Follow-up of Developmental Profiles in Children with Spastic Quadriplegic Cerebral Palsy

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Background: The aim of this study was to investigate longitudinal changes in the developmental profiles of children with spastic quadriplegic (SQ) cerebral palsy (CP). Additionally, the relationship of developmental functions between the initial and final stages was determined.

Methods: This prospective study enrolled forty-six children with SQ CP between 2-6 years old and assessed their developmental profiles using the Chinese Child Developmental Inventory on the initial and final assessments. The interval between two assessments was 1.0 ± 0.3 years. Eight developmental domains, including gross motor, fine motor, expressive language, concept comprehension, situation comprehension, self help, personal social and general development, were evaluated and qualified by the development quotient (DQ). The DQ change index (%) was calculated to evaluate the differences in each domain between the two assessments. The paired t test was used to compare differences in each domain between the two assessments. Pearson's correlation was used to analyze the relationship of each domain between the final and initial assessments.

Results: Children with SQ CP had lower DQs than normal children in all developmental functions on both assessments (23 - 66%). The DQ distributions were lowest in the gross motor and self help domains, higher in the fine motor, situation comprehension, and personal social domains, and highest in the expressive language, concept comprehension, and general development domains. Except for the fine motor and concept comprehension domains, the DQs of the developmental functions were significantly decreased on the final assessment ($p < 0.05$).

Conclusion: These findings suggest preschool children with SQ CP had impairments in the full spectrum of developmental profiles. The course of developmental profiles evolves with age. Most developmental functions did not increase proportionally with increasing age in children with SQ CP.

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Key words: cerebral palsy, developmental delay, functional outcome, prognosis, follow-up study

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Cerebral palsy (CP) is one of the most common developmental disabilities, with an estimated prevalence of 2.0 to 2.5 cases per 1000 children.[1] This condition comprises a group of permanent disorders in the development of movement and posture which cause activity limitation and are attributed to non-progressive disturbances in the developing fetal or infant brain.[2] The motor disorders of CP are often accompanied by disturbances in sensation, perception, cognition, communication, and behavior; by epilepsy; and by secondary musculoskeletal problems. One of the common classifications of CP is based on the type of movement impairment and prevailing muscle tone. The majority of CP cases (70-85%) are the spastic type and are subdivided on the basis of the topographic distribution of spasticity.[3] Quadriplegia, diplegia, and hemiplegia account for approximately 90% of spastic CP cases.

Although CP is caused by a non-progressive disorder of the brain, the clinical manifestations evolve over time.[4] Voorman et al. observed that the health of some children with CP deteriorated between the ages of 9 and 15 years old.[5] Other studies have shown that the physical, social, and emotional functions of adult patients with CP deteriorated with increasing age.[6-9] Although these studies assessed changes in various functional outcomes, few researchers have assessed the full spectrum of developmental function in various domains (e.g., motor, speech, and social skills) in children with CP in a single study.

The aim of the present longitudinal study was to investigate changes in developmental profiles, including the full spectrum of developmental functions, over a 1-year period in preschool-aged children with spastic quadriplegic (SQ) CP. The relationship of developmental functions between the initial and final assessments was also compared.

METHODS

Participants

Children with SQ CP from the Rehabilitation Department of a tertiary hospital were recruited for this longitudinal study. The inclusion criteria were a diagnosis of SQ CP and age between 2 and 5 years. Spastic quadriplegia was defined as massive total motor disability involving all four limbs and the trunk, with upper motor neuron signs.[10] The exclusion criterion included the following: (1) presence of a progressive neurological disorder, (2) disease not typically associated with CP, such as traumatic brain injury, (3) a severe concurrent illness such as active pneumonia. Ultimately, 46 children with SQ CP were enrolled in the study. The study protocol was approved by the Institutional Review Board for Human Studies in our hospital, and the parents of all participants provided informed consent.

Assessment procedures

Developmental profile assessments were performed for all children at their initial visit and repeated at the final follow-up visit, a mean ± SD of 1.0 ± 0.3 years after the initial visit. Developmental profiles were determined using the Chinese Children Developmental Inventory (CCDI),[11] which is widely used in Taiwan to assess children with developmental delay.[12-15] The CCDI, a 320-item questionnaire, consists of statements describing various behaviors, to which parents/caregivers are asked to respond "yes" or "no" according to whether the child has ever exhibited that behavior. The scoring process yields a development age in eight domains of developmental function: gross motor (34 items), fine motor (44 items), expressive language (54 items), concept comprehension (67 items), situation comprehension (44 items), self help (36 items), personal social (34 items), and general development (131 items). The general development domain combines seven new items with 124 items from the other seven domains. The validity and reliability of the CCDI have been found to be higher than 0.83 and 0.88, respectively.[11]

The following data were recorded: age, body weight, body height, gender, and birth history, including gestational age, body weight at birth, and delivery mode (natural delivery or cesarean section).

Data analysis

The development quotient (DQ) was calculated as the development age divided by the chronological age, expressed as a percentage. Because of the high DQ variability among children with CP on the initial assessment, this study used the DQ change index to represent the change in developmental profile from the initial to the final assessment. The DQ change index, expressed as a percentage, was calculated as follows: 100% x (final DQ – initial DQ) / initial DQ. A positive value indicated an increase in DQ from

the initial to the final assessment, whereas a negative value indicated a decrease in DQ over time.

The initial and final DQs for each domain were compared using a paired *t* test. Pearson's correlation was used to determine the relationships among the developmental functions measured by the CCDI and demographic data. A *p* value less than 0.05 was considered to indicate statistical significance.

RESULTS

The data for the study participants are summarized in Table 1. Most of the children had histories of prematurity and low body weight at birth. Equal percentages of children were delivered naturally and by cesarean section.

The DQ change indexes for all developmental domains were negative (Fig. 1). The DQs of the gross motor and self help domains decreased by 10-17%; those of the situation comprehension, expressive language, personal social and general development domains decreased by 5-10%; and those of the fine motor and concept comprehension domains decreased by 4-8%.

The developmental profiles of children with SQ CP showed low DQs (23-66%) in all developmental functions, especially the gross motor and self care domains, on both the initial and final assessments (Table 2). Statistically significant differences were found between the initial and final DQs for all developmental functions except the fine motor and con-

Table 1. Data of Children with Spastic Quadriplegic Cerebral Palsy

Data	N = 46
Age	3.3 ± 1.2
Body height (cm)	89.8 ± 12.4
Body weight (kg)	12.3 ± 3.6
Sex	
Male	22 (48%)
Female	24 (52%)
Gestational age (weeks)	32.0 ± 4.0
Birth body weight (gm)	1941 ± 922
Delivery mode	
Natural	23 (50%)
Cesarean section	23 (50%)

Data are expressed as mean ± standard deviation or number (%).

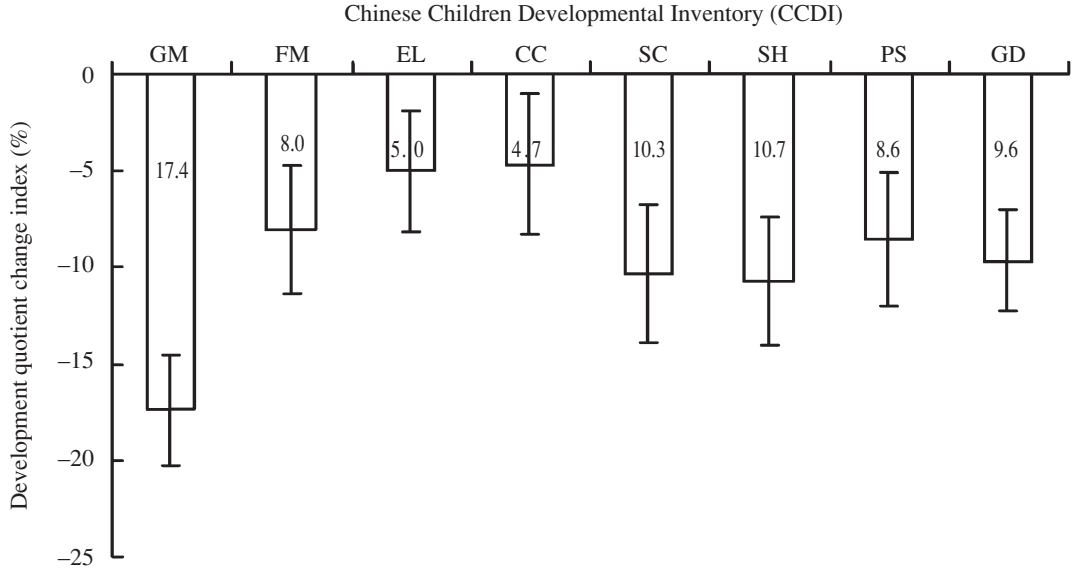

Fig. 1 Development quotient change index measured using the Chinese Children Developmental Inventory (CCDI) in children with spastic quadriplegic cerebral palsy. The development quotient (DQ) change index (%) is calculated as follows: 100% x (final DQ – initial DQ) / initial DQ; Data are expressed as mean ± standard error; Abbreviations used: GM: gross motor; FM: fine motor; EL: expressive language; CC: concept comprehension; SC: situation comprehension; SH: self help; PS: personal social; GD: general development.

Table 2. The Developmental Quotients Measured by the Chinese Children Developmental Inventory at the Initial and Final Assessments in Children with Spastic Quadriplegic Cerebral Palsy

Functional domai	Developmental quotient (DQ, %)		ΔDQ	*p* value
	Initial	Final		
Gross motor	26.9 ± 14.5	22.6 ± 14.2	4.3 ± 6.7	< 0.001*
Fine motor	51.0 ± 32.8	47.3 ± 32.0	3.7 ± 13.2	0.064
Expressive language	59.5 ± 33.1	55.1 ± 29.2	4.4 ± 13.2	0.027†
Concept comprehension	65.5 ± 37.4	61.3 ± 34.9	4.2 ± 16.3	0.089
Situation comprehension	48.0 ± 30.0	42.1 ± 27.0	6.0 ± 14.8	0.009*
Self help	41.3 ± 22.1	38.0 ± 25.3	3.2 ± 10.1	0.035†
Personal social	48.3 ± 26.8	42.3 ± 21.8	6.0 ± 13.0	0.003*
General development	57.3 ± 27.8	52.1 ± 27.2	5.1 ± 10.2	0.001*

Data are expressed as mean ± standard deviation; A paired t test was selected for continuous data analysis; Abbreviations used: ΔDQ: the difference between the final and initial DQ; *: $p < 0.01$; †: $p < 0.05$.

cept comprehension domains ($p < 0.05$) (Table 2). The DQ distributions were similar on the initial and final assessments (Table 2). On the initial assessment, the DQ distributions were lowest for the gross motor and self help domains (27-41%); higher for the fine motor, situation comprehension, and personal social domains (48-51%); and highest for the expressive language, concept comprehension, and general development domains (60-66%) (Table 2). On the final assessment, the DQ distributions were also lowest for the gross motor and self help domains (23-38%); higher for the fine motor, situation comprehension, and personal social development domains (42-47%); and highest for the expressive language, concept comprehension, and general development domains (52-61%) (Table 2).

Pearson's correlation analysis showed that the final DQs for all developmental functions were positively correlated with the initial DQs (r = 0.37-0.93, $p < 0.05$; Table 3). The final DQ for each domain was highly correlated to the initial DQ for the same domain (r = 0.88-0.93, $p < 0.01$). In addition, the final DQ for the self help domain was highly correlated to the initial DQs for the gross motor and fine motor domains ($r > 0.80$, $p < 0.01$), and the final DQ for the personal social domain was highly correlated to the initial DQs for the fine motor, expressive language, concept comprehension, and situation comprehension domains ($r > 0.81$, $p < 0.01$).

DISCUSSION

The children with SQ CP in this study had impairments across the full spectrum of developmental functions, especially in the gross motor and self care functions. The DQ distributions across all domains were similar on both initial and final assessments. Functional impairment in all developmental domains in children with SQ CP may be related to the more diffuse and severe brain damage in these children than in children with other types of CP. Children with SQ CP often have a history of difficult delivery, with evidence of perinatal asphyxia, periventricular leukomalacia in preterm children, and brain anomalies in full-term children.[10,16,17] A previous study also suggested that CP is one of a group of neurodevelopmental disorders involving numerous developing functions.[18] Therefore, a comprehensive approach to children with SQ CP must involve multidimensional assessment and management.

The developmental profiles of preschool-aged children with SQ CP evolve as the children mature. Most developmental functions do not improve in proportion to increasing age in this patient population. In this study, the DQs for all developmental functions except the fine motor and concept comprehension domains decreased significantly from the initial to the final assessment. The deterioration in DQs over time may result from various factors,

Table 3. Correlation Analysis Assessing the Relationships between the Final and Initial Developmental Quotient (DQ) Values for Each Developmental Function Measure in Children with Spastic Quadriplegic Cerebral Palsy

	r value (95% confidence interval)							
	GMf	FMf	ELf	CCf	SCf	SHf	PSf	GDf
GMi	0.89* (0.81, 0.94)	0.71* (0.53, 0.84)	0.50* (0.25, 0.70)	0.46* (0.20, 0.66)	0.66* (0.46, 0.80)	0.85* (0.75, 0.92)	0.62* (0.41, 0.78)	0.65* (0.45, 0.79)
FMi	0.78* (0.64, 0.88)	0.92* (0.87, 0.96)	0.70* (0.52, 0.83)	0.71* (0.53, 0.84)	0.84* (0.73, 0.91)	0.80* (0.66, 0.89)	0.81* (0.68, 0.90)	0.85* (0.75, 0.92)
ELi	0.42* (0.15, 0.64)	0.66* (0.46, 0.80)	0.92* (0.87, 0.96)	0.89* (0.81, 0.94)	0.69* (0.50, 0.82)	0.51* (0.26, 0.70)	0.85* (0.75, 0.92)	0.84* (0.73, 0.91)
CCi	0.37† (0.09, 0.60)	0.68* (0.49, 0.82)	0.87* (0.78, 0.93)	0.90* (0.83, 0.95)	0.72* (0.55, 0.84)	0.46* (0.20, 0.66)	0.82* (0.70, 0.90)	0.85* (0.75, 0.92)
SCi	0.70* (0.52, 0.83)	0.84* (0.73, 0.91)	0.74* (0.58, 0.85)	0.79* (0.65, 0.88)	0.87* (0.78, 0.93)	0.74* (0.58, 0.85)	0.84* (0.73, 0.91)	0.84* (0.73, 0.91)
SHi	0.85* (0.75, 0.92)	0.81* (0.68, 0.90)	0.57* (0.34, 0.75)	0.55* (0.31, 0.73)	0.80* (0.66, 0.89)	0.92* (0.87, 0.96)	0.73* (0.56, 0.85)	0.74* (0.58, 0.85)
PSi	0.58* (0.35, 0.75)	0.77* (0.62, 0.87)	0.86* (0.77, 0.93)	0.84* (0.73, 0.91)	0.76* (0.61, 0.86)	0.60* (0.38, 0.77)	0.88* (0.80, 0.94)	0.86* (0.77, 0.93)
GDi	0.62* (0.41, 0.78)	0.83* (0.72, 0.91)	0.91* (0.85, 0.95)	0.90* (0.83, 0.95)	0.82* (0.70, 0.90)	0.70* (0.52, 0.83)	0.90* (0.83, 0.95)	0.93* (0.88, 0.97)

Pearson's correlation was selected for data analysis. The 95% confidence interval for the correlations were expressed as "(lower limit, upper limit)". Abbreviations: GM: gross motor; FM: fine motor; EL: expressive language; CC: concept comprehension; SC: situation comprehension; SH: self help; PS: personal social; GD: general development; i: initial assessment; f: final assessment; *: $p < 0.01$; †: $p < 0.05$.

including physical function, activities, participation in social or school activities, and environmental factors. As with other neurodevelopmental disorders, various manifestations of disordered brain function may be more pronounced in some people than in others, or in the same person at different stages of life.[18] Previous studies have reported a significant trend toward deterioration in physical, functional, social, and emotional well-being with increasing age in adolescents and adults with CP.[6-8]

The DQs for the self care domains and especially gross motor functions decreased significantly with age in this study. The DQ change indexes showed reductions of 10-17% in the DQs for these two domains, which were highly correlated with each other. This may indicate that motor impairment severity is the dominant factor in the gross motor functions and self-care activities in children with SQ CP. This result was consistent with findings of previous studies.[5,19,20] Motor impairment has been strongly associated with locomotion, self care, and domestic life.[5] In a 4-year longitudinal study, gross motor development decreased in children with CP as the severity of impairment increased.[19] Similarly, improvements in gross motor function with aging in children with CP were limited by the severity of motor impairment.[20]

Expressive language functions did not improve in proportion to age in this study. The DQ change indexes indicated that the DQ for this domain decreased by 5% from the initial to final assessment. Expressive language function was correlated with gross motor function. Previous research demonstrated that a higher percentage (18-51%) of 217 children with CP exhibited abnormalities in language skills compared with the general population.[21] These children had strong scores for receptive language but poor scores for expressive language.[21] In our study, the DQ for expressive language in children with SQ CP was approximately 55%. Adequate expressive language function requires good cognitive function, language function, and oromotor control function.

Impairment in these 3 functions further interferes with the development of expressive speech in children with SQ CP.

Social skills did not increase in proportion to age in children in this study. The DQ change indexes indicated that the DQs for the situation comprehension, personal social and general development domains on the final assessment were decreased by 8-10%. Personal social development in healthy children is characterized by various innate, universal facial expressions,[22] the ability to differentiate the mother's face from that of a stranger,[23] and imitation of facial expressions.[24] Personal social function drives are also seen in the newborn's preference for human voices, especially the mother's, over other sounds.[25,26] Impaired motor and speech functions in children with SQ CP would be likely to negatively affect communication and participation in social activities. In support of this assertion, we found that personal social function was positively correlated to gross and fine motor function, expressive language, concept comprehension, and situation comprehension. A lack of involvement in social relationships in children with CP has been found to contribute to poor development of social skills and social isolation.[8] Therefore, children with CP may have inadequate exploring environments, communication, learning, locomotion, and interaction with others, which may further inhibit the development of social skills.

Complex interaction among different developmental functions during the developmental process was also found in this study. In the correlation analysis, we found that the final development functions for each domain were positively related not only to that particular domain but also to other domains. The developmental profiles of children with SQ CP seemed not to be strictly determined by brain damage, but regulated by a complex interaction of various developmental functions and environmental factors.

This study was limited by various factors related to its design. The sample size was small, and the characteristics of the subjects analyzed were limited. Another limitation was that intervention strategies were not analyzed because the children had different rehabilitation programs and / or combinations of other complementary and alternative medicine. Because the study focused on hospital-based children with SQ CP, patients with other types of CP were not evaluated. Therefore, the results of this study cannot be generalized to all cases of CP. Despite these limitations, the study convincingly showed changes in the development profiles of children with SQ CP over time.

Conclusions

In this study, children with SQ CP had low DQs in all developmental functions, especially the gross motor and self care functions, on both the initial and final assessments. The DQ distributions were lowest for the gross motor and self help domains; higher for the fine motor, situation comprehension, and personal social domains; and highest for the expressive language, concept comprehension, and general development domains. The DQs for all developmental functions except the fine motor and concept comprehension domains decreased significantly from the initial to the final assessment.

These findings suggest that children with SQ CP have impairments across the full spectrum of developmental functions, especially in gross motor and self-care functions. The developmental profiles of preschool-aged children with SQ CP evolve as the children mature. Most developmental functions do not improve in proportion to increasing age. These study results may help clinicians customize rehabilitation strategies to better address the associated functional deficits in these children.

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四肢痙攣型腦性麻痺孩童之發展追蹤

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背 景： 本研究旨在追蹤四肢痙攣型腦性麻痺學齡前孩童各面向發展功能的改變，並探討前後兩次評估各發展面向的關係。

方 法： 本前瞻性研究針對 46 位二至六歲四肢痙攣型腦性麻痺孩童，以學齡前兒童行爲發展量表 (Chinese Child Developmental Inventory, CCDI) 進行前後兩次評估。平均追蹤時間爲 1.0 ± 0.3 年 (平均值 ± 標準差)。評估面向包括粗動作、精細動作、溝通表達、概念理解、環境理解、身邊處理、人際社會及一般發展，並以發展商數 (development quotient) 量化各面向的發展程度，以發展商數改變指數 (developmental quotient change index, %) 評估前後兩次發展商數的差異。以成對樣本 t 檢定 (Paired t test) 分析各面向發展商數前後兩次的差異，以皮爾森相關性 (Pearson's correlation) 分析兩次評估中各面向的關係。

結 果： 在兩次評估中發現，四肢痙攣型腦性麻痺孩童各面向的發展商數都呈現較低分的情形 (23 - 66%)，以粗動作及身邊處理的發展商數最低，次爲精細動作、環境理解及人際社會，發展商數分數最高爲溝通表達、概念理解及一般發展。在追蹤評估發現，除了粗動作和概念理解功能外，其他面向的發展商數皆明顯下降 ($p < 0.05$)，追蹤評估各面向的發展商數與首次評估同一面向成高度相關 ($r = 0.87$- 0.93, $p < 0.01$)。

結 論： 本研究發現四肢痙攣型腦性麻痺學齡前孩童各面向的功能皆有發展障礙，隨著年齡的增長，各面向的發展仍持續改變，大多數的發展功能跟不上年齡的增長。
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關鍵詞： 腦性麻痺，發展遲緩，功能發展，預後，追蹤研究

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