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Original Article

Diagnostic validity of the Chinese Child Development Inventory in screening children with developmental language delay

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ABSTRACT

Objectives: The Chinese Child Developmental Inventory (CCDI) is one of the most commonly used developmental screening tools. However, limited data are available regarding the diagnostic validity (sensitivity and specificity) of the CCDI in identifying children with developmental language disorders. The aim of this study was to determine how well the CCDI functions within a hospital-based setting when administered by clinicians.

Materials and Methods: A hospital-based sample of 235 children (aged 15–78 months) with suspected developmental language delay was included for a validity test. The subscales of the CCDI examined in this study were expressive language (EL), comprehension conceptual (CC), situation comprehension (SC), self-help, personal–social (PS), and general development (GD).

Results: Acceptable high specificities (77.9–95.1%) were found for most of the subscales, except for the PS (57.6%). The EL subscale was the most suitable for the screening of children with language delay, but the sensitivity was only at the acceptable (66%) level. The EL and PS subscales were good predictors of autistic spectrum disorders with specificities of 70% and 76.2%, respectively. Rather high sensitivities were observed for the EL, CC, and SC subscales (71–80%) for children with developmental delay.

Conclusion: The CCDI completed by parents is a valid screening tool for identifying children with risks of developmental language delay.

1. Introduction

The major purpose of a developmental screening tool is to identify children at risk of developmental delay. Physicians can obtain information relevant to the development of a child from the parents or main caregiver, or from the results of developmental screening tests [1–4]. In Taiwan, there are several developmental screening tests that help physicians and caregivers monitor children's development problems. The Chinese Child Developmental Inventory (CCDI), a screening tool for children aged 6–78 months, is a comprehensive and commonly used screening instrument. The CCDI includes a total of 320 items with concrete behavioral descriptions in eight developmental dimensions: gross motor (GM), fine motor (FM), expressive language (EL), comprehension conceptual (CC), situation comprehension (SC), self-help (SH), personal–social (PS), and general development (GD). The CCDI was first modified from the Minnesota Child Development Inventory (MCDI) [5] and has Taiwanese normative data for children aged 6–78 months [6]. There are, however, only a few validity studies of the CCDI. Hence, it is important to evaluate further the evidence-based validity of the CCDI to rationalize its clinical use.

One validity study investigated the concurrent criterion-related validity of the CCDI and compared it with the mental developmental index of the Bailey Scales of Infant Development (BSID II) – Mental Developmental Index and reported good sensitivity (80.8%) and excellent specificity (90.5%). The criterion-related validity of the CCDI also had moderately high sensitivity (81%) and specificity (77.8%) when compared with the psychomotor developmental index [7]. From a clinical diagnosis perspective, sensitivity and specificity are measures that reflect the diagnostic accuracy of a screening tool. The accepted standards for sensitivity and specificity are approximately 70% and 80%, respectively [8]. However,

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few studies have examined the sensitivity of the CCDI, and that of MCDI was low (56%) [9]. Recently, Lo et al [10] reported that the sensitivity of CCDI was 33% in detecting children with developmental problems based on clinical diagnosis. However, they only used the GD subscale of the CCDI to evaluate the sensitivity with a small sample of 119 children with developmental delay. To provide empirical support and better understand the accuracy of the CCDI, we examined the diagnostic validity (sensitivity and specificity) of several subscales of the CCDI in detecting developmental problems in children.

2. Materials and methods

2.1. Patients

From 2006 to 2011, a total of 235 children were recruited from a clinic in our hospital for children suspected of having developmental delay. The Institutional Review Board of the hospital approved the study protocol. We included children aged 15–78 months who had suspected language delay, and excluded children whose parents or main caregivers failed to complete the CCDI questionnaire. We retrospectively reviewed data for assessment of the CCDI and clinical diagnosis for analysis.

2.2. Assessment of CCDI

All children were screened by the CCDI, which has been validated and is commonly used by physicians in clinical practice. The CCDI is a parent report with a total of 320 observable and easily comprehended behavioral items measuring eight dimensions of development in children as follows: GM (34 items), FM (44 items), EL (54 items), CC (67 items), SC (44 items), SH (36 items), PS (34 items), and GD (131 items out of the 320 items of the CCDI). The raw scores for each dimension can be grouped into three categories, delayed, borderline, or normal, based on an age-appropriate norm. In each developmental dimension, a child is considered delayed if the score is <30% of the chronological age-level cutoff value, and borderline (i.e., doubtful developmental delay) if the score is 20–30% of the chronological age-level cutoff value [6].

2.3. Clinical diagnosis of speech delay, autistic spectrum disorders, and developmental delay

All participants visited the Comprehensive Combined Evaluation Clinic of Child Development in New Taipei city and were examined by a senior pediatric neurologist, child psychiatrist, and physiatrist for a thorough clinical study. Then, they were referred to a senior clinical psychologist and speech therapist for cognition, emotion–behavior, and language evaluation. These assessments included the following: CCDI, BSID-III, Wetzlar Preschool and Primary Scale of Intelligence – Revised, Preschool Language Scale, and Communication and Language Screening Test for 0–3 Year Old Chinese-Speaking Infants and Toddlers [11]. The final diagnosis for each child was made at a joint meeting of the above-mentioned specialists. The children were further divided into two groups, the language delay group and no language delay group, according to the evaluation by the clinical psychologist and speech therapists. Children with language delay were diagnosed as follows: (1) developmental language disorder (DLD, $n = 57$, 47 boys) if there was a delay in language alone; (2) developmental delay (DD, $n = 33$, 19 boys) if there was a delay in both cognition and language; (3) autistic spectrum disorder (ASD, $n = 27$, 26 boys) if there was a delay in language and social skills; and (4) comorbid DD and ASD if there was a delay in cognition, language, and social skills ($n = 29$, 28 boys). The remaining group with no language developmental delay (NLD group) consisted of children with no delays, and those with attention deficit hyperactivity disorder (ADHD), motor coordination disorder, and articulation disorder ($n = 86$, 63 boys).

Table 1
Demographic data of the sample by age group.

Variable		Total ($n = 235$)	Age ≤ 4 yr ($n = 117$)	Age > 4 yr ($n = 118$)	p
Sex					0.654
Boys		186 (79.1)	94 (80.3)	92 (78.0)	
Girls		49 (20.9)	23 (19.7)	26 (22.0)	
Age [mo; mean (SD)]		47.67 (15.13)	34.78 (8.80)	60.46 (7.07)	< 0.001*
CCDI screening					
GM	normal	80 (34)	71 (60.7)	9 (7.6)	< 0.001*
	doubt	47 (20)	21 (17.9)	26 (22.0)	
	delay	108 (46)	25 (21.4)	83 (70.3)	
FM	normal	153 (65.1)	82 (70.1)	71 (60.2)	0.187
	doubt	26 (11.1)	13 (11.1)	13 (11)	
	delay	56 (23.8)	22 (18.8)	34 (28.8)	
EL	normal	97 (41.3)	48 (41)	49 (41.5)	0.467
	doubt	28 (11.9)	9 (7.7)	19 (16.1)	
	delay	110 (46.8)	60 (51.3)	50 (42.4)	
CC	normal	135 (57.4)	61 (52.1)	74 (62.7)	0.018*
	doubt	23 (9.8)	8 (6.8)	15 (12.7)	
	delay	77 (32.8)	48 (41.0)	29 (24.6)	
SC	normal	115 (48.9)	65 (55.6)	50 (42.4)	0.097[a]
	doubt	26 (11.1)	13 (11.1)	13 (11)	
	delay	94 (40.0)	39 (33.3)	55 (46.6)	
SH	normal	114 (48.5)	56 (47.9)	58 (49.2)	0.784
	doubt	48 (20.4)	26 (22.2)	22 (18.6)	
	delay	73 (31.1)	35 (29.9)	38 (32.2)	
PS	normal	77 (32.8)	50 (42.7)	27 (22.9)	0.002*
	doubt	45 (19.1)	15 (12.8)	30 (25.4)	
	delay	113 (48.1)	52 (44.4)	61 (51.7)	
GD	normal	122 (51.9)	66 (56.4)	56 (47.5)	0.33
	doubt	32 (13.6)	13 (11.1)	19 (16.1)	
	delay	81 (34.5)	38 (32.5)	43 (36.4)	
Developmental disorders					0.078[a, **]
NLD group		86 (36.6)	32 (27.3)	54 (45.8)	
ADHD and motor delay		3 (1.3)	1 (0.9)	2 (1.7)	
DLD		57 (24.3)	34 (29.1)	23 (19.5)	
ASD		27 (11.5)	15 (12.8)	12 (10.1)	
DD		33 (14.0)	19 (16.2)	14 (11.9)	
DD and ASD		29 (12.3)	16 (13.7)	13 (11.0)	

Data are presented as n (%) unless otherwise identified.
* $p < 0.05$.
** $0.05 < p < 0.1$.
ADHD = attention deficit hyperactivity disorder; ASD = autistic spectrum disorder; CC = comprehension conceptual; CCDI = Chinese Child Developmental Inventory; DD = developmental delay; DLD = developmental language disorder; EL = expressive language; GD = general development; GM = gross motor; FM = fine motor; NLD = no language developmental delay; PS = personal–social; SC = situation comprehension; SD = standard deviation; SH = self-help.
[a] Based on Fisher's exact test.

2.4. Statistical analysis

Descriptive statistics were obtained for each subscale of the CCDI in the present sample as a whole and in subgroups defined by age at 48 months (median) as the threshold, as well as developmental disorders as the grouping variable. Differences between age groups were assessed using the two-sample t test for continuous data and the χ^2 test or Fisher's exact test for categorical data. Analysis of variance tests were performed on all of the CCDI subscales with developmental disorders as the grouping variable. In addition, Dennett's t test was utilized in *post hoc* analysis with the NLD group as a control compared with the other groups. The validity of the subscales of the CCDI except for the motor domain, was examined using two approaches. First, the sensitivity and specificity were calculated for the relationship between the screening results of the CCDI and developmental disorders. Sensitivity described the percentage of children with a

developmental disorder whose CCDI score fell below 30% of the chronological age-level cutoff value. Specificity described the percentage of children diagnosed as not having a developmental disorder whose CCDI score was > 20% of the chronological age-level cutoff value [6]. Statistical significance was set at $p < 0.05$.

3. Results

3.1. Participant clinical characteristics

Table 1 shows data for children aged ≤ 4 years and > 4 years. The mean age of the 235 children referred to our clinic for initial evaluation of Dads was 47.67 months (standard deviation = 15.13 months, median = 49 months). Nearly 80% (79.1%) were boys (Table 1). However, there was no significant difference in age between the boys and girls (boys: 47.53 months and girls: 48.2 months). A higher percentage of children aged > 4 years than ≤ 4 years had delays in the GM and PS subscales of the CCDI. However, a significantly higher percentage of children aged ≤ 4 years than > 4 years had delays in the CC subscale. Table 2 presents the mean scores of each subscale by age and DD/NLD group. The NLD group consisted of children with ADHD; therefore, the mean scores of the motor domains such as GM and FM were affected when comparing between different Dads. Generally, there was an increasing trend in the mean score of each subscale of the CCDI for each disorder as age increased. We found that the mean scores for each scale (motor domains not included) of the CCDI of children aged < 4 years with at least one developmental disorder, that is, DLD, ASD, or DD, were significantly lower than those of the NLD group. However, scores among children aged > 4 years with DLD were not significantly different from those of the NLD group. In addition, there was only borderline significance for the PS subscale and no difference in the mean score of the SH subscale between children with ASD and those in the NLD group aged > 4 years, although there were significance differences among the remaining subscales. The mean scores remained significantly lower for children with DD and DD comorbid with ASD than that for those in the NLD group.

Table 3
Diagnostic validity of subscales of CCDI in detecting children with a developmental disorder.

CCDI subscale	Specificity	Developmental disorder			
		DLD sensitivity	ASD sensitivity	DD sensitivity	DD and ASD sensitivity
EL	**81.5**[a]	66.0	**70.0**[a]	**80.0**[a]	**96.2**[a]
CC	**95.1**[a]	34.8	44.0	**71.0**[a]	**92.3**[a]
SC	**77.9**[a]	34.6	54.5	**72.4**[a]	**96.2**[a]
SH	**84.5**[a]	39.5	38.1	55.6	**95.7**[a]
PS	57.6	50.0	**76.2**[a]	67.7	**96.3**[a]
GD	**85.1**[a]	31.3	45.5	64.5	**96.0**[a]

Data are expressed as %.
ASD = autistic spectrum disorder; CC = comprehension conceptual; CCDI = Chinese Child Developmental Inventory; DD = developmental delay; DLD = developmental language disorder; EL = expressive language; GD = general development; PS = personal–social; SC = situation comprehension; SH = self-help.
[a] Bold values indicate good validity (≥ 70%).

3.2. Validity of the CCDI in screening DLD, ASD, and developmental delay

A borderline (i.e., doubtful developmental delay) result on CCDI screening could not contribute to validity analysis, hence, we calculated the validity of the remaining sample without considering stratification analysis by age. We did this because stratification analysis based on small sample size in each age group after excluding those samples might lead to varying validity estimate results. Table 3 shows the sensitivity and specificity for the EL, CC, SC, SH, PS, and GD subscales of the CCDI. The classifications based on the results of the CCDI were compared with a clinical diagnosis of developmental disorder as the gold standard. The CCDI had a moderate to high specificity ranging from 57.6% (PS subscale) to 95.1% (CC subscale), and 85.1% for GD. When screening children with DLD ($n = 57$), the CCDI had a rather low to moderate sensitivity ranging from 34.6% (SC subscale) to 66% (EL subscale), and 31.3% for the GD subscale. When screening children with ASD ($n = 27$), it was found that the EL and PS subscales had high levels of sensitivity (70.0% and 76.2%, respectively). Within the developmental delay subgroup ($n = 33$), the EL, CC, and SC subscales

Table 2
Mean scores (and standard deviations) on the subscales of the CCDI by developmental disorders for two age groups.[a]

CCDI subscale	Age group (yr)	DLD ($n = 57$)	ASD ($n = 27$)	DD ($n = 33$)	DD and ASD ($n = 29$)	NLD group ($n = 86$)
EL	Total	35.05 (13.99)*	31.59 (16.86)*	31.76 (14.33)*	26.97 (12.43)*	48.65 (6.29)
	≤ 4	26.30 (10.69)*	24.00 (14.96)*	24.89 (14.35)*	21.94 (10.45)*	45.94 (7.09)
	> 4	47.61 (6.60)	41.08 (14.50)*	41.07 (7.62)*	33.15 (12.20)*	50.20 (5.24)
CC	Total	32.38 (18.42)*	29.48 (21.07)*	25.76 (14.33)*	19.90 (12.19)*	50.06 (11.21)
	≤ 4	19.76 (9.92)*	19.80 (16.77)*	19.26 (13.16)*	13.81 (8.41)*	42.78 (11.03)
	> 4	50.48 (11.12)	41.58 (20.08)*	34.57 (10.96)*	27.38 (12.18)*	54.21 (9.05)
SC	Total	29.45 (7.85)*	27.22 (8.76)*	26.58 (8.49)*	22.93 (5.37)*	35.13 (5.76)
	≤ 4	25.55 (6.23)*	23.80 (7.47)*	23.16 (8.82)*	20.63 (3.24)*	32.59 (5.76)
	> 4	35.04 (6.48)	31.50 (8.64)*	31.21 (5.44) *	25.77 (6.20) *	36.57 (5.28)
SH	Total	22.55 (8.16)*	20.96 (8.06)*	21.24 (8.53)*	18.69 (6.91)*	28.49 (4.94)
	≤ 4	18.06 (6.69)*	15.80 (5.55)*	17.53 (7.86)*	14.69 (6.27)*	25.53 (5.33)
	> 4	29.00 (5.26)	27.42 (5.71)	26.29 (6.78)*	23.62 (3.82)*	30.18 (3.81)
PS	Total	22.46 (6.87)*	19.59 (8.63)*	20.67 (8.17)*	14.55 (7.02)*	27.57 (4.82)
	≤ 4	19.03 (5.63)*	15.67 (7.50)*	18.11 (8.08)*	11.50 (5.47)*	25.34 (5.10)
	> 4	27.39 (5.36)	24.50 (7.56)**	24.14 (7.16)*	18.31 (7.06)*	28.84 (4.19)
GD	Total	85.46 (29.79)*	80.15 (34.32)*	76.27 (27.72)*	67.97 (22.94)*	113.47 (16.06)
	≤ 4	65.82 (18.84)*	62.8 (26.51)*	62.26 (26.05)*	56.75 (17.76)*	102.9 (14.75)
	> 4	113.65 (17.11)	101.83 (31.07)**	95.29 (16.62)*	81.77 (21.43)*	119.54 (13.53)

*$p < 0.05$.
**$0.05 < p < 0.1$.
ASD = autistic spectrum disorder; CC = comprehension conceptual; CCDI = Chinese Child Developmental Inventory; DD = developmental delay; DLD = developmental language disorder; EL = expressive language; GD = general development; NLD = no language developmental delay; PS = personal–social; SC = situation comprehension; SH = self-help.
[a] The p values were obtained from Dunnett's t test as *post hoc* analysis that treated NLD group as a control group.

had high sensitivity (80%, 71%, and 72.4%, respectively). For children with developmental delay comorbid with ASD ($n = 29$), the CCDI had relatively high levels of sensitivity at each subscale in our study.

4. Discussion

The overall rate of language-delay-related disorders in 235 children suspected of having these delays was 62.1%. The high rate of developmental disability is consistent with previous evidence that parental concerns offer useful information for clinicians in screening children with developmental delay [12,13]. Evidence indicates that nearly 70% of children with developmental delay are boys, which was confirmed in our study [14]. More boys (82.2%) than girls were diagnosed with language developmental disorders. We also determined the diagnosis-related validity using the clinical diagnosis as the gold standard and found that the CCDI had high specificities ($> 75\%$) on subscales such as the EL, CC, SC, SH, and GD in children with disorders not related to language delay. However, the specificity of the PS subscale was low to moderate (57.6%). Although the screening results based on the PS might lead to over-referrals, previous research [15] has shown that the performance of the false-positive group was substantially poorer than peers in the true-negative group in intelligence, language, and academic achievement. Hence, it is important for a screening tool such as the CCDI to identify children at risk, even if these children have false-positive results.

For specific diagnoses, the CCDI had relatively high ($> 70\%$) sensitivity in identifying ASD and DD, and excellent sensitivity in ASD comorbid with DD, but low to moderate (31.3–66%) sensitivity when differentiating the DLD from the NLD group. For ASD, the EL and PS subscales had good sensitivity to the degree that screening missed only a few cases. This might substantiate previous evidence that children with ASD share common impairments in social interaction, the use of language for communication, and cognitive abilities, even prior to when they are school aged. Thus, these domains are said to be the most important variables predicting the outcome of ASD [16,17]. For severe disorders (e.g., DD) or comorbid disorders (e.g., DD and ASD), the sensitivity for each subscale was relatively good. This indicates that children with positive screening results among the several subscales of the CCDI should be referred for comprehensive developmental assessment to determine whether they have severe developmental disorders or comorbidity with different disorders. In the current sample, we found that the mean scores of each scale of the CCDI for children aged > 4 years with DLD were not significantly different from those of children in the NLD group. Age may affect the discriminative sensitivity when used to screen children with DLD, thus resulting in low sensitivity for the CCDI. A previous study has indicated that the diagnostic validity in screening children with ASD may vary depending on the age of the child and severity of symptoms [18]. In future studies, larger samples are needed to determine if age affects the diagnostic discrimination of sensitivity and specificity. Other factors related to study design might have an impact on the estimates of sensitivity and specificity, such as the moderate sample size for each group, and the possibility that some children in the NLD group have other coordination and articulation disorders. Moreover, several variables related to disease that may result in emotional, behavioral, and psychological symptoms, which may further influence a child's development, were not considered in the present study. These should be also considered in future studies.

The diagnosis-related validity of the CCDI was based on the screening results according to norms that were established and utilized over the past three decades. Parents have a relatively higher education level and children receive more stimulation from their environment than they did years ago, so the normative data might need to be revised. Revised new normative data should influence the estimation of sensitivity and specificity of the CCDI. The original instrument from which the CCDI was developed, the MCDI, was revised in 1994 and was also divided into two parts: (1) the Child Developmental Inventory (15 months–6 years) which includes 300 questions, (sensitivity 80%, specificity 70%) and (2) the Infant Developmental Inventory (birth–18 months) which includes 60 questions (sensitivity 85%, specificity 77%) [2,19]. Ku et al [20] developed new normative data for the CCDI in 2007 based on a sample of children in Southern Taiwan, and concluded that children had better performance in the EL, CC, SC, SH, and GD, and poorer performance in the PS than previously reported. In other words, the sensitivity might be higher and the specificity might be lower according to new normative data (higher cutoff point for delay) for the EL, CC, SC, SH, and GD subscales. On the contrary, a lower cutoff point based on new norms might lead to lower sensitivity and higher specificity for the PS. However, the new norms constructed by Ku et al [20] are limited for use in clinical screening. Although they proposed normalized standardized scores for each subscale, there is still a lack of screening criteria that identify children at risk, and so far, there has been no validity study related to a normalized score. To increase the sensitivity and specificity of the CCDI, we strongly suggest that new normative data be developed for the CCDI and that the criteria-related validity be evaluated for clinical usage.

The CCDI used by the clinicians was designed for screening rather than diagnostic purposes. With comprehensible wording for each behavioral item, the CCDI can easily be completed by the parents or main caregivers of children. In conclusion, our findings suggest that the CCDI is a valid and useful screening instrument for children at risk of developmental disorders. The EL subscale is not a satisfactory predictor of language delay. The EL and PS subscales are good for screening children at risk of ASD. The EL, CC, and SC subscales have high validity when identifying children with developmental disorder. It is essential to refer those with positive results on screening to a group of specialists in child development for comprehensive diagnostic assessment.

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