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Comparison between Ages & Stages Questionnaire and Bayley Scales, to predict cognitive delay in school age☆

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A B S T R A C T

Objective: To compare the predictive value of the Spanish Ages & Stages Questionnaire third edition adapted for Chilean population (ASQ-Cl) and the Bayley Scale of Infant and Toddler Development 3rd edition (Bayley-III) for cognitive delay at school age, and to identify the domain predictors.
Methodology: Data were collected from 306 term and preterm children of medium-high socio-economic level enrolled in a prospective cohort study. Developmental outcomes at 8, 18 and 30 months were assessed via the ASQ-Cl and Bayley-III; at 6–8 years cognitive development was assessed using the Wechsler Intelligence Scale for Children (WISC-III). The area under the curve (AUC), sensitivity, specificity and predictive values were calculated, and logistic regression analysis was used.
Results: Of 227 children studied, 6.6% had cognitive delay. ASQ-Cl and Bayley-III generate equivalent AUC [0.77 and 0.80]. Sensitivity 67% and 53%; specificity of 72% and 88%, positive predictive value of 14% and 24%, negative predictive values of 97% and 96% respectively. Greater predictive validity was obtained at 30 months assessment. Deficit in the communication and gross motor skills and problem-solving domains of the ASQ-Cl and all the Bayley-III domains were significantly associated with cognitive delay.
Conclusions: ASQ-Cl can be used to identify children at risk for cognitive delay at 6–8 years of age, being comparable with the Bayley-III. Some domains of ASQ-Cl and all domains of Bayley-III were significant predictors for cognitive delay. These results support the use of ASQ-Cl as a screening tool for developmental delay.

1. Introduction

Early detection and intervention for children with developmental delays (DD) is recognized as an essential part of health care to optimize outcomes for children and families [1,2].

To ensure the identification of children at risk of DD (children not developing adequately and/or acquiring skills in the expected time frame), the American Academy of Pediatrics (AAP) recommends the application of standardized developmental screening tests at 9, 18, and 30 month follow-up visits, using standardized, valid and reliable tools [3]. The Public Health System recommendations in Chile are similar [4]. When developmental screening identifies a child as being at high risk of DD, a diagnostic developmental evaluation should be pursued [3].

The use of parent-completed screening test, such as the Ages and Stages Questionnaire (ASQ), has increased in recent years in the USA [5,6]. The ASQ was updated in 2009, as ASQ-3 [7]. This questionnaire has been validated in several countries with promising results [8–11]. The Bayley Scale of Child Development (Bayley) has been considered the gold standard as a developmental assessment tool, both clinically and in research [12]. Studies that analyze the concurrent validity of ASQ and Bayley have shown high specificity but variable sensitivity

Abbreviations: ASQ, Ages & Stages Questionnaire; ASQ-3, Ages & Stages Questionnaire third edition; ASQ-Cl, Ages & Stages Questionnaire third edition translated to Spanish and adapted for Chilean population; Bayley, Bayley Scale of Child Development; Bayley-III, Bayley Scales of Infant and Toddler Development 3rd edition; WISC-III, Wechsler Intelligence Scale for Children; AUC, area under the curve; ROC, receiver operating characteristic; DD, developmental delays; AAP, American Academy of Pediatrics; OR, odds ratio

☆ Research Ethics Board of Clinical Alemana and Universidad del Desarrollo approved the study.

What's known on this subject

Studies have shown adequate concurrent validity between Ages & Stages Questionnaire and the Bayley Scale of Child Development; the predictive value for cognitive delay has been studied separately for both tests.

What this study adds

ASQ-Cl and Bayley-III have equivalent predictive validity for cognitive delay at the age of 6–8 years. Communication, gross motor skills and problem solving of the ASQ-Cl and all the domains of the Bayley-III scale are significantly associated with cognitive delay.

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values [13–16]. According to the AAP, sensitivity and specificity levels of 70% to 80% have been considered acceptable for developmental screening tests [3]. These values are lower than those commonly used in other screening tests, due to the challenges implicit in the developmental assessment and the absence of clearly defined therapies.

The ASQ-3 was validated in Chile, in a representative sample of children from different socioeconomic strata, showing that the psychometric properties make it appropriate for its application in this cultural setting (ASQ-Cl) [17].

In a subsample of healthy children of different gestational ages, from a medium high socioeconomic setting, the concurrent validity of the assessment at 8, 18 and 30 months of the ASQ-Cl was evaluated, using the Bayley Scales of Infant and Toddler Development 3th edition (Bayley-III) as the reference standard; the sensitivity and specificity were 73% and 81% respectively [18]. In a preliminary analysis of 123 children ASQ-Cl was found highly predictive for the lowest cognitive coefficient during the first years of school education, but cognitive delay was not analyzed in this sample [19], nor comparisons were made with the predictive capacity of Bayley. Studies have analyzed the predictive value for cognitive delay of ASQ and Bayley of ASQ separately describing adequate values of sensitivity and specificity for cognitive delay, but with shorter of follow-up periods [20,21] or in high risk groups, as the extremely preterm born children [22,23]. No published study has yet compared ASQ with Bayley for predicting long term cognitive delay.

The aim of the present study is to compare the predictive value of the 8, 18 and 30-month assessment with ASQ-Cl and Bayley-III for cognitive delay at age 6–8 years, and to identify the domain predictors.

2. Methods

2.1. Study population

A convenience sample of 306 children who attended a pediatric ambulatory clinic in Santiago, Chile, was recruited from April 2008 to April 2011. The sample comprised term and preterm infants from families of medium-high socio-economic level and 95% of the mothers had > 13 years of scholar education. The sample was evaluated at 8, 18 months (corrected gestational age for preterm), and at 30 months. ASQ-Cl and Bayley-III test were applied concurrently.

Each child was evaluated only at one point in time with both tests. The specifications of the original cohort and the application of the ASQ-Cl and Bayley-III tests in the studied cohort are previously published [18].

Subsequently, every mother was contacted by the research team when their children were between 6 and 8 years of age, for an evaluation with the Wechsler Intelligence Scale for Children (WISC-III). Children with a history of intercurrent disease that could affect development, such as meningitis, central nervous system tumor pathology, severe cranial trauma; and children who were > 9 years old at the time of recruitment were excluded.

In our hospital, premature infants < 32 weeks or < 1500 g at birth, had access to early intervention as a part of the follow-up program. At the time of the study this was not available for moderate and late preterm born children.

2.2. Instruments

The Ages and Stages Questionnaire Third Edition translated to Spanish and adapted for Chilean population (ASQ-Cl) [7,17]: is an instrument in which parents rate their child's current skills and development, from 1 to 66 months of age. In this test twenty-one questionnaires are available but only the 8, 18 and 30 months have been validated for the local population in Chile [17,18]. Parents answer 30 questions covering 5 domains of development, including communication, gross motor, fine motor, problem-solving, and socio-emotional skills. Infants were two standard deviations below the mean in any domain have positive screen and were considered in referral zone, or at risk of DD [7]. Parents completed the ASQ-Cl before de Bayley III assessment.

The Bayley Scale of Infant and Toddler Development 3rd edition (Bayley III) [12]: is a comprehensive developmental assessment, for children ages 1 to 42 months. Three subscales were administered (cognitive, language, and motor) by an accredited occupational therapist, who was blinded to the ASQ results. A child was considered to have a positive screen if the score is below 80 points in at least one domain (equivalent to < −2 SD for the study sample).

The Wechsler Intelligence Scale for Children, Third Edition (WISC-III) [24]: is an instrument that evaluates the intellectual capacity of children from 6 to 17 years. The instrument uses 13 sub-tests, of which 6 are verbal and 7 manual and is reported in performance intellectual quotient and verbal intellectual quotient scores. The WISC-III was applied by a group of trained psychologists and blinded to the child's clinical and developmental history, gestational age, and the results previously obtained in the ASQ-Cl and the Bayley-III scale. A score of < 85 points (equivalent to < −1.5 SD) in verbal and/or performance scales was defined as cognitive delay according to the Chilean validation [25], Parents were informed of the results.

Children unable to complete the test because of severe developmental difficulties were considered as having a cognitive delay (or true positives for the analysis).

All three tests were applied and scored independently in every child and unaware of the results from other tests. Additionally, the researchers interpreted the results of each test independently and unaware of other scores.

Written informed consent was obtained. Research Ethics Board of Clinical Alemana and Universidad del Desarrollo approved the study.

2.3. Statistical analysis

Descriptive analysis was done using chi-square and *t*-test for categorical and continuous variables respectively.

Receiver operating characteristic (ROC) and area under the curve (AUC) were calculated for ASQ-Cl and Bayley-III total scores, using as reference cognitive delay.

The analyses were done for the total group and segmented according to the age of application of the tests (8, 18 and 30 months). Bayley-III and ASQ-Cl AUC were compared using the method described by DeLong [26]. Although an absolute standard for the interpretation of AUC does not exist, it is considered that values of 0.5 indicate a random result; between 0.6 and 0.7 are acceptable; between 0.7 and 0.9 are good and > 0.9 are excellent [27]. Sensitivity, specificity, positive and negative predictive values were calculated.

Logistic regression analysis was used to test the significance of deficit in each domain, to predict cognitive delay. All the analyses were performed on the R platform, using the pROC module [28,29].

3. Results

Loss to follow-up rate in this study was 25.2% (Fig. 1). Differences between included and not included children are shown in Table 1. Included population had a lower gestational age, a higher percentage of males and twins, and a trend towards lower scores in ASQ-Cl and Bayley-III scale (not reaching statistical significance).

Analyses were conducted on 227 children assessed at 6–8 years of age. Of all the evaluations with ASQ-Cl and Bayley-III scale, 85 were performed at 8 months, 75 at 18 months and 67 evaluations were done at 30 months of age. Table 2 shows no differences in biodemographic characteristics between the children evaluated at 8, 18 and 30 months.

Of the 227 children, 221 were evaluated with WISC-III. Because of severe deficits in their development, 6 cases could not be evaluated and were therefore considered positive for the analysis reaching a total of

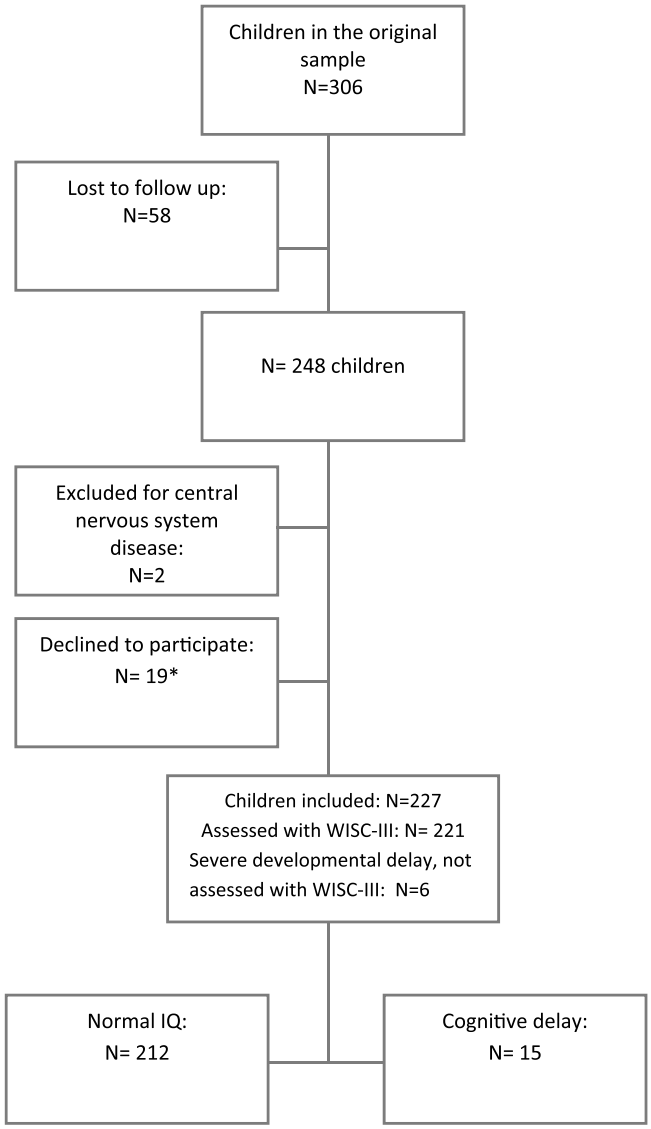

Fig. 1. Recruitment flowchart of eligible children in the study population.
* The parents of 4 children who declined to participate declared being already intervened for school performance difficulties.

Table 1
Biodemographic data. Comparison between included and non-included children.

		Included	Non-included	P[a]
		227	79	
Age of assessment[b]; n (%)	8	85 (37)	25 (32)	0.468
	18	75 (33)	25 (32)	
	30	67 (30)	29 (37)	
Male gender	n (%)	128 (56)	33 (42)	**0.025**[c]
Twin birth	n (%)	84 (37)	16 (20)	**0.006**[c]
Gestational age (weeks)	M (SD)	34.5 (3.91)	36.34 (3.68)	**0.000**[c]
ASQ-Cl total score	M (SD)	232.49 (37.62)	241.58 (39.95)	0.070
Bayley-III total score	M (SD)	297.55 (29.31)	302.73 (29.72)	0.178

ASQ-Cl = Ages and Stages Questionnaire Third Edition translated to Spanish and adapted for Chilean population; Bayley Scales of Infant and Toddler Development 3rd edition.
n = number of children included; M = media; SD = standard deviation.
[a] Chi-square for categorical data and *t*-student for continues variables.
[b] Corrected age at 8 and 18 months for preterm born children.
[c] $p > 0.05$

15 children with cognitive delay (6.6%) (Fig. 1).

Fig. 2 shows the predictive accuracy of the ASQ-Cl and Bayley-III for cognitive delay. Both tests generate good and equivalent AUC 0.77 [IC95% 0.65–0.89] and 0.80 [CI 95% 0.68–0.93] ($p = 0.580$) (Fig. 2). Considering at least one domain in the risk zone, the sensitivity was 67% for ASQ-Cl and 53% for Bayley-III, while the specificity was 72% and 88% respectively; positive predictive value of 14% and 24%, negative predictive values of 97% and 96% respectively (Table 3).

No significant differences were found, when comparing the 3 evaluation points in the AUC when comparing ASQ-Cl and Bayley-III, observing a greater AUC in the evaluation done at 30 months (Fig. 3).

Univariate analysis was done considering results at all evaluation time points for the sample as predictors for cognitive delay; having at least positive screen in any ASQ-Cl domain represented an odds ratio of 5.07 [CI 95% 1.73–16.84], $p = 0.004$ while for the Bayley-III test the odds ratio was 8.18 [CI 95% 2.74–24.42] $p < 0.001$. In ASQ-Cl the analysis by domain showed that having a risk zone performance in communication, gross motor skills and problem-solving domains, were significantly associated with cognitive delay. The deficit in any domain of the Bayley-III scale, showed significance for cognitive delay (Table 4).

4. Discussion

In the present study we found that both ASQ-Cl and Bayley-III tests were good predictors of cognitive delay, without significant differences between them (AUC 0.77 and 0.80 respectively). These results could be expected given the good correlation and concurrent validity between the two tests previously reported [18]. A recent systematic review, showed that parent-report screening tools for language, achieved higher sensitivity, specificity and negative predictive values than direct child assessment [30]. Another advantage of using parent-report screening tools such as ASQ is its low cost, and the fact that they do not require trained personnel for their application. It also empowers and involves the parents in the neurodevelopment of their children [31,32].

We found modest sensitivity values for ASQ-Cl and Bayley-III (67% and 53%, respectively), adequate specificity (72 and 88%, respectively), low positive predictive values (14% and 24%) and excellent negative predictive values (97% and 96%). These results are comparable with previous studies [20,21]. However, we must highlight the longer follow-up period in the present cohort. It is known that the time span between testing and end point measurement, may influence its predictive capacity [33]. Charkaluk et al. studied the predictive value of the 36-month ASQ assessment for cognitive delay at age 5 to 6 years in the general population, reporting sensitivity values of 77% and a specificity of 68% [20]. Kerstjens et al. reported sensitivity and specificity of 89 and 80%, respectively, to predict the need for special education within 1 year of follow-up, in children evaluated at 4 years with ASQ from Netherland's general population [10]. Halbwachs et al. analyzed the predictive capacity of ASQ at 18, 24, or 36 months for severe learning difficulties at 5 years of age in a sample of preterm children, obtaining AUC between 0.66 and 0.77 [21].

In the analysis by age of assessment, we found good predictive capacity in all ages in which the ASQ-Cl and Bayley-III were applied, being greater at 30 months, which coincides with the study by Halbwachs et al. with ASQ and Doyle LW et al. with the Bayley scale [21] [22]. There are currently no published studies that compare both tests.

In our study the domains that best predicted cognitive delay were communication, gross motor and problem-solving skills of ASQ-Cl. All the Bayley-III domains predicted accurately the cognitive delay. In a cohort of children with low risk in which the trajectory of development with ASQ was evaluated in 11 intervals between 4 months and 4 years and then the intellectual quotient was measured between 6 and 11 years, Piek et al. demonstrated a relationship between early motor development and later cognitive function [34]. While in the study of

Table 2
Demographic characteristics of the study sample according to age of assessment.

		8 months[b] $N = 85$	18 months[b] $N = 75$	30 months $N = 67$	p[a]
Gestational age group; n (%)[b]	At term born $> 37^0$	32 (38)	28 (37)	18 (27)	NS
	Moderately and late preterm 32^0–36^{+6}	33 (39)	32 (43)	31 (46)	
	Extremely preterm $< 32^0$ and/or < 1500 g	20 (24)	15 (20)	18 (27)	
Birth weight	M (SD)	2820.81 (891.56)	2529.17 (832.48)	2557.05 (869.68)	NS
Male gender	n (%)	54 (64)	43 (57)	31 (46)	NS
Twin birth	n (%)	25 (29)	26 (35)	33 (49)	NS
Hospitalized newborn period	n (%)	44 (52)	39 (52)	42 (63)	NS
Mother age at delivery	M (SD)	31 (5)	32 (4)	32 (4)	NS
Mothers with > 13 years of scholar education	n (%)	81 (95)	72 (96)	65 (97)	NS

ASQ-Cl = Ages and Stages Questionnaire Third Edition translated to Spanish and adapted for Chilean population; Bayley Scales of Infant and Toddler Development 3rd edition.
n = number of children included; M = media; SD = standard deviation; NS = not significant.
[a] Chi-square for categorical data and ANOVA for continues variables.
[b] Corrected age at 8 and 18 months for children born before term.

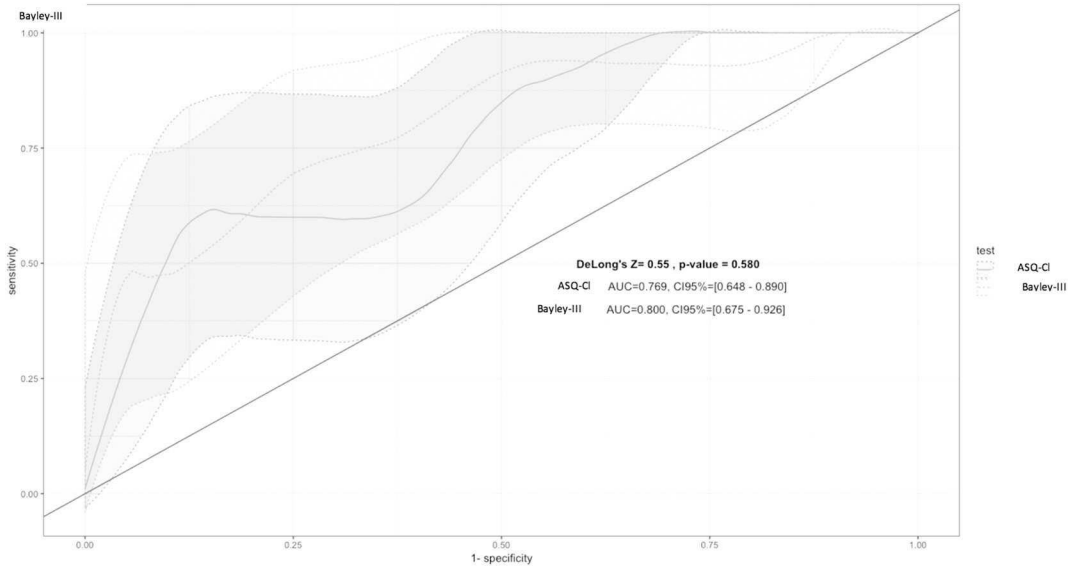

Fig. 2. Comparison of the ASQ-Cl and Bayley-III ROC curves for predicting cognitive delay.

Table 3
Comparison of psychometric properties of the ASQ-Cl and the Bayley-III for predicting cognitive delay.

	ASQ-Cl[a]	Bayley-III[b]
Sensitivity	67 (39–87)	53 (27–78)
Specificity	72 (65–78)	88 (82–92)
Positive predictive value	14 (7–25)	24 (11–42)
Negative predictive value	97 (92–99)	96 (92–98)

ASQ-Cl = The Ages and Stages Questionnaire Third Edition translated to Spanish and adapted for Chilean population; Bayley III = Bayley Scales of Infant and Toddler Development 3rd edition.
[a] Children that scored two standard deviations below the mean in any domain were considered as a positive screen.
[b] Children that scored below 80 points in at least one domain were considered to have a positive screen.

Peyre et al. early language skills more strongly predict later intellectual quotient disabled children at 5–6 years old [35]. In a meta-analysis that considered studies performed in children born extremely premature, Luttikhuizen dos Santos et al. described that mental developmental index scores in Bayley were strongly predictive for poor cognitive performance [23].

When studying the predictive capacity of questionnaires, it is important to consider that prediction is difficult because of numerous factors that can modify the natural history of children's development, which include: rapid developmental change, biologic or environmental variables, developmental interventions, and the fact that testing itself has an impact on the developmental trajectory [33,36,37]. The enriched environment and access to early interventions could have improved the outcome in our studied cohort, explaining in part the low positive predictive value.

One of the limitations of our study is that we only measure cognitive development without evaluating other aspects such as motor or socio-emotional performance, aspects that escaped the objectives of this study. On the other hand, we could not analyze in depth the intensity of the interventions received by children and their impact on subsequent cognitive performance. The small number of children with deficit probably diminishes the power of our results, and the external validity is limited as the participants were from medium to high socioeconomic level in Chile.

Due to the mentioned limitations we should probably consider these results as preliminary. Nevertheless, our study, with high adherence rate and long follow-up period, shows promising evidence suggesting a strong predictive validity of a parent-completed screening test with a professionally administered cognitive test for cognitive delay at early

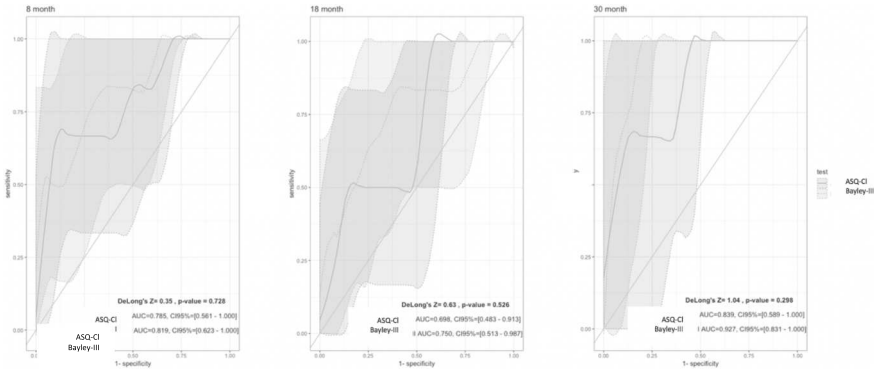

Fig. 3. Comparison of psychometric properties of ASQ-CI and Bayley-III for predicting cognitive delay according to age of assessment.

Table 4
Univariate analysis of the different developmental domains for predicting cognitive delay in the total sample (n = 227 children).

Predictor	OR	95% CI	p
ASQ-Cl *positive screen*[a]			
Communication	9.42	2.82; 30.22	< 0.001
Gross motor	5.22	1.63; 15.81	0.003
Fine motor	2.35	0.34; 9.79	0.291
Problem solving	4.17	1.07; 13.75	0.024
Social-personal	0.58	0.03; 3.13	0.615
At least one domain at risk zone	5.07	1.73; 16.84	0.004
Bayley-III Scales*delay*[b]			
Cognitive	26.25	4.00; 172.27	< 0.001
Language	7.65	2.28; 25.700	0.001
Motor	6.12	1.87; 20.10	0.003
At least one domain at risk zone	8.18	2.74; 24.42	< 0.001

[a] Domain at risk zone was defined as a performance under the cutoff point (> −2DS) in The Ages and Stages Questionnaire Third Edition translated to Spanish and adapted for Chilean population (ASQ-Cl).

[b] Delay was defined as a performance under < 80 points in the Bayley Scales of Infant and Toddler Development 3rd edition (Bayley-III).

school age (6 to 8 years). Additional studies with a more heterogeneous and diverse group of children and families are needed to confirm these results.

5. Conclusions

Our results suggest that, the 8, 18 and 30-month ASQ-Cl assessment, could be used to identify children at risk of cognitive delay at 6 to 8 years of age, being comparable with the Bayley-III scale, traditionally considered as the gold standard for developmental assessment. The elevated negative predictive value indicates that if a child has a normal evaluation early in life, there is a high probability of not having cognitive difficulties in early school age. On the other hand, a low positive predictive value suggests that even a child with an early evaluation showing deficit, still has the possibility of an adequate cognitive development later in life in the adequate enriched environment. It is probably important to continue to monitor cognitive development throughout childhood with special attention to those children with positive screen in communication, gross motor and problem-solving domains in the ASQ, and any delay in the Bayley Scale.

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Declaration of competing interest

The authors have indicated they have no potential conflicts of interest to disclose.

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