Predicting Early Emergence of Childhood Obesity in Underserved Preschoolers

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Objective To determine the magnitude of risk of factors that contribute to the emergence of childhood obesity among low-income minority children.

Study design We conducted a prospective cohort analysis of parent−child pairs with children aged 3-5 years who were nonobese (n = 605 pairs) who participated in a 3-year randomized controlled trial of a healthy lifestyle behavioral intervention. After baseline, height and weight were measured 5 times over 3 years to calculate body mass index (BMI) percentiles and classify children as normal, overweight, or obese. Multivariable logistic regression was used to estimate the odds of obesity after 36 months. Predictors included age, sex, birth weight, gestational age, months of breastfeeding, ethnicity, baseline child BMI, energy intake, physical activity, food security, parent baseline BMI, and parental depression.

Results Among this predominantly low-income minority population, 66% (398/605) of children were normal weight at baseline and 34% (n = 207/605) were overweight. Among normal weight children at baseline, 24% (85/359) were obese after 36 months; among overweight children at baseline, 55% (n = 103/186) were obese after 36 months. Age at enrollment (OR 2.11, 95% CI 1.64-2.72), child baseline BMI (OR 3.37, 95% CI 2.51-4.54), and parent baseline BMI (OR for a 6-unit change 1.36, 95% CI 1.09-1.70) were significantly associated with the odds of becoming obese for children.

Conclusions The combination of child age, parent BMI, and child overweight as predictors of child obesity suggest a paradigm of family-centered obesity prevention beginning in early childhood, emphasizing the relevance of child overweight as a phenotype highly predictive of child obesity. *(J Pediatr 2019;213:115-20)*.

Trial registration Clinicaltrials.gov: NCT01316653.

Although the overall prevalence of obesity in preschoolers appears to be plateauing,[1] there is a continued rise in the prevalence of obesity for minority population subgroups.[2] Estimates indicate that 25.8% of Latino children and 22.0% of black children aged 2-17 years have childhood obesity, compared with 14.1% of white children.[3] These racial disparities in obesity prevalence develop before children enter kindergarten[4] and are attributable to a range of risk factors, including genetic, family, and environmental factors; health behaviors like diet and physical activity; cultural norms; and socioeconomic influences.[5] Developing strategies to prevent disparities in childhood obesity requires careful examination of how these factors from multiple levels of a child's social ecology contribute to the emergence of childhood obesity during the early periods of child development.

Observational studies have identified a host of early life factors that are associated with developing childhood obesity, including birth weight,[6,7] breastfeeding,[8,9] and maternal gestational weight gain.[10] In addition, parental feeding behaviors and early-life dietary quality have been associated consistently with later childhood obesity. However, despite these well-recognized risk factors, childhood obesity-prevention interventions have demonstrated modest effect sizes and often disappointing results.[11] Furthermore, relatively little attention has been paid to the risk of developing overweight or to the risk factors that predict which overweight children will develop obesity.

This study used a prospective cohort analysis to determine the magnitude of risk among combinations of factors that contribute to the emergence of childhood obesity among minority children from low-income families. Multiple

BMI Body mass index

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determinants of childhood obesity were considered, including individual, family, and social/community factors.

Methods

Using a prospective cohort design, we conducted a secondary analysis of data collected as a part of a randomized clinical trial (Growing Right Onto Wellness, clinicaltrials.gov: NCT01316653) implementing a behavioral intervention to prevent childhood obesity among low-income families in Nashville, Tennessee. The full methods of the intervention have been published previously, and the intervention did not lead to a difference in early child body mass index (BMI) trajectory between the intervention and control groups at 3 years of follow-up.[12,13] The Vanderbilt University Medical Center institutional review board approved the study protocol. Bilingual data collectors obtained written informed consent in participants' language of choice using an enhanced, low-literacy approach.[14]

Parent−child pairs were recruited in Nashville, Tennessee, from community centers, doctor's offices, and other community settings between December 2012 and June 2014. Children were included if their BMI percentile was ≥50th and <95th based on standardized growth curves developed by the Centers for Disease Control and Prevention (BMI percentile ≥50th and <95th).[15] By including children in the upper range of normal weight and children with overweight, this inclusion criterion was chosen to identify children at greatest risk of developing obesity.[16] To be eligible, participants had to qualify for 1 or more services for underserved populations (eg, Special Supplemental Nutrition Program for Women, Infants, and Children, Medicaid). Additional inclusion criteria consisted of (1) child age between 3 and 5 years, (2) parent age ≥18 years, (3) parents and children spoke English or Spanish, (4) commitment to participate in the 36-month study, and (5) consistent phone access. Exclusion criteria consisted of medical condition precluding routine physical activity or footpath (eg, lived or worked) outside a 5-mile radius of participating community centers.

Data on parents and children were collected at baseline, 3, 9, 12, 24, and 36 months. Exposures for this analysis are grouped into 4 sets: (1) child baseline characteristics, (2) child early life characteristics (ie, in the first year of life),[17] (3) child baseline health behaviors during preschool, and (4) parent/family characteristics. Child baseline demographics consisted of child baseline BMI (calculated from measured height and weight), age (years), and sex. Child early life predictors consisted of birth weight (grams), gestational age (weeks), and breastfeeding length (0 months, any to 5 months, and 6 months or longer). Child baseline demographics (except BMI) and individual child early life predictors were collected by parent report during baseline data collection. Child health behaviors during preschool included mean daily total energy intake (kilocalories) and mean daily minutes of moderate/vigorous physical activity (adjusting for mean daily total wear time). Child energy intake was assessed by parent-report using 24-hour diet recalls on 2 weekdays and 1 weekend day (using Nutrition Data System for Research software; Nutrition Coordinating Center, Minneapolis, Minnesota). Child physical activity was measured using accelerometry, asking children to wear a GT3X+ accelerometer (ActiGraph, Pensacola, Florida) on their waist for 7 consecutive days. Previously validated cut points determined time spent in moderate and vigorous physical activity.[18] Parent/family characteristics included parent BMI calculated from measured height and weight, parent depression from self-report using the Center for Epidemiologic Studies−Depression scale,[19] parent race/ethnicity from parent self-report, and food security from self-report using the 6-item short form of the US Household Food Security Survey Module.[20]

The primary outcome was child obesity at 36-month follow-up. Data collectors prospectively measured a child's height (without shoes, to nearest 0.1 cm, using wall-mounted stadiometers) and weight (to nearest 0.1 kg, using research-grade scales). These measurements were used to calculate a child's BMI, which was then classified as normal weight (BMI percentile ≥50th and <85th); overweight (BMI percentile ≥85th and <95th); or obese (BMI ≥95th) based on the Centers for Disease Control and Prevention standardized growth curves.[15] Data collectors responsible for measuring height and weight were trained, certified, and blinded to study group assignment.

Multivariable logistic regression models were used to analyze the association between each of the predictors of interest and childhood obesity at 36-month follow-up. Results are presented as ORs with corresponding 95% CIs.

We considered 4 sequential, nested multivariable models that contained (1) child baseline characteristics, (2) child baseline characteristics and child early life characteristics, (3) child baseline and early life characteristics and child baseline health behaviors during preschool, or (4) child baseline and early life characteristics, child baseline health behaviors during preschool, and parent/family characteristics. We define early life characteristics as those factors in the first year of life that may affect the emergence of later childhood obesity. This approach facilitates understanding of the unique contributions of child demographics, child early life predictors, child health behaviors, and parent/household predictors. We present the C statistic (area under the receiver operating characteristic curve) for each of these models to summarize the predictive ability of each model. The C statistic represents the ability of the model to discriminate between participants who experienced the outcome event (in this case, children who became obese at 36-month follow-up) and those who did not. Specifically, it is the probability that the model-predicted risk will be greater for a random participant who experienced the event as compared with the predicted risk for a random participant who did not experience the event.[21,22]

Likelihood ratio tests were used to compare model fit between each pair of models. To test the assumption that allocation to the intervention condition in the original randomized controlled trial had a negligible effect on the emergence of obesity, we conducted an additional sensitivity

Table. Descriptive statistics for baseline characteristics for total baseline sample* and by child obesity status at 36-month follow-up

Participant baseline characteristics	Baseline sample (N = 605)	Children without obesity at 36-month follow-up (n = 357)	Children with obesity at 36-month follow-up (n = 188)
Child baseline characteristics			
Age at anthropometry collection, y	4.3 (0.9)	4.2 (0.9)	4.6 (0.9)
Sex			
Male	290 (47.9%)	160 (44.8%)	95 (50.5%)
Female	315 (52.1%)	197 (55.2%)	93 (49.5%)
BMI, kg/m^2	16.6 (0.8)	16.5 (0.7)	17.0 (0.7)
BMI category			
Normal	398 (65.8%)	274 (76.8%)	85 (45.2%)
Overweight	207 (34.2%)	83 (23.2%)	103 (54.8%)
BMI z score	0.8 (0.5)	0.7 (0.4)	1.0 (0.4)
Child early life characteristics			
Birth weight, g (N = 547)	3309.7 (574.6)	3313.0 (545.9)	3302.8 (621.1)
Gestational age, wk (N = 506)	38.9 (2.2)	39.0 (2.2)	38.9 (2.0)
Breastfeeding (N = 603)			
None	99 (16.4%)	62 (17.4%)	29 (15.5%)
Any to <6 mo	214 (35.5%)	128 (35.9%)	60 (32.1%)
≥6 mo	290 (48.1%)	167 (46.8%)	98 (52.4%)
Child baseline health behaviors during preschool			
Mean daily total energy intake, kcal (N = 604)	1194.3 (384.6)	1179.9 (409.1)	1206.0 (340.0)
Mean daily total wear time, min (N = 599)	1010.2 (152.3)	1010.7 (148.2)	1013.8 (159.7)
Mean daily moderate/vigorous physical activity, min (N = 599)	85.2 (30.9)	81.7 (30.8)	90.3 (31.8)
Parent/family characteristics			
BMI, kg/m^2	29.6 (5.8)	29.1 (5.8)	30.5 (5.6)
BMI category			
Underweight	2 (0.3%)	1 (0.3%)	0 (0.0%)
Normal	119 (19.7%)	85 (23.8%)	26 (13.8%)
Overweight	237 (39.2%)	141 (39.5%)	70 (37.2%)
Obese	247 (40.8%)	130 (36.4%)	92 (48.9%)
Race/ethnicity			
Hispanic Mexican	383 (63.3%)	226 (63.3%)	125 (66.5%)
Hispanic non-Mexican	168 (27.8%)	97 (27.2%)	49 (26.1%)
Non-Hispanic	54 (8.9%)	34 (9.5%)	14 (7.4%)
CES-D scale (N = 604)	9.8 (9.0)	9.7 (9.3)	10.2 (9.0)
Food security† (N = 601)			
Food secure	346 (57.6%)	214 (60.5%)	96 (51.3%)
Food insecure without hunger	173 (28.8%)	95 (26.8%)	61 (32.6%)
Food insecure with hunger	82 (13.6%)	45 (12.7%)	30 (16.0%)
WIC and/or SNAP participation (N = 601)	525 (87.4%)	310 (87.3%)	161 (86.1%)

CES-D, Center for Epidemiologic Studies—Depression; *SNAP*, Supplemental Nutrition Assistance Program; *WIC*, Women, Infants, and Children.
Total baseline sample N = 605, 36-month follow-up sample n = 545, and 34.5% (n = 188) were obese at 36-month follow-up.
*Total baseline sample is defined as all children who were either normal weight or overweight at baseline (n = 605), which excludes 5 children who were already obese at baseline.
†Standard 6-item indicator set for classifying households by food security status level. The scale ranges from 0 to 6, with lower scores indicating greater food security.

analysis by including the randomization condition (ie, intervention vs control) to the fully adjusted model. There was no substantive difference in the model output (data not shown).

In addition, to understand how specific combinations of predictors identified in the primary models contributed to the emergence of child obesity over time, we used generalized estimating equations to fit 2 marginal logistic regression models with covariate main effects and covariate-by-time interactions. The first model included the main effects of child baseline BMI category (overweight vs normal weight) and parent baseline BMI (continuous) and each of their interactions with time to assess whether their respective relationships to child obesity differed over time. Similarly, the second model included child baseline BMI category (overweight vs normal weight) and child baseline age (continuous) and each of their interactions with time. The Huber—White sandwich estimator, clustering on subject identifier, was used to account for correlation arising from taking repeated measurements on the same child over time. Model-based estimates for the probability of child obesity at 36 months were calculated using representative covariate profiles, and the results were plotted across the follow-up period. To illustrate the effect of parent BMI on the probability of child obesity at 36 months, we show the model-based estimates as a continuous function of parent BMI. Then, to illustrate the combined effect of parent BMI with other predictors on the probability of child obesity at 36-month, we selected a parent BMI of 24 kg/m^2 (normal weight) and a parent BMI of 34 kg/m^2 (obesity).

For all analyses, multiple imputation (10 imputed datasets) for missing covariates was performed using the "aregImpute" function available in the rms package for R. All analyses were conducted in R, version 3.4.4 (R Foundation for Statistical Computing, Vienna, Austria).

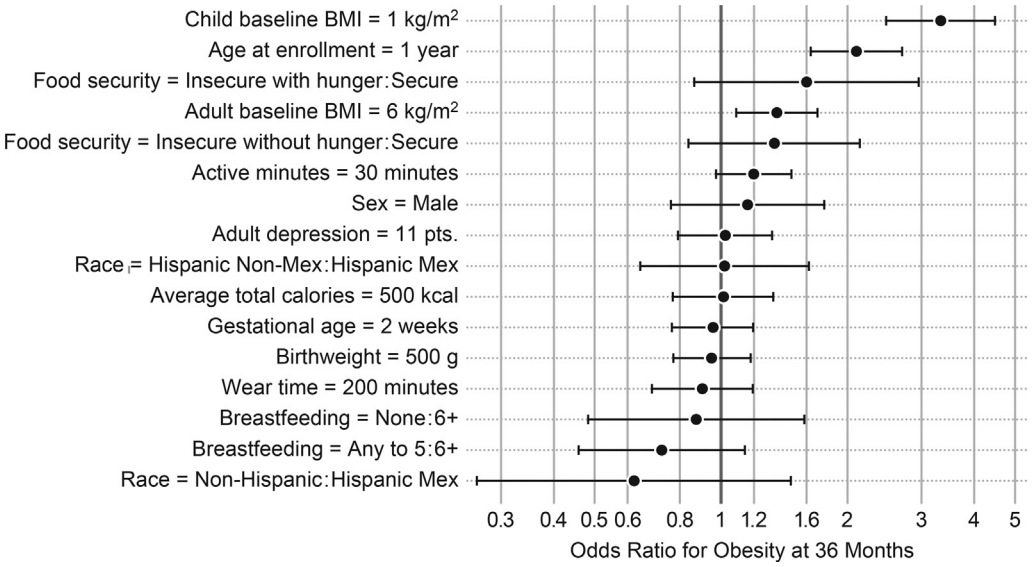

Figure 1. Predictors of childhood obesity emergence. The plot displays results from adjusted multivariable logistic regression, showing ORs and 95% CIs of covariates predicting childhood obesity at 36 months among children who were overweight or normal weight at baseline. For each covariate, ORs are shown for the comparison (e.g., "Insecure with hunger: Secure") or difference (e.g., 1kg/m^2). The unit of measure for breastfeeding is reported in months.

Results

At baseline, 610 parent−child pairs were included in the original study, 605 of which included a child who was not obese at baseline. At 36-month follow-up, child BMI was available for 90% (n = 545) of the nonobese original sample. The **Table** displays baseline data on parent−child pairs according to whether the children developed obesity at 36 months. At baseline, as per study design, 66% (n = 398) of children were normal weight and 34% (n = 207) were overweight. Just more than one-half of children (52%, n = 315) were female, and 91% (n = 550) were Hispanic. Mean child age at baseline was 4.3 years, with all child participants between 3 and 5 years. Mean parent BMI at baseline was 29.6 (SD 5.8), and 91% of parents (n = 551) were Hispanic. Among children who were normal weight at baseline and had follow-up BMI, 24% (n = 85/359) became obese by the 36-month follow-up. In children who were overweight at baseline and had follow-up BMI, 55% (n = 103/186) were obese by the 36-month follow-up.

In the fully adjusted logistic regression model (with baseline, early life, preschool, and parent predictors), child age at enrollment (OR 2.11, 95% CI 1.64-2.72), child baseline BMI (OR 3.37, 95% CI 2.51-4.54), and parent baseline BMI (OR 1.36 for a 6-unit change, 95% CI 1.09-1.70) all demonstrated statistically significant increased odds of childhood obesity at 36-month follow-up (**Figure 1**).

To evaluate the combined effect of child baseline weight status and other predictors on the emergence of child obesity, we conducted 2 additional models. Results from the first longitudinal logistic regression model, with baseline child BMI category, parent baseline BMI, and each of their interactions with time, indicated that the greatest predicted probability of childhood obesity occurred among children who were overweight at baseline, and the probability was even greater for children whose parents had a greater baseline BMI (**Figure 2**). The second model, with baseline child BMI category, child baseline age, and each of their interactions with time, indicated that the greatest predicted probability of childhood obesity occurred, again, among children who were overweight at baseline, and the probability was greater for children who were older at baseline (**Figure 2**). Model-based estimates indicated that a child with normal weight at baseline whose participating parent had obesity had a greater probability of having obesity by 36-month follow-up (27% probability) compared with a child whose participating parent was normal weight (18% probability). This effect appeared to be even more pronounced among children who were overweight at baseline; model-based estimates indicated that an overweight child whose parent had obesity had a 61% probability of having obesity after 36 months, compared with a 49% probability for a child whose parent was normal weight. To illustrate the combined effect of parent BMI and child baseline obesity status on the predicted probability of child obesity at 36 months, we show model-based estimates for a range of parent BMI values in **Appendix 1** (available at www.jpeds.com).

To evaluate the added contribution of early life, preschool, and parent/family characteristics, each set of variables was added sequentially to the base child demographics model (**Appendix 2**; available at www.jpeds.com). **Appendix 3** (available at www.jpeds.com) contains the C statistics for each of the 4 models. The predictive ability of each

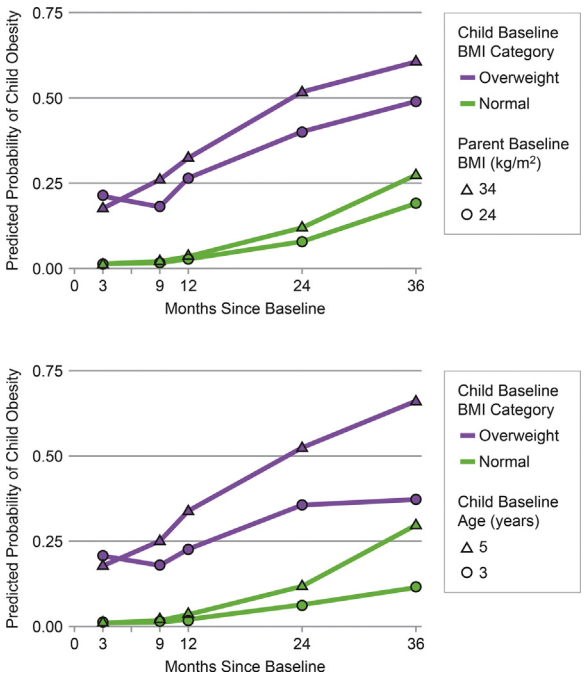

Figure 2. Predicted probability of childhood obesity across 36 months of follow-up. Graphs from 2 separate models using generalized estimating equations to fit marginal logistic regressions are shown. *Top*, The first model included the main effects of child baseline BMI category and parent baseline BMI and each of their interactions with time. *Bottom*, The second model included child baseline BMI category and child baseline age and each of their interactions with time.

sequential model improves from 0.75 for the base model to 0.78 for the full model. Likelihood ratio test results comparing model fit for each pair of models also are presented in **Appendix 3**. Results indicate that none of the more complex models significantly improved model fit.

Discussion

In this cohort analysis of low-income minority preschoolers who were at risk for obesity but not yet obese, older age at cohort enrollment, child overweight, and parent BMI at baseline were the main predictors of the emergence of childhood obesity at 36-month follow-up after we controlled for a comprehensive set of individual child and family covariates. This specific combination of child age, parent BMI, and child overweight as predictors of emerging early child obesity suggest a paradigm of family-centered obesity prevention that would need to begin in early childhood, emphasizing the clinical relevance of child overweight as a phenotype highly predictive of child obesity.

The main contribution of this cohort analysis is to recognize the magnitude of the risk of childhood obesity for the combined predictors of interest. Models including interactions between statistically significant predictors of later childhood obesity indicated the predicted probability of a child developing obesity at 36-month follow-up was 61% if the child was overweight and the child's parent had obesity (ie, parent BMI 34 kg/m^2). By comparison, the predicted probability of a child developing obesity at 36-month follow-up was 18% when the child was normal weight at baseline and the child's parent was normal weight (ie, BMI 24 kg/m^2) at baseline. Based on this absolute difference of 43 percentage points in the predicted probability of developing early childhood obesity,[23] the importance of treating parents for overweight/obesity cannot be overstated. In addition, identifying child age as a significant predictor of later child obesity supports the growing body of literature that indicates child obesity prevention efforts should begin before the preschool period.

Previous literature has identified these specific risk factors,[24] although many published analyses use large population datasets with repeated cross-sectional analysis.[23,25,26] Moreover, previous studies have not considered the simultaneous contribution of these covariates on the emergence of child obesity.[16,17,27-29] In addition, the current literature has under-reported on data from traditionally underrepresented minority children. Our study adds to this literature with a prospectively collected longitudinal dataset of underserved minority preschool age children, examining the magnitude of combination of risk factors to examine emerging child obesity.

With obesity-prevention efforts proving especially challenging in these specific population subgroups, using epidemiologic methods to identify the most salient risk factors will directly inform future clinical management strategies and research agendas. The current study suggests that clinical practice should shift from the traditional paradigm of treating childhood obesity and its comorbidities to include a prevention strategy that focuses on preventing the development of overweight in early childhood. In addition, our findings direct us to a family-centered approach that encourages a 2-generation strategy to reduce childhood obesity, addressing both parental obesity and early childhood overweight, as major risk factors for childhood obesity. Future research should focus on these multilevel influences across the lifespan to develop approaches for obesity prevention among low-income minority populations.

This study has several limitations. As in any cohort study, there is the possibility of residual or unmeasured confounding. Some of the measured confounders were based on parental report and therefore subject to recall or social desirability bias. We had incomplete data on household income, as 27% (n = 164) of participants did not know their annual household income. As such, the main measure of socioeconomic status was Women, Infants, and Children/Supplemental Nutrition Assistance Program participation, which may not account for variability in socioeconomic condition among this low-income population.

In this cohort analysis of normal weight and overweight minority preschoolers living in poverty, the combination of

child age at enrollment, child overweight, and parent BMI at baseline predicted the greatest probability of the emergence of childhood obesity at 36-month follow-up. ■

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