Predictors of Poor School Readiness in Children Without Developmental Delay at Age 2

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abstract

BACKGROUND AND OBJECTIVES: Current recommendations emphasize developmental screening and surveillance to identify developmental delays (DDs) for referral to early intervention (EI) services. Many young children without DDs, however, are at high risk for poor developmental and behavioral outcomes by school entry but are ineligible for EI. We developed models for 2-year-olds without DD that predict, at kindergarten entry, poor academic performance and high problem behaviors.

METHODS: Data from the Early Childhood Longitudinal Study, Birth Cohort (ECLS-B), were used for this study. The analytic sample excluded children likely eligible for EI because of DDs or very low birth weight. Dependent variables included low academic scores and high problem behaviors at the kindergarten wave. Regression models were developed by using candidate predictors feasibly obtainable during typical 2-year well-child visits. Models were cross-validated internally on randomly selected subsamples.

RESULTS: Approximately 24% of all 2-year-old children were ineligible for EI at 2 years of age but still had poor academic or behavioral outcomes at school entry. Prediction models each contain 9 variables, almost entirely parental, social, or economic. Four variables were associated with both academic and behavioral risk: parental education below bachelor's degree, little/no shared reading at home, food insecurity, and fair/poor parental health. Areas under the receiver-operating characteristic curve were 0.76 for academic risk and 0.71 for behavioral risk. Adding the mental scale score from the Bayley Short Form–Research Edition did not improve areas under the receiver-operating characteristic curve for either model.

CONCLUSIONS: Among children ineligible for EI services, a small set of clinically available variables at age 2 years predicted academic and behavioral outcomes at school entry.

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Dr Nelson conceptualized the study design, supervised the data analyses and interpretation, and drafted the manuscript and revisions; Drs Dudovitz, Coker, Barnert, and Szilagyi assisted with study design, interpretation of data analyses, and revision of the manuscript; Mr Biely and Dr Li conducted the data analyses and assisted with interpretation of results and drafting of the manuscript; Drs Larson, Halfon, and Zimmerman provided expert consultation on study design, data analysis and interpretation, and manuscript revision; and Dr Chung supervised all aspects of

WHAT'S KNOWN ON THIS SUBJECT: Although current clinical recommendations support developmental screening and surveillance as the primary methods of detecting early developmental and behavioral concerns, developmental status alone may not accurately predict poor academic or behavioral readiness at school entry.

WHAT THIS STUDY ADDS: Among 2-year-old children likely ineligible for early intervention services, poor school readiness may be better predicted with a discrete set of clinically available variables, including family-level sociodemographic factors, than through developmental assessment alone.

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The American Academy of Pediatrics (AAP) recommends that primary care clinicians conduct universal surveillance and screening for early childhood developmental and behavioral problems.[1,2] These recommendations are based on decades of research that demonstrate improved developmental, academic, and social outcomes from a wide range of early intervention services.[3–5] The Individuals with Disabilities Education Act requires states to provide intervention services for children with developmental disabilities, through Part C early intervention (EI) for children 0 to 36 months and Part B special education for children aged ≥3 years.[6] Eligibility criteria for EI services vary according to state but typically include demonstrated developmental delays and established risk conditions such as very low birth weight or specific genetic anomalies.[7,8] Children not eligible for EI may or may not receive other support services, depending on local availability and provider practices, and some children without delays may receive EI services.[8,9] Furthermore, there is evidence that many children with delays improve over time,[10] even without intervention,[11] suggesting that better methods are needed to identify which children need services.

Although eligibility for EI is usually based on the presence of developmental delays and disabilities, long-term developmental-behavioral and educational outcomes are strongly associated with socioeconomic factors.[12–15] Previous investigators have argued for: (1) revising the AAP developmental-behavioral surveillance and screening recommendations in children from birth to 5 years[16]; and (2) reforming the entire US EI and learning system[17] to better account for psychosocial factors. One recently introduced developmental surveillance tool, the Survey of Well-Being of Young Children,[18–20] includes assessments of potentially modifiable family risk factors such as food insecurity,[21] domestic violence,[22] tobacco[23] and other substance use,[24] and parental depression.[25] In addition, the AAP's Bright Futures guidelines[26] include recommended assessment of family psychosocial risks, and a recent AAP clinical report advocated for expanding mental health and behavioral screening in well-child care.[27] However, the specific combination of risks associated with developmental-behavioral outcomes is not clearly delineated in any practice guidelines. Meanwhile, the predictive validity of direct developmental assessment of young children using even gold standard assessment tools, much less screening instruments, has been shown to be suboptimal (positive predictive values of 37% for the Bayley Scales of Infant Development–Second Edition and 34% for the Ages and Stages Questionnaires).[28,29] Therefore, it is unclear whether, under current guidelines and recommended practices, many of the children most at risk for poor long-term developmental-behavioral trajectories are targeted to receive any support at all.

The number of 2-year-old children ineligible for Part C EI services who will have poor developmental-behavioral outcomes at kindergarten entry may be even larger than the number of equivalent Part C–eligible children.[30–32] Predicting which of these children are on such a downward trajectory likely requires assessment of family psycho-social variables. Previous studies have demonstrated steep socioeconomic gradients in cognitive outcomes at school entry[33] and have highlighted strong effects of social variables, such as maternal education, on the persistence or improvement of early developmental delays.[10] Other studies have reported associations of cognitive and social functioning at kindergarten entry with longer term academic[13,34–37] and health outcomes,[38] suggesting that poor school readiness may be linked to serious downstream consequences such as school failure, disease, and even mortality.[39–41]

The present study developed and validated risk prediction models for poor developmental-behavioral outcomes among children usually deemed ineligible for EI services.

METHODS

Data Source

The Early Childhood Longitudinal Study, Birth Cohort (ECLS-B), is a nationally representative sample of children born in the United States in 2001 and followed up longitudinally through kindergarten entry in 2006 through 2008.[42] Data were collected from birth certificates and then parent and guardian interviews, direct child assessment, and reports from child care providers and teachers when children were ∼9 months, 24 months, 4 years, and 5 to 6 years old (kindergarten entry). Children with low birth weight were oversampled. Approximately 14 000 births were sampled for the study and yielded 10 700 cases in the first wave, for a response rate of 76%. Response rates in subsequent waves were 91% to 93%. There was a planned 15% reduction in the sample before the kindergarten entry waves; 6900 children in the kindergarten entry waves completed direct assessments. Statistical analyses (with Stata version 12 [Stata Corp, College Station, TX]) used survey sampling weights as recommended in the ECLS-B manuals. This study was approved by the University of California, Los Angeles, institutional review board; investigators were licensed to use the restricted-use ECLS-B data.

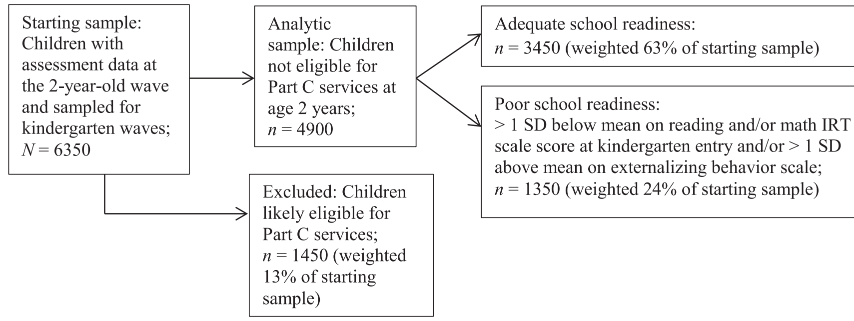

FIGURE 1

Description of analytic sample and primary outcomes. Unweighted sample sizes are rounded to the nearest 50, as required by the National Center for Education Statistics, and subsamples may not add up perfectly due to rounding as well as missing data in the kindergarten waves. Weighted proportions differ from the values obtained calculating the unweighted samples due to oversampling of children with low birth weight. IRT, item response theory. [medium]

Analytic Sample

We examined records from all 6350 children with assessment data available at the 2-year wave and sampling weights in the kindergarten waves (Fig 1). Developmental delays at the 2-year wave were determined by direct child assessment by using the Bayley Short Form–Research Edition (BSF-R), mental and motor scales, adapted from the Bayley Scales of Infant Development–Second Edition.[43] We assumed developmental delay if either the BSF-R mental or motor scale score was ≥1.5 SDs below the mean or if both mental and motor scores were ≥1 SD below the mean.[7,32] Consistent with eligibility requirements for most states from the Individuals with Disabilities Education Act, Part C,[7] children were excluded if they were likely to be eligible for EI services at age 2 years, based on either: (1) very low birth weight (<1500 g); or (2) developmental delays. This subset of excluded subjects comprised 1450 children due to presumed Part C eligibility (13% of the total weighted sample), leaving an analytic sample of 4900 children for model building and validation.

Outcomes

We sought to understand which risk and protective factors among 2-year-old children likely ineligible for EI services predict low academic scores and high problem behaviors at kindergarten entry. Academic scores were assessed in the ECLS-B kindergarten waves by using direct measures of early literacy (basic language and literacy skills, vocabulary, understanding, and interpretation) and mathematics (number sense, counting, operations, geometry, and pattern understanding), adapted from validated tools (Peabody Picture Vocabulary Test and PreLAS 2000) for use in the Early Childhood Longitudinal Survey, Kindergarten Cohort (ECLS-K). These measures are described in detail elsewhere[33,42] and have been associated with early school function.[34] Poor academic school readiness was defined as an item response theory score ≥1 SD below the mean on early reading or mathematics tests. This cutoff represents a middle ground between previous studies that have shown worse school function among children with a range of cognitive scores, from the bottom quartile (0.67 SD below the mean) on these same assessments to an IQ ≤75 (~1.7 SD below the mean).[44]

Problem behaviors were reported by parents at the kindergarten waves by using 8 items taken from the Preschool and Kindergarten Behavior Scale (PKBS) externalizing subscale,[45] including behaviors such as aggression, impulsivity, and hyperactivity. The ECLS-B items from the PKBS externalizing subscale have previously shown better internal consistency than other PKBS items used in the ECLS-B,[46] and externalizing behaviors are highly predictive of poor academic outcomes.[44,47–49] Children were considered to have poor behavioral school readiness when they scored >1 SD above the mean on the externalizing behaviors scale (higher scores representing worse problem behaviors). This assessment was based on ECLS-K analyses showing worse school function among children with socio-emotional risks, defined as >1 SD below the mean on measures of socioemotional development.[34]

Predictors

We considered a wide range of variables as candidate predictors, based on previous studies. Measures were prioritized that could be feasibly obtained during a typical 2-year well-child visit through parent report or administrative data. Child-level variables included sex,[15,34,47] race/ethnicity,[34,50–52] gestational age (<34, 34–36 weeks, and ≥37 weeks),[15,47,53,54] low birth weight (<2500 g),[10,34,47] parent-reported child health status,[50] breastfeeding history (0–3 months or ≥4 months),[55] enrollment in Medicaid,[56,57] enrollment in the Supplemental Nutrition Program for Women, Infants, and Children,[56–58] participation in a center-based child care program,[59] whether the child combines words at age 2 years,[60] and parent's expectation for the child's educational attainment.[33,59] Family-level variables included mother's age,[49] highest level of parental education,[10,33,49] household income and poverty status,[10,33,49,50,56,61] whether both parents live with the child,[34,49,62] primary language spoken at home (English or other language),[51,52] whether parent is a US citizen,[63] self-reported parental health status,[50] family history of learning disability,[64] household food insecurity (based on 6 US Department of Agriculture survey items),[65,66] history of parental depression,[67,68] current parental smoking,[46,49,69] and frequency of shared reading with the child.[15,33,59] Home- and neighborhood-level variables included quality of home for raising children, quality of neighborhood for raising children, and neighborhood safety (all based on parent report).[70]

Security of toddler attachment and parent supportiveness[33,71–73] were measured in the ECLS-B through direct observation. We excluded these variables, however, out of concern that they might not be feasibly and reliably obtainable during well-child visits.

Model Selection and Validation

Analyses were conducted by using the "svy" suite of commands in Stata version 12 to account for the 3 survey design elements: stratification, clustering, and weighting. Separate models were developed to predict poor school readiness based on low academic scores or high problem behaviors. Because parsimony might enhance clinical applicability, these 2 logistic regression models were built by using a forward selection process, adding variables 1 by 1, based on incremental increase in the area under the receiver-operating characteristic curve (AUC) of the overall model, with a threshold of $P < .05$ as the limit for inclusion. We also tested the AUC for the BSF-R mental scale alone and added it to each of the final models to investigate the incremental increase in AUC provided by the BSF-R score. Finally, we developed a risk index for each outcome, based on predicted probability transformed into a linear predictor and scaled to represent scores from 0 (lowest risk) to 100 (highest risk).

Both prediction models were then cross-validated internally. The analytic sample was split into 2 equal-sized, randomly selected subsamples. Cross-validation was then performed, with the prediction models fit to 1 subsample and tested on the other, and vice versa.[74] Validation statistics included the AUC, Brier score (mean squared difference between the predicted probability and the observed outcome, with 0 the best and 1 the worst),[75] and calibration slope (regression slope of the linear predictor, with optimal performance equal to 1),[76] all designed to measure the accuracy of the predictions. Validation statistics were calculated taking survey weights into account, and the average performance of the prediction models was calculated over the 2 repetitions.

RESULTS

Among the 4900 children aged 2 years in the analytic sample, 1350 demonstrated poor school readiness at the time of kindergarten entry, either due to low academic scores or high problem behaviors (Fig 1). These results indicate that nearly one-quarter of all 2-year-old children appeared ineligible for EI services but nevertheless demonstrated inadequate school readiness at kindergarten entry.

Table 1 displays the characteristics of the analytic sample, with weighted proportions of each candidate predictor considered in the risk prediction model selection process, separated into subsamples based on the outcomes of interest: adequate school readiness, poor school readiness due to low academic scores, poor school readiness due to high behavior problems, and poor school readiness based on both low academic scores and high problem behaviors. All candidate variables demonstrated statistically significant bivariate associations with the outcomes of interest. Missing data for these variables ranged from 0% to 4%.

After the forward selection process, 9 candidate predictors were retained in each of the final models predicting risk for poor school readiness due to poor academic scores (Table 2) or behavioral function (Table 3) at kindergarten entry. Four predictors are present in both models: highest level of parental education, self-reported parental health status, frequency of shared reading with child at home, and food insecurity. Predictors retained in the academic risk model also included: child not combining words at age 2 years; parental expectation of child educational attainment at less than a 4-year college degree; household income <185% of the federal poverty level; family history of learning disability; and parental rating of the quality of the house for raising children (good/fair/poor versus very good/excellent). Predictors retained in the behavioral risk model also included: child sex; single-parent household; and parental depression, smoking, and rating of neighborhood safety. The AUC for the academic model was 0.76, and the AUC for the behavior model was 0.71.

The unadjusted odds ratio of the standardized, BSF-R mental scale t score was 0.92 (95% confidence interval, 0.91–0.93) in predicting low academic scores and 0.96 (95% confidence interval, 0.95–0.97) in predicting high problem behavior. We also tested whether adding the BSF-R score at age 2 years would substantially improve the predictive ability of the models. The AUC of the BSF-R mental score alone in predicting low academic scores was 0.67, and for problem behaviors it was 0.60. Adding the BSF-R to the final risk prediction models increased the AUC of the academic risk model minimally (from 0.76 to 0.77) and did not change the AUC of the behavior risk model.

Using the aforementioned model-validation approach, the averages for the AUC, Brier score, and calibration

TABLE 1 Characteristics of 2-Year-Old Children Likely Ineligible for Part C Intervention Services

Variables Considered in Model Selection	Poor School Readiness at Kindergarten (High Problem Behaviors or Low Academic Scores) (n = 1350)			Adequate School Readiness at Kindergarten (n = 3450)
	High Problem Behaviors and Low Academic Scores (n = 200)	High Problem Behaviors (n = 650)	Low Academic Scores (n = 900)	
Child-level				
Sex				
Male	0.67	0.62	0.54	0.46
Female	0.33	0.38	0.46	0.54
Race/ethnicity				
White, non-Hispanic	0.39	0.49	0.40	0.60
African American	0.19	0.18	0.18	0.12
Hispanic or Latino	0.34	0.25	0.37	0.20
Asian	0.01	0.02	0.01	0.03
Multiracial or other	0.08	0.06	0.04	0.05
Gestational age				
<34 wk	0.01	0.02	0.03	0.02
34–36+6/7 wk	0.10	0.10	0.09	0.08
≥37 wk	0.89	0.88	0.88	0.91
Birth weight				
≥2500 g	0.91	0.93	0.93	0.95
<2500 g	0.09	0.07	0.07	0.05
Parent-reported child health status				
Excellent or very good	0.86	0.85	0.85	0.91
Good, fair, or poor	0.14	0.15	0.15	0.09
Breastfeeding				
≥4 mo	0.28	0.30	0.32	0.45
0–3 mo	0.72	0.70	0.68	0.55
Child has Medicaid	0.65	0.52	0.53	0.26
Child enrolled in WIC	0.68	0.57	0.60	0.33
Child is in center-based child care at 2 y	0.13	0.18	0.13	0.18
Child does not combine words	0.17	0.16	0.19	0.10
Parent’s expectation for child’s highest education				
4-y degree or higher	0.57	0.64	0.64	0.81
<4-y degree	0.43	0.36	0.36	0.19
Parent/family-level				
Mother’s age, mean ± SD, y	24.8 ± 5.9	25.5 ± 5.8	25.5 ± 5.9	28.0 ± 5.7
Highest level of parental education				
Bachelor’s degree or higher	0.05	0.17	0.11	0.40
Some college	0.22	0.24	0.19	0.27
High school diploma	0.44	0.42	0.42	0.25
Less than high school diploma	0.29	0.17	0.28	0.08
Household income/poverty status				
≥185% of FPL	0.25	0.39	0.31	0.64
100%–185% of FPL	0.27	0.26	0.28	0.20
<100% of FPL	0.48	0.35	0.41	0.16
Single-parent household	0.35	0.34	0.30	0.17
English is primary home language	0.79	0.84	0.74	0.85
Parent is US citizen	0.85	0.88	0.79	0.88
Self-reported health status of parent				
Good to excellent	0.77	0.84	0.84	0.95
Fair or poor	0.23	0.16	0.16	0.05
Family history of learning disability	0.32	0.22	0.21	0.13
Food insecurity	0.19	0.15	0.14	0.05
Parental depression	0.25	0.22	0.16	0.13
Parental smoking	0.42	0.34	0.26	0.16
Frequency of shared reading with child				
Every day	0.30	0.40	0.32	0.53
3–6 times/wk	0.23	0.25	0.27	0.26
1–2 times/wk	0.37	0.30	0.36	0.20
Not at all	0.10	0.05	0.05	0.02
Home/neighborhood-level				

TABLE 1 Continued

Variables Considered in Model Selection	Poor School Readiness at Kindergarten (High Problem Behaviors or Low Academic Scores) (*n* = 1350)			Adequate School Readiness at Kindergarten (*n* = 3450)
	High Problem Behaviors and Low Academic Scores (*n* = 200)	High Problem Behaviors (*n* = 650)	Low Academic Scores (*n* = 900)	
Quality of house for raising children				
Excellent or very good	0.48	0.59	0.56	0.75
Good, fair, or poor	0.52	0.41	0.44	0.25
Quality of neighborhood for raising children				
Excellent or very good	0.40	0.53	0.48	0.69
Good, fair or poor	0.60	0.47	0.52	0.31
Neighborhood safety				
Very or fairly safe	0.72	0.82	0.86	0.94
Fairly or very unsafe	0.28	0.18	0.14	0.06

For all candidate predictor variables, we present the weighted proportion of each variable in the subsample represented in each column, except for maternal age, which is presented as the mean ± SD. FPL, federal poverty level; LD, learning disability; WIC, Supplemental Nutrition Program for Women, Infants, and Children.

slope were 0.75, 0.1358, and 0.9130, respectively, for the academic model, and 0.69, 0.1034, and 0.8554 for the behavior model. These validation measures suggest that the prediction models work fairly well, although a calibration slope of <0.9 for the behavioral model indicates that predictions are widely spread (closer to 0 and 1) and that its predictive ability may vary when applied to new sets of data. Based on a sensitivity of each model set at 0.60, 0.70, and 0.80, Table 4 presents the corresponding specificity and calculated cutoff scores for the scaled risk index, along with the proportion of the population at or above that score and corresponding information for the BSF-R mental scale.

TABLE 2 Predictors at Age 2 Years for Low Academic Scores at Kindergarten Entry

Predictor	Unadjusted OR (95% CI)	Adjusted OR (95% CI)	Risk Index Weight (= β/5.3 × 100)
Child does not combine words	2.0 (1.5–2.7)	1.7 (1.2–2.3)	9.8
Parent's expectation for child's highest education is less than a 4-y degree	2.2 (1.8–2.8)	1.3 (1.0–1.7)	5.1
Highest level of parental education: (bachelor's degree or higher is reference)			
Some college	2.4 (1.8–3.4)	1.7 (1.2–2.5)	10.3
High school diploma or equivalent	5.4 (4.0–7.3)	3.1 (2.2–4.3)	21.1
Less than high school diploma	11.2 (8.0–15.8)	5.2 (3.5–7.9)	31.2
Parent health status is fair or poor	3.0 (2.3–4.0)	1.5 (1.1–2.1)	8.2
Household income is <185% of FPL	3.6 (2.9–4.4)	1.4 (1.1–1.8)	6.0
Frequency of shared reading at home (every day is reference)			
3–6 times/wk	1.7 (1.3–2.2)	1.3 (1.0–1.8)	5.4
1–2 times/wk	2.8 (2.2–3.6)	1.6 (1.2–2.1)	8.4
Not at all	4.6 (2.9–7.1)	2.1 (1.3–3.5)	14.1
Family has food insecurity	2.9 (2.1–4.1)	1.7 (1.2–2.4)	9.5
Family history of learning disability	1.6 (1.3–2.1)	1.6 (1.2–2.1)	9.2
Parent rates quality of house as good, fair, or poor for raising children	2.2 (1.8–2.7)	1.4 (1.1–1.8)	6.7

Unadjusted odds ratios (ORs) were derived from bivariate logistic regressions by using each predictor individually to calculate association with low academic scores (≥1 SD below mean on language and/or math assessment) at kindergarten. Adjusted ORs and regression coefficients were calculated by using a multivariate logistic regression that includes all of the variables listed in the table. Regression coefficients (β) were used to weight each variable to calculate the risk index, which was scaled to represent a range from 0 (lowest risk) to 100 (highest risk), using the maximum possible sum of all β values (5.3). CI, confidence interval; FPL, federal poverty level.

DISCUSSION

To the best of our knowledge, this study is the first published report to characterize, at a national level, the large population of young children who are likely ineligible for EI but who are nevertheless at high risk for poor cognitive and behavioral outcomes at kindergarten entry. This group accounts for up to one-quarter of all 2-year-old children who, under current practice guidelines, often do not receive any targeted supports unless more serious consequences occur. When combined with the ~13% of children who may be eligible for EI but often do not actually receive services,[32] the level of unmet need in the present system of care is tremendous. This study provides 2 potentially clinically feasible risk-prediction models that identify children who might benefit from timely developmental support, based on a short set of parent-report and administrative data. The models demonstrated reasonable sensitivity and specificity, with better predictive validity than developmental assessment alone, including after cross-validation on split samples of the data set.

The risk and protective factors found in the prediction models presented here have been associated with developmental outcomes in previous studies. There is a vast literature documenting the detrimental effects of poverty on child development,[10,12–15,33,34,49,50,57,59,61]

TABLE 3 Predictors at Age 2 Years for Problem Behaviors at Kindergarten Entry

Predictor	Unadjusted OR (95% CI)	Adjusted OR (95% CI)	Risk Index Weight (= β/4.9 × 100)
Male sex	1.9 (1.4–2.5)	1.8 (1.4–2.4)	12.4
Highest level of parental education (bachelor's degree or higher is reference)			
Some college	2.0 (1.5–2.7)	1.4 (1.0–1.9)	7.1
High school diploma or equivalent	3.2 (2.4–4.3)	1.9 (1.3–2.7)	12.9
Less than high school diploma	3.2 (2.3–4.5)	1.5 (1.0–2.3)	8.2
Parent health status is fair or poor	2.7 (1.9–4.0)	1.8 (1.2–2.6)	11.6
Single-parent household	2.2 (1.7–2.8)	1.5 (1.2–2.0)	8.8
Parental depression	1.9 (1.4–2.7)	1.4 (1.0–2.0)	7.5
Parental smoking	2.5 (1.9–3.1)	1.8 (1.4–2.4)	12.4
Frequency of shared reading at home (every day is reference)			
3–6 times/wk	1.2 (0.9–1.6)	0.9 (0.6–1.3)	−2.1
1–2 times/wk	1.6 (1.2–2.2)	1.1 (0.8–1.6)	2.2
Not at all	2.7 (1.6–4.6)	1.7 (1.1–2.8)	11.3
Family has food insecurity	2.6 (1.8–4.0)	1.6 (1.1–2.5)	10.0
Parent rates neighborhood as fairly or very unsafe	2.9 (2.1–4.1)	2.0 (1.4–2.8)	13.6

Unadjusted odds ratios (ORs) were derived from bivariate logistic regressions by using each predictor individually to calculate association with high externalizing behaviors (>1 SD above mean) at kindergarten. Adjusted ORs and regression coefficients were calculated by using a multivariate logistic regression that includes all of the variables listed in the table. Regression coefficients (β) were used to weight each variable to calculate the risk index, which was scaled to a range of 0 (lowest risk) to 100 (highest risk) using the maximum sum of all β values (4.9). CI, confidence interval.

but understanding the effects of additional risk and protective factors may be helpful in discriminating clinically between children likely to be resilient versus vulnerable to poor developmental outcomes. Previous ECLS-B analyses showed increased risks of cognitive delay at 9 months with higher social risk index scores (including race, poverty, low maternal education, single-parent household, and ≥3 children in the home).[77] Others have found that maternal education and frequency of shared reading, in addition to household income, were associated with early elementary academic scores.[15] Similarly, members of our research group recently found that parenting behaviors and expectations between 9 months and 3 to 4 years may mitigate the steep socioeconomic gradient seen in cognitive development at the time of kindergarten entry.[33] Other predictors in our models (child sex,[15,34,49] parental smoking,[46,69] parental depression,[67,68] family history of learning disability,[64] and food insecurity[65,66]) have also been associated with worse cognitive and/or behavioral outcomes for children in previous research. However, several predictors found in our study are novel: self-reported parental health status, parent-rated neighborhood safety, and parent-rated quality of house for raising children. Although these questions may not be currently assessed routinely, these items could be asked of parents before or during well-child visits to improve prediction of developmental-behavioral risk.

Although many clinicians focus on biological factors such as perinatal risks and low birth weight, social influences may prove more predictive of longer term developmental and academic outcomes. A recent ECLS-B study found that although late-preterm infants had worse academic scores than term infants, BSF-R scores had poor predictive validity, and maternal education, race, and family income were also associated with academic readiness.[53] In the present study, which excluded

TABLE 4 Cutoff Scores for Risk Indices at Selected Sensitivity and Specificity Values

Low Academic Scores						High Problem Behaviors					
Risk Index		Cutoff Score	Proportion Positive	BSF-R		Risk Index		Cutoff Score	Proportion Positive	BSF-R	
Sens.[a]	Spec.			Sens.[a]	Spec.	Sens.[a]	Spec.			Sens.[a]	Spec.
0.60	0.78	38	0.28	0.60	0.64	0.60	0.72	27	0.32	0.60	0.55
0.70	0.68	32	0.38	0.70	0.53	0.70	0.60	22	0.41	0.70	0.45
0.80	0.57	25	0.50	0.80	0.41	0.80	0.46	16	0.57	0.80	0.34

[a] We set sensitivity at 0.60, 0.70, and 0.80 for each model and show the corresponding specificity, cutoff score (rounded to the nearest whole number), and estimated proportion of the population screening positive, at or above each cutoff score, weighted to reflect ECLS-B sampling design. The corresponding sensitivities and specificities of the BSF-R mental scale are also shown, for comparison.

very low birth weight children and children demonstrating early developmental delays, birth weight and gestational age did not exhibit associations with developmental or behavioral outcomes. A previous ECLS-B study assessing children with developmental delay at the 2- and 4-year waves similarly showed that, although low and very low birth weight were associated with higher risk of developmental delay at age 2 years, maternal education and family income became much stronger predictors for delays in 4-year-old children and were highly predictive of persistent delays.[10] These studies, and our analyses, support the need for universal family psychosocial screening in early childhood. Our findings could improve future revisions of family psychosocial screening instruments routinely used in primary care. For example, the Survey of Well-Being of Young Children screens for parental tobacco use, food insecurity, and parental depression but not for other predictive academic and behavioral risk factors such as parental education level below bachelor's degree and little or no shared reading at home.

The present study has several limitations. We developed the models and validated them internally using the same data set, which may have resulted in over-optimized models. The sensitivity and specificity of the models we present here are not optimal as stand-alone screening instruments, although they would likely improve prediction of poor school readiness compared with the current practice of using developmental screening alone. We were also limited by the variables available in the ECLS-B, and thus created cutoffs, which may have limited applicability in practice. For example, we used a numerical definition of EI eligibility that has been used previously[32] but differs from the actual eligibility in many states, with 22 different numerical definitions currently used across the United States.[8] Because there are likely to be other developmental-behavioral variables important to school readiness, our specific choices of outcome measures (academic scores and externalizing behaviors) may not capture all of the children at risk. We limited the candidate predictors to variables that could be feasibly obtained in a typical clinical encounter, thus excluding variables that could improve predictive validity, such as direct observation of attachment security and parent–child interactions. As clinical tools evolve, and these direct clinical observations become more feasible, we should revisit these analyses and consider including those factors to create more optimal models.

Identifying children with serious developmental-behavioral risks who are ineligible for formal EI services raises the difficult but important policy and clinical question of how best to support these children to mitigate their predictable risks for poor school readiness. Given that EI services currently fail to consistently reach eligible children,[8,32] proposing that a much larger group of children at high risk now be given full access to EI seems impractical without increases in Part C funding. Although additional research is needed to better determine best policies and practices, several categories of development-supporting interventions have demonstrated effectiveness for children at high risk and are available in many communities. Interventions that typically fall outside of Part C EI services (such as high-quality early care and education programs,[4,78] evidence-based Maternal, Infant, and Early Childhood Home Visiting programs,[79] parent training programs,[80,81] and brief interventions delivered in primary care settings,[82–84] including Reach Out And Read,[85] the Video Interaction Project,[86,87] and others) might be important resources to emphasize for high-risk families and to teach pediatric trainees.[88] Finally, partnering with care coordination programs such as Help Me Grow[89] or 2-1-1[90] could help connect targeted interventions with the children and families most in need.

CONCLUSIONS

A discrete set of variables, obtained through parent report or administrative data, may predict which 2-year-old children without overt and identifiable developmental delays will have low academic scores and high problem behaviors at kindergarten entry better than common developmental assessment tools. These variables largely consist of family-level socioeconomic factors, which are not systematically considered in current developmental screening and surveillance practices but could be feasibly obtained, with several included in a recent AAP policy statement on poverty.[91] Including identification of these risk factors in clinical practice, along with recommended developmental screening and surveillance, may identify a large group of young children who have developmental-behavioral risks that could benefit from additional support.

ABBREVIATIONS

AAP: American Academy of Pediatrics
AUC: area under the receiver-operating characteristic curve
BSF-R: Bayley Short Form–Research Edition
ECLS-B: Early Childhood Longitudinal Study, Birth Cohort
EI: early intervention
PKBS: Preschool and Kindergarten Behavior Scale

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