Motor Deficit Severity Mediates Effects of Intellectual Function in Predicting Speech Motor Control in Children with Cerebral Palsy

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Abstract

Objective: To elucidate whether motor deficit severity mediates effects of intellectual function in predicting motor speech functions in children with cerebral palsy (CP).

Method: Twenty-five children with spastic CP aged 5-8 were classified into two groups, levels I-II (n=13) and levels III-IV (n=12) based on Gross Motor Function Classification System (GMFCS) levels. Predictor was the intelligence quotient (IQ). Speech outcome measures were Percentage of Consonants Correct (PCC) and Verbal Motor Production Assessment for Children (VMPAC). Pearson correlation analysis was used to investigate relationships between IQ and speech outcomes. A mediation analysis (a three-variable path model) was used to explain how GMFCS levels (the mediator) affect IQ to predict speech outcome.

Results: Children with GMFCS levels I-II had greater scores in all IQ and all VMPAC sub scores, and PCC than those with GMFCS levels III-IV (p<0.05). Pearson correlation analysis showed that full IQ (FIQ) was correlated with all VMPAC scores (r=0.42-0.62, p<0.05), but not with PCC scores. The path model assumes a path a from the predictor variable (FIQ) to the mediator (GMFCS levels), path b from the impact of the mediator (GMFCS levels) on the outcome variable (VMPAC), and two causal paths to the outcome variable (paths c and c’). Mediation analysis revealed that GMFCS level completely mediated the effect of FIQ when predicting global motor control (a=-0.027 ± 0.01, p=0.01; b=-17.910 ± 3.620, p<0.001; c=0.537 ± 0.235, p=0.032; c’=0.161 ± 0.133, p=0.241). GMFCS levels partially mediated the effect of FIQ when predicting the VMPAC sequence (a=-0.027 ± 0.01, p=0.01; b=-10.976 ± 2.521, p<0.001; c=0.455 ± 0.154, p=0.007; c’=0.058 ± 0.192, p=0.611).

Conclusion: Motor deficit severity mediates effect of intellectual functions on speech motor control. The findings allow clinicians to identify early motor speech problems in children with CP using the GMFCS level alone.

Keywords: Cerebral palsy; Motor deficit severity; Speech motor control; Speech intelligibility; Intelligence; Mediation analysis

Abbreviations GMFCS: Gross Motor Functional Classification System; VMPAC: Verbal Motor Production Assessment for Children; FIQ: Full Intelligence Quotient

Introduction

The motor disorders that are symptomatic of cerebral palsy (CP) are often associated with other disturbances, such as sensation, perception, cognition, communication, and behaviour, as well as secondary musculoskeletal problems [1]. Language and speech disorders, such as articulation disorders, are associated impairment in children with CP [2]. Among children with early-onset CP (n=1268), 36% have been found to have motor speech problems and 42% have been found to have impaired communication [3]. Motor speech problems in these children can adversely affect functional communication and diminish their quality of life [4].

Motor speech is a complex motor activity that involves the coordination and integration of respiratory, laryngeal and articulatory systems [5]. The primary aspects of speech motor control are central pattern generators, motor programs, motor commands, and sensorimotor integration [6]. Motor speech problems associated with CP have been attributed to underlying neuromuscular control impairment that affects the speech mechanism [7]; these include impaired control of respiration, phonological and articulatory muscles [8]. Impaired oro-motor functions, such as poor oro-motor coordination, and poor tongue and lip movements, can cause speech production errors in children with CP. These speech production errors in children with CP include stopping, voicing, backing, fronting and de-affrication [9].

Relationships among motor deficit severity, intelligence, and motor speech functions are complex. The motor processes involved in speech are affected by multiple intrinsic and extrinsic factors [10] and therefore they are difficult to delineate. Children with CP can exhibit speech disorders as a consequence of their motor impairments, as well as disorders that arise from speech, language, and cognitive processing deficits [11]. The severity of CP is correlated with degree of impairment of speech abilities [12]. Motor speech impairments have been found to be associated significantly with poorer gross motor function and with intellectual impairment [3,13]. Furthermore, motor

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deficit severity has been associated with intellectual impairment. However, literature reviews depicting relationships among motor deficit severity, intellectual functions, and motor speech functions are limited.

Motor deficit severity, IQ and motor speech functioning are known to be associated in children with CP but are complex in nature. Most children with CP who have an intelligence quotient (IQ) of less than 70 usually have poor motor speech skills [14]. However, those with an IQ>70 may still present with the same issue [14]. Based on the above, it is reasonable to suspect that a mediator exists that modifies the effects of IQ on motor speech function in these children. Hence, motor deficit severity among children with CP was selected as the mediator while IQ was used as the predictor for the motor speech function. Whether motor deficit severity partially or completely acts as a mediator that modifies IQ when predicting the outcome of motor speech function remain to be delineated.

Mediation analysis is widely used in psychology and social sciences. Mediation analysis help to elucidate the mechanisms that govern the relationships between a predictor and an outcome and to clarify how these variables are linked to a third intermediate variable, which is called the mediator [15,16]. Hence, this type of analysis helps to clarify whether the mediator variable modifies the effects of the predictor variable on the outcome variable. A path model herein is used to explain the causal chain associated with a mediator (Figure 1) [16]. For example, a study might wish to determine how a rehabilitation program combined with the administration of a muscle relaxant such as baclofen may reduce spasticity in children with cerebral palsy and how this the drug can mediate the spasticity reduction. The path model assumes a three-variable system consisting of a path (Path a) from the predictor variable (rehabilitation programs) to the mediator (baclofen), another path (Path b) from the impact of the mediator (baclofen) on the outcome variable (spasticity), and two causal paths to the outcome variable (Paths c and c') [16].

This study aims to determine whether severity of motor deficit mediates the effect of intellectual functioning on motor speech functions. Motor speech functions of different motor severities in children with CP are also compared. Motor speech functions, including speech motor control and speech intelligibility, were measured by the Verbal Motor Production Assessment for Children (VMPAC) and the Percentage of Consonants Correct (PCC) methods, respectively. Motor deficit severity and intellectual function were measured using the Gross Motor Function Classification System (GMFCS) level and full intelligence (FIQ), respectively. Instead of a direct causal relationship between intellectual functioning and speech motor control, we hypothesized that motor deficit severity is a mediator that affects how intellectual function is able to predict the speech motor control. To clarify this mediation effect, a path diagram model is used to depict a causal chain and explains how GMFCS level mediates effects of FIQ in predicting speech motor control. It is important for clinicians to know that GMFCS levels mediate effects of intellectual function on motor speech functions to plan treatment promptly for children with CP who have motor speech problems.

Methods
Participants
Children with CP who were visiting the rehabilitation clinic of a tertiary hospital were recruited for this study. The inclusion criteria were as follows: (1) a diagnosis of spastic CP, including spastic diplegia (SD) or spastic quadriplegia (SQ), with spastic hemiplegia; (2) an age of five to eight years old; (3) GMFCS levels I-IV [17]; (4) good cooperation during examination; (5) ability to understand verbal commands and to complete the speech assessment with a developmental age for verbal comprehension and expression of greater than three years old, and (6) the ability to take the intellectual tests with a developmental age for fine motor skills of greater than 3.5 years. Exclusion criteria were a history of any of the following conditions: (1) other types of CP (such as dyskinetic or ataxic CP), (2) a progressive neurological disorder, (3) significant medical problems, such as active pneumonia, within the preceding three months, (4) any major surgical or invasive treatment, such as orthopaedic surgery or neurosurgical surgery, within the preceding three months, (5) the use of augmentative communication systems or strategies and (6) severe intellectual and speech impairment. A total of 25 children with spastic CP were recruited. These children were classified into two groups, levels I-II (n=13) and levels III-IV (n=12), based on the severity of their motor deficit. These levels are their GMFCS levels [17]. The Institutional Review Board for Human Studies at Chang Gung Memorial Hospital approved this protocol, and all participants and their parents or caregivers provided informed consent.

Procedures
All children underwent assessments of their intellectual abilities, speech motor control, specific speech production errors, speech intelligibility, and motor deficit severity. All intellectual functions were evaluated by a single psychologist; all speech motor control and specific speech production errors were evaluated by a single speech therapist and all speech intelligibility assessments are conducted by a single research assistant. Motor deficit severity was evaluated by the same physiatrist (C.L. Chen). Those who assessed intellectual function and motor deficit severity were blinded to the motor speech function results.

Instruments
The intellectual function of the preschool children was evaluated using the Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R) [18] and that of the school children was evaluated using the Wechsler Intelligence Scale for Children, Third Edition (WISC-III) [19]. The Taiwanese versions of the WPPSI-R and WISC-III were used to evaluate children between the ages of three and six years, and greater than six years, respectively. The WPPSI-R and WISC- assessments yielded intelligence quotients (IQs) that comprised verbal IQ (VIQ), performance IQ (PIQ), and full-scale IQ (FIQ).

Speech motor control was evaluated using the three-point VMPAC scale (0: incorrect, 1: partly incorrect, and 2: correct) [20]. Only the main areas of the VMPAC were used in this study owing to cultural differences. The main areas involved global motor control, focal oro-motor control, and sequencing. Global motor control, involving global motor control and oro-motor integrity, is associated with neuro-motor innervation to peripheral muscles in the torso, neck, head, and oro-facial region that are required for the efficient production of speech [20]. The focal oro-motor control, which involves both non-speech and speech oro-motor movements, is utilized to assess volitional mandibular, labial-facial, and lingual oro-motor control [20]. Sequencing, which involves sequences of both non-speech and speech oro-motor movements, is used to assess the ability to perform non-speech and speech movements in the correct order [20]. The
percentage score in each area of the assessment consisted of the raw score divided by the sum of the scores of the items associated with that area. The main VMPAC score (%) was calculated as the average percentage score for the three main areas. The intra-rater reliability (r=0.56-0.90, p<0.01) and inter-rater correlations (r =0.93– 0.99, p<0.01) of VMPAC have been confirmed previously [20].

The severity of the motor deficit associated with CP was in each case classified using the GMFCS [21]. The GMFCS grades the self-initiated movement of CP patients, with particular emphasis on their functional abilities (sitting, crawling, standing and walking), and their need for assistive devices (such as walkers, crutches canes and wheelchairs). The GMFCS adopts a five-point scale (I-V) from “independent” (level I) to “dependent” (level V). Demographic characteristics, including age, and gender, were also recorded.

**Experimental setup for measuring speech intelligibility**

Each participating child was seated in a quiet room. The recording system, consisting of an external microphone and a laptop computer (IBM ThinkPad 570E) with a sampling rate of 16 kHz and a resolution of 16 bit, was used to measure speech intelligibility. The microphone was placed on a table about 15 cm from the mouth of the child. Children were shown pictures or text, printed on cards, and asked to name them or read them aloud in a normal voice. If the child encountered an unfamiliar word, the examiner explained the word or asked the child to read it with the assistance of phonetic transcription. The examiner did not model the correct sound or provide other assistance. The speech recording tasks involved 69 picture-cards for preschool children and 140 word-cards for school children. During the task, the examiner recorded a speech sample from each subject.

The PCC was used to determine the severity of the speech intelligibility deficit [22]. A rater, who is a native Mandarin speaker with normal hearing, measured the PCC by making correct–incorrect judgments of the individual sounds that were produced in the recorded speech sample from each subject. The PCC was calculated as 100 × (number of correct consonants/number of correct plus number of incorrect consonants) [22]. To evaluate intra-rater and inter-rater reliabilities, a research assistant rated the sounds for ten children. The intra-class correlation coefficient (ICC) values of inter-rater and intra-rater reliability for PCC were 0.812 and 0.977, respectively.

A speech pathologist identified the specific speech production errors, such as omission, substitution, and distortion [23] based on a place-manner-voicing analysis using phonological process analysis of the recorded speech samples. The patterns identified by phonological process analysis were assimilation, fronting, backing, stopping, voicing, and de-affrication. Six children with GMFCS levels III-IV exhibited specific speech production errors of assimilation, fronting, backing, stopping, voicing, and de-affrication (Table 1). Children with GMFCS levels I-II exhibited specific speech production errors, although they may have occasionally pronounced consonants incorrectly. Four (31%) children with GMFCS levels I-II did not demonstrate specific speech production errors.

**Statistical analysis**

Differences in continuous variables (age, IQ and PCC) between the two CP groups were evaluated by performing an independent t-test. Differences in the gender and CP subtypes between the groups were analyzed using Fisher’s exact tests. The Pearson correlation test was selected for categorical data analysis and an independent t test was selected for continuous data analysis. The mean VIQ, PIQ and FIQ scores of the children with GMFCS levels I-II (81-102) exceeded those of the children with GMFCS levels III-IV (65-83) (p<0.05, Table 2). According to subtests, both CP groups had similar IQ distribution patterns with VIQ being greater than PIQ. Children with GMFCS levels I-II had greater VMPAC scores in all domains than children with GMFCS levels III-IV (p<0.01, Table 2).

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**Table 1:** Demographic data, motor deficit severity, and specific speech production errors between children with different motor severities (CP: Cerebral Palsy; GMFCS: Gross Motor Function Classification System; Values are expressed as mean ± SD or n (%)). The Fisher’s exact test was selected for categorical data analysis and an independent t test was selected for continuous data analysis.

<table>
<thead>
<tr>
<th>Data</th>
<th>CP groups</th>
<th>p</th>
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<tbody>
<tr>
<td></td>
<td>GMFCS levels I-II</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(n=13)</td>
<td></td>
</tr>
<tr>
<td>Demographic data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>6.1 ± 1.0</td>
<td>6.7 ± 1.0</td>
</tr>
<tr>
<td>Sex</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td></td>
<td>9 (69)</td>
<td>6 (50)</td>
</tr>
<tr>
<td>Motor Severity</td>
<td>GMFCS levels</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Level I</td>
<td>Level II</td>
</tr>
<tr>
<td></td>
<td>8 (62)</td>
<td>5 (38)</td>
</tr>
</tbody>
</table>

PCC ranged from 87-100% in children with levels I-II, and 75-97% in children with levels III-IV. The mean PCC were higher for children with levels I-II (95%) than for children with levels III-IV (90%) (p=0.015, Table 2).

<table>
<thead>
<tr>
<th>Data</th>
<th>CP groups</th>
<th>p</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>GMFCS levels I-II</td>
<td>GMFCS levels III-IV</td>
</tr>
<tr>
<td></td>
<td>(n=13)</td>
<td>(n=12)</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Intelligence quotient (IQ)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbal IQ</td>
<td>102.2</td>
<td>19.6</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>81.2</td>
<td>15.3</td>
</tr>
<tr>
<td>Full IQ</td>
<td>90.7</td>
<td>16.2</td>
</tr>
<tr>
<td>VMPAC (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global motor control</td>
<td>91.9</td>
<td>4.8</td>
</tr>
<tr>
<td>Focal oromotor control</td>
<td>94.5</td>
<td>3.2</td>
</tr>
<tr>
<td>Sequencing</td>
<td>97.9</td>
<td>4.2</td>
</tr>
<tr>
<td>Average (Main)</td>
<td>94.8</td>
<td>2.2</td>
</tr>
<tr>
<td>Speech intelligibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of consonants correct (%)</td>
<td>95</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 2: Intelligence, speech motor control, and speech intelligibility between children with different motor severities (Abbreviations: CP, Cerebral Palsy; GMFCS, Gross Motor Function Classification System. VMPAC, Verbal Motor Production Assessment for Children; Values are expressed as mean ± SD.*p<0.01 and †p<0.05 by independent t test).

Pearson correlation analysis revealed that all FIQ were correlated with average scores VMPAC scores and all VMPAC sub scores, including global motor control, focal oro-motor control, and sequencing subtests (r =0.42-0.62, p<0.05, Table 3). VIQ were correlated with average VMPAC scores and all sub scores except focal oro-motor control (r=0.40-0.62, p<0.05, Table 3). PIQ were correlated with average VMPAC scores and all sub scores except global oro-motor control (r =0.40-0.48, p<0.05). However, PCC was not correlated with IQs across all subtests.

Better FIQ was correlated with better VMPAC scores and all sub scores, but not with the PCC scores. Furthermore, better GMFCS levels were associated with better VMPAC scores. Therefore, a three-variable path diagram model utilized the FIQ as the predictor, VMPAC as the outcome variable and GMFCS levels as the mediator for analysis. That is, a mediation analysis was used to test whether GMFCS level acts as a mediator on the effects of FIQ when predicting the VMPAC. Mediation analysis on PCC was not tested since FIQ was not correlated with PCC. The path model assumes a three-variable system consisting of a path (path a) from the predictor variable (FIQ) to the mediator (GMFCS levels), another path (path b) from the impact of the mediator (GMFCS levels) on the outcome variable (VMPAC), and two causal paths to the outcome variable (paths c and c'). Mediation analysis revealed that GMFCS level completely mediated the effect of FIQ when predicting global motor control (a=-0.027 ± 0.01, p=0.01; b=-17.910 ± 3.620, p<0.001; c=0.537 ± 0.235, p=0.032; c'=0.058 ± 0.192, p=0.766), focal motor control (a=-0.027 ± 0.01, p=0.01; b=-9.287 ± 2.441, p=0.001; c=0.315 ± 0.140, p=0.035; c'=0.067 ± 0.129, p=0.611), and average VMPAC (a=-0.027 ± 0.01, p=0.01; b=-10.976 ± 2.521, p<0.001; c=0.455 ± 0.154, p=0.007; c'=0.161 ± 0.133, p=0.241), as presented in Figure 1. GMFCS level was also found to partially mediate the effect of FIQ when predicting the VMPAC sequence (a=-0.027 ± 0.01, p=0.01; b=-5.732 ± 2.767, p=0.050; c=0.51 ± 0.135, p=0.001; c'=0.359 ± 0.146, p=0.023), as shown in Figure 1.
Figure 1: Mediation analysis was performed to determine whether GMFCS level significantly mediated the effect of FIQ when predicting VMPAC. To clarify the meaning of mediation, a three-variable path diagram of a causal chain is provided. (A) The GMFCS level completely mediated the effects of FIQ on global motor control, (B) focal motor control, (C) and average VMPAC, and (D) partially mediated the effect of FIQ on sequence.

Table 3: Pearson correlation coefficients among intelligence, speech motor control, and speech intelligibility (VMPAC: Verbal Motor Production Assessment for Children. *p<0.01; †p<0.05)

<table>
<thead>
<tr>
<th>Intelligence quotient (IQ)</th>
<th>Global motor control</th>
<th>Focal oro-motor control</th>
<th>VMPAC</th>
<th>Sequencing</th>
<th>VMPAC Average</th>
<th>Speech Intelligibility Percentage of consonants correct (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal IQ</td>
<td>.40†</td>
<td>.34</td>
<td>.62*</td>
<td>.48†</td>
<td>.06</td>
<td></td>
</tr>
<tr>
<td>Performance IQ</td>
<td>.33</td>
<td>.40†</td>
<td>.48†</td>
<td>.43†</td>
<td>.12</td>
<td></td>
</tr>
<tr>
<td>Full IQ</td>
<td>.43†</td>
<td>.42†</td>
<td>.62*</td>
<td>.53*</td>
<td>.09</td>
<td></td>
</tr>
</tbody>
</table>

Discussion

This study is the first to use a mediation analysis to elucidate the link between intellectual functions, the motor deficit severity and speech motor control. Previous investigations have reported that the severity of functional motor limitations and of intellectual functional deficit is related to motor speech problems [3,13,14]. Most studies have examined the relationship between two variables (between motor deficit severity and motor speech; IQ and motor speech; or motor deficit severity and IQ), while none have examined the relation among the three. The extent of the ability of motor deficit severity to predict speech motor control has not been previously examined. Hence, our study used mediation analysis and found that the GMFCS level is completely or partially mediate the effect of FIQ when predicting VMPAC. Our findings provide valuable evidence that will help clinicians to identify motor speech problem early; this will allow timely intervention based on a patient's simple GMFCS level when treating children with CP.

Our results suggest that motor deficit severity does act as a mediator of the effect of intellectual functioning when predicting speech motor control. GMFCS level could completely mediate the effect of FIQ on global and focal motor control, while partially mediate the effect of FIQ on VMPAC sequence. Hence, children with CP having a normal IQ may still present with reduced speech motor control (global or focal). The core components of speech production are complex and involve many areas ranging from the central nervous system to peripheral nervous system [6]. Motor deficit severity reflects not only the impairment in gross motor control, but also pathogenesis of brain damage [24]. Motor deficit severity also reflects disturbances in both physiological mechanisms and motor programming for speech production [7], such as the generation of motor commands and acquisition of motor speech skills [25]. The VMPAC test is used to detect motor disruption in speech production and to identify the levels of disruption in a speech motor control system [20]. However, it is more time-consuming to complete an intellectual assessment and VMPAC, it is relative simple and time-efficient (can be completed within five minutes) to assess a patient's GMFCS level. These findings suggest that the GMFCS levels may be useful when probing the motor speech problems in children with CP.

In this investigation, children with GMFCS levels III-IV were found to be more impaired in speech motor control, especially in the global area, than children with GMFCS levels I-II. Children with GMFCS levels III-IV frequently exhibit more weakness and spasticity, more primitive or pathological reflexes, more impaired oro-motor coordination and voluntary control of the respiratory, phonological, and articulatory muscles for speech production than those with GMFCS levels I-II. Abnormal reflexes that interfere with articulatory control, generalized paresis, abnormal muscle tone or spasticity [26],
and disruption of the voluntary speech motor control of motor speech [7, 25] have all been suggested as components of the pathophysiology of the motor speech impairments that are associated with CP. The findings herein suggest that, for children with severe CP, motor speech interventions should focus not only on focal motor control, but also on the integration of most aspects of speech motor control, and especially postural, respiratory, and phonatory training in the area of global motor control.

Children with high motor functions exhibited better speech motor control and speech intelligibility than those with low motor functions. Children with mild CP had better speech motor control and speech intelligibility than those with severe CP because coordination of the oral motor control influences speech sound acquisition [10]. Coordinating the spatial and temporal demands of individual phonemes and phone combinations is important to speech development [10]. Hence, speech motor control is important for articulation development [10]. Children with severe (spastic quadriplegia) and mild CP (spastic diplegia) showed high oro-motor variability and required more effort to coordinate labiomandibular movement during speech production [9, 27]. Even for children with mild CP (spastic diplegia), a high oro-motor variability of the durations of utterances reflects deficits in spatial and/or especially temporal control during speech production [9]. The goal of motor speech intervention should be based on assessments of the neuromotor system, motor speech system and coordination among the various articulating muscles [20]. These findings should lead to suggestions in terms of treatment strategies for speech motor control, such as temporal and spatial oro-motor stability training, which can then be conducted in order to enhance the speech intelligibility of children with CP.

Intelligence functions are correlated with speech motor control, but not with the speech intelligibility of children with CP. Pearson correlation analysis indicated that IQ was positively correlated with all VMPAC scores, but not with the PCC scores. One possibility is that the acquisition of phonemes is a linguistic [10], rather than being simply a cognitive process. The relevant neurophysiology has revealed that speech development continues until approximately 12 years of age [28]. However, articulation itself changes little after seven years of age, by which time all of the phonemes have been mastered [28]. Therefore, articulation test scores reach a ceiling between six and nine years of age, whereas speech motor control [10] and intellectual functions continue to improve after this period. Previous studies have also demonstrated that intelligence is related to language and motor speech problems in children with CP [3, 13, 14]. These findings suggest treatment strategies to enhance cognitive function may also improve speech motor control, but may not affect speech intelligibility. The subsets of both CP groups herein exhibited similar IQ distribution patterns, although the children with mild CP had higher IQs than those of their severe counterparts. Both CP groups had a larger VIQ than PIQ. The discrepancy between VIQ and PIQ can be explained by the presence of fine motor impairment and, especially, the presence of visual-perception or visual-motor dysfunction in children with spastic bilateral CP, which is related to periventricular leukomalacia [29]. Visual-perception or visual-motor problems will further impair the children’s ability to explore their environment, their visual-perception of the environment, their visual-motor skills, and thus their performance in intelligence subtests. Previous studies [29, 30] have found that children with CP have lower PIQs than VIQs. These findings suggest that it is important for clinicians to carry out early identification of visual cognitive problems, which will allow prompt intervention.

The major limitations of this study are its small sample size and its limited inclusion criteria. Recruiting children with CP is very difficult since most participants with GMFCS levels III–IV were unable to meet the inclusion criteria. Only children with spastic CP, GMFCS levels I–IV with the ability to understand verbal commands and to perform the required tasks were recruited, since children with severe fine motor impairment often fail to complete standardized tests (such as the IQ test). Subjects with severe intellectual, speech, and fine motor impairments were therefore excluded from this study. As a result, the findings from this study cannot be generalized to all cases of CP. Despite these limitations, this investigation provides important evidence on the relationship between the severity of motor deficit, intellectual function, and motor speech functions in children with CP.

Conclusion

In conclusion, this study elucidated the extent to which motor deficit severity acts as a mediator of the effects of intellectual function on speech motor control. All aspects of speech motor control, especially global motor control, were more severely impaired in children with poorer GMFCS levels. The findings in this study will help clinicians to identify early motor speech problems in children with CP using the GMFCS level alone. Further research is needed to elucidate the underlying mechanisms involved in the speech motor control of children with CP and to test the efficacy of therapeutic strategies for treating motor speech dysfunctions in these children.

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Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper. No party has a direct interest, neither a financial relationship nor will they be conferred any benefits from writing this submission or the results of this research.

References
