during standing and walking could affect afferent proprioceptive impulses from the lower extremities, as well as neural output in the spinal cord [15]. Since the common pathological pathway in CP is central neurologic morbidity, it leads to peripheral musculoskeletal disorders. However, the study results suggested a reverse pathway from peripheral biomechanical disorders (correction of knee flexion gait) to spinal neural excitability (decrease of neural tone). It is a mutual interaction between central neural network and peripheral musculoskeletal disorders in patients with CP.

This study has several limitations. First, the number of included patients was small and the follow-up period was short. Second, this study did not include kinematic data or electromyographic data to record gait parameters and muscle neuro-excitability. Further studies including more cases to analyze kinematic and electromyographic data are needed to conclude more detailed and in-depth findings other than knee flexion contracture. Third, it was a clinical observational study using the MAS and ROM limitation score. They were ordinary variables to measure apparent and clinically significant changes, but other measurements with continuous variables are likely to offer more information.

In conclusion, this study reports a spontaneous decrease in spasticity of the gastrocnemius after surgery for knee flexion contracture. The association with knee flexion contracture suggests that neuropathy and musculoskeletal disorder affect each other mutually. Cautious surgical decision-making by neuro-excitability, which is susceptible to other co-existing disorders, is required. The findings also support preservation of the gastrocnemius in treating knee flexion gait, especially for patients with knee flexion contracture.

References

1. Johnson DC, Damiano DL, Abel MF. The evolution of gait in childhood and adolescent cerebral palsy. J Pediatr Orthop. 1997; 17: 392-396.
2. Bell KJ, Ounpuu S, DeLuca PA, et al. Natural progression of gait in children with cerebral palsy. J Pediatr Orthop. 2002; 22: 677-682.
3. Rodda JM, Graham HK, Carson L, et al. Sagittal gait patterns in spastic diplegia. J Bone Joint Surg Br. 2004; 86: 251-258.
4. Thomason PBR, Dodd K, Taylor N, et al. Single-event multilevel surgery in children with spastic diplegia: a pilot randomized controlled trial. J Bone Joint Surg Am. 2011; 93: 451-460.
5. Sakuma K, Ohata K, Izumi K, et al. Relation between abnormal synergy and gait in patients after stroke. J Neuroeng Rehabil. 2014; 11: 141.
6. Palisano R, Rosenbaum P, Walter S, et al. Development and reliability of a system to classify gross motor function in children with cerebral palsy. Dev Med Child Neurol. 1997; 39: 214-223.
7. Sutherland D, Davids JR. Common gait abnormalities of the knee in cerebral palsy. Clin Orthop Relat Res. 1993; 288: 139-147.
8. Bartlett D, Purdie B. Testing of the spinal alignment and range of motion measure: a discriminative measure of posture and flexibility for children with cerebral palsy. Dev Med Child Neurol. 2005; 47: 739-743.
9. Mutlu A, Livanelioglu A, Gunel MK. Reliability of Ashworth and Modified Ashworth scales in children with spastic cerebral palsy. BMC Musculoskelet Disord. 2008; 9: 44.
10. Palisano RJ, Hanna SE, Rosenbaum PL, et al. Validation of a model of gross motor function for children with cerebral palsy. Phys Ther. 2000; 80: 974-985.

11. Russell DJ, Rosenbaum PL, Cadman DT, et al. The gross motor function measure: a means to evaluate the effects of physical therapy. Dev Med Child Neurol. 1989; 31: 341-352.
12. Russell DJ, Avery LM, Rosenbaum PL, et al. Improved scaling of the gross motor function measure for children with cerebral palsy: evidence of reliability and validity. Phys Ther. 2000; 80: 873-885.
13. Gage JR. The clinical use of kinetics for evaluation of pathologic gait in cerebral palsy. Instr Course Lect. 1995; 44: 507-515.
14. Gage JR. Gait analysis in cerebral palsy. London: Mac Keith Press, 1991.
15. Maas JC, Huijing PA, Dallmeijer AJ, et al. Decrease in ankle-foot dorsiflexion range of motion is related to increased knee flexion during gait in children with spastic cerebral palsy. J Electromyogr Kinesiol. 2015; 2: 339-346.

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