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PEDIATRIC ORIGINAL ARTICLE

Factors predicting severe childhood obesity in kindergarteners

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BACKGROUND: Severe obesity has increased >300% in US children since 1976, and is associated with multiple cardiovascular risk factors and high adult obesity rates.
OBJECTIVE: The objective of this study was to identify predictors of severe obesity in kindergarteners.
METHODS: Multivariable logistic regression and recursive partitioning analysis (RPA) were used to identify prenatal/pregnancy, infant, and early childhood predictors of severe kindergarten obesity (body mass index (BMI) ⩾99th percentile) in the Early Childhood Longitudinal Study Birth Cohort, a nationally representative longitudinal study that followed children from birth through kindergarten.
RESULTS: For the 6800 children, the severe kindergarten obesity prevalence was 5.7%, with higher adjusted odds for crossing the 85th percentile of BMI at 2 years old (odds ratio (OR), 8.0; 95% confidence interval (CI), 4.1–15.7), preschool age (OR, 7.9; 95% CI, 4.9–12.8) and 9 months old (OR, 1.8; 95% CI, 1.2–2.6); maternal severe obesity (OR, 3.4; 95% CI, 1.9–5.8) and gestational diabetes (OR, 2.9; 95% CI, 1.5–5.5); drinking tea or coffee between meals/before bedtime at 2 years old (OR, 3.3; 95% CI, 1.3–8.5); Latino (OR, 2.3; 95% CI, 1.4–3.7) and multiracial (OR, 2.3; 95% CI, 1.1–4.8) race/ethnicity; and drinking sugary beverages at kindergarten age at least weekly (OR, 2.3; 95% CI, 1.4–3.7). Ever-attending center-based daycare (OR, 0.3; 95% CI, 0.1–0.9), eating fruit at least weekly at kindergarten age (OR, 0.3; 95% CI, 0.1–0.7), and maternal history of a prior newborn birth weight ⩾4000 g (OR, 0.1; 95% CI, 0.02–0.6) were associated with reduced odds of severe obesity. RPA identified low severe obesity prevalence (1.9%) for non-85th BMI-percentile preschool crossers and high severe obesity (56–80%) for predictor clusters which included crossing the 85th BMI percentile at earlier ages, low parental education, specific maternal age cutoffs, preschooler bedtime rules, and outside walking/play frequency for 9-month-olds.
CONCLUSIONS: Certain parental, prenatal/pregnancy, infant, and early childhood factors, both alone and in combination, are potent predictors of severe obesity in kindergarteners.

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Keywords: overweight; children; early childhood; recursive partitioning analysis

INTRODUCTION

Severe obesity in children is defined as ⩾99th percentile of body mass index (BMI) for age and gender.[1] Among 2- to 19-year-old US children, the severe obesity prevalence has increased by >300%, from 0.8% in 1976–1980 to 3.8% in 1999–2004.[2] Severe childhood obesity is associated with multiple cardiovascular risk factors, including elevated total cholesterol, triglycerides, serum glucose, glycohemoglobin, and systolic blood pressure, and low high-density lipoprotein.[3] Almost half of severely obese children have elevated/borderline total cholesterol, more than 1/3 have abnormal serum glucose, 19% have high/borderline systolic blood pressure, 59% have ⩾2 cardiovascular risk factors, and 94% have excess adiposity.[3,4] Severely obese children have significantly higher levels of multiple inflammatory markers,[5] and school absenteeism rates 11% greater than healthy-weight children.[6] The Bogalusa Heart Study documented that all severely obese children became obese adults, and 88% attained adult BMIs ⩾35 kg m^{-2}.[4]

Little is known, however, about predictors of severe childhood obesity. To our knowledge, no studies have examined the risk and protective factors for severe kindergarten obesity, a particularly important issue, given research documenting that the higher number of adipocytes in obese adults is set during childhood, the mean age of adipocyte number expansion is two years old for those eventually becoming obese adults, and deviations from normal adipocyte size and number can occur as early as one year old.[7,8] The aim of this study, therefore, was to analyze data from a nationally representative prospective cohort to identify predictors of severe kindergarten obesity.

MATERIALS AND METHODS

Data source

The Birth Cohort of the Early Childhood Longitudinal Study (ECLS-B) is a nationally representative longitudinal study that followed 14 000 children from birth in 2001 to kindergarten entry. The cohort was followed through 2008; data were collected by the National Center for Education Statistics Institute of Education Sciences (IES) when children were 9 months old, 2 years old, and 4 years old (preschool age). For the final kindergarten wave, data were collected from all participating sample children, either in 2006, for the approximately 75% of the sample in kindergarten or higher, or in 2007–2008, for the remaining 25% of the sample who had not entered kindergarten previously or were repeating kindergarten in the 2007–2008 school year. ECLS-B participants came from diverse socio-economic and racial/ethnic backgrounds, with oversampling of children who were Chinese, of other Asian/Pacific Islander groups, American Indian/Alaska Native, twins, and of low or very low birth weight.

ECLS-B conducted interviews, across the United States, of children, parents, childcare and early-education providers, and teachers. Questions

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addressed children's early development, health care, nutrition, physical well-being, and kindergarten experiences. Additional items examined parental characteristics and prenatal/pregnancy factors, including maternal weight status before pregnancy, gestational weight gain, prior birth history, prenatal care, maternal health during the pregnancy, health behaviors during the pregnancy, and physician counseling during the pregnancy. Computer-assisted personal interviewing and audio computer-assisted self-interviewing were conducted, except for teachers, who were surveyed by mail.

Children's weights were directly measured by instructing the child to stand unassisted on a SECA scale (Hamburg, Germany). Children were asked to remove their shoes, jackets, and heavy outerwear. Weight was recorded in kilograms; three independent measures were taken, and the two measurements closest in value were averaged to calculate the child's average weight. Height was measured using a SECA portable stadiometer. The child stood erect at the base of the stadiometer, with his or her head in the correct position (head upright), facing away from the stadiometer. Then, a crown piece was lowered, and the child's height was measured in centimeters. Three measurements were taken, with the child stepping off the stadiometer between measurements. The two closest measurements were averaged to calculate the child's average height. Direct weight and height measurements were obtained for all children at 9 months old, 2 years old, preschool age, and kindergarten age.

Full details on ECLS-B methods and procedure are provided elsewhere.[9,10] Study approval was provided by IES (license no. 11040020).

Analyses

SAS 9.1 (Cary, NC, USA) was used for bivariate analyses and multivariable logistic regression. Severe obesity at kindergarten entry, the primary outcome, was defined as an age- and gender-specific BMI $\geqslant$99th percentile, consistent with prior work.[2] BMI was calculated using direct weight and height measurements and Centers for Disease Control and Prevention national reference standards.[11]

Bivariate analyses (using Pearson's χ^2 test and *t*-statistic) examined associations of 32 parental, 21 prenatal/pregnancy, 32 infant, and 46 early childhood characteristics with severe obesity. To adjust for the complex survey design and provide national estimates, ECLS-B weights and variance estimation techniques were used. Initial statistical significance was assessed using a two-tailed $P<0.05$; subsequent adjustment for multiple comparisons was carried out using Bonferroni, Sidák, and Bootstrap *P*-values.[12] Significant bivariate analyses findings are summarized in the Results section; nonsignificant findings are noted in table footnotes.

Weighted, forward stepwise procedures were used for the multivariable logistic regression. Given the large number of variables, potential multicollinearity was assessed using a variance inflation factor. The best-fitting model was identified using the log-likelihood χ^2, pseudo-R^2, and Hosmer and Lemeshow's goodness-of-fit tests. For independent variables with a high outcome prevalence, odds ratios (ORs) are accompanied by relative risks, calculated using the method of Zhang and Yu.[13] ORs and 95% confidence intervals (CIs) are presented in the Results section in descending order of ORs for all independent variables found to be significantly associated with severe obesity in kindergarteners.

Recursive partitioning analysis (RPA) was performed to identify clusters of characteristics predicting a high and low prevalence of severe kindergarten obesity. RPA is a multivariable targeted-cluster procedure that iteratively evaluates predictor variables to identify optimal binary splits, yielding groups with the highest and lowest severe obesity prevalence. This process is repeated until either a subpopulation contains one class of individuals or is too small to divide. Reduction in variance, rather than *P*-values, determines branch points, as RPA is nonparametric. For continuous variables, however, binary splits are executed at the highest level of statistical significance. The final product is a tree-like pattern of stepwise branching partitions. To correct for potential overfitting, cross-validation was performed using the 10-fold method and 1-s.e. rule.[14] RPA was conducted using R 2.9.1 (R Development Core Team, Vienna, Austria).

RESULTS

Bivariate analyses

The severe obesity prevalence was 5.7%. The only sociodemographic factors predicting severe kindergarten obesity were Latino and multiracial race/ethnicity, male gender, lower parental educational attainment, poverty, a non-English primary language spoken at home, and a higher number of adults in the household (Table 1). Several prenatal/pregnancy and infant factors were associated with severe kindergarten obesity (Table 2). More than 9% of severely obese kindergarteners had mothers who were severely obese just before pregnancy, compared with only 3% in those without maternal severe obesity. Taking vitamin/mineral supplements at least 3 days weekly during the 3 months before pregnancy and a maternal history of prior birth of a baby weighing $\geqslant$4000 g were associated with a lower prevalence of severe kindergarten obesity, whereas maternal gestational diabetes, talking with a doctor about the effects of smoking on the fetus, and a younger maternal age were associated with a higher severe obesity prevalence. Vaginal delivery, lower birth weight, and lower weight-for-gestational age categories were associated with a lower severe obesity prevalence, whereas higher weight-for-gestational categories and middle upper-arm and head circumferences at 9 months old were associated with a higher severe obesity prevalence. No other prenatal/pregnancy or newborn factors were associated with severe obesity, including maternal gestational weight gain.

Multiple early childhood factors predicted severe kindergarten obesity (Table 3). Crossing the 85th percentile of BMI at an earlier

Table 1. Bivariate analysis of sociodemographic factors associated with severe obesity at kindergarten entry in US children[a,b]

Characteristic	*Weight status*		*P*-value
	Not severely obese (N = 6400; 94.3%)	*Severely obese (N = 400; 5.7%)*	
Age (years)	5.7 (± 0.01)	5.6 (± 0.03)	<0.01
Race/ethnicity (%)			<0.01
White	55.2	35.5	
Latino	23.9	43.1	
African-American	14.0	13.8	
Asian/Pacific Islander	2.8	1.7	
American Indian/ Alaska Native	0.4	0.6	
Multiracial	3.7	5.3	
Male gender (%)	50.7	58.8	0.02
Highest educational attainment in household (%)			<0.01
Not high-school graduate	12.7	20.7	
High-school graduate	24.8	35.6	
At least some college	62.5	43.7	
Family income ever below poverty threshold (%)	67.9	82.7	0.01
Primary language spoken at home, not English (%)	17.6	28.5	<0.01
Number of adults in household	2.2 (± 0.01)	2.3 (± 0.06)	<0.01

[a]The '±' values are means ± s.d. [b]No significant associations with severe obesity were found for the biological mother's marital status when the child was born, food security with hunger, employment status of mother or father, maternal or paternal age at the time of the child's birth, number of children in the household, child's insurance coverage, urban location for the household, or geographic region of the country.

Table 2. Bivariate analysis of prenatal/pregnancy and infant factors associated with severe obesity at kindergarten entry in US children[a]

Characteristic	*Weight status*		*P*-value
	Not severely obese (N = 6400; 94.3%)	*Severely obese (N = 400; 5.7%)*	
Prenatal/pregnancy risk factors[b]			
Mother severely obese just before getting pregnant (%)[d]	2.6	9.3	<0.01
Took vitamin/mineral supplement at least 3 days weekly during 3 months before pregnancy (%)	37.2	29.9	0.01
Maternal history of giving birth to baby ⩾4000 g (%)	1.1	0.2	<0.01
Maternal gestational diabetes (%)	2.9	8.1	<0.01
Talked with doctor about how smoking would affect baby during pregnancy (%)	84.9	90.9	<0.01
Maternal age when first child born, mean (s.e.)	23.8 (0.2)	22.5 (0.5)	<0.01
Newborn risk factors[c]			
Vaginal delivery (%)	74.8	65.2	0.01
Birthweight (g)	3300.4 (± 11.1)	3481.5 (± 33.7)	<0.01
Weight for gestational age percentile (%)			<0.01
<10 (SGA)	10.9	5.1	
10–24	14.9	12.3	
25–49	24.4	20.2	
50–74	24.3	23.7	
75–89	15.0	21.1	
⩾90% (LGA)	10.6	17.6	
Middle upper-arm circumference (cm) at 9 months old	15.8 (± 0.1)	16.7 (± 0.2)	<0.01
Head circumference (cm) at 9 months old	44.1 (± 0.1)	45.5 (± 1.2)	<0.01

Abbreviations: BMI, body mass index; CDC, Centers for Disease Control and Prevention; LGA, large for gestational age; SGA, small for gestational age. [a]The '±' values are means ± s.d. [b]No significant associations with severe obesity were found for maternal hypertension during pregnancy; maternal chronic hypertension; maternal anemia during pregnancy; a prior maternal history of giving birth to a LGA baby; a prior maternal history of giving birth to a preterm or SGA baby; maternal weight gain during pregnancy; adequacy of prenatal care; maternal weight gain after child was born; visiting a doctor for prenatal care; the mother talking with her doctor during pregnancy about breastfeeding; the mother talking with her doctor during pregnancy about what she should eat while pregnant or the effects of drinking alcohol during pregnancy; taking vitamins 3 months after pregnancy; mother currently smoking; mother smoking at least 100 cigarettes in entire life; the number of cigarettes smoked in the 3 months before the pregnancy or in the last 3 months of the pregnancy; the number of alcoholic drinks 3 months before the pregnancy or in the last 3 months of pregnancy; the number of weeks being pregnant before knowing about the pregnancy; and the number of biological children that the mother has. [c]No significant associations with severe obesity were found for the number of weeks of gestation or any abnormal conditions of the newborn noted on the birth certificate. [d]By maternal report of height and weight, using CDC definition of severe obesity for adults with a BMI ⩾40 kg m^{-2}.

age was substantially predictive of severe kindergarten obesity. Half of 85th percentile of BMI crossers at 9 months old became severely obese, vs about one-fourth of non-crossers, and almost three-fourth of preschool crossers vs about one-fourth of non-crossers became severely obese. Younger ages at the first formula feed and introduction of solid and finger foods, putting the child to sleep with a bottle at 9 months old, maternal agreement that toilet training should occur before the age of 1 year, and needing but not getting health care (which was no longer significant after adjustment for multiple comparisons) were associated with severe obesity, whereas rules about bedtime for the child at 2 years old, a greater number of hours slept daily at kindergarten age, and a nonrelative caretaker for the child were associated with a lower severe obesity prevalence. The mean hours of daily TV viewing at preschool and kindergarten ages and the frequency of using home computers were higher for severely obese kindergarteners, whereas the mean weekly days eating dinner together as a family at preschool and kindergarten age (except after adjustment for multiple comparisons), the mean weekly days of eating dinner at a regular time at preschool and kindergarten age, participation in organized athletic activities after school at preschool (except after multiple comparisons adjustment) and kindergarten age, and mean weekly days of caregiver vigorous exercise when the child was of preschool and kindergarten ages were lower for severely obese kindergarteners. Drinking milk with meals at 2 years old was associated with a lower risk of severe obesity (except after multiple comparisons adjustment), as was having rules about the kinds of food the child ate at preschool and kindergarten age, whereas drinking fruit-flavored drinks or nothing with meals at 2 years old, drinking 100% fruit juice more than four times daily, drinking sugary beverages at least once daily, and eating fast food at kindergarten age more than three times weekly were associated with a higher severe obesity prevalence. No other early childhood factors were associated with severe obesity.

Multivariable logistic regression

Those crossing the 85th percentile of BMI at earlier ages had especially higher adjusted odds of severe kindergarten obesity (Table 4). Severe maternal obesity, drinking tea or coffee between meals or before bedtime at 2 years old, and maternal gestational diabetes were associated with triple the odds of severe obesity. Latino and multiracial race/ethnicity, drinking sugary beverages at kindergarten age at least once weekly, the number of adults in the household, and middle upper-arm circumference at 9 months old also were associated with severe obesity. Maternal age at having the first child and the child's age were associated with reduced odds of severe obesity. Ever attending center-based daycare, eating fruit at least once weekly at kindergarten age, and a maternal history of a prior newborn birth weight of ⩾4000 g were associated with substantially reduced odds of severe obesity.

Recursive partitioning analysis

The proportion of children with severe obesity at kindergarten entry was 5.7%. Crossing the 85th percentile of BMI at preschool age resulted in a severe kindergarten obesity prevalence of 16%, compared with only 2% in non-crossers (Figure 1). Among preschool-age crossers, crossing the 85th percentile of BMI at 9 months old predicted a severe kindergarten obesity prevalence of 20%, compared with only 12% for non-crossers. Among crossers both at preschool age and at 9 months old, those in households with the highest educational attainment being at least in some college had a 15% severe obesity prevalence, compared with 28% for lower educational attainment. For the latter group, older maternal age ($\geqslant$29.5 years old) predicted severe obesity in 43%, compared with 25% for a younger maternal age. For the latter group, having $\geqslant$5 adults in the household resulted in severe obesity in 56%, compared

Table 3. Bivariate analysis of early childhood factors associated with severe obesity at kindergarten entry in US children[a, b]

Characteristic	*Weight status*		*P*-value
	Not severely obese (N = 6400; 94.3%)	*Severely obese (N = 400; 5.7%)*	
Crossed 85th percentile of BMI at 9 months old (%)	28.1	50.1	<0.01
Crossed 85th percentile of BMI at 2 years old (%)	7.6	15.6	<0.01
Crossed 85th percentile of BMI at preschool age (%)	27.0	71.6	<0.01
Age when first fed formula (months)	3.7 (±0.1)	2.5 (±0.2)	<0.01
Age when solid food introduced (months)	4.5 (±0.04)	4.1 (±0.1)	0.04
Age when given finger food (months)	7.0 (±0.03)	6.7 (±0.1)	<0.01
Put child to bed for sleep with bottle at 9 months old (%)	29.0	38.6	0.01
Rules about the time the child went to bed at 2 years old (%)	85.4	79.1	0.02
Number of hours slept each day at kindergarten age	10.4 (±0.02)	10.2 (±0.05)	0.02
Mother agrees that toilet training should occur before child is 1 year old (%)	11.2	20.9	<0.01
Non-relative taking care of child living in household (%)	15.8	3.7	0.04
Child needed health care but could not get it (%)	1.9	4.3	0.02[d]
Hours of watching TV each day on weekdays at preschool age	2.3 (±0.04)	3.2 (±0.3)	<0.01
Hours of watching TV each day on weekdays at kindergarten age	2.1 (±0.05)	2.6 (±0.2)	<0.01
Frequency of child using home computer at kindergarten age (%)			0.02
Never	6.5	4.9	
Once or twice a week	58.1	53.5	
3–6 times a week	24.0	21.0	
Every day	11.4	20.6	
Days per week eating dinner together as a family at preschool age	5.5 (±0.04)	5.1 (±0.1)	<0.01[d]
Days per week eating dinner together as a family at kindergarten age	5.6 (±0.04)	5.3 (±0.1)	0.01[d]
Days per week eating dinner at regular time at preschool age	4.9 (±0.1)	4.4 (±0.2)	0.03
Days per week eating dinner at regular time at kindergarten age	5.0 (±0.05)	4.6 (±0.2)	<0.05
Child participated in organized athletic activities after school at preschool age (%)	30.9	20.4	<0.01[d]
Child participated in organized athletic activities after school at kindergarten age (%)	44.5	32.6	<0.01
Days per week caregiver got exercise that causes rapid breathing and fast heartbeat for $\geqslant$30 continuous minutes at preschool age	2.0 (±0.04)	1.7 (±0.2)	0.05
Days per week caregiver got exercise that causes rapid breathing and fast heartbeat for $\geqslant$30 continuous minutes at kindergarten age	1.9 (±0.1)	1.6 (±0.1)	0.04
Child usually drank milk with meals at 2 years old (%)	55.9	48.7	<0.05[d]
Child usually drank fruit-flavored drink with meals at 2 years old[c] (%)	14.3	23.1	<0.01
Child usually drank sodas with meals at 2 years old (%)	6.2	12.5	<0.01
Child usually drank nothing with meals at 2 years old (%)	0.3	1.0	0.04
Had rules about kinds of food child ate at preschool age (%)	76.9	67.9	0.01
Had rules about kinds of food child ate at kindergarten age (%)	77.2	69.4	0.02
Frequency of child drinking 100% fruit juices (such as orange juice, apple juice, or grape juice) (%)			0.02
None in past 7 days	11.4	15.2	
1–3 times in past 7 days	19.4	18.5	
4–6 times in past 7 days	9.2	5.0	
Once daily	27.6	25.3	
Twice daily	18.5	19.4	
Three times daily	9.1	13.4	
$\geqslant$ 4 times daily	4.9	3.3	
Frequency of child drinking sugary beverages (soda pop, sports drinks, or fruit drinks that are not 100% fruit juice) (%)			<0.01
None in past 7 days	27.8	16.8	
1–3 times in past 7 days	36.4	33.3	
4–6 times in past 7 days	7.9	4.6	
Once daily	15.9	24.1	
Twice daily	6.7	10.9	
Three times daily	3.4	3.8	
$\geqslant$4 times daily	1.9	6.5	

Table 3. (Continued)

Characteristic	*Weight status*		*P*-value
	Not severely obese (N = 6400; 94.3%)	*Severely obese (N = 400; 5.7%)*	
Frequency of child eating fast food at kindergarten age (%)			0.01
None in past 7 days	27.4	19.9	
1–3 times in past 7 days	64.3	65.6	
4–6 times in past 7 days	2.2	3.1	
Once daily	4.3	6.4	
Twice daily	1.0	2.7	
Three times daily	0.4	0.9	
⩾4 times daily	0.4	1.3	

Abbreviation: DUI, drunk driving conviction. [a]The '±' values are means ± s.d. [b]No significant associations with severe obesity were found for the child able to drink from self-held cup or feed self at 9 months old; age at which first fed cow's milk; age sitting without support; age started crawling; age pulled self to stand; age walking with help; age started feeding self; needed a lot of help to fall asleep at 9 months old; routinely put child to bed for sleep when child was awake at 9 months old; contents of bottle for child put to bed with bottle at 9 months old; has regular routine for bedtime at 2 years old; parent's rating of difficulty raising child at 9 months old; parent used book/magazine on parenting; mother did not live with child for longer than 1 week; frequency of taking child out to walk or play at 9 months old; frequency of playing peek-a-boo with child at 9 months old; frequency of tickling child, blowing, or moving child's arms and legs around in playful way when the child was 9 months old; mother agrees that 'It is important to see that a young child does not form bad habits'; mother agrees that 'Most mothers nowadays let their children get away with too much'; child ever had care from a relative; a relative living in the household is taking care of child; child ever had care from a non-relative; non-relative living in household taking care of child; child ever attended center-based child care; child ever seen by a medical specialist; number of well-baby checkups at 9 months old; caregiver ever had drinking or drug problem; caregiver ever convicted of DUI; caregiver ever arrested or convicted; maternal depression; hours of watching TV each day on weekdays or weekends at 2 years old; hours of watching DVDs each day on weekdays at preschool or kindergarten age; frequency of child using home computer at preschool age; child used computer to get on internet at preschool or kindergarten age; has home computer that child used at kindergarten age; frequency of child using home computer at kindergarten age; number of days per week eating breakfast as family at 2 years old; number of days per week eating dinner as family at 2 years old; number of days per week eating dinner at regular time at 2 years old; frequency of going out to eat; frequency of taking child outside for walk or play at 2 years old or preschool age; number of days per week caregiver got exercise that causes rapid breathing and a fast heartbeat for 30 continuous minutes or more at preschool age; child usually drank soda, coffee, tea, or nothing with meals at 2 years old; drinking milk, juice, fruit-flavored drinks, soda, water, coffee, tea, or other drinks between meals or before bedtime at 2 years old; type of milk consumed at 2 years old; age at which child discontinued formula or breastfeeding; child spent most afterschool time at kindergarten age eating snacks, using computer, watching TV/videos/listening to music, or in outdoor play/sports/activities; frequency of drinking milk at kindergarten age; frequency of drinking 100% fruit juices; frequency of child eating fresh fruits or vegetables (other than French fries and other fried potatoes); frequency of child eating candy, ice cream, cookies, cakes, brownies, or other sweets; frequency of child eating salty snack foods; or whether child ate any salty snack foods during the past 7 days. [c]Other than milk, water, juice, fruit-flavored drinks, soda, coffee, or tea. [d]Not statistically significant after Bonferroni, Šidák, and/or Bootstrap adjustment for multiple comparisons.

Table 4. Multivariable logistic regression analysis of factors predicting severe obesity at kindergarten entry in US children

Variable	*Odds ratio (95% CI) for severe Obesity in kindergarten*
Crossed 85th percentile of BMI at 2 years old	8.0 (4.1, 15.7)[a]
Crossed 85th percentile of BMI at preschool age	7.9 (4.9, 12.8)[b]
Mother severely obese just before getting pregnant	3.4 (1.9, 5.8)
Child usually drank tea or coffee between meals or before bedtime when 2 years old	3.3 (1.3, 8.5)
Maternal gestational diabetes while pregnant with index child	2.9 (1.5, 5.5)
Latino	2.3 (1.4, 3.7)
Drank sugary beverages[c] at kindergarten age at least once in the past 7 days	2.3 (1.4, 3.7)
Multiracial	2.3 (1.1, 4.8)
Crossed BMI percentile at 9 months old	1.8 (1.2, 2.6)
Number of adults in household	1.3 (1.0,1.5)
Middle upper-arm circumference at 9 months old	1.2 (1.1, 1.3)
Maternal age at birth of first child	0.96 (0.93, 0.99)
Child's age	0.6 (0.4, 0.96)
Ever attended center-based child care[d] on a regular basis	0.3 (0.1, 0.9)
Ate fruit[e] at least once in past 7 days at kindergarten age	0.3 (0.1, 0.7)
Birth weight of a previous newborn ⩾4000 g	0.1 (0.02, 0.6)

Abbreviations: BMI, body mass index; CI, confidence interval. [a]Relative risk (95% CI): 5.2 (3.3, 7.4). [b]Relative risk (95% CI): 2.8 (2.4, 3.1). [c]Including soda, sports drinks, and fruit drinks that are not 100% fruit juice. [d]Including early-learning centers, nursery schools, and preschools. [e]Including fresh, canned, frozen, and dried fruit.

with 23% for those with fewer household adults. Among crossers both at preschool age and at 9 months old with lower educational attainment and older maternal age, the severe obesity prevalence was 79% for those without preschooler bedtime rules, compared with 35% for those with rules. For the latter group, the severe obesity prevalence was 14% in those with non-vaginal deliveries compared with 46% for vaginal deliveries. For the latter group, taking the child outside to walk or play a few times monthly or less at 9 months old predicted a severe obesity prevalence of 80%, compared with 33% for those with outside

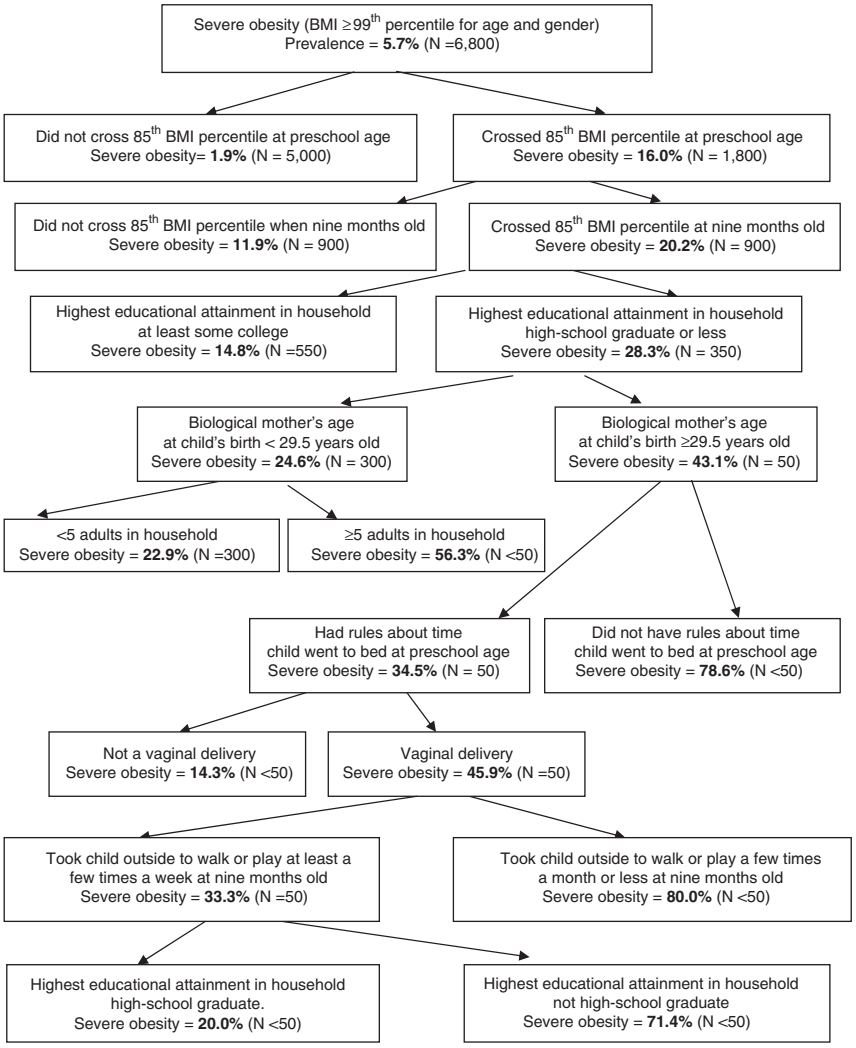

Figure 1. RPA-identified clusters of parental, prenatal/pregnancy, infant, and early childhood factors associated with severe obesity at kindergarten entry in US children.

walk/play sessions at least a few times weekly. For the latter group, the severe obesity prevalence was 71% for those in households with less than a high-school graduate highest educational attainment, vs 20% for those in households with at least a high-school graduate highest educational attainment.

DISCUSSION

This observational cohort study indicates that certain parental, prenatal/pregnancy, infant, and early childhood factors, both alone and in combination, may be potent predictors of severe obesity in kindergarteners. Crossing the 85th percentile of BMI before kindergarten age was an especially powerful predictor of severe obesity in kindergarten. Crossers at 9 months old had about double the odds of severe obesity in kindergarten, and crossing at 2 years old and at preschool age each was associated with eight times the odds of becoming a severely obese kindergartener. In RPA, crossing at preschool age and at 2 years old generated the first two splits and the foundation for all subsequent risk clusters. This is the first study, to our knowledge, to document such findings. Although not specifically examining severe obesity, other research has shown a relationship between upward weight percentile crossing or early rapid weight gain and childhood obesity.[15–20] Our findings suggest that carefully monitoring the growth curves of children as young as 9 months old for crossing the 85th percentile of BMI might prove useful in identifying young children at highest risk for future severe obesity and who might benefit most from parental education, counseling, and potential interventions; additional research is needed on these crucial issues.

Certain study limitations and strengths should be noted. Although ECLS-B contains extensive data on numerous variables, information was unavailable on paternal BMI. To date, ECLS-B data are also unavailable past kindergarten. There is some debate regarding the optimal cutoff point for categorizing children as 'severely obese,' with arguments for using either 120% of the Centers for Disease Control and Prevention 95th percentile or 112% of the Centers for Disease Control and Prevention 97th percentile, rather than the 99th percentile;[21] it would therefore be useful to determine whether our study findings persisted using these alternate cutoff points. Certain cutoff points for variables with multiple states were chosen on the basis of prior studies and clinical experience, but the use of different cutoff points might result in somewhat different findings. Some data—such as information on the type and frequencies of children's food and beverage consumption—were available in ECLS-B only via maternal self-report, and thus may or may not accurately reflect data collected using more objective measures. Strengths include a nationally representative cohort of several thousand children; rich data on parental, prenatal/pregnancy, infant, and early childhood

variables; multivariable analyses, which include both multivariable logistic regression and RPA; and the first analysis (to our knowledge) of predictors of severe kindergarten obesity in US children.

Certain maternal factors were associated with severe kindergarten obesity. Severe maternal obesity just before pregnancy was associated with more than triple the odds of severe kindergarten obesity. Although prior research has not examined such an association for severe obesity, these findings complement previous studies documenting associations between maternal and child overweight and obesity.[22–27] Maternal gestational diabetes additionally was associated with triple the adjusted odds of severe kindergarten obesity. The association of maternal gestational diabetes with severe childhood obesity has not been previously noted in the literature, but two recent systematic reviews found inconsistent evidence for an association between maternal gestational diabetes and childhood overweight or obesity.[28,29] One study, however, which adjusted for confounders, including weight gain during pregnancy but not prepregnancy BMI, revealed that untreated maternal gestational diabetes resulted in double the odds of the child's weight being $>$95th percentile.[30] Our study also found that a more advanced maternal age at the first child's birth and especially a previous newborn birth weight $\geqslant$4000 g protected against severe kindergarten obesity. The reasons for these findings are unclear and have not been previously reported. One might speculate that a more advanced maternal age could possibly confer a higher likelihood of greater life experiences and increased proficiency and familiarity with children's dietary and weight issues (because of a higher probability of having other children with older maternal age), and that having a high-birth-weight newborn could trigger a greater awareness of, or focus on, early childhood weight and feeding issues, but these intriguing findings require additional confirmation and research. Taken together, these maternal risk and protective factors for severe kindergarten obesity merit further study, particularly regarding whether treatment of the potentially modifiable risk factors of maternal prepregnancy severe obesity and gestational diabetes might prevent severe childhood obesity. For example, one study indicated that although untreated gestational diabetes is associated with childhood obesity, there is no such association for treated gestational diabetes.[28]

Latino and multiracial children have more than double the odds of white children of severe kindergarten obesity. Two prior National Health and Nutrition Examination Survey studies limited to three racial/ethnic groups (whites, Mexican-Americans and African-Americans) found that the unadjusted severe obesity prevalence was highest in Mexican-Americans and African-Americans aged 2–19 years.[2,31] A recent study indicates that prevention and treatment components of particular promise for severely obese Latino children include integrating traditional dietary customs and preferences, family-centered approaches to physical activity, and healthy, acceptable substitutions for traditional Latino meal items.[32] The severe obesity disparity for multiracial children adds to the growing list of disparities for this group.[33]

Multivariable logistic regression revealed three potentially modifiable factors associated with severe obesity in kindergarteners. Those drinking tea or coffee between meals or before bedtime at 2 years old had triple the odds of severe kindergarten obesity. This is the first study, to our knowledge, to report such a finding. The reason for this association is unclear and warrants additional study, although one might speculate that tea and coffee consumption might possibly increase the overall amount and frequency of daily sugary beverage consumption, or be an indirect marker of a more permissive parenting style. Although tea and coffee consumption are uncommon in young children,[34] this finding is potentially noteworthy because it is possible that this habit might be modifiable through early parental counseling and education, although additional observational and intervention studies of this issue are needed. Sugary beverage consumption in kindergarten at least weekly was associated with more than double the odds of severe kindergarten obesity; again, this is the first report of such an association (to our knowledge). Two systematic reviews, however, concluded that sugary beverage intake is associated with increased energy intake, body weight, and obesity in children and adults.[35,36] Reduction of sugary beverage consumption also would seem to be a potentially promising, modifiable mechanism as part of interventional approaches to preventing severe childhood obesity, given that effective interventions for reducing sugary and carbonated beverages exist and are efficacious in reducing BMI (especially for those with the highest BMIs)[37] and childhood overweight/obesity.[38] In contrast, kindergarteners who consume fruit are more than three times less likely to be severely obese. A systematic review of intervention studies of fruit and vegetable consumption concluded that fruits are the most satiating foods tested, and increased fruit and vegetable consumption is a beneficial component of weight management.[39] Encouraging frequent fruit consumption early in childhood might thus represent a particularly useful strategy in interventions aimed at the prevention of severe obesity, particularly in light of a recent study showing that an obesity prevention intervention targeting preschoolers can significantly increase fruit and vegetable consumption and reduce BMI *Z*-scores.[40]

Attending center-based childcare was protective against severe kindergarten obesity, with a severe obesity odds more than three times lower in attenders vs non-attenders. This is the first study, to our knowledge, to demonstrate such an association. Certain studies have shown that preschool and limited center-based attendance are associated with decreased childhood overweight or obesity,[41,42] whereas others indicated no such association.[43,44] The reasons for the strong protective association between center-based daycare attendance and severe kindergarten obesity are unclear, and warrant further study. One potential avenue of investigation might be whether center-based daycare decreases exposure to obesogenic home risk factors and increases healthy behaviors for those at risk for severe obesity. For example, a recent study indicated that high proportions of center-based childcare programs have outside play areas, fixed and portable play equipment, at least 30 min of teacher-led physical activities daily, and provision of water, and rarely/never offer soda.[45]

RPA identified clusters of parental, prenatal/pregnancy, infant, and early childhood characteristics associated with a markedly high and low prevalence of severe kindergarten obesity. Although the overall prevalence of severe kindergarten obesity was 6%, RPA revealed a 2% severe obesity prevalence in preschooler non-crossers of the 85th percentile of BMI, and also yielded four groups in which over 50% of children were severely obese, including three groups with a 71–80% severe obesity prevalence. RPA is a powerful tool because of several key advantages over traditional algebraic methods of multivariable analyses, including: (1) allowing direct inspection and immediate understanding of results; (2) categorical tables requiring no data assumptions; (3) clarity about operational or methodological decisions; (4) routine searching for interactions; and (5) findings that are especially compatible with clinical and biological thought processes and rarely include mathematical combinations of weighted variables.[46] RPA recently has shed light on a wide variety of clinical issues, including glioblastoma prognosis,[47] asthma exacerbations,[48] extremely premature infants at high risk for rehospitalization[49] and prediction of pneumonia in pediatric emergency departments.[50]

The study results suggest certain implications for practice, research and policy. Both multivariable logistic regression analysis and RPA identified that crossing the 85th percentile of BMI at an

earlier age appears to be one of the most potent factors associated with severe obesity in kindergarteners. These findings indicate that careful monitoring of BMI percentile patterns at as early as 9 months old might be a powerful means of identifying children at greatest risk for severe obesity in the future. In addition, low household educational attainment and high numbers of adults in the household were key factors associated with severe obesity in kindergarteners and important in defining high-risk clusters. Although additional research is needed on the relationship of these characteristics with severe childhood obesity, identifying these factors might prove useful in screening, counseling, and interventions for severe childhood obesity. RPA revealed that not having preschooler bedtime rules and infrequently taking the child outside to walk or play at 9 months old were crucial in defining risk clusters with a markedly high severe obesity prevalence of approximately 80%. Although additional study is needed, bedtime rules for preschoolers and taking young children outside to walk or play several times weekly would seem to be easily attainable goals that might prove useful in the prevention of severe childhood obesity.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Dr Flores 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. Flores and Lin were responsible for the study concept and design, acquisition of data, analysis and interpretation of data, drafting of the manuscript, critical revision of the manuscript for important intellectual content, and statistical analysis. Administrative, technical or material support, and study supervision were provided by Flores.

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