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Original Article

Relation of selective voluntary motor control of the lower extremity and extensor strength of the knee joint in children with spastic diplegia

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Abstract. [Purpose] The aim of this study was to investigate differences in selective voluntary motor control of the lower extremities by objective assessment and determine the relationship between selective voluntary motor control and knee extensor strength in children with spastic diplegia. [Subjects and Methods] Forty individuals who had spastic cerebral palsy, with Gross Motor Function Classification System levels ranging from I to III, were assessed using the Selective Control Assessment of the Lower Extremity and by testing the maximum knee extensor strength. The unaffected side was defined as the lower limb with the higher score, and the affected side was defined as the lower limb with the lower score. [Results] The Selective Control Assessment of the Lower Extremity score on the affected side had a lower average than that on the unaffected side. The scores showed a significant inverse correlation with the maximum knee extensor strength. [Conclusion] There was bilateral difference in the selective voluntary motor control of the lower extremities in children with spastic diplegia, and the selective voluntary motor control of the lower extremity was related to maximum knee extensor strength.
Key words: Cerebral palsy, Extensor strength of knee joint, Selective voluntary motor control

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INTRODUCTION

Selective voluntary motor control (SVMC) is defined as “the ability to isolate the muscle activity in a selected pattern in response to the demands of a voluntary motion or posture”[1)], and is the basis of all exercise. In cerebral palsy (CP), corticospinal tract dysfunction disrupts the ability to control the force, speed, and timing of muscle contractions and disturbs the pattern of voluntary movements[1, 2)]. Therefore, the loss of SVMC is considered to be an important contributor to the impairment of motor function in patients with CP[2)].

Compared to healthy children, those with CP have not only impaired SVMC, but also lower muscular strength and endurance[3–6)]. Patients with spastic diplegia and spastic quadriplegia often show exercise paralysis of both lower limbs[5, 6)]. The severity of exercise paralysis is clinically varied, and there is often right and left asymmetry in patients with diplegia and quadriplegia. Therefore, when arising and walking, these patients tend to repeat typical movements asymmetrically, which may favor the development of secondary disabilities, such as pain and joint contracture; this requires preventive intervention by rehabilitation[7)].

Lower limb muscle strength, including knee extensor strength, is strongly correlated with long-term ambulatory func-

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tion[4, 5]. A lack of maximal voluntary muscle contraction reveals an inability to use the muscles from individual muscles group selectively[8]. The SVMC of the lower extremities may be linked to the strength of these extremities; yet, it is important that there is no laterality of muscular strength upon arising and walking. Differences in the SVMC of the bilateral lower extremities have not yet been evaluated objectively in patients with diplegia and quadriplegia.

Therefore, the aim of present study was to investigate differences in the SVMC of the lower extremities by objective assessment and determine the relationship between SVMC and knee extensor strength in children with spastic diplegia.

SUBJECTS AND METHODS

This study was approved by the Tokyo University of Technology of Health Sciences Ethical Review Board (Authorization Number: E13H3-023), and was financially supported by JSPS KAKENHI Grant Number 26750232. All authors declare that there is no conflict of interest. Participants were children with spastic diplegic CP, who were recruited from 3 hospitals in Tokyo and Kanagawa if they met the following inclusion criteria: (1) 6 to 18 years-old; (2) diagnosis of spastic diplegia; (3) gross motor level I to III based on the Gross Motor Function Classification System-Expanded & Revised version (GMFCS-E&R); and (4) ability to communicate and follow instructions. Exclusion criteria were: (1) orthopedic intervention or botulinum toxin injection to the lower extremities in the last 6 months and (2) orthopedic problems or medical conditions that prevented children from participating in the exercises. In total, 53 patients with spastic CP were referred to us, of whom 40 patients and/or their parents provided written informed consent for participation. These 40 individuals, with GMFCS levels ranging from I to III, were included in the study (mean age ± standard deviation: 13.3 ± 3.4, range: 6–18, GMFCS level I: 12, level II: 19, level III: 9).

The Selective Control Assessment of the Lower Extremity (SCALE) tool, which analyzes monarthric active movement, was used to measure SVMC. The inter-rater reliability (ICC range: 0.88–0.91) of the SCALE was high for children with spastic CP[9]. For each joint, the participants were asked to perform the following movement patterns for 3 s each: hip flexion and extension; knee extension and flexion; ankle dorsiflexion and plantar flexion with the knee extended; subtalar inversion and eversion; and toe flexion and extension. Measurement was performed in the lateral recumbent position for the hip joint and in the sitting position for the knee, ankle, subtalar, and toe joints. For each joint, the SCALE tool was scored from 0 to 2: 2 points indicated normal function; 1 point, impaired function; and 0 points, unable to move. The SCALE score was the sum of scores for each joint (maximum: 10 points per limb).

When the SCALE score of the peripheral parts is low, the severity of exercise paralysis is high[10]. Therefore, the unaffected side was defined as the lower limb with the higher SCALE score, and the affected side was defined as the lower limb with the lower SCALE score. When the SCALE scores of the right and left side were the same, the unaffected side was defined as the peripheral part of the lower limb with the higher score, and the affected side was defined as the peripheral part of the lower limb with the lower SCALE score.

A previous study has shown that inter-rater reliability of the knee extensor strength is high (ICC=0.81) for children with spastic diplegia[11]. To test the knee extensor strength, the participants were placed in a sitting position, with the knee flexed at 90° and without arm support. Resistance was applied anteriorly, 5 cm proximal to the lateral malleolus. The examiner gradually applied force with a hand-held dynamometer for 3 s to allow the participants to adjust and to recruit the maximum number of muscle fibers. Three attempts for each muscle group were recorded. The left and right sides were tested alternatively, with a 1-minute break after each trial to prevent muscle fatigue. The distance from the cleft of the knee joint to the point of resistance was measured using a cloth measure, and was calculated as the torque weight ratio [Nm/kg]. The maximum torque of each lower limb was used as the maximum knee extensor strength.

The canonicity of the SCALE score and maximum knee extensor strength were confirmed first by the Shapiro-Wilk test for both the unaffected side and the affected side. Next, the characteristics of the participants were compared using two-sample *t*-tests and chi-squared tests. Third, the SCALE score and maximum knee extensor strength were assessed for each side using Pearson's product-moment correlation coefficient. All analyses were conducted using the SPSS statistical package for Windows, version 21.0. P values of<0.05 were considered statistically significant.

RESULTS

Table 1 shows the results from the two-sample t-tests and chi-squared tests. The SCALE score on the affected side had a lower average than that on the unaffected side (p=0.01). The maximum knee extensor strength was not significantly different between the two groups (p=0.31).

SCALE scores showed a significant inverse correlation with the maximum knee extensor strength (Pearson's correlation coefficient: unaffected side: 0.42, affected side: 0.43, p<0.01).

DISCUSSION

As shown by the lower SCALE score on the affected side compared to that on the unaffected side, there was clearly a difference bilaterally in the SVMC of the lower extremities in children with spastic diplegia. The SCALE tool indicates the

Table 1. Value of each parameter on the unaffected side and the affected side

	Unaffected side	Affected side
Left limb, number (%)	21 (52.5)	19 (47.5)
SCALE (point)	6.0 ± 2.2	4.4 ± 2.0*
Maximum knee extensor strength (Nm/kg)	1.25 ± 0.45	1.21 ± 0.44

Mean ± standard deviation, SCALE: Selective Control Assessment of the Lower Extremity, *$p<0.05$.

relationships of knee extension acceleration as well as the relationships of the movement of the hip and knee joints during the swing phase of gait[12]. Thus, the SCALE score is an important tool for the objective assessment of the SVMC of the lower extremities in children with spastic diplegia.

As the SCALE scores showed a significant inverse correlation with the maximum knee extensor strength, SVMC is clearly related to maximum knee extensor strength. However, there was no difference between the unaffected side and the affected side in terms of maximum knee extensor strength. If SVMC was strongly correlated with maximum knee extensor strength, it would be expected that the maximum knee extensor strength of the affected side would be lower than that of the unaffected side. Children with CP often show spasticity in exercise, such as strengthening of the dynamic equinus when walking[13]. The SCALE score involves the measurement of weak muscle activity, while measuring maximum knee extensor strength involves evaluating strong muscle activity. The limb with the lower SCALE score is likely to have increased maximum knee extensor strength, due to spasticity. This may explain why the maximum knee extensor strength was not different between the unaffected and affected sides.

Muscle strength is affected by the number of active motor units, the firing rate of motor units, and the principal of size of the motor unit[14]. Children with CP, who have injuries of the corticospinal tract, find it difficult to increase the firing rate of the motor unit when stronger contractions are required[15]. Therefore, the maximum knee extensor strength of the limb with the higher SCALE score would not be able to attain the full firing rate of the motor unit needed for maximum voluntary contraction. This may result in variable maximum knee extensor strength.

The severity of spasticity may not necessarily be associated with gross motor function and activities[16]. However, spasticity and contractures may lead to various disabilities in children with spastic CP[17, 18], and the lack of SVMC may lead to equally severe impairments[2]. If there is a difference in the SVMC but no difference in the maximum knee extensor strength between the unaffected side and the affected side in children with spastic diplegia, as seen here, movements requiring coordinated use of both limbs will be asymmetrical. Such movements, such as rising from a sitting to a standing position and walking, will require compensatory motion. Longitudinal asymmetrical movements may lead to various contractures and deformities. There is therefore a need for a physiotherapy program that aims to prevent secondary disabilities. Evaluation of the SVMC of the lower limbs may be important in addition to evaluating the muscular strength in children with CP.

This study had some limitations. This study was a cross-sectional study, and long-term effects were not determined. Moreover, only children with limited severity and diagnoses were included. Therefore, further studies are needed to determine how SVMC and maximum knee extensor strength affect contractures and deformities.

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