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Early predictors and correlates of communication function in children with cerebral palsy

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Author contributions

All authors critically revised the manuscript, gave final approval, and agreed to be accountable for all aspects. MJCH and JS also contributed to design, analysis, interpretation, and drafted manuscript. PA also contributed to analysis and interpretation. NTH also contributed to design, analysis and interpretation. ND also contributed to design, acquisition and interpretation. EH also contributed to design, acquisition, analysis, and interpretation. MW also contributed to interpretation. RK and PR also contributed to analysis and interpretation. ML and NP also contributed to conception, design, acquisition, analysis, and interpretation. SVB and SD also contributed to acquisition and interpretation.

Declaration of conflicting interests

The authors declare no conflict of interest.

Ethical approval

The case-control study which includes the cases used in this analysis had ethics approval from:

- Michigan State University Biomedical and Health Institutional Review Board (BIRB) #04-977MS
- Sparrow Health System Institutional Review Committee #K1050M
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Abstract

Birth characteristics and developmental milestones were evaluated as early predictors/correlates of communication in children with cerebral palsy. The hypothesis was that maternal report of child's age for vocal play and first words would predict current functional communication. A case series of 215 children, 2 to 17 years (mean age=8.2 years, SD=3.9), with cerebral palsy was recruited from medical practices in three Michigan cities. Early developmental data were collected by maternal interview. The child's Communication Function Classification System (CFCS) level was obtained from parent. Predictors of less functional communication included gestational age >32 weeks, number of comorbidities, age of first words after age 24 months, and use of communication methods other than speech. Several birth characteristics and developmental language milestones were predictive of later communication performance for children with cerebral palsy. These characteristics and milestones should trigger referrals for communication evaluations, including speech, language, hearing, and/or augmentative and alternative communication.

Keywords

Cerebral palsy; Communication Function Classification System (CFCS); Gross Motor Function Classification System (GMFCS); Manual Ability Classification System (MAC); Communication milestone

Cerebral palsy is the most common physical disability of childhood with a prevalence rate of 2.1/1000.¹ In addition to the hallmark life-long motor development impairments, individuals with cerebral palsy may have communication disorders due to underlying problems in speech, language, and/or hearing.² Previous studies estimate that 30% to 80% of children with cerebral palsy have communication impairment;^{3, 45} however, the cited studies have limited information on communication and no validation of their various communication variables.⁵

Classifications help professionals to make meaningful discriminations.⁶ They do not replace appropriate assessments nor outcome measures. Instead, classifications can describe "levels" of functioning.⁶ The Communication Function Classification System (CFCS; <http://cfcs.us>;⁷) was designed and validated to classify communication at the activity/participation level in the World Health Organization (WHO) International Classification of Functioning, Disability, and Health (ICF).^{8, 9} Instead of categorizing communication difficulties in the traditional "mild," "moderate," "severe," or "profound" continuum, the CFCS provides 5 distinct but comprehensive levels of communication performance described with "word pictures." (See Table 1.) The CFCS can be used as part of a functional profile¹⁰ with mobility (GMFCS, Gross Motor Function Classification System <https://canchild.ca/en/>

resources/42-gross-motor-function-classification-system-expanded-revised-gmfc-e-r) and handling objects (MACS, Manual Ability Classification System, <http://www.macs.nu/>), other areas of functioning that are often challenging for children with cerebral palsy.⁶ See Table 1 for a description of the five CFCS, GMFCS, and MACS levels.

Early prediction and classification of communication are vital to diagnose and manage communication issues effectively in children with cerebral palsy.¹¹ However, little is known about correlates and early predictors of communication performance in these children.^{12, 13} Closing this gap between early predictors, correlates, and communication performance can potentially lead to earlier intervention for children with cerebral palsy.¹⁴ This is important because communication disorders often have lifelong negative effects. For example, the inability to communicate effectively with unfamiliar partners puts adolescents and adults at risk for attaining meaningful careers and fulfilling relationships.^{15, 16} Communication disorders can also limit educational opportunities, community participation and negatively affect the mental health of individuals with cerebral palsy.^{16–21}

Objectives

This study investigated whether selected birth characteristics and developmental milestones act as potential predictors and correlates of a child's current functional communication performance as represented by the child's CFCS level. We also investigated whether childhood demographics, comorbidities, cerebral palsy typology and motor function were associated with the child's CFCS level. We hypothesized that the age when vocal play and first words emerge, two communication milestones often used in developmental delay surveillance, would predict functional communication. We also hypothesized the type and the number of comorbidities may influence the severity of communication performance in individuals with cerebral palsy.

Methods

Study Design

We assessed possible early predictors and correlates of functional communication in a large case series of children with cerebral palsy who participated in a case-control study that focused on the etiology of cerebral palsy, titled "Origins, Wellness & Life-history in cerebral palsy (OWL) Study."²² Children with cerebral palsy in the OWL study were recruited from child neurology, developmental pediatric, or psychiatry clinics in three cities in Michigan. Any potential recruitment bias would tend towards identifying children with more severe disabilities. Institutional Review Boards are listed at the end of the article in the Ethical Approval section. Informed consent was obtained from parents/legal guardians of the children. We used the guidelines, STrengthening the Reporting of OBservational studies in Epidemiology (STROBE)²³ for cross-sectional studies, in this paper.

Participants

All participants were born in Michigan, were between the ages of 2 to 17 years at the time of recruitment and had a primary diagnosis of cerebral palsy. Children were excluded if their cerebral palsy was postnatally acquired or had muscle tone abnormalities associated as

an epiphenomenon of a principal diagnosis of a major malformation syndrome or genetic disorder (e.g., Miller-Dieker syndrome or neural tube defects). The case series was further restricted to children whose mothers provided their children's communication function level (CFCS); a total of 215 children with cerebral palsy (mean age=8.2 years, SD=3.9) were included in this study.

Materials and Procedure

Data for all children were collected via a maternal interview about the case history of the child, the child's birth certificate, and maternal and infant-hospital discharge abstracts. Using clinical expertise, the child's physician noted cerebral palsy topographical classification and motor type as well as the presence of any associated comorbidities. Mothers of the children completed forms requesting information on levels of communication (CFCS), gross motor (GMFCS), and manual (MACS) function, as well as cerebral palsy typology and motor type, either by mail, phone or in person.

Variables

This section describes potential predictors, possible correlates, and communication classification collected for each child.

Potential Predictors: Childhood Demographics and Birth Characteristics

1. The following childhood demographics from the child's birth certificate were included: sex, race and ethnicity. Birth characteristics also obtained from the birth certificate, include gestational age and plurality. Gestational age was dichotomized into two groups: 1) very preterm (< 32 weeks), and 2) moderately preterm (33 to 36 weeks) or full-term (≥ 37 weeks). The maternal report included the age of the child when the mother first suspected a developmental problem.
2. Comorbidities often accompany cerebral palsy. The comorbidities examined include cognitive, hearing, speech, and visual impairments, and/or seizures.²
3. Details of limb involvement (quadriplegia, diplegia, and hemiplegia) were abstracted from the parent report. Quadriplegia refers to impairment in all limbs; diplegia refers to more impairment in the legs than in the arms; and hemiplegia means one side of the body has more impairment than the other side of the body.² Physician report included CP motor type of spastic, athetoid/dyskinetic, ataxic, and atonic.
4. Developmental communication milestones were recorded in the maternal interview and included the baby's age when reciprocating sound play (parent/caregiver and baby take turns making speech and nonspeech sounds, occurred between the baby and caretaker) first occurred as well as the age of first words. Reciprocating sound play for neuro-typical babies occurs by 6 months of age, and first words occurs around 1 year of age.²⁴ Since cerebral palsy is often not definitively diagnosed until age 2 years, our analysis used the predictor of first words by age 2 years, which is a year past the time most children acquire first words.

Possible Correlates: Motor Function Classifications—Both the GMFCS and MACS^{2, 825}, were used to classify functional abilities in gross motor skills and manual ability skills, respectively. Each classification system consists of 5 distinct but comprehensive levels described by “word pictures” where Level I is most able and Level V is least able. (See Table 1 for descriptions of each level.) Both the reliability and content validity have been established for the GMFCS and the MACS.^{25–30} The GMFCS validation included children with cerebral palsy from ages 2 to 18, and the original MACS from ages 4 to 18.^{25–30} (Note: The Mini-MACS, which has now been validated from ages 1 to 4, was not available at the time of this study.³¹)

Possible Correlates: Communication Methods.—Communication methods, collected in the CFCS questionnaire, refer to whether the child was able to communicate using speech, sounds, aided methods (communication boards, books, pictures and voice output device or a speech-generating device), and/or unaided methods (eye gaze, facial expressions, gesturing, or pointing and manual signs). Aided augmentative and alternative communication (AAC) refers to any communication method that supplements or replaces verbal communication.³² Using the above information, a communication methods variable for use in multivariate regression analyses was created. Children were classified into the following categories: 1) speech only, 2) aided regardless of speech, 3) unaided and speech use, and 4) unaided but no speech use.

Possible Correlates: Communication Therapies.—During the maternal interview, mothers were asked if their child had ever participated in speech therapy and augmentative and alternative communication or aided therapy (therapy to help develop skills in using aided communication methods such as communication boards, books, pictures and voice output device or speech-generating devices).

Communication Classification—The CFCS is a classification of the child’s daily communication performance with familiar and unfamiliar communication performance but does not describe the child’s underlying speech, language, and hearing skills.⁶ The CFCS validation included children with CP from ages 2 to 18.⁷ In the development and later use, inter-rater reliability among professionals for scoring the CFCS level^{7, 33, 34} has ranged from good (weighted kappa =.66) to excellent (weighted kappa=.98). The reliability of CFCS levels between professionals and parents^{7, 35} ranged from moderate (weighted kappa =.49) to excellent (weighted kappa =.91). Hidecker et al. (2011) demonstrated the CFCS had good test-retest reliability (weighted kappa =0.82). The CFCS also has a section to collect communication methods as described in the previous communication method section.

Analysis

Statistical analyses were conducted using SAS software, version 9.3 (SAS, Inc., Cary, NC). Bivariate analyses using chi-square tests were used to assess the relationships between CFCS levels and variables in each of the following categories: Child demographics, birth characteristics, comorbidities, cerebral palsy limb involvement, communication developmental milestones, motor function classifications, communication methods, and communication therapies. After list wise deletion of children with missing values on at least

1 of the aforementioned variables, 182 children were retained in analyses. Proportional odds models were used to estimate crude and adjusted odds ratios (OR) with 95% confidence intervals (95% CI).

The GMFCS and the MACS were each grouped into 3 categories to minimize degrees of freedom used with levels I-II, III, and IV-V collapsed for each. For modeling the CFCS was grouped into 4 levels: a) CFCS Level I b) CFCS Level II, c) CFCS Level III, d) CFCS Level IV and V, due to a small sample size for CFCS Level V. A probability level of $p < 0.05$ was considered statistically significant. Due to: (i) the possibility that some of the variables may share underlying properties and (ii) limitations in sample size, some univariate variables were not included in the final adjusted regression model. For example, the age of the child's first words was chosen for inclusion instead of the age of reciprocating sound play since there were fewer missing data and parents were more likely to note the milestone of first words.

Results

Participant characteristics for the 215 children (average age = 8 years, SD., = 3.9 years; 58% male) with cerebral palsy are presented in Table 2. The children's communication performance as provided by their parents varied by CFCS Level: Level I, n=81 (38%); Level II, n=42 (20%); Level III, n=42 (20%); Level IV, n=35 (16%); and Level V, n=15 (7%). Potential child predictors of sex, plurality, age, or race/ethnicity characteristics did not significantly vary by CFCS level, as shown by non-significant chi-squares of these relationships. In contrast, the predictors of gestational age, cerebral palsy limb involvement, and comorbidities varied significantly by CFCS levels (noted by the asterisk after the characteristics in Tables 2 and 3). Maternal education, as shown in Table 2, varied by CFCS levels.

Comorbidities (4 of the 5) significantly varied by CFCS levels, as shown in Table 3. The motor type of the children was reported by physicians for 188 of the 215 children; 85% of children were spastic (n= 182), 5% athetoid/dyskinetic, 4% ataxic, and 4% atonic. In Table 3, cerebral palsy limb distribution results were contrasted with CFCS levels. Motor function of mobility (GMFCS) and handling objects (MACS) are shown in Table 3 and both varied significantly by CFCS Levels.

As expected, children's communication milestones varied significantly by CFCS levels, as shown in Table 4. In this retrospective study of communication milestones, 19% of children were missing age data for reciprocating sound play, compared to only 3% of age for first words. The communication methods also significantly differed by the child's CFCS level as shown in Table 4. Almost a quarter of the total sample (51/215 or 24%) was nonverbal (no speech).

Parents reported that 28% of the children had neither speech nor augmentative and alternative communication therapy; 70% had speech therapy (which may include augmentative and alternative communication), fewer than 2% had only augmentative and alternative communication therapy (Table 4). The utilization of therapy varied significantly

by CFCS levels. Nearly 56% of CFCS Level I children were not receiving speech or augmentative and alternative communication therapy. Speech therapy was given to more than 80% of children in CFCS Levels II, III, IV, and V. The children most likely to have both augmentative and alternative communication and speech therapy were children in CFCS Level IV.

The results of the bivariate proportional odds models are presented in Table 5. Analyses were done on the 182 children who had complete data on all variables. In the bivariate model, each potential predictor and correlate was considered in relation to the child's functional communication (CFCS level). The following variables showed a significant association with CFCS level: gestational age, race/ethnicity, number of comorbidities, cerebral palsy limb involvement, age at which mother suspected problems, and age of first words, and the possible correlate of communication method(s). Of note, individual comorbidities as well as the number of comorbidities were associated with differing CFCS levels. Hearing did not meet the proportional odds assumption so odds ratios are not reported.

In the adjusted odds ratio model, the degrees of freedom limited the number of variables included in the final model. Significant predictors of CFCS levels included gestational age, number of comorbidities, and the age of first words, and the possible correlate of communication method(s) while controlling for sex, current child's age, race/ethnicity, limb involvement, and age problems were suspected (Table 5).

Discussion

This cross-sectional case series measured associations between selected birth characteristics and maternal report of early communication milestones on children's current functional communication performance. As hypothesized, these predictors include communication milestones often used in developmental delay surveillance, age of vocal play and age of first words, as well as the type and number of co-morbidities. Professionals should provide early referrals to speech-language pathology services for children with the birth characteristics and/or correlates with the highest odds ratio associated with less functional communication.

Cerebral palsy is often not definitively diagnosed until after the child's second birthday.² If a two-year old child is diagnosed with cerebral palsy, he or she should immediately be referred to speech-language pathology if predictors of later difficulty in communication function are present.¹⁴ These predictors include not yet producing first words, or showing comorbidities of speech difficulties, cognition, or a history of seizures. Children with quadriplegia, cognitive deficits, and late first words had significantly higher odds of having a CFCS level indicating less effective communication. Children with comorbidities were nearly twice as likely as those without comorbidities to demonstrate less effective communication performance.

Most children in this study used multiple communication methods. Children with cerebral palsy who communicate via speech tended to have CFCS levels that reflected more effective communication than those who communicate via other methods, who tended

to have CFCS levels which classified them as less effective communicators. This could be due to the need for additional or different communication methods and/or targeted augmentative and alternative communication intervention. Most children using multiple communication methods and their familiar communication partners need speech-language pathology intervention to maximize their functional communication performances when using augmentative and alternative communication.³²

Children who are not performing in CFCS Level 1 should be referred for speech-language and/or augmentative and alternative communication evaluations. These referrals should be made as early as possible to lessen the children's (and indeed parents') frustration with communication breakdowns and decrease possible learned helplessness by integrating other communication methods in addition to speech.³² Not all children who are in need of those services are receiving communication (speech, language, augmentative and alternative communication) therapy. Aided augmentative and alternative communication was not noted for almost two-thirds of the children who were not effective communicators with unfamiliar partners (CFCS Levels III-V) and nearly 80% of these children did not have access to a speech-generating device which may be necessary for effective communication with familiar and unfamiliar communication partners. The lack of augmentative and alternative communication for many children with cerebral palsy was also noted in results from the Norwegian Cerebral Palsy Registry.³⁶ Future research should measure the type, timing, and amount of communication therapy and especially for augmentative and alternative communication intervention.

Few studies have tried to predict communication functioning in children with cerebral palsy. Those studies that do try to predict communication functioning have suggested that child characteristics (GMFCS levels III-V, epilepsy, and speech problems) and environmental factors (low parental education and parental stress) are associated with greater impairment in social functioning and communication.^{5, 37, 38} Mothers with lower parental education (high school degree or less) had a higher percentage of children in the most severe CFCS Level (V) compared to mothers with college degrees. However, this result should be interpreted with caution due to the small number of children in CFCS level V (n=15), the higher percentage of children in the next most severe level (IV) whose mothers had a college degree as well as whether maternal education is a marker for SES or other social determinants.³⁹ As noted in our previous research,¹⁰ the CFCS, GMFCS and MACS levels are often partially correlated, perhaps due to the location of any underlying brain impairments. However, these correlations are far from constituting a one-to-one correspondence. This is not surprising since mobility, handling objects, and communication are functionally (and to an extent, neuro-anatomically) distinct. Thus, we strongly recommend not using either GMFCS or MACS to predict CFCS levels or other communication impairment, but instead to classify communication directly using the CFCS and/or other communication variables.

No consensus exists on which communication variables are important to descriptive and predictive studies in cerebral palsy. For example, Zhang et al.⁵ reported on Quebec Cerebral Palsy Registry communication data with 1) 66% having "communication impairment" (2/3 of these with "some verbal communication" and 1/3 non verbal). They noted, as did we, that children with communication impairment were significantly more likely to be born

at term. This may be due to differences in the underlying causes of cerebral palsy and/or the location or amount of brain damage. This is consistent with the Swedish finding that periventricular lesions were associated with speech and more functional CFCS levels, while later developing cortical/subcortical and basal ganglia lesions were associated with the absence of speech and less functional CFCS levels.⁴⁰ Zhang et al. also noted the limitations of describing communication as either verbal or nonverbal. Parkes et al.³³ reported on Northern Ireland Cerebral Palsy Register communication data: 1) 36% with motor speech disorder (articulation defects or dysarthria), 2) 37% with expressive speech and language difficulty but excluding articulation, and 3) method of communication (14% able to use speech, 5% speech and augmentative/alternative communication, 2% augmentative communication alone, or 17% unable to communicate with any method.) Children were assessed at a median age of 5 years, 11 months (interquartile range 3 to 9 years). They noted, as did we, of the increased risk for communication problems in children with seizures. The correlation between abnormal white matter and language skills has been noted in children with epilepsy.⁴¹ This finding needs to be further studied in the CP population, comparing the language abilities of those with and without seizures. Voorman et al.³⁴ used the communication semi-structured interview of the Vineland Adaptive Behavior Scales in parent interviews regarding their children (N=110, mean age 11 years, 3 months, ranges 9 to 16 years). As noted by Voorman et al., these Scales “may be limited as a communication measure, with its increasing focus on written communication, including handwriting, and the use of reference materials as the child enters adolescence.” These communication studies illustrate the difficulties in choosing variables to model communication which is a complex interaction of the child’s motor speech skills, language understanding and production, hearing skills, familiarity of communication partners and settings, and use of augmentative and alternative communication. Future research should look for common data elements in capturing children’s communication performance including the effects of children’s speech, language, hearing, and augmentative/alternative communication. The challenge continues to be prediction of which children (with and without cerebral palsy) need to be referred for evaluation and intervention of a wide range of communication disorders. None of these previous studies captured early communication milestones nor a current communication classification (e.g., CFCS). These variables may be useful in coordinating future collaborative research and potentially triggering referrals to speech-language pathologists.

Limitations of our study include the potential of both maternal recall bias and recruitment bias. These biases could influence the accuracy of some of the early milestones ages, especially for older children who were many years past those early milestones. For example, mothers were less likely to recall the age of reciprocal sound play but most reported when the child produced his first word. However, this error in recall is likely non-differential; any potential bias in a case series (i.e., all children were diagnosed with cerebral palsy) would produce measures of association closer to the null. This has been shown in studies on adverse birth outcomes such as congenital malformations with little evidence of differential recall by mothers.^{42, 43} Prospective studies that collect the birth characteristics and developmental milestones of young children would decrease any maternal recall bias. Children were recruited from physicians’ practices, a process that may

result in a bias towards including children with more notable impairments from cerebral palsy. Any potential recruitment bias would tend toward identifying children with more severe disabilities. Nonetheless, the internal validity of the study should not be influenced by these possible biases. Future research could also explore maternal education and other measures of SES as predictors of CFCS.³⁹

Another limitation is that topographical and motor types were collected from parent and physician report. Nearly all the children with cerebral palsy presented with spasticity. Increasing the number of children with athetoid/dyskinetic CP, a motor type which is known for demonstrating more motor speech disorder, may provide additional insight into early communication milestones and any association with CP topographical and motor types. However, the CP motor and topographical types do not necessarily correspond to the child's communication performance with different communication partners, the motor speech characteristics, the receptive and expressive language skills, and the use of augmentative and alternative communication.^{12, 44–52} A limitation of this research is that the only treatment variable was whether the child had ever received intervention. Future research could prospectively follow the dosage, timing, and focus of intervention including whether the intervention factors vary by the child's age and/or the child's CFCS level.

Although the GMFCS and CFCS have been used with children as young as 2 years old, the MACS was used to capture hand function although it had only been validated to age 4. Future studies could use both the MACS and the newly-validated Mini-MACS³⁰ (for ages 1 to 4) in creating functional profiles. The CFCS was created to classify communication function into 5 distinct groups. However, due to limits in sample size, the 5 communication function levels were combined into 4, aggregating Levels IV and V for analyses.

This study is the first large study to correlate current CFCS functional communication levels to early developmental milestones and possible correlates. Future research will compare CFCS levels by age ranges and any changes over time. More research is also needed to understand how gestational age, MRI findings, and possible underlying cerebral palsy causes may interact to affect functional communication in children with cerebral palsy. Prospective studies are needed to assess whether these early milestones and early CFCS classifications will be useful as predictors of later communication performance for children with cerebral palsy. The influence of epilepsy on the prognosis for speech and language function suggests that more studies need to be done about the effects of treatment, including anti-epileptic medications and surgical treatment. Speech delay may be an independent and parallel risk factor for seizures (assuming that seizures and speech delay may be caused by the same underlying brain dysfunction).

To date, most studies of individuals with cerebral palsy have provided only limited measurements of communication variables (including speech, language, hearing, and augmentative and alternative communication), despite an increasing recognition of the importance of communication in the daily life of individuals with cerebral palsy. We strongly urge that communication come to the forefront of cerebral palsy studies with more direct measurement of communication variables and outcomes. Clinically, physicians and other professionals can collaborate with parents to determine a consensus CFCS level

for the child, which should be documented in the medical chart.⁵³ This quick process can be important groundwork to using a common language to describe the child's current communication performance. Clinical and research use of a communication classification such as the CFCS could be an important first step in ensuring that children with CP obtain necessary communication assessments and intervention as early as possible.

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Table I:

The five levels of Gross Motor Function Classification System, Manual Ability Classification System, and Communication Function Classification System

Classification systems			
Levels	GMFCS	MACS	CFCS
I	Walks without limitations	Handles objects easily and successfully	Sends and receives information with familiar and unfamiliar partners effectively and efficiently
II	Walks with limitations	Handles most objects but with somewhat reduced quality and/or speed of achievement	Sends and receives information with familiar and unfamiliar partners but may need extra time
III	Walks using a hand-held mobility device	Handles objects with difficulty; needs help to prepare and/or modify activities	Sends and receives information with familiar partners effectively, but not with unfamiliar partners
IV	Self-mobility with limitations; may use powered mobility	Handles a limited selection of easily managed objects in adapted situations	Inconsistently sends and/or receives information even with familiar partners
V	Transported in a manual wheelchair	Does not handle objects and has severely limited ability to perform even simple actions	Seldom effectively sends and receives information even with familiar partners

GMFCS, Gross Motor Function Classification System; MACS, Manual Ability Classification System; CFCS, Communication Function Classification System.

Adapted with permission from Hidecker MJC, Paneth N, Rosenbaum PL, Kent RD, Lillie J, Eulenberg JB, Chester K, Johnson B, Michalsen L, Evatt M, Taylor K. Developing and validating the Communication Function Classification System (CFCS) for individuals with cerebral palsy. *Dev Med Child Neurol* 2011; **53**: 704–10.

Table 2:

Demographics of Children with cerebral palsy by Communication Function Classification System Level

Child Characteristics, n (%)	All 215	CFCS Level				
		I 81 (37.7)	II 42 (19.5)	III 42 (19.5)	IV 35 (16.3)	V 15 (7.0)
Sex						
Female	94 (43.7)	38 (46.9)	19 (45.2)	18 (42.9)	14 (40.0)	5 (33.3)
Male	121 (56.3)	43 (53.1)	23 (54.8)	24 (57.1)	21 (60.0)	10 (66.7)
Plurality						
Singleton	172 (80.0)	63 (77.8)	30 (71.4)	33 (78.6)	30 (85.7)	13 (86.7)
Multiple	43 (20.0)	17 (21.0)	12 (28.6)	8 (19.0)	4 (11.4)	2 (13.3)
Gestational age ^a						
32 weeks	107 (50.2)	50 (61.7)	20 (47.6)	16 (38.1)	14 (40.0)	7 (46.7)
>32 weeks	108 (49.8)	31 (38.3)	22 (52.4)	26 (61.9)	21 (60.0)	8 (53.3)
Age in years						
5	64 (29.8)	23 (28.4)	11 (26.2)	17 (40.5)	8 (22.9)	5 (33.3)
6 – 11	96 (44.7)	35 (43.2)	20 (47.6)	17 (40.5)	17 (48.6)	7 (46.7)
12	55 (25.6)	23 (28.4)	11 (26.2)	8 (19.0)	10 (28.6)	3 (20.0)
Race/Ethnicity						
Black	26 (12.1)	4 (4.9)	9 (21.4)	3 (7.1)	5 (14.3)	5 (33.3)
Hispanic	13 (6.1)	6 (7.4)	1 (2.4)	5 (11.9)	2 (5.7)	1 (6.7)
White	168 (78.1)	68 (84.0)	31 (73.8)	32 (76.2)	28 (80.0)	9 (60.0)
Other ^b	8 (3.7)	9 (11.1)	2 (4.8)	7 (16.7)	2 (5.7%)	1 (6.7)
Marital Status						
Single	45 (20.9)	15 (18.5)	8 (19.0)	11 (26.2)	5 (14.3)	6 (40.0)
Married/Cohabiting	164 (76.3)	63 (77.8)	33 (78.6)	31 (73.8)	28 (80.0)	9 (60.0)
Other	6 (2.8)	3 (3.7)	1 (2.4)	0 (0)	2 (5.7)	0 (0)
Maternal Education ^a						
< High school	19 (8.8)	7 (8.6)	5 (11.9)	2 (4.8)	1 (2.9)	4 (26.7)
High school or GED	117 (54.4)	41 (50.6)	24 (57.1)	27 (64.3)	15 (42.9)	10 (66.7)
College Degree	79 (36.7)	33 (40.7)	13 (31.0)	13 (31.0)	19 (54.3)	1 (6.7)
Home Ownership						
Yes	137 (63.7)	54 (66.7)	25 (59.5)	25 (59.5)	26 (46.7)	7 (46.7)
No	78 (36.3)	27 (33.3)	17 (40.5)	17 (40.5)	9 (25.7)	8 (53.3)

^a Some participants chose multiple categories; percentages may not sum to 100%^b Other includes Asian, Native American, and Indian.

Significant chi square

* p<.05

** p<.01

Table 3:

cerebral palsy limb involvement, comorbidities, and motor function by Communication Function Classification System Level

Child Characteristics, n (%)	CFCS Level					
	All	I	II	III	IV	V
	215	81 (37.7)	42 (19.5)	42 (19.5)	35 (16.3)	15 (7.0)
Comorbidities ^a						
Cognitive impairment ^{**}	60 (27.9)	9 (11.1)	13 (31.0)	15 (35.7)	16 (45.7)	7 (46.7)
Hearing impairment [*]	9 (4.2)	4 (4.9)	0	1 (2.4)	2 (5.7)	2 (13.3)
Seizure ^{**}	59 (27.4)	9 (11.1)	10 (23.8)	10 (23.8)	18 (51.4)	12 (80.0)
Speech impairment ^{**}	76 (35.4)	8 (9.9)	18 (42.9)	20 (47.6)	22 (62.9)	8 (53.3)
Visual impairment	67 (31.2)	24 (29.6)	13 (31.0)	11 (26.2)	13 (37.1)	6 (40.0)
Number of comorbidities ^{**}						
Zero	74 (34.4)	43 (53.1)	16 (38.1)	12 (28.6)	2 (5.7)	1 (6.7)
One	57 (26.5)	25 (30.9)	8 (19.0)	14 (33.3)	8 (22.9)	2 (13.3)
Two	51 (23.7)	11 (13.6)	10 (23.8)	6 (14.3)	17 (48.6)	7 (46.7)
Three or more	33 (15.4)	2 (2.4)	8 (19.1)	10 (23.8)	8 (22.9)	5 (33.3)
cerebral palsy limb involvement ^{**}						
Hemiplegic (unilateral)	52 (27)	26 (32.1)	9 (21.4)	11 (26.2)	6 (17.1)	0 (0)
Diplegic	62 (32)	33 (40.7)	14 (33.3)	9 (21.4)	4 (11.4)	2 (13.3)
Quadriplegic	80 (41)	16 (19.8)	14 (33.3)	18 (42.9)	20 (57.1)	12 (80.0)
Missing	21	6	5	4	5	1
GMFCS level ^{**}						
I	55 (26.6)	32 (39.5)	13 (31.0)	5 (11.9)	5 (14.3)	0
II	64 (29.8)	28 (34.6)	15 (35.7)	13 (31.0)	6 (17.1)	2 (13.3)
III	24 (11.2)	12 (14.8)	4 (9.5)	3 (7.1)	4 (11.4)	1 (6.7)
IV	24 (11.2)	6 (7.4)	3 (7.1)	9 (21.4)	5 (14.3)	1 (6.7)
V	48 (22.3)	3 (3.7)	7 (16.7)	12 (28.6)	15 (42.9)	11 (73.3)
MACS level ^{**}						
I	53 (24.7)	38 (46.9)	9 (21.4)	4 (9.5)	2 (5.7)	0
II	70 (32.6)	27 (33.3)	18 (42.9)	15 (35.7)	9 (25.7)	1 (6.7)
III	43 (20.0)	13 (16.0)	9 (21.4)	12 (28.6)	8 (22.9)	1 (6.7)
IV	33 (15.4)	3 (3.7)	5 (11.9)	9 (21.4)	12 (34.3)	4 (26.7)
V	16 (7.4)	0	1 (2.4)	2 (4.8)	4 (11.4)	9 (60.0)

^a.Some participants chose multiple categories; percentages may not sum to 100%

Note: GMFCS, Gross Motor Function Classification System; MACS, Manual Ability Classification System; CFCS, Communication Function Classification System

Significant chi square

*
p<.05

**
p<.01

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Table 4:

Children's communication milestones, methods, and therapy by Communication Function Classification System Level

Child Characteristics, n (%)	CFCS Level					
	All	I	II	III	IV	V
	215 (100)	81 (38)	42 (20)	42 (20)	35 (16)	15 (7)
Child’s communication milestones						
Reciprocating sound play *						
6 months old	115 (53.5)	59 (72.8)	20 (47.6)	17 (40.5)	12 (34.3)	7 (46.7)
> 6 months old	59 (27.4)	11 (13.6)	11 (26.2)	17 (40.5)	15 (42.9)	5 (33.3)
Missing	41 (19.1)	11 (13.6)	11 (26.2)	8 (19.0)	8 (22.9)	3 (20.0)
First words **						
24 months old	142 (66.1)	72 (88.9)	31 (73.8)	25 (59.5)	10 (28.6)	4 (26.7)
> 24 months old	66 (30.7)	6 (37.4)	8 (19.0)	16 (38.1)	25 (71.4)	11 (73.3)
Missing	7 (3.3)	3 (7.4)	3 (7.1)	1 (2.4)	0	0
Communication methods used						
Speech **	164 (76.3)	81 (100)	37 (88.1)	29 (69.0)	15 (42.9)	2 (13.3)
Speech only **	58 (27.0)	43 (53.1)	11 (26.2)	2 (4.8)	1 (2.9)	1 (6.7)
Sounds **	125 (58.1)	28 (34.6)	23 (54.8)	33 (78.6)	29 (82.9)	12 (80.0)
Unaided: Eye gaze, facial expressions, gesturing, and/or pointing **	130 (60.5)	36 (44.4)	27 (64.3)	37 (88.1)	26 (74.3)	5 (33.3)
Unaided: Manual sign *	53 (24.7)	13 (16.0)	11 (26.2)	17 (40.5)	12 (34.3)	0
Aided: Communication boards, books, and/or pictures **	38 (17.7)	8 (9.9)	4 (9.5)	12 (28.6)	14 (40.0)	0
Aided: VOCAs or SGDs **	21 (9.8)	1 (1.2)	3 (7.1)	7 (16.7)	11 (31.4)	2 (13.3)
Aided AAC (communication boards/VOCAs/SGD) **	46 (21.4)	8 (9.9)	5 (11.9)	14 (33.3)	18 (51.4)	1 (6.7%)
Communication therapy						
No speech and no AAC therapy	60 (27.9)	45 (55.6)	5 (11.9)	5 (11.9)	2 (5.7)	3 (20.0)
“Speech therapy” **	152 (70.7)	34 (42.0)	37 (88.1)	37 (88.1)	32 (91.4)	12 (80.0)
“AAC therapy” ** (3 children were listed as having AAC & no speech therapy)	59 (27.0)	4 (4.9)	12 (28.6)	16 (38.1)	22 (62.9)	5 (33.3)
“Speech” or “AAC” therapy	155 (72.0)	36 (44.4)	37 (88.1)	37 (88.1)	33 (94.3)	12 (80.0)
Both speech and AAC therapy	56 (26.1)	2 (2.5)	12 (28.6)	16 (38.1)	21 (60.0)	5 (33.3)

^a. Some participants chose multiple categories; percentages may not sum to 100%

Note: CFCS, Communication Function Classification System; VOCA, Voice output communication aid; SGD, speech-generating device

P-value calculated using Chi-square Test

*
p<.05

**
p<.01

Table 5.

Odds Ratios between CFCS Level, Demographic/Birth Characteristics and Developmental Milestones
(n=182) **

	Unadjusted Odds Ratio (95% CI)	Adjusted Odds Ratio (95% CI)
Sex		
Female	1.0	1.0
Male	1.4 (0.9–2.5)	1.2 (0.7–2.3)
Plurality		
Singleton	1.4 (0.7–2.7)	
Multiple	1.0	
Gestational age		
32 weeks	1.0	1.0
>32 weeks	2.1 (1.2–3.6) *	2.8 (1.5–5.4) *
Age in years		
5	1.4 (0.7–2.9)	2.2 (0.9–5.4)
6 – 11	1.4 (0.7–2.7)	1.3 (0.6–3.0)
12	1.0	1.0
Race/Ethnicity		
Black	2.3 (1.0–5.2) *	1.6 (0.6–4.3)
White	1.0	1.0
Other	1.0 (0.4–2.3)	1.0 (0.4–2.8)
Comorbidities		
Cognitive impairment	3.3 (1.8–6.0) *	
Hearing impairment	2.8 (0.4–19.3)	
Seizure	6.0 (3.2–11.4) *	
Speech impairment	7.2 (3.9–13.0) *	
Visual impairment	1.3 (0.8–2.4)	
Number of comorbidities (continuous)	2.0 (1.7–2.6) *	1.9 (1.4–2.5) *
cerebral palsy limb involvement		
Quadriplegia	3.6 (1.8–7.2) *	2.2 (1.0–5.1)
Diplegia	0.8 (0.4–1.6)	1.0 (0.4–2.5)
Hemiplegia	1.0	1.0
Mother suspected a problem		
< 6 months old	1.0	1.0
6 months old	2.5 (1.3–4.7) *	1.2 (0.5–2.5)
First words		
24 months old	1.0	1.0
> 24 months old	10.4 (5.4–20.0) *	3.8 (1.7–8.2) *
Communication methods used		
Speech only	1.0	1.0

	Unadjusted Odds Ratio (95% CI)	Adjusted Odds Ratio (95% CI)
Aided regardless of speech use	25.5 (9.6–67.8) *	10.7 (3.6–32.5) *
Unaided and speech use	6.7 (2.9–15.9) *	6.2 (2.3–16.6) *
Unaided but no speech use	90.3 (26.5–307.4) *	32.9 (7.8–137.8)

Note: CFCS, Communication Function Classification System;

Bolding indicates those variables that are significant;

* Denotes statistically significant odds ratio ($p < 0.05$)-

** Final analytic sample