

Change in Prevalence of Chronic Conditions Between Childhood and Adolescence Among Extremely Low-Birth-Weight Children

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THERAPEUTIC CHANGES IN PERINATAL care in the 1990s resulted in improved survival among extremely low-birth-weight (ELBW) infants (weight <1 kg). The school-aged outcomes for these children indicate very high rates of chronic health conditions and developmental problems compared with normal-birth-weight (NBW) controls.^{1,2} There have been few reports of the outcomes of ELBW children during adolescence, which is a time of enormous social, health, and developmental change.^{3,4}

We previously reported significantly higher rates of chronic conditions, functional limitations, and special health care needs among 8-year-old ELBW children born from 1992 through 1995 compared with NBW controls.¹ As part of a longitudinal cohort study, we sought to examine the critical changes in the rates of chronic conditions between the age of 8 years and the age of 14 years (adolescence) according to a noncategorical measure, the revised Questionnaire for Identifying Children With Chronic Conditions (QUICCC-R),⁵ and 2 specific conditions, asthma and obesity,

Context Extremely low-birth-weight (ELBW) children have high rates of chronic conditions during childhood. Information on their trajectory of health during adolescence is needed for health care planning.

Objective To examine changes in the rates of chronic conditions between the ages of 8 and 14 years among ELBW children compared with normal-birth-weight (NBW) controls.

Design, Setting, and Participants Cohort study conducted from 2004 through 2009 of 181 ELBW children (weight < 1 kg) and 115 NBW controls of similar sociodemographic status born from 1992 through 1995 in Cleveland, Ohio.

Main Outcome Measures Rates of chronic conditions overall (measured with the revised Questionnaire for Identifying Children With Chronic Conditions) and rates of asthma and obesity.

Results The overall rates of chronic conditions did not change significantly between the ages of 8 and 14 years among ELBW children (75% at age 8 years vs 74% at age 14 years) or NBW controls (37% at age 8 years vs 47% at age 14 years). In generalized estimating equations logistic regression adjusting for sociodemographic status, sex, and race, ELBW children continued to have a higher rate of chronic conditions than NBW controls at age 14 years (74% vs 47%, respectively, adjusted odds ratio [AOR], 2.8 [95% confidence interval [CI], 1.7 to 4.6]). Rates of asthma requiring medication did not change between the ages of 8 and 14 years among ELBW children (23% at both ages) but increased among NBW controls from 8% at age 8 years to 17% at age 14 years ($P = .002$). Differences in rates of asthma between ELBW and NBW children were no longer significant at the age of 14 years (23% vs 17%, respectively; AOR, 1.5 [95% CI, 0.8 to 2.8]). Mean z scores for body mass index increased in ELBW children from 0.06 at age 8 years to 0.38 at age 14 years ($P < .001$) and rates of obesity increased from 12% at age 8 years to 19% at age 14 years ($P = .02$). However, the scores and rates did not change among NBW controls such that at the age of 14 years the differences between ELBW and NBW children in mean z scores for body mass index (0.38 vs 0.56, respectively; adjusted mean difference -0.2 [95% CI, -0.5 to 0.1]) or rates of obesity (19% vs 20%, respectively; AOR, 1.1 [95% CI, 0.6 to 2.0]) were not significant.

Conclusions Among ELBW children, rates of overall chronic conditions and asthma did not change between the ages of 8 and 14 years but the rate of obesity increased. Compared with NBW controls, the rates of chronic conditions were higher but there were no significant differences in the rates of asthma or obesity.

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which are major health problems that are prevalent among children today.

Based on reports of increased rates of chronic conditions during adolescence in normal populations⁶ and of adolescent catch-up growth among ELBW children,^{7,8} we hypothesized that the high rates of chronic conditions identified at the age of 8 years would increase by the age of 14 years and that catch-up growth would predispose them to obesity.

METHODS

ELBW Cohort

The population included survivors of the cohort of 344 ELBW children admitted to Rainbow Babies and Children's Hospital, Cleveland, Ohio, from 1992 through 1995.¹ Thirteen children (10 with major malformations, 2 with AIDS, and 1 with tuberous sclerosis) were excluded. Of the remaining 331 children, 238 survived and 181 (76%) were followed up at the ages of 8 and 14 years. They did not differ significantly from the 57 children who were not followed up regarding sociodemographic or birth data; however, fewer were male (39% vs 54%, respectively) and fewer had bronchopulmonary dysplasia during the neonatal period (41% vs 57%).

For the analyses concerning obesity, we excluded 35 children (31 with neurosensory impairment who may have had abnormal growth and 4 who had missing growth measures). The 146 children with growth measures compared with the 35 who were excluded had a significantly higher gestational age (26.5 vs 25.9 weeks, respectively) and fewer were male (35% vs 54%).

Comparison Group

An NBW group of 176 children born at term gestation was recruited at the age of 8 years from the same schools as the ELBW children and of the same sex, race, and age within 3 months; of whom 115 children (65%) were reassessed at the age of 14 years.¹ They did not differ in sociodemographic factors, sex, rates of chronic conditions, or subnor-

mal IQ from the 61 children who were not followed up. Two children had missing growth measures. Thus, 113 NBW children were considered for the obesity outcome.

Study Protocol

Parent Report Questionnaires. During 2004 and 2009 at the ages of 8 and 14 years, respectively, questionnaires were administered to the parent and included the QUICCC-R⁵ and medical diagnoses of whether the child had ever been diagnosed with asthma and, if so, whether medications for asthma had been prescribed during the past 12 months. Race was self-identified by the parent from the list of racial and ethnic categories used for federal reporting.

The QUICCC questionnaire is based on a unified conceptual definition of chronic conditions and incorporates the consequences of these conditions lasting or expected to last 12 months or longer. It does not assess specific diagnoses but rather classifies children non-categorically. The original version, which we used when children were aged 8 years, has 39 questions.⁹ A shortened version, the QUICCC-R, which has 16 questions, was administered when children were aged 14 years and was compared with the same 16 questions administered in the longer version used at age 8 years.⁵ Similar to the QUICCC, the QUICCC-R is divided into 3 domains of health-related consequences of chronic conditions: (1) functional limitations, (2) dependence on compensatory aids, and (3) need or use of services above those routinely required by children.

To qualify as having a chronic condition, a child must have at least 1 of the consequences of a chronic condition, and each consequence must be attributable to a condition lasting or expected to last 12 months or longer. The QUICCC has good test-retest reliability⁹ and has an 89% agreement ($\kappa=0.78$) with physician classification of chronic disease.¹⁰ Compared with the QUICCC, the QUICCC-R has a sensitivity of 87% and a specificity of 89% ($\kappa=0.75$).⁵

Child Assessment. The children were measured by research assistants who were unaware of their birth-weight status. Participants were weighed unclothed at age 8 years but lightly clothed at age 14 years. To correct for this weight of clothing, we subtracted 0.5 kg from the measured weight of females and 1.0 kg from that of males. Height was measured with a Harpenden stadiometer.

Weight and height *z* scores were computed from the revised Centers for Disease Control and Prevention growth data, which are age- and sex-specific.¹¹ Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared and the *z* scores were computed using the Centers for Disease Control and Prevention's norms.¹¹ Obesity was defined as a BMI in the 95th percentile or higher.¹¹

The study protocol was approved by the institutional review board of University Hospitals Case Medical Center. Written informed consent was obtained from parents when the children were aged 8 and 14 years and written assent from children at 14 years.

Statistical Analyses

Univariate comparisons between groups were made using *t* tests for continuous variables. χ^2 Tests or logistic regression was used to examine differences in dichotomous outcomes. We considered 3 measures of chronic conditions. First, chronic conditions lasting or expected to last 12 months or longer were analyzed as binary variables (ie, the proportion having ≥ 1 consequences) and also as the mean number of consequences. Second, asthma was considered as ever diagnosed and as requiring medication during the most recent 12 months. Third, obesity was defined using age- and sex-specific BMI *z* scores and rates of obesity.¹¹ Sample sizes of 181 ELBW children and 115 NBW controls provide 80% power to detect odds ratios (ORs) of 3.40, 2.60, 2.06, and 1.97 when comparing proportions with a binary outcome at each age, assuming rates of 0.05, 0.10, 0.25,

Table 1. Maternal Demographic Risk Factors, Perinatal Data, and 14-Year Neurodevelopmental Outcome

	ELBW Children (n = 181)	NBW Controls (n = 115)
Maternal demographic data ^a		
Age, mean (SD), y ^b	43 (6)	41 (6)
Married, No. (%)	79 (44)	63 (55)
Education, No. (%)		
<High school	13 (7)	12 (10)
High school graduate ^c	57 (32)	22 (19)
>High school	111 (61)	81 (70)
Race, No. (%)		
White	73 (40) ^d	39 (34)
Black	108 (60)	76 (66)
Below poverty level, mean (SD), % ^e	13 (12)	15 (13)
Family income, mean (SD), US\$ ^f	44.3 (19)	40.2 (19)
Perinatal data		
Birth weight, mean (SD), g	815 (124)	3260 (524)
Gestational age, mean (SD), wk	26.4 (2)	≥37 (NA)
Female sex, No. (%)	111 (61)	73 (64)
Multiple birth, No. (%)	32 (18)	0
14-y neurodevelopmental outcome, No. (%)		
Neurosensory impairment ^g	31 (17)	0
IQ <70	32 (18)	4 (4) ^h
Individualized education program	88 (49)	11 (10) ^h
Receive supplemental security income	38 (21)	7 (6) ^h

Abbreviations: ELBW, extremely low birth weight; NA, data not applicable; NBW, normal birth weight.

^aUnless otherwise indicated, data refer to primary caregiver; for 156 ELBW children (86%) and 103 NBW controls (90%), the primary caregiver was the biological or adoptive mother.^bIndicates age of biological mothers only. For comparison of ELBW children with NBW controls, the *P* value was less than .05.^cIncludes those who received the general equivalency diploma.^dIncludes 2 Asian mothers.^eBased on the 2000 Census tract neighborhood in which the families lived.^fIndicates mean of median family income in thousands of dollars according to the 2000 Census tract neighborhood in which the families lived.^gIncludes 27 children with cerebral palsy, 1 with blindness, and 3 with deafness requiring a hearing aid.^hFor comparison of ELBW children with NBW controls, the *P* value was less than .001.

and 0.50, respectively in the NBW group, an increased rate in ELBW group, and 2-sided tests with a significance level of .05.

McNemar tests were used to test the significance of within-group changes in the prevalence of chronic conditions in children between the ages of 8 and 14 years; paired *t* tests were used to compare the BMI *z* scores. Generalized estimating equations logistic regression (using SAS Proc GENMOD, SAS Institute Inc, Cary, North Carolina) was used to compare changes in chronic conditions between the ELBW children and the NBW controls at the ages of 8 and 14 years, controlling for the variables of socioeconomic status, race, sex, and neurosensory impairment. Interactions between birth-weight status and age at time of study were exam-

ined. Analogous analyses were performed on the BMI *z* scores using linear mixed models with SAS Proc MIXED (SAS Institute Inc) and generalized estimating equations models with the identity-link function were used to analyze the total numbers of chronic conditions because these outcomes had a skewed nonnormal distribution.

Socioeconomic status was defined as the mean of the sample *z* scores for maternal education and median family income according to the 2000 Census tract of the family's neighborhood. We did not adjust for multiple comparisons. Statistical analyses were conducted using SPSS version 19 (SPSS Inc, Chicago, Illinois) and SAS version 9.2 (SAS Institute Inc). Two-sided tests were used and a *P* value of less than .05 was considered statistically significant.

RESULTS

The ELBW children and NBW controls did not differ significantly in maternal sociodemographic descriptors. Among the ELBW children, neonatal complications included bronchopulmonary dysplasia defined as oxygen dependence at 36 weeks corrected age in 107 children (59%) and a severely abnormal cerebral ultrasound in 44 children (24%). Thirty-one ELBW children (17%) had neurosensory impairments.

Compared with NBW controls, ELBW children had significantly higher rates of subnormal IQ and enrollment in individual education programs (TABLE 1). The ELBW children were significantly younger than the NBW children at the time of the 8-year follow-up (mean [SD] age: 8.7 [0.6] years vs 9.2 [0.8] years, respectively) but their ages were similar at the time of the 14-year follow-up (mean [SD] age: 14.7 [0.7] years vs 14.8 [0.7] years).

Chronic Conditions

Within the ELBW cohort, the overall rates of chronic conditions did not change between the ages of 8 and 14 years (75% and 74%, respectively; TABLE 2) but there was a significant decrease in the mean number of chronic conditions per child (TABLE 3). Within the domains of the QUICCC-R, the rates of functional limitations decreased significantly from 56% to 46% (*P* = .02); the rates did not decrease for compensatory dependencies or needs for services. Specific decreases in functional limitations included the parent report of mental or emotional delay. Service needs that decreased included occupational or physical therapy and rehospitalizations (TABLE 4).

Within the NBW cohort, neither the overall rates and numbers of chronic conditions nor the functional limitations or special health care needs changed. However, the rates of compensatory dependencies increased significantly from 22% to 34% (*P* = .02) due to an increase in prescribed medication.

Group comparisons revealed that the significantly higher rates and num-

bers of chronic conditions among the ELBW children at age 8 years persisted at age 14 years (74% for ELBW children vs 47% for NBW controls; adjusted OR [AOR], 2.8 [95% confidence interval {CI}, 1.7-4.6]; Table 2 and Table 4). At age 14 years, 46% of ELBW children had functional limitations compared with 16% of NBW controls (AOR, 4.2; 95% CI, 2.2-7.9), including mental or emotional delay, trouble understanding simple instructions, and speaking and communicating.

Forty-eight percent of ELBW children had compensatory dependencies compared with 34% of NBW controls (AOR, 1.7; 95% CI, 1.0-2.8), including prescribed medication and more needs for services such as special arrangements in school. The ELBW children had higher rates of postneonatal hospitalization compared with NBW controls at 8 years but not at 14 years.

Asthma

The rate of ELBW children with asthma requiring medication did not change between the ages of 8 and 14 years (23% at both ages). For the NBW controls, the rate of asthma increased significantly between the ages of 8 and 14 years from 8% to 17%, respectively ($P=.002$). The significantly higher rates of asthma among the ELBW children compared with NBW controls at age 8 years persisted at age 14 years when defined as ever-diagnosed asthma (39% vs 21%, respectively; AOR, 2.7 [95% CI, 1.5-4.7]) but were no longer significant when defined as receiving medication during the previous 12 months (ie, current asthma) (23% vs 17%, respectively; AOR, 1.5 [95% CI, 0.8-2.8]). Fifty-two percent of ELBW children ever diagnosed with asthma at the 8-year follow-up had a history of bronchopulmonary dysplasia compared with 34% who had no history of asthma ($P=.01$).

Obesity

The ELBW children had significantly lower BMI z scores than the NBW controls at age 8 years (0.06 vs 0.43, respectively; β , -0.4 [95% CI, -0.7 to -0.1]). The mean BMI z scores increased in ELBW children from 0.06 at age 8 years to 0.38 at age 14 years ($P<.001$) and the rates of obesity increased from 12% at age 8 years to 19% at age 14 years ($P=.02$). These scores and rates did not change among the NBW controls; at age 14 years, the mean BMI scores and rates of obesity did not differ significantly between the ELBW children and NBW controls (Table 2).

In the multivariable analyses, in addition to ELBW status, neurosensory impairments, lower socioeconomic status, and male sex were significantly associated with overall chronic conditions, functional limitations, and greater need for services; male sex was

Table 2. Chronic Conditions at 8 and 14 Years of Age

	No. (%) of Children [95% CI]				Odds Ratio (95% CI) ^a		
	ELBW (n = 181)		NBW (n = 115)		ELBW vs NBW		Significant Predictors ^b
	Age 8 y	Age 14 y	Age 8 y	Age 14 y	Age 8 y	Age 14 y	
Chronic conditions	136 (75) [68 to 81]	134 (74) [67 to 80]	43 (37) [29 to 47]	54 (47) [38 to 56]	4.3 (2.6 to 7.3) ^b	2.8 (1.7 to 4.6) ^b	Neurological: 25.8 (3.4 to 195.0) Socioeconomic status: 0.7 (0.5 to 0.9)
Functional limitations	101 (56) [48 to 63]	84 (46) [39 to 54] ^b	17 (15) [9 to 23]	18 (16) [10 to 24]	6.0 (3.3 to 11.0) ^b	4.2 (2.2 to 7.9) ^b	Male sex: 1.9 (1.2 to 2.9) Neurological: 10.2 (4.3 to 23.9) Socioeconomic status: 0.6 (0.5 to 0.8)
Compensatory dependencies	79 (44) [36 to 51]	87 (48) [41 to 56]	25 (22) [15 to 30]	39 (34) [25 to 43] ^b	2.6 (1.5 to 4.5) ^b	1.7 (1.0 to 2.8) ^b	
Service needs or use	113 (62) [55 to 70]	104 (58) [50 to 65]	24 (21) [14 to 29]	28 (24) [17 to 33]	5.2 (2.9 to 9.0) ^b	3.4 (1.9 to 5.8) ^b	Neurological: 26.5 (6.4 to 110.1) Socioeconomic status: 0.7 (0.5 to 0.9)
Asthma							
Ever diagnosed	67 (37) [30 to 45]	71 (39) [32 to 47]	17 (15) [9 to 23]	24 (21) [14 to 29] ^b	3.6 (2.0 to 6.7) ^b	2.7 (1.5 to 4.7) ^b	Male sex: 1.9 (1.2 to 3.0)
Medication use ^c	43 (24) [18 to 31]	41 (23) [17 to 29]	9 (8) [4 to 14]	19 (17) [10 to 25] ^b	3.7 (1.7 to 8.1) ^b	1.5 (0.8 to 2.8)	
BMI (obesity) ^d	(n = 146)	(n = 146)	(n = 113)	(n = 113)			
z Score (95% CI) ^e	0.06 (−0.15 to 0.27)	0.38 (0.20 to 0.56) ^b	0.43 (0.21 to 0.64)	0.56 (0.35 to 0.78)	β−0.4 (−0.7 to −0.1) ^b	β − 0.2 (− 0.5 to 0.1)	
≥95th percentile	17 (12) [7 to 18]	28 (19) [13 to 27] ^b	18 (16) [10 to 24]	23 (20) [13 to 29]	1.4 (0.7 to 2.9)	1.1 (0.6 to 2.0)	

Abbreviations: BMI, body mass index; CI, confidence interval; ELBW, extremely low birth weight; NBW, normal birth weight.

^aObtained from the generalized estimation equations logistic regression model, which simultaneously analyzed data from ELBW children and NBW controls at both time points (8 years and 14 years) and was adjusted for socioeconomic status, race, sex, and neurosensory impairment in analyses concerning chronic conditions.

^bFor comparison of ELBW children with NBW controls, the P value was less than .05.

^cIndicates asthma medication use during the last 12 months. For the interaction of age $\times$ study group, the P value was equal to .004.

^dCalculated as weight in kilograms divided by height in meters squared.

^eIndicates β -estimated difference in mean BMI z score obtained for ELBW children minus NBW controls and was obtained from a mixed-model analysis, which was adjusted for socioeconomic status, race, and sex.

associated with higher rates of ever-diagnosed asthma (Table 2 and Table 4). Obesity was not associated with any of the examined variables.

COMMENT

We previously reported on the high rates of chronic health conditions among ELBW children compared with NBW controls at the age of 8 years and sought to examine possible changes during the critical period of adolescence. Our results reveal that the overall rates of chronic conditions among both ELBW children and NBW controls were relatively stable. During adolescence, ELBW children continue to have significantly higher rates of functional limitations, compensatory dependencies, and increased use of or need for services than NBW controls. Rates of asthma among ELBW children also remained stable whereas they increased among NBW controls such that when defined as current asthma,

the differences between ELBW children and NBW controls were no longer significant at the age of 14 years.

Of major concern is the significant increase between the ages of 8 and 14 years in mean BMI *z* scores and rates of obesity among ELBW children compared with the relatively stable rates among NBW controls. Our results indicate both positive and negative changes in the health trajectories of ELBW children during adolescence.

Reports of adolescent health outcomes of ELBW children born in the 1990s pertain to the early adolescence of children born prior to 26 weeks gestation in Sweden and the United Kingdom.^{3,4} Similar to our finding, Farooqi et al³ reported significantly higher rates of chronic conditions as measured with the QUICCC at the ages of 11 to 12 years. Fawke et al⁴ reported significantly higher rates of impaired respiratory morbidity in the British Epicure study population at the age of 11

years and a current rate of asthma of 25%, which is similar to our rate of 23%. Longitudinal changes in these outcomes have not been reported.

The studies of children born prior to 1990 similarly reported significantly higher rates of chronic illnesses among ELBW children during adolescence. These pertained mainly to neurocognitive disorders^{13,14} and asthma,¹⁵ with functional problems and rehospitalizations resulting from a combination of these respiratory and neurological conditions.^{16,17} Similar to our findings, Saigal et al¹⁶ reported stability in the rates of chronic conditions among ELBW children born from 1977 through 1982 but reported an increase in medication use between the ages of 8 and 14 years.

Our results among the NBW controls are similar to those reported nationally. Rates of chronic conditions or special health care needs during childhood range from 12% to 37%, depend-

Table 3. Functional Limitations, Compensatory Dependencies, and Use of Services Associated With a Chronic Condition

	ELBW Children (n = 181)		<i>P</i> Value	NBW Controls (n = 115)		<i>P</i> Value	Difference in Adjusted Means for ELBW Minus NBW (95% CI)		Significant Predictors, β (95% CI) ^a
	Age 8 y	Age 14 y		Age 8 y	Age 14 y		Age 8 y	Age 14 y	
Chronic conditions ^b									
Mean (SD)	3.12 (2.79)	2.77 (2.74)	.02	0.83 (1.45)	1.00 (1.40)	.28	1.68 (1.23 to 2.13) ^a	1.19 (0.76 to 1.62) ^a	Neurological: 3.59 (2.71 to 4.46) Socioeconomic status: -0.35 (-0.62 to -0.08) Male sex: 0.69 (0.24 to 1.13)
Median (IQR)	3 (1 to 5)	2 (0 to 5)		0 (0 to 1)	0 (0 to 2)				
Functional limitations ^c									
Mean (SD)	1.23 (1.50)	0.97 (1.32)	.004	0.23 (0.65)	0.21 (0.55)	.43	0.75 (0.51 to 0.98) ^a	0.53 (0.34 to 0.72) ^a	Neurological: 1.52 (1.02 to 2.03) Socioeconomic status: -0.21 (-0.36 to -0.06) Male sex: 0.33 (0.11 to 0.55)
Median (IQR)	1 (0 to 2)	0 (0 to 2)		0	0				
Compensatory dependencies									
Mean (SD)	0.49 (0.61)	0.55 (0.64)	.24	0.27 (0.57)	0.46 (0.74)	.004	0.19 (0.05 to 0.33) ^a	0.06 (-0.11 to 0.23)	
Median (IQR)	0 (0 to 1)	0 (0 to 1)		0	0 (0 to 1)				
Service needs or use									
Mean (SD)	1.39 (1.37)	1.25 (1.37)	.09	0.32 (0.71)	0.33 (0.65)	.92	0.75 (0.53 to 0.96) ^a	0.60 (0.39 to 0.82) ^a	Neurological: 1.88 (1.53 to 2.24) Socioeconomic status: -0.17 (-0.29 to -0.04) Male sex: 0.28 (0.07 to 0.48)
Median (IQR)	1 (0 to 2)	1 (0 to 2)		0	0				

Abbreviations: CI, confidence interval; ELBW, extremely low birth weight; IQR, interquartile range; NBW, normal birth weight.

^aFor comparison of ELBW children with NBW controls, the *P* value was less than .05.

^bFor comparison of interaction of age $\times$ study group, the *P* value was equal to .01.

^cFor comparison of interaction of age $\times$ study group, the *P* value was equal to .048.

ing on the definition.¹⁸⁻²⁰ Between the ages of 12 and 17 years, the rate of ever-diagnosed asthma is 16.6% and the rate of current asthma is 10.2%.²¹ Twenty percent of children are obese between the ages of 6 and 11 years and 18% are obese between the ages of 12 and 19 years.²² Chronic conditions and spe-

cial health care needs are also reported to increase during adolescence.⁶ The high rate of chronic conditions in our NBW controls might be due to the lower socioeconomic status of our cohort (60% of whom are minorities) and to current parent perceptions of children's health.²⁰

Our findings of an increase in the rates of asthma in the NBW population during adolescence reflect epidemiological studies²³ and national trends.²⁴ The lack of an increase in our ELBW population during adolescence supports suggestions of a different asthma phenotype among preterm chil-

Table 4. Functional Limitations, Compensatory Dependencies, and Use of Services Associated With a Chronic Condition Lasting 12 Months or Longer

	No. (%) of Children [95% CI]				Odds Ratio (95% CI) ^a		
	ELBW (n = 181)		NBW (n = 115)		ELBW vs NBW		Significant Predictors ^b
	Age 8 y	Age 14 y	Age 8 y	Age 14 y	Age 8 y	Age 14 y	
Functional limitations							
Physical delay	35 (19) [14-26]	25 (14) [9-20]	2 (2) [0-6]	0 [0-3]	9.7 (2.2-42.3) ^{b,c}	NA ^d	Neurological: 5.3 (2.2-13.1) ^c
Mental or emotional delay	48 (27) [2-34]	32 (18) [12-24] ^b	4 (3) [1-9]	3 (3) [1-7]	8.6 (3.1-24.1) ^b	6.7 (2.0-21.9) ^b	Neurological: 0.5 (1.5-7.8) Socioeconomic status: 0.5 (0.3-0.9)
Reduced effort in activity	35 (19) [14-26]	37 (20) [15-27]	6 (5) [2-11]	7 (6) [2-12]	2.5 (0.9-6.4)	2.3 (0.9-5.6)	Neurological: 8.4 (4.0-17.5)
Difficulty seeing ^e	15 (8) [5-13]	16 (9) [5-14]	1 (1) [0-5]	3 (3) [1-7]	7.0 (0.9-55.8)	2.5 (0.7-9.0)	Neurological: 4.2 (1.6-11.4)
Difficulty hearing ^e	17 (9) [6-15]	13 (7) [4-12]	1 (1) [0-5]	2 (2) [0-6]	6.5 (0.8-52.0)	2.3 (0.5-11.0)	Neurological: 7.1 (2.7-18.3)
Trouble understanding simple instructions	38 (21) [15-28]	23 (13) [8-18] ^b	7 (6) [2-12]	5 (4) [1-10]	4.9 (2.0-11.6) ^b	3.9 (1.4-10.7) ^b	Socioeconomic status: 0.5 (0.3-0.8)
Trouble speaking or communicating	35 (19) [14-26]	30 (17) [11-23]	6 (5) [2-11]	4 (3) [1-9]	3.6 (1.4-9.1) ^b	4.7 (1.4-9.1) ^b	Neurological: 2.7 (1.2-5.8) Male sex: 2.0 (1.1-3.6)
Compensatory dependencies							
Regularly prescribed medication	72 (40) [33-47]	86 (48) [40-55]	19 (17) [10-25]	38 (33) [25-42] ^b	3.0 (1.7-5.5) ^b	1.7 (1.0-2.8) ^b	
Life-threatening allergy ^e	7 (4) [2-8]	4 (2) [1-6]	4 (3) [1-9]	6 (5) [2-11]	1.0 (0.3-3.6)	0.4 (0.1-1.4)	White race: 2.9 (1.2-7.5)
Physician-ordered special diet ^e	10 (6) [3-10]	10 (6) [3-10]	8 (7) [3-13]	9 (8) [4-14]	0.8 (0.3-2.0)	0.7 (0.3-1.8)	
Service needs or use							
Visits a physician or specialist on a regular basis	42 (23) [30-53]	53 (29) [23-36]	9 (8) [4-14]	10 (9) [4-15]	2.0 (0.9-4.5)	2.7 (1.2-5.8) ^b	Neurological: 9.7 (4.9-19.8)
Visits counselor, psychiatrist, psychologist, or social worker ^e	16 (9) [5-14]	17 (9) [6-15]	5 (4) [1-10]	9 (8) [4-14]	2.1 (0.8-6.0)	1.4 (0.5-2.8)	
Receives physical, occupational, or other therapy	56 (31) [24-38]	42 (23) [17-30] ^b	3 (3) [1-7]	0 [0-3]	8.3 (2.4-28.4) ^{b,c}	NA ^d	Neurological: 59.6 (13.3-268.1)
Ever been hospitalized ^f	49 (27) [21-34]	22 (12) [8-18] ^b	9 (8) [4-14]	3 (3) [1-7]	3.1 (1.4-7.0) ^b	3.3 (0.9-11.8)	Neurological: 5.2 (2.6-10.4) Socioeconomic status: 0.6 (0.4-0.9)
Unable to get medical or mental health services ^e	7 (4) [2-8]	11 (6) [3-11]	1 (1) [0-5]	5 (4) [1-10]	4.6 (0.6-37.8)	1.4 (0.5-4.2)	
Special arrangements in school ^g	82 (45) [38-53]	81 (45) [37-52]	10 (9) [4-15]	11 (10) [5-16]	6.9 (3.4-14.1) ^b	6.2 (3.1-12.4) ^b	Neurological: 9.1 (3.8-21.9) Socioeconomic status: 0.6 (0.5-0.9)

Abbreviations: CI, confidence interval; ELBW, extremely low birth weight; NBW, normal birth weight.

^aGeneralized estimating equations logistic regression model simultaneously analyzed data from ELBW and NBW children at both time points (8 years and 14 years) and was adjusted for socioeconomic status, race, sex, and neurosensory impairment. When the total number of events was less than 50, only significant predictors determined by backward selection were adjusted for in the model.

^bFor comparison of ELBW children with NBW controls, the *P* value was less than .05.

^cLogistic regression was used to estimate this odds ratio.

^dData not available because unable to calculate odds ratio due to zero value. Interaction between birth weight group and year was not statistically significant using an alternative test statistic.¹²

^eModel only adjusts for predictors significant at a *P* value of less than .05; if no predictors were significant, reported odds ratios comparing ELBW with NBW at each age are unadjusted.

^fPostneonatal hospitalizations prior to age 8 years compared with hospitalizations between the ages of 8 and 14 years.

^gIncludes modified schedule, classroom made accessible, special lunch, transportation, and tutoring.

dren.^{25,26} The major etiological determinant of asthma in normative populations is genetic susceptibility to atopic disease, which interacts with environmental factors, whereas the pathophysiology of asthma in preterm children is mainly associated with abnormal lung development, bronchopulmonary dysplasia, and obstructive airway disease.^{4,26-29} Improvement in pulmonary function^{28,29} and stabilization in the rates of asthma during adolescence have been reported among ELBW children^{16,29}; however, the way in which the trajectory differs from that of NBW children has not been reported.

Our rates of adolescent obesity among ELBW children and NBW controls reflect the current obesity epidemic.²² The increase in BMI among ELBW children during adolescence compared with NBW children has been reported previously in addition to the long-term implications of catch-up growth for metabolic and cardiovascular disease.^{7,8,30,31} However, the considerable catch-up in obesity among ELBW children to the current very high prevalence among NBW children may further intensify the known threat to adult health.

Our findings of a significant association of neurosensory impairments and lower socioeconomic status with functional limitations and need for services indicates both biological and sociodemographic influences on children's health in both NBW and preterm children. The significant association of male sex with functional limitations, need for services, and childhood asthma has been reported.^{20,24,27,32}

Strengths of this study include our longitudinal design and use of both noncategorical and specific diagnostic categories of chronic illness, each of which has important epidemiological and clinical implications. Our use of a generic or noncategorical approach, independent of diagnoses, provides an assessment of the multiple chronic sequelae of preterm birth and also incorporates a functional classification as suggested by the World Health Organization.³³

Children's special health care needs are used for the identification and planning of federal aid and services and also provide an indirect measure of the enormous cost of providing health care and education for these children, of whom preterm survivors constitute an important subgroup.³⁴⁻³⁶ We chose to examine longitudinal changes in the rates of asthma and obesity because asthma is a common consequence of preterm birth and obesity may have long-term metabolic and cardiovascular implications.³⁰

We did not consider cerebral palsy or cognitive impairment, which are chronic conditions that are also prevalent among preterm children, because their rates are fairly stable after middle childhood³⁷; however, the QUICCC-R does include parent report of developmental problems and need for special education.

The possible limitations of our study include the fact that our population is based on birth weight rather than gestational age and that our sample of ELBW children represents an urban perinatal center and is not representative of the entire United States. The follow-up rate of the NBW controls is lower than that of the ELBW children, which is probably due to their lesser commitment to the study. However, there were no sociodemographic differences between the 2 groups.

We excluded children with neurosensory abnormalities from the examination of obesity because they tend to grow poorly, which might have influenced outcomes. Fewer of the ELBW children followed up had bronchopulmonary dysplasia compared with those children who were not followed up, which might have influenced their rates of asthma.

Our results are based mainly on parent report, which may be biased and inconsistent between periods. However, the QUICCC has been validated as a parent measure of child health.¹⁰ Some outcomes had small numbers of events, which was reflected in the wide 95% CIs. There is always the possibility of detection bias among ELBW children; however, the detection of an in-

creased rate of asthma in NBW controls argues against this. Finally, because the QUICCC-R provides a noncategorical measure of chronic health conditions, specific diagnoses aside from asthma and obesity were not examined.

Because mortality of ELBW infants has reached a plateau with the majority of infants currently surviving, the residual rates of neonatal morbidity and resultant chronic illness have become critical.³⁸ Rates of neonatal morbidity have decreased since 2000 but there is, as yet, no evidence of improved health outcomes.

Our results may have relevance to current survivors. The ELBW status may be considered a marker for the risk of multiple chronic conditions that warrant closer than average health surveillance during adolescence. In addition to therapy for neurodevelopmental disorders, ELBW children with asthma or obesity should receive interventions such as smoking prevention and exercise encouragement to reduce the consequences of these conditions and to possibly enhance their long-term adult outcomes.^{39,40}

Author Contributions: Dr Hack had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Hack, Taylor, Drotar.

Acquisition of data: Hack, Andreias.

Analysis and interpretation of data: Hack, Schluchter, Andreias, Margevicius, Taylor, Drotar, Cuttler.

Drafting of the manuscript: Hack, Cuttler.

Critical revision of the manuscript for important intellectual content: Hack, Schluchter, Andreias, Margevicius, Taylor, Drotar, Cuttler.

Statistical analysis: Hack, Schluchter, Andreias.

Obtained funding: Hack.

Administrative, technical, or material support: Hack, Margevicius, Taylor, Cuttler.

Study supervision: Hack, Taylor.

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REFERENCES

- Hack M, Taylor HG, Drotar D, et al. Chronic conditions, functional limitations, and special health care needs of school-aged children born with extremely low birth-weight in the 1990s. *JAMA*. 2005;294(3):318-325.
- Anderson P, Doyle LW; Victorian Infant Collaborative Study Group. Neurobehavioral outcomes of school-age children born extremely low birth weight or very preterm in the 1990s. *JAMA*. 2003;289(24):3264-3272.
- Farooqi A, Hägglöf B, Sedin G, Gotheffors L, Serenius F. Chronic conditions, functional limitations, and special health care needs in 10- to 12-year-old children born at 23 to 25 weeks' gestation in the 1990s: a Swedish national prospective follow-up study. *Pediatrics*. 2006;118(5):e1466-e1477.
- Fawke J, Lum S, Kirkby J, et al. Lung function and respiratory symptoms at 11 years in children born extremely preterm: the EPIcure study. *Am J Respir Crit Care Med*. 2010;182(2):237-245.
- Stein RE, Silver EJ, Bauman LJ. Shortening the Questionnaire for Identifying Children With Chronic Conditions: what is the consequence? *Pediatrics*. 2001;107(4):E61.
- Newacheck PW, Kim SE. A national profile of health care utilization and expenditures for children with special health care needs. *Arch Pediatr Adolesc Med*. 2005;159(1):10-17.
- Hack M, Schluchter M, Cartar L, Rahman M, Cuttler L, Borawski E. Growth of very low birth weight infants to age 20 years. *Pediatrics*. 2003;112(1 pt 1):e30-e38.
- Saigal S, Stoskopf B, Streiner D, Paneth N, Pinelli J, Boyle M. Growth trajectories of extremely low birth weight infants from birth to young adulthood: a longitudinal, population-based study. *Pediatr Res*. 2006;60(6):751-758.
- Stein RE, Westbrook LE, Bauman LJ. The Questionnaire for Identifying Children With Chronic Conditions: a measure based on a noncategorical approach. *Pediatrics*. 1997;99(4):513-521.
- Stein RE, Bauman LJ, Epstein SG, Gardner JD, Walker DK. How well does the Questionnaire for Identifying Children With Chronic Conditions identify individual children who have chronic conditions? *Arch Pediatr Adolesc Med*. 2000;154(5):447-452.
- Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, et al. CDC growth charts: United States. *Adv Data*. 2000;314(314):1-27.
- Feuer EJ, Kessler LG. Test statistic and sample size for a two-sample McNemar test. *Biometrics*. 1989;45(2):629-636.
- Taylor HG, Minich NM, Klein N, Hack M. Longitudinal outcomes of very low birth weight: neuropsychological findings. *J Int Neuropsychol Soc*. 2004;10(2):149-163.
- Doyle LW, Casalaz D; Victorian Infant Collaborative Study Group. Outcome at 14 years of extremely low birthweight infants: a regional study. *Arch Dis Child Fetal Neonatal Ed*. 2001;85(3):F159-F164.
- Mai XM, Gäddlin PO, Nilsson L, et al. Asthma, lung function and allergy in 12-year-old children with very low birth weight: a prospective study. *Pediatr Allergy Immunol*. 2003;14(3):184-192.
- Saigal S, Stoskopf BL, Streiner DL, Burrows E. Physical growth and current health status of infants who were of extremely low birth weight and controls at adolescence. *Pediatrics*. 2001;108(2):407-415.
- Gäddlin PO, Finnström O, Hellgren K, Leijon I. Hospital readmissions and morbidity in a fifteen-year follow-up of very low birthweight children in Southeast Sweden. *Acta Paediatr*. 2007;96(4):499-505.
- van der Lee JH, Mookink LB, Grootenhuys MA, Heymans HS, Offringa M. Definitions and measurement of chronic health conditions in childhood: a systematic review. *JAMA*. 2007;297(24):2741-2751.
- Data Resource Center for Child and Adolescent Health Web site. Child and Adolescent Health Measurement Initiative: 2005/2006 national survey of children with special health care needs. <http://www.cshcndata.org>. Accessed January 30, 2011.
- Bethell CD, Read D, Blumberg SJ, Newacheck PW. What is the prevalence of children with special health care needs? toward an understanding of variations in findings and methods across three national surveys. *Matern Child Health J*. 2008;12(1):1-14.
- Bloom B, Cohen RA, Freeman G. Summary health statistics for US children: National Health Interview Survey, 2008. *Vital Health Stat*. 2009;(244):1-81.
- Ogden CL, Carroll MD, Curtin LR, Lamb MM, Flegal KM. Prevalence of high body mass index in US children and adolescents, 2007-2008. *JAMA*. 2010;303(3):242-249.
- Sears MR, Greene JM, Willan AR, et al. A longitudinal, population-based, cohort study of childhood asthma followed to adulthood. *N Engl J Med*. 2003;349(15):1414-1422.
- Akinbami LJ, Moorman JE, Garbe PL, Sondik EJ. Status of childhood asthma in the United States, 1980-2007. *Pediatrics*. 2009;123(suppl 3):S131-S145.
- Baraldi E, Filippone M. Chronic lung disease after premature birth. *N Engl J Med*. 2007;357(19):1946-1955.
- Halvorsen T, Skadberg BT, Eide GE, Røksund O, Aksnes L, Øymar K. Characteristics of asthma and airway hyper-responsiveness after premature birth. *Pediatr Allergy Immunol*. 2005;16(6):487-494.
- Subbarao P, Mandhane PJ, Sears MR. Asthma: epidemiology, etiology and risk factors. *CMAJ*. 2009;181(9):E181-E190.
- Doyle LW, Chavasse R, Ford GW, Olinsky A, Davis NM, Callanan C. Changes in lung function between age 8 and 14 years in children with birth weight of less than 1,501 g. *Pediatr Pulmonol*. 1999;27(3):185-190.
- Koumbourlis AC, Motoyama EK, Mutich RL, Mallory GB, Walczak SA, Fertal K. Longitudinal follow-up of lung function from childhood to adolescence in prematurely born patients with neonatal chronic lung disease. *Pediatr Pulmonol*. 1996;21(1):28-34.
- Eriksson JG, Forsén T, Tuomilehto J, Winter PD, Osmond C, Barker DJ. Catch-up growth in childhood and death from coronary heart disease: longitudinal study. *BMJ*. 1999;318(7181):427-431.
- Bhargava SK, Sachdev HS, Fall CHD, et al. Relation of serial changes in childhood body-mass index to impaired glucose tolerance in young adulthood. *N Engl J Med*. 2004;350(9):865-875.
- Van Cleave J, Gortmaker SL, Perrin JM. Dynamics of obesity and chronic health conditions among children and youth. *JAMA*. 2010;303(7):623-630.
- World Health Organization. *International Classification of Functioning, Disability and Health*. Geneva, Switzerland: World Health Organization; 1999.
- McPherson M, Arango P, Fox H, et al. A new definition of children with special health care needs. *Pediatrics*. 1998;102(1 pt 1):137-140.
- Wise PH, Huffman LC, Brat G. *A Critical Analysis of Care Coordination Strategies for Children With Special Health Care Needs*. Rockville, MD: Agency for Healthcare Research and Quality; 2007.
- Perrin JM, Bloom SR, Gortmaker SL. The increase of childhood chronic conditions in the United States. *JAMA*. 2007;297(24):2755-2759.
- Breslau N, Paneth NS, Lucia VC. The lingering academic deficits of low birth weight children. *Pediatrics*. 2004;114(4):1035-1040.
- Stoll BJ, Hansen NI, Bell EF, et al; Eunice Kennedy Shriver National Institute of Child Health and Human Development Neonatal Research Network. Neonatal outcomes of extremely preterm infants from the NICHD Neonatal Research Network. *Pediatrics*. 2010;126(3):443-456.
- Barton M; US Preventive Services Task Force. Screening for obesity in children and adolescents: US Preventive Services Task Force recommendation statement. *Pediatrics*. 2010;125(2):361-367.
- Doyle LW, Olinsky A, Faber B, Callanan C. Adverse effects of smoking on respiratory function in young adults born weighing less than 1000 grams. *Pediatrics*. 2003;112(3 pt 1):565-569.