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Original Article

Characteristics of selective motor control of the lower extremity in adults with bilateral spastic cerebral palsy

Takahito Inoue, RPT, MSc[1)*], Yuichiro Yokoi, RPT, PhD[2)]

[1)] *Division of Rehabilitation Medicine, Hokkaido Medical Center for Child Health and Rehabilitation: 1-240-6 Kanayama 1, Teine-ku, Sapporo, Hokkaido 006-0041, Japan*
[2)] *Department of Physical Therapy, Faculty of Human Science, Hokkaido Bunkyo University, Japan*

Abstract. [Purpose] We aimed to examine the relationship between gross motor function, selective motor control (SMC), range of motion (ROM), and spasticity in the lower extremities of adults with cerebral palsy (CP), as well as the proximal to distal distribution of SMC impairment in lower extremity joints. [Participants and Methods] We recruited 11 adults with bilateral spastic CP, ranging from levels I to III according to the Gross Motor Function Classification System (GMFCS). We evaluated participants according to the Selective Control Assessment of the Lower Extremity (SCALE), ROM, and the Modified Ashworth Scale (MAS). We conducted the Friedman test to assess differences among the SCALE scores of each joint. The relationship between GMFCS level, SCALE scores, ROM, and MAS scores was assessed. [Results] The mean SCALE scores were lower for distal than for proximal joints. The SCALE scores of each leg showed significant inverse correlations with the GMFCS level. [Conclusion] SMC in adults with CP strongly influences gross motor function. SMC did not have a significant relationship with spasticity or ROM. SMC, ROM, and spasticity independently influenced gross motor function in adults with CP. SMC impairment in adults with CP was higher in distal than in proximal joints.

Key words: Cerebral palsy, Adults, Selective motor control

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INTRODUCTION

Cerebral palsy (CP) includes a variety of disorders caused by abnormal brain development or damage during the neonatal period[1)]. Several factors, such as selective motor control (SMC), spasticity, and range of motion (ROM), interact and affect the gross motor function of children with CP[2–4)]. Clarification of the relationships among these factors will help us better understand the disorder. Among the factors, SMC reportedly has the strongest effect on gross motor function[3)], and it is correlated with other factors, such as spasticity and muscle strength[5, 6)]. Therefore, it is important to evaluate the SMC of individuals with CP. Previous studies have reported that selective motor impairment increases at the distal joints in children with CP[7)].

Currently, the need for interventions for adults with CP is increasing because with the advancements in the treatments and knowledge of the disorders, the life expectancy of patients with CP is increasing[8)]. Therefore, it is important to clarify the characteristics of CP in adults. Loss of motor function begins before patients with CP reach adulthood[9)]. In addition, a limited range of motion due to shortening of soft tissue, etc., and weakness due to sarcopenia have been reported in adults with CP[10)]. The relationships among the aforementioned factors may change with age. In fact, previous studies on children with CP showed a significant correlation between muscle strength and spasticity[11, 12)], whereas previous studies on adults with CP did not[13)]. In previous studies, the characteristics of SMC or the relationships between SMC and other factors were mostly investigated in children, adolescents, and young adults. There are few reports on adults with CP because previous studies of adults with CP did

*Corresponding author. Takahito Inoue (E-mail: takahito.inoue1@gmail.com)

not assess SMC. Thus, the characteristics of SMC in adults with CP remain unclear. This study aimed to examine the relationships among the SMC, gross motor function, ROM, and spasticity in the lower extremities in adults with CP. We also aimed to examine the proximal to distal distribution of SMC impairment in lower extremity joints of adults with CP.

PARTICIPANTS AND METHODS

The study included 11 adults with bilateral spastic CP recruited from among community-dwelling or facility residents (9 males, 3 females; mean age ± SD: 40.4 ± 11.2). Gross Motor Function Classification System (GMFCS) levels were assessed in the 12–18 year age band because some studies have used the GMFCS in adults with CP[6, 8] (GMFCS level I: 1 participant, level II: 2 participants, level III: 4 participants, level IV: 4 participants). The inclusion criteria were as follows: (1) over 18 years of age; (2) diagnosed with bilateral spastic CP; (3) GMFCS level I to IV; and (4) able to follow simple instructions. The exclusion criteria were as follows: (1) orthopedic surgery within the previous 6 months or (2) botulinum toxin injections to the lower extremities within the previous 3 months. All procedures were approved by the ethics committee of Hokkaido Bunkyo University (authorization number: 30016), and all participants provided written informed consent before starting this study. The authors have no conflicts of interest to declare.

SMC was assessed using the Selective Control Assessment of the Lower Extremity (SCALE)[2, 14]. The participants were asked to perform the following movement patterns for 3 seconds each: (1) hip flexion and extension with the knee extended, (2) knee extension and flexion, (3) ankle dorsiflexion and plantarflexion with the knee extended, (4) subtalar inversion and eversion, and (5) toe flexion and extension. The hip-joint test was performed in the side-lying position; the other joints test were performed in the sitting position. The SCALE grade was scored as normal (2 points), impaired (1 point), or unable (0 points). The total SCALE score was defined as the total of the points for each joint per limb (maximum: 10 points). The assessment was videotaped on a sagittal plane to reconfirm mirror movement and other joint movements.

The ROM of each lower limb was assessed using a goniometer for hip extension (Thomas test), knee extension with the hip flexed at 90 degrees (popliteal angle), and ankle dorsiflexion with the knee extended. All measurements were taken by three researchers with the participant in the supine position. One researcher fixed the pelvis, the second researcher moved the lower limb, and the third researcher measured the ROM with a goniometer. The ROM of each joint was scored based on the Spinal Alignment and Range of Motion Measure (SAROMM)[15]. SAROMM has been reported to be reliable and valid. The total ROM score was defined as the total of the points for each joint per limb (maximum: 12 points).

The spasticity of each lower limb was assessed using the Modified Ashworth Scale (MAS)[16] for hip flexors, knee flexors, and ankle flexors. All measurements were taken in the supine position. The total MAS score was defined as the total of the points for each joint per limb (maximum: 12 points).

The normality of all data was confirmed using the Shapiro-Wilk test. Next, the relationships among GMFCS level, SCALE score, ROM, and MAS score were assessed using Spearman's rank correlation coefficient. Furthermore, the Friedman test and post-hoc test were used to assess differences among the SCALE scores of each joint. Furthermore, as described in a previous study[7], the percentage of proximal to distal concordance (PDC) between joint pairs of each limb was calculated using cross-tabulation. PDC is the percentage score assigned when a proximal joint is larger than a distal joint; 100% PDC indicates that the distal joint scores never exceeded the proximal joint scores.

All data analyses were performed using SPSS software version 21.0 for Windows (IBM Corp., Armonk, NY, USA). P-values <0.05 were considered statistically significant.

RESULTS

Table 1 shows the mean SCALE scores by joint for the left and right extremities. The mean SCALE scores were lower for the distal joints than for the proximal joints. Table 2 shows the differences among the SCALE scores for five joints and the PDC values. In the left lower limb, the score of the distal joint was low for all combinations except hip vs. knee and subtalar vs. toes. The percentage of PDC ranged from 73% to 100%. The SCALE scores, ROM measurements, and MAS scores are presented in Table 3. The correlation coefficients of GMFCS level, SCALE scores, ROM, and MAS scores are presented in Table 4. The SCALE scores of each leg showed a significant inverse correlation with GMFCS level. Other factors were not significantly correlated.

DISCUSSION

Our findings indicate that SMC in adults with CP is an important factor that strongly influences gross motor function. However, we did not find significant relationships between SMC and spasticity or ROM. It is suggested that SMC, ROM, and spasticity were independent factors in adults with CP.

The SCALE scores were lower for the distal joints than for the proximal joints, which is consistent with the findings of a previous study on children with CP[7]. These findings suggested that this characteristic of SMC—that the distal joint is more impaired than the proximal joint—does not change with age. On the other hand, the SCALE scores for each joint were lower than those reported in previous studies[2, 7, 14]. The SCALE scores for each joint in adults with CP were approximately 0.2 points lower than the SCALE scores reported in the previous study on children with CP. In healthy elderly participants,

Table 1. SCALE scores for each joint

	Hip	Knee	Ankle	Subtalar	Toe
Left	1.2 ± 0.6	1.2 ± 0.6	0.6 ± 0.8	0.2 ± 0.4	0.2 ± 0.4
Right	1.3 ± 0.5	1.1 ± 0.5	0.4 ± 0.7	0.1 ± 0.3	0.4 ± 0.5

Mean ± SD; SCALE: Selective Control Assessment of the Lower Extremity.

Table 2. P-values when comparing SCALE scores for each joint, and percentage of proximal to distal concordance (PDC)

	Left	Right	Left PDC (%)	Right PDC (%)
Hip vs. knee	1.000	0.157	91	100
Hip vs. ankle	0.034*	0.004*	100	100
Hip vs. subtalar	0.002*	0.002*	100	100
Hip vs. toes	0.002*	0.004*	100	100
Knee vs. ankle	0.034*	0.011*	100	100
Knee vs. subtalar	0.002*	0.002*	100	100
Knee vs. toes	0.002*	0.011*	100	100
Ankle vs. subtalar	0.025*	0.083	100	100
Ankle vs. toes	0.025*	1.000	100	82
Subtalar vs. toes	1.000	0.083	100	73

SCALE: Selective Control Assessment of the Lower Extremity. *p<0.05.

Table 3. Parameter values

	Left	Right
Total SCALE scores	3.4 ± 2.5	3.2 ± 1.9
Total ROM scores	2.1 ± 0.7	2.5 ± 0.8
Total MAS scores	4.5 ± 2.6	4.6 ± 2.3

Values are expressed as Mean ± SD.
SCALE: Selective Control Assessment of the Lower Extremity; ROM: range of motion; MAS: Modified Ashworth Scale.

Table 4. Correlation coefficients among GMFCS level, SCALE score, ROM, and MAS score

	SCALE		ROM		MAS	
	Left	Right	Left	Right	Left	Right
GMFCS	−0.81*	−0.79*	0.19	0.06	0.29	0.34
SCALE	-	-	0.04	−0.08	−0.24	−0.29
ROM	-	-	-	-	0.59	0.44

*p<0.05, Spearman's rank correlation coefficient. GMFCS: Gross Motor Function Classification System; SCALE: Selective Control Assessment of the Lower Extremity; ROM: range of motion; MAS: Modified Ashworth Scale.

skilled movement and coordination in the periphery (i.e., fingers) were deteriorated[17, 18]. Moreover, age leads to alterations in the sensory system, such as a decrease in the number of sensory receptors in the nervous system, such as decreased nerve cell counts and myeloid degeneration, and in the musculoskeletal system, such as a decrease in the muscle mass and muscle tissue alterations. Healthy elderly people also often experience reduced muscle synergy[17, 18]. For these reasons, SMC disorder symptoms may increase with age. However, we were unable to differentiate changes due to aging, as we did not compare children and adults. Furthermore, our results may include lower SCALE scores due to a higher proportion of participants with GMFCS levels III or IV than in previous studies.

In this study, SCALE scores were strongly correlated with GMFCS level. This finding is similar to those of previous studies on children with CP[2, 5, 6]. The brain injury that initially causes CP does not progressively worsen[19]. Because SMC impairment is affected by such brain injuries[2, 5, 7], it seldom improves and tends to be worsened by age-related neurodegeneration. Thus, SMC is a major factor affecting consistent gross motor function in children and adults with CP[17, 18]. In addition, we found no

significant relationships among gross motor function, spasticity and ROM; there was also no significant relationship between SMC and spasticity or ROM. In previous studies on children with CP, spasticity and ROM were significantly correlated with gross motor function[3, 4]. A previous study has also reported correlations among SMC, strength, spasticity, and ROM[16]. In contrast, the previous study on adults with CP showed no significant correlation between strength and spasticity[17]. Previous studies have observed that, children with CP develop secondary disorders, such as exacerbation of spasticity, metabolic disease, abnormalities of the musculoskeletal system, fatigue, chronic pain, and deformity as they grow[10, 19, 20]. Recent studies have reported that, in addition to such CP-related disorders, these children also develop age-related conditions, such as obesity, diabetes, sarcopenia, osteoporosis, cardiac and vascular disease, and decreased soft tissue elasticity[10, 19, 20]. Therefore, in adults with CP, the relationship between each factor may be more complex than anticipated. These factors may have caused the differences in noted between children and adults with CP. We suggest that adults with CP need multidirectional assessments and treatment, including those for disabilities that occur secondary to CP and age-related disorders.

This study had some limitations. The sample size was small, and there is a possibility of bias, because we included only one patient with GMFCS level I. It should also be considered that changes due to age cannot be clarified because we targeted only adults with CP in this cross-sectional study. Therefore, further longitudinal studies with larger sample sizes are needed.

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Conflict of interest

The authors have no conflicts of interest to declare.

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