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Five-minute Apgar score as a marker for developmental vulnerability at 5 years of age

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ABSTRACT

Objective To assess the relationship between the 5 min Apgar score and developmental vulnerability at 5 years of age.

Design Population-based retrospective cohort study.

Setting Manitoba, Canada.

Participants All children born between 1999 and 2006 at term gestation, with a documented 5 min Apgar score.

Exposure 5 min Apgar score.

Main outcome measures Childhood development at 5 years of age, expressed as vulnerability (absent vs present) on five domains of the Early Development Instrument: physical health, social competence, emotional maturity, language and cognitive development, and communication skills.

Results Of the 33 883 children in the study, most (82%) had an Apgar score of 9; 1% of children had a score <7 and 5.6% had a score of 10. Children with Apgar scores <10 had higher odds of vulnerability on the physical domain at age 5 years compared with children with a score of 10 (eg, adjusted OR (aOR) for Apgar 9=1.23, 95% CI 1.05 to 1.44). Similarly, children with Apgar scores of <10 were more vulnerable on the emotional domain (eg, aOR for Apgar 9=1.20, 95% CI 1.03 to 1.41). Nevertheless, the Apgar-based prognostic model had a poor sensitivity for physical vulnerability (19%, 95% CI 18% to 20%). Although the Apgar score-based prognostic model had reasonable calibration ability and risk-stratification accuracy for identifying developmentally vulnerable children, classification accuracy was poor.

Conclusions The risk of developmental vulnerability at 5 years of age is inversely associated with the 5 min Apgar score across its entire range, and the score can serve as a population-level indicator of developmental risk.

What is already known on this topic

- Low 5 min Apgar scores are associated with adverse short-term and long-term cognitive outcomes and developmental impairment.
- A comprehensive view of the relation between Apgar scores and the child's early developmental health has been largely overlooked in the existing literature.

What this study adds

- The 5 min Apgar score is inversely associated with a risk of developmental vulnerability in early childhood across its entire range.
- There is an increased risk of developmental vulnerability among children with an Apgar score of 9, compared with children with a score of 10.
- The Apgar score based prognostic model created reasonably acceptable categories of low and high-risk children for developing an early intervention program.

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INTRODUCTION

Introduced by Virginia Apgar in 1952, the Apgar score measures the health status of newborn children based on heart rate, respiration, colour, muscle tone and reflex irritability.[1] The Apgar score at birth and 1 min after birth was initially developed to assess the immediate condition of the newborn and the potential need for resuscitation. Subsequent studies have demonstrated the 5 min Apgar score's ability to predict longer-term cognitive outcomes such as a reduced IQ, a lower numeracy and literacy score,[2] neurological disability and low cognitive function at age 19 years.[3] In school-age children, low Apgar scores have been linked to minor motor, language, speech and developmental impairments.[4–6]

Most follow-up studies examining the long-term prognostic value of the Apgar score on child outcomes have focused on the association between extremely low 5 min Apgar scores, such as those linked to severe birth asphyxia, and distinct neurocognitive profiles such as IQ and academic ability. Virtually, no prior study has examined the developmental correlates of the Apgar score as a continuous variable, across the entire spectrum of recorded scores.[2 7 8] In addition, there are no studies that have assessed the prognostic performance of the 5 min Apgar score for identifying developmental vulnerability among school-age children. A programme of early diagnosis could identify high-risk children who would potentially benefit from interventions designed to mitigate the developmental problems at school-going age. We, therefore, carried out a population-based study to comprehensively examine the relationship between the 5 min Apgar score and developmental vulnerability at 5 years of age.

METHODS

Study design

All children born in Manitoba, Canada, between 1 January 1999 and 31 December 2006, with a gestational age of 37 weeks or greater and a

documented 5 min Apgar score, as well as a completed Early Development Instrument (EDI) assessment at age 5 years between 2005 and 2011, were included in the study cohort. Data were obtained from the Manitoba Population Health Research Data Repository, which collates information on health and social services utilisation for all residents of Manitoba.[9] Two data sources were used to determine the socioeconomic status (SES) of children in the study: the provincial Employment and Income Assistance data (identifying those requiring social assistance or income supplementation) and Census data (providing mean household income by area of residence). Finally, EDI[10] data, which provided information on early childhood developmental outcomes and school readiness, were accessed through linkage with the Healthy Child Manitoba Office. All data files used in this study were anonymised, and linkage at the individual level was performed using a scrambled personal health identification number. The reliability and validity of these data sources have been previously documented.[11 12]

Prognostic variables and outcomes

The primary prognostic variable of interest was the routinely collected 5 min Apgar score (hereafter referred to as the 'Apgar score') from the hospital record. Apgar scores were analysed in several ways: (a) using conventional categories: Apgar values of 0–6, 7, 8 and 9–10; (b) revised categories: Apgar values of 0–3, 4, 5, 6, 7, 8, 9 and 10 (values from 0 to 3 were grouped together because of small numbers); (c) as a continuous variable and (d) as a continuous variable with a quadratic term to evaluate the potential for a non-linear relationship with developmental outcomes.

Other independent variables included in the prognostic model were infant sex (male vs female), birth weight-for-gestational age, age of the child in years at the time of EDI assessment, gestational age at birth in completed weeks (37, 38, 39, 40, 41 and ≥42), breastfeeding initiation (yes vs no) and SES. Birth weight-for-gestational age was categorised as: small (<10th percentile), appropriate (10th–90th percentile) and large (>90th percentile).[13] Each child's family income was derived from the mean household income in the child's residential area (based on postal code) obtained from the 2006 Canadian Census data.[14–16] This was complemented by parental receipt of income assistance at any time from the child's birth to the EDI assessment. Family SES was based on income quintile and receipt of income assistance, and was categorised as low (quintile 1 or income assistance recipients),[12] medium (quintiles 2 and 3) and high (quintiles 4 and 5).

The primary outcome of interest was childhood development, as measured by the EDI. The EDI was routinely administered biennially in all 37 public school divisions in Manitoba beginning in 2005/06. Teachers—remunerated by their school district—completed the EDI for each child in their kindergarten class (age range 5–7 years) midway through the school year. The EDI consists of 104 binary and Likert-scale items designed to tap five core areas of early childhood development:[10 17] physical health and well-being; social competence, emotional maturity, language and cognitive development and communication skills and general knowledge. Children were considered vulnerable on a domain if their scores fell below the 10th percentile value[18] based on the national EDI scores.[19]

Statistical analyses

The frequency of each Apgar-score value was calculated within categories of maternal and infant characteristics. Variables chosen as prognostic determinants were selected because of presumed association with developmental vulnerability based on the literature,[18 20] as well as availability in our data source. Multivariable logistic regression was used to examine the association between each independent variable and vulnerability on each domain of the EDI. Results were expressed as ORs with 95% CIs. Models were evaluated for goodness of fit using the Akaike information criterion (AIC).

In addition to modelling vulnerability on the EDI, we also assessed the performance of the prognostic model for identifying any developmental vulnerability. The model-predicted probability of vulnerability on *each* EDI domain was categorised as identifying low risk (<10%), medium risk (10%–19%) and high risk (≥20%) of an adverse developmental outcome. The model-predicted probability of vulnerability on *any* of the EDI domains was categorised as identifying low risk (<30%), medium risk (30%–44%) and high risk (≥45%) of any adverse developmental outcome. These cut-off values were chosen based on the provincial prevalence of vulnerability, since approximately 11% of children are vulnerable on an EDI domain, and 28% of children are vulnerable on one or more domains.[21] We assessed performance of the prognostic model in terms of calibration ability, stratification capacity and classification accuracy[22 23] to identify children at high risk for developmental vulnerability.

A two-sided p value <0.05 was used to define statistical significance. No adjustment was made for multiple comparisons in this exploratory study. The University of Manitoba Health Research Ethics Board sanctioned the study, and the Manitoba Health Information Privacy Committee approved data access. Analyses were performed using SAS V.9.2 (SAS Institute, Cary, North Carolina, USA).

RESULTS

There were 33 883 children (mean age=5.7 years) with a gestational age of ≥37 weeks and complete Apgar and EDI data who were included in the study. The majority (82%) of children had an Apgar score of 9, and 1% had a score <7. Only 0.2% of children had an Apgar score ≤4 (table 1). As expected, low Apgar scores were also more common among males, small-for-gestational age live births, children of mothers who did not initiate breast feeding and those with a low SES.

The prevalence of vulnerability within each of the five EDI domains by Apgar score is shown in figure 1. Overall, the prevalence of vulnerability in one or more domains of the EDI was 28%, with physical and language domains having the highest rates of vulnerability at 12% and 12%, respectively. There was a graded, decreasing trend in the rate of vulnerability on all domains of the EDI with increasing Apgar score. Vulnerability rates for the physical (23%), social (18%) and emotional (16%) domains were highest among children with an Apgar score of 5.

The prognostic model for categorising children into low (<10%), medium (10%–19%) and high risk groupings (≥20%) for vulnerability on the physical domain showed reasonable calibration ability; 7.6% and 25% of low-risk versus high-risk children were found to be vulnerable on the physical domain (table 2). Similar results were obtained with regard to calibration ability on the other EDI domains. The model also successfully stratified children into reasonably sized risk categories, with a large proportion of children classified as low or medium risk, and approximately 5%–12% of children identified as being at high risk for vulnerability in each of the five EDI domains. However, the classification accuracy of the model was poor; the model had a detection rate

Table 1 Maternal and infant characteristics in the study population by Apgar score at 5 min, Manitoba

Birth and demographic characteristics	Total		Apgar 0–4		Apgar 5		Apgar 6		Apgar 7		Apgar 8		Apgar 9		Apgar 10	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Sex of the child																
Female	16 719	49	24	0.1	36	0.2	84	0.5	283	1.7	1556	9.31	13 776	82	960	5.7
Male	17 164	51	36	0.2	45	0.3	103	0.6	326	1.9	1865	10.9	13 850	81	939	5.5
Child's age at EDI completion (years)																
Mean (SD)	33 883	0.5	60	5.7 (0.3)	81	5.6 (0.4)	187	5.6 (0.4)	609	5.7 (0.4)	3421	5.7 (0.3)	27 605	5.7 (0.7)	1899	5.7 (0.7)
Neighbourhood income (SES)																
Highest SES	17 215	51	26	0.2	38	0.2	85	0.5	316	1.8	1666	9.7	14 174	82	910	5.3
Middle SES	12 328	36	25	0.2	30	0.2	69	0.6	226	1.8	1330	11	9873	80	775	6.3
Lowest SES or income assistance	4326	13	8	0.2	13	0.3	33	0.8	67	1.5	422	9.8	3570	83	213	4.9
Gestational weeks																
37	2253	6.7	<5	<0.1	<5	<0.1	12	0.5	59	2.6	301	13	1803	80	78	3.5
38	4951	15	10	0.2	11	0.2	25	0.5	74	1.5	551	11	4008	81	272	5.5
39	7901	23	15	0.2	18	0.2	34	0.4	113	1.4	660	8.4	6638	84	423	5.4
40	13 205	39	20	0.2	30	0.2	74	0.6	250	1.9	1277	9.7	10 760	82	794	6.0
41	5167	15	12	0.2	13	0.3	38	0.7	104	2.0	581	11	4106	80	313	6.1
≥42	396	1.2	<5	<0.1	6	1.5	<5	<0.1	9	2.3	51	13	311	79	19	4.8
Birth weight for gestational age																
Appropriate	26 447	78	41	0.2	66	0.3	131	0.5	456	1.7	2582	9.8	21 659	82	1512	5.7
Small	2565	7.6	9	0.4	8	0.3	31	1.2	69	2.7	319	12	2026	79	103	4.0
Large	4871	14	10	0.2	7	0.1	25	0.5	84	1.7	520	11	3941	81	284	5.8
Breastfeeding initiation																
Yes	28 337	84	49	0.2	58	0.2	150	0.5	511	1.8	2871	10	23 183	82	1515	5.3
No	5546	16	11	0.2	23	0.4	37	0.7	98	1.8	550	9.9	4443	80	384	6.9
Total	33 883		60	0.2	81	0.2	187	0.6	609	1.8	3421	10	27 626	82	1899	5.6

EDI Early Development Instrument; SES, socioeconomic status.

(sensitivity) between 11% and 26% for vulnerability on the five different domains of the EDI. Similar results were obtained for the prognostic model identifying vulnerability on *any* of the EDI domains (table 2).

Using the conventional categorisation of Apgar scores (table 3), we observed that compared with those with an Apgar score of 9–10, the odds of vulnerability on the physical domain of the EDI were significantly higher among children with an Apgar score of

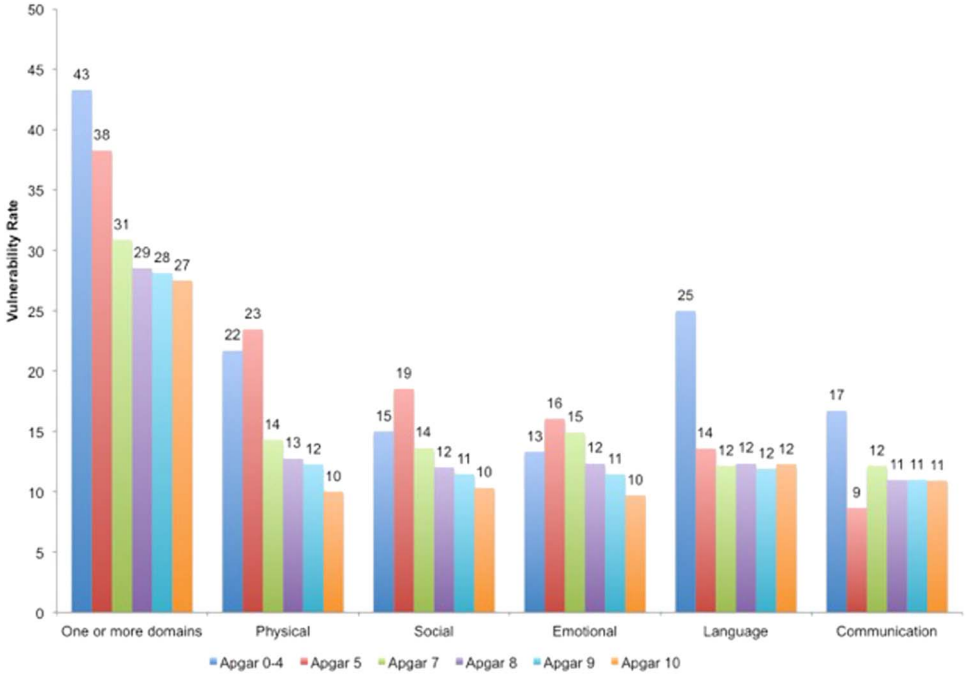

Figure 1 Rates of vulnerability within the five Early Development Instrument (EDI) domains by Apgar score at 5 min, Manitoba. Numbers for children with an Apgar score of 0–4 were grouped because of small numbers.

Table 2 Prognostic performance of the 5 min Apgar score-based model for identifying children with developmental vulnerability on each or any of the five Early Developmental Instrument (EDI) domains

	Calibration ability*		Stratification capacity*			Classification accuracy*	
EDI domains	Probability of vulnerability if in high-risk group, %	Probability of vulnerability if in low-risk group, %	Low-risk category†, %	Mid-risk category†, %	High-risk category†, %	Detection rate/ sensitivity, % (95% CI)	False-positive rate, % (95% CI)
Physical	25	7.6	39	52	9.4	19 (18 to 20)	8 (7 to 8)
Social	24	6.0	43	48	9.7	20 (19 to 22)	8 (8 to 9)
Emotional	23	6.0	48	44	7.8	16 (14 to 17)	7 (6 to 7)
Language and cognitive	26	6.8	49	39	12	26 (24 to 27)	10 (9 to 10)
Communication	24	7.3	54	41	5.2	11 (10 to 12)	4 (4 to 5)
Any EDI domain*	51	21	60	31	9.3	17 (16 to 18)	6 (6 to 7)

*Calibration ability identifies whether the risk of vulnerability calculated from the model reflects the actual fraction of children in the population with developmental vulnerability (ie, positive predictive value, whether the high-risk group had a high rate of developmental vulnerability). Risk stratification capacity shows whether the proportion in which children are assigned to low-risk and high-risk categories is reasonable from an early intervention standpoint. Classification accuracy describes the extent to which the model assigns children with vulnerability to the high-risk category (sensitivity) and children with no vulnerability to the low-risk category (specificity).
†Risk categories for vulnerability on each EDI domain were based on model-predicted probabilities of developmental vulnerability: low risk <10%, mid risk 10%–19%, high risk ≥20%). Risk categories for vulnerability on any EDI domain were based on model-predicted probabilities of developmental vulnerability: low risk <30%, mid risk 30%–44% and high risk ≥45%).

0–6 (OR 1.55, 95% CI 1.17 to 2.06). A graded excess in odds of vulnerability was evident with increasing Apgar score though rates of developmental vulnerability among those with Apgar scores of 7 and 8 were not significantly different from those with an Apgar score of 9–10.

Analyses with modelling Apgar scores using the revised categories, however, revealed that the odds of vulnerability on the physical domain increased in a graded fashion across the full range of scores (table 4). Children with an Apgar score of 7, 8 or 9 had significantly higher odds of vulnerability on the physical domain compared with children with an Apgar score of 10 (OR 1.45, 1.24 and 1.23 for Apgar 7, 8 and 9, respectively; table 4). Similarly, children with an Apgar score of 7, 8 or 9 had higher odds of vulnerability on the emotional domain compared with children with an Apgar score of 10 (OR 1.60, 1.24 and 1.20 for Apgar 7, 8 and 9, respectively). Children with scores <4 had 2.71 times higher odds of vulnerability in the language domain compared with children with an Apgar score of 10 (OR 2.71, 95% CI 1.22 to 6.01).

Finally, analyses with Apgar score modelled as a continuous variable (see online supplementary appendix table 1) showed that unit increase in the Apgar score was associated with a significant decrease in vulnerability on the physical (OR 0.91, 95% CI 0.86 to 0.95), social (OR 0.94, 95% CI 0.89 to 0.99) and emotional domains (OR 0.93, 95% CI 0.89 to 0.98). Non-significant decreases in vulnerability were observed on the language and communication domain. Modelling Apgar scores as a continuous variable or as a continuous variable with a quadratic term did not improve model fit (as assessed by the AIC) or change the pattern of the findings.

DISCUSSION

Our population-based study showed an association between the Apgar score and early childhood developmental vulnerability at 5 years of age, with lower 5 min Apgar scores being associated, in a graded continuous manner, with an increased risk of vulnerability on the physical health and well-being, emotional and social domains of the EDI. The Apgar score-based prognostic model created reasonably acceptable categories of low-risk and high-risk children for creating an early intervention programme, but failed to identify a significant proportion of children who were subsequently found to be vulnerable on one or more developmental domains. On the other hand, our study showed an increased risk of vulnerability on the physical and emotional domains even among children with an Apgar score of 9, compared with children with a score of 10.

Although the literature suggests that low Apgar scores are of concern in the short and long term, our results showed that the negative association between Apgar scores and developmental adversity extended in a linear, graded fashion across the entire range of scores. Such a finding—revealing a continuous linear association with a conventionally categorical predictor variable—parallels the identification of SES as a graded, continuous, population-level predictor of morbidity, whereas previously only outright poverty was viewed as important for health and well-being.[24] Our findings are consistent with previous studies showing an increased need for special education among children with Apgar scores of 7 or 8 at 5 min after birth compared with children with Apgar score 9 or 10 and the need for extra resources in kindergarten.[2 4 8 20]

A neurobiological account for why Apgar scores might be significant, continuous-level predictors of developmental outcomes cannot be provided by the data available in this study. Many of the observable physiological components of the Apgar score are mediated by shifts in autonomic nervous system (ANS) activation, and autonomic reactivity to emotional and physical stressors (stressors such as labour and birth) has been linked to chronic disease processes in adults[25] and to both developmental[26] and health outcomes[27] in children. Mothers' prenatal adversity, moreover, has been associated with trajectories of postnatal development of autonomic reactivity,[28] suggesting that even emotional stressors antecedent to birth can influence ANS responses. Thus, the present finding—that the full range of Apgar scores predicts developmental vulnerability at kindergarten—could represent the influence of heightened stress reactivity (indexed via ANS responses to the stress of birth) on long-term developmental endpoints.

Our prognostic model's findings are in line with previous studies that showed that the specificity of the Apgar score as a prognostic tool was far better than its sensitivity.[3 29 30] Further, risk assessment research also shows that biological criteria alone fail to identify 65% of children who, subsequently, experience high rates of poor health and disappointing educational outcomes.[31] Although our findings indicate that Apgar scores cannot be effectively used at the individual level to determine prognosis or trigger preventive intervention, our findings could have

Table 3 Adjusted ORs and 95% CIs showing the association between 5 min Apgar score (conventional categories) and vulnerability within the five EDI domains

	Physical health and well-being domain			Social domain			Emotional domain		
Factors	**OR**	**95% CI**	**p Value**	**OR**	**95% CI**	**p Value**	**OR**	**95% CI**	**p Value**
Apgar score at 5 min (vs 5 min Apgar 9–10)									
0–6	1.55	(1.17 to 2.06)	**<0.001**	1.36	(1.01 to 1.84)	**0.05**	1.09	(0.78 to 1.51)	0.62
7	1.19	(0.94 to 1.51)	0.14	1.21	(0.95 to 1.54)	0.12	1.34	(1.07 to 1.69)	**0.01**
8	1.02	(0.92 to 1.14)	0.72	1.01	(0.91 to 1.13)	0.84	1.04	(0.94 to 1.17)	0.44
Sex of the child, male (vs female)	1.75	(1.63 to 1.87)	**<0.0001**	2.51	(2.33 to 2.70)	**<0.0001**	3.12	(2.89 to 3.36)	**<0.0001**
Child's age at EDI completion (years)	0.85	(0.79 to 0.91)	**<0.0001**	0.82	(0.76 to 0.88)	**<0.0001**	0.86	(0.80 to 0.92)	**<0.0001**
SES (vs highest SES)									
Middle SES	2.40	(2.19 to 2.63)	**<0.0001**	2.27	(2.07 to 2.50)	**<0.0001**	1.77	(1.60 to 1.95)	**<0.0001**
Lowest SES or income assistance	1.47	(1.36 to 1.58)	**<0.0001**	1.44	(1.33 to 1.55)	**<0.0001**	1.19	(1.11 to 1.29)	**<0.0001**
Gestational weeks (vs 40 weeks)									
37	1.24	(1.09 to 1.42)	**<0.01**	1.16	(1.02 to 1.34)	**0.03**	1.13	(0.98 to 1.29)	0.10
38	1.07	(0.97 to 1.19)	0.17	1.14	(1.03 to 1.26)	**0.01**	1.06	(0.95 to 1.18)	0.28
39	1.05	(0.96 to 1.15)	0.28	1.09	(0.99 to 1.19)	0.06	1.06	(0.97 to 1.16)	0.19
41	1.01	(0.92 to 1.12)	0.83	1.07	(0.97 to 1.19)	0.19	1.08	(0.98 to 1.20)	0.12
≥42	1.24	(0.93 to 1.65)	0.14	1.06	(0.78 to 1.45)	0.71	1.44	(1.09 to 1.90)	**0.01**
Birth weight for gestational age (vs 'appropriate')									
Large	1.09	(0.99 to 1.19)	0.09	1.02	(0.93 to 1.13)	0.68	1.03	(0.93 to 1.13)	0.59
Small	1.33	(1.19 to 1.49)	**<0.0001**	1.26	(1.12 to 1.42)	**<0.001**	1.16	(1.02 to 1.31)	**0.02**
Breastfeeding initiation, yes (vs no)	1.41	(1.30 to 1.53)	**<0.0001**	1.40	(1.29 to 1.52)	**<0.0001**	1.16	(1.06 to 1.27)	**0.001**

	Language domain			Communication domain		
Factors	**OR**	**95% CI**	**p Value**	**OR**	**95% CI**	**p Value**
Apgar score at 5 min (vs 5 min Apgar 9–10)						
5-Apgar 0–6	1.33	(0.98 to 1.79)	0.06	0.96	(0.68 to 1.35)	0.80
5-Apgar 7	1.03	(0.80 to 1.32)	0.85	1.10	(0.86 to 1.41)	0.45
5-Apgar 8	1.00	(0.90 to 1.12)	0.99	0.96	(0.86 to 1.08)	0.50
Sex of the child, male (vs female)	1.97	(1.83 to 2.11)	**<0.0001**	1.90	(1.77 to 2.04)	**<0.0001**
Child's age at EDI completion (years)	0.66	(0.60 to 0.72)	**<0.0001**	0.84	(0.78 to 0.91)	**<0.0001**
SES (vs highest SES)						
Middle SES	2.97	(2.71 to 3.26)	**<0.0001**	2.06	(1.87 to 2.27)	**<0.0001**
Lowest SES or income assistance	1.62	(1.50 to 1.75)	**<0.0001**	1.45	(1.34 to 1.56)	**<0.0001**
Gestational weeks (vs 40 weeks)						
37	1.16	(1.02 to 1.33)	**0.03**	1.18	(1.02 to 1.35)	**0.02**
38	1.04	(0.94 to 1.15)	0.48	1.08	(0.97 to 1.20)	0.16
39	1.04	(0.95 to 1.14)	0.38	1.14	(1.04 to 1.24)	**0.01**
41	0.96	(0.86 to 1.06)	0.40	1.00	(0.90 to 1.11)	0.96
≥42	1.11	(0.82 to 1.49)	0.51	1.19	(0.88 to 1.61)	0.26
Birth weight for gestational age (vs AGA)						
Large	0.99	(0.90 to 1.09)	0.78	1.05	(0.95 to 1.16)	0.37
Small	1.26	(1.12 to 1.42)	**<0.001**	1.51	(1.34 to 1.69)	**<0.0001**
Breastfeeding initiation yes (vs no)	1.65	(1.53 to 1.79)	**<0.0001**	1.63	(1.50 to 1.77)	**<0.0001**

Bold represents p value <0.05.
AGA appropriate gestational age; EDI, Early Development Instrument; SES, socioeconomic status.

substantial public health significance as a population's Apgar profile could serve as an indicator of the burden of adverse developmental outcomes in children. Additionally, documentation of differences in 5 min Apgar profiles between populations (eg, a lower frequency of infants with a 5 min Apgar score of 9) could lead to an aetiological search for causes and interventions that improve developmental outcomes in children.

The strengths of our study included the ability to access comprehensive health and education-related databases at the population level. The EDI assessment by teachers avoided reliance on parental or self-report of developmental outcomes. Nevertheless, there may have been some individual differences in teachers' ability to evaluate developmental outcomes.[19] The SES of children was determined by their SES in the first 5 years after birth, although SES at birth would have been preferable for a prognostic model. However, SES as constructed in our study is unlikely to have changed substantially during the study period. Further, our study was restricted to the comparatively healthy subset of all term live births, as children with severe chronic illnesses may not have enrolled in kindergarten or may have enrolled in special needs schools. This was not a serious limitation as our objective was to examine the role of the Apgar score as a marker of childhood development in normal children.

Table 4 Adjusted ORs and 95% CIs showing the association between 5 min Apgar score and vulnerability within each of the five Early Development Instrument (EDI) domains

	Physical health and well-being domain*			Social domain*			Emotional domain*			Language domain*			Communication domain*		
Factors	OR	95% CI	p Value	OR	95% CI	p Value	OR	95% CI	p Value	OR	95% CI	p Value	OR	95% CI	p Value
Apgar															
0–3	2.70	(1.19 to 6.13)	**0.01**	0.84	(0.25 to 2.81)	0.77	1.18	(0.40 to 3.34)	0.70	2.71	(1.22 to 6.01)	**0.01**	1.73	(0.70 to 4.28)	0.20
4	1.74	(0.64 to 4.73)	0.28	2.10	(0.82 to 5.43)	0.12	1.36	(0.45 to 4.06)	0.59	1.77	(0.69 to 4.56)	0.24	1.20	(0.41 to 3.58)	0.74
5	2.43	(1.41 to 4.20)	<0.01	1.77	(0.97 to 3.20)	0.06	1.60	(0.85 to 2.98)	0.14	0.95	(0.49 to 1.84)	0.87	0.66	(0.30 to 1.47)	0.31
6	1.55	(1.02 to 2.36)	**0.04**	1.48	(0.97 to 2.27)	0.07	1.17	(0.73 to 1.87)	0.52	1.19	(0.78 to 1.83)	0.41	0.96	(0.59 to 1.54)	0.86
7	1.45	(1.10 to 1.91)	**0.01**	1.36	(1.03 to 1.81)	**0.03**	1.60	(1.21 to 2.10)	**<0.001**	1.01	(0.76 to 1.34)	0.97	1.12	(0.84 to 1.49)	0.45
8	1.24	(1.03 to 1.49)	**0.02**	1.14	(0.95 to 1.37)	0.16	1.24	(1.03 to 1.50)	**0.02**	0.98	(0.82 to 1.17)	0.84	0.98	(0.81 to 1.17)	0.79
9	1.23	(1.05 to 1.44)	**0.01**	1.14	(0.97 to 1.33)	0.11	1.20	(1.03 to 1.41)	**0.02**	0.98	(0.85 to 1.13)	0.78	1.02	(0.87. to 1.18)	0.83
10	1.00	(–)	–	1.00	(–)	–	1.00	(–)	–	1.00	(–)	–	1.00	(–)	–

Bold represents p value <0.05.
*Logistic regression models adjusted for child's sex (male vs female), age of the child at EDI (years), socioeconomic status (low or income assistance, middle vs high), gestational weeks (37, 38, 39, 41, ≥42 vs 40 weeks of gestational), birth weight for gestational age (large, small vs appropriate), breastfeeding initiation (yes vs no).

In summary, our study showed that the risk of developmental vulnerability at 5 years of age was inversely associated with the 5 min Apgar score and that this relation extended across the entire range of scores. Thus, even a minor degree of physiological dysfunction soon after birth, reflected in the Apgar score, may indicate a slightly higher risk for developmental vulnerability in later childhood. Although the low sensitivity of the prognostic model based on the 5 min Apgar score limits the *clinical* utility of this model for early intervention, the Apgar score might well serve as a population-level indicator of developmental risk.

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