# Association Between Age and Obesity Over Time

Ashley Wendell Kranjac, PhD,[a,b] Robert L. Wagmiller, PhD[c]

abstract

**BACKGROUND AND OBJECTIVES:** A decline in the prevalence of obesity among 2- to 5-year-olds in the United States was recently reported. This decline may be due to changes in the population composition of children over time or may be a consequence of changes in how strongly individual- or family-level factors are linked to childhood obesity. We applied regression decomposition techniques to identify the sources of the decline.

**METHODS:** We used data from the 2003–2004 and 2011–2012 NHANES restricted to 2- to 5-year-old children and Blinder-Oaxaca regression decomposition techniques to partition the decline in early childhood obesity into 2 components: changes resulting from (1) how demographic, economic, and health characteristics of children have changed over this period (ie, changes in population composition) and (2) changes in how these demographic, economic, and health factors are associated with obesity (ie, changes in associations).

**RESULTS:** The obesity rate was lower in 2011–2012 than it was in 2003–2004 mainly because obesity was strongly and positively associated with age in 2003–2004 (ie, older children were more likely to be obese than younger children) but not in 2011–2012 (ie, older children were not more likely to be obese than younger children).

**CONCLUSIONS:** If the weaker association between age and obesity we observed for this cohort of 2- to 5-year-old children in 2011–2012 persists for subsequent cohorts of young children, the obesity rate for young children will remain at or near the lower rate seen in 2011–2012.

[a]*Department of Sociology and* [b]*Kinder Institute for Urban Research, Rice University, Houston, Texas; and* [c]*Department of Sociology, Temple University, Philadelphia, Pennsylvania*

Dr Kranjac conceptualized and designed the study, drafted the initial manuscript, carried out the data analyses, interpreted the data, and reviewed and revised the manuscript; Dr Wagmiller designed the study, interpreted the data, and critically reviewed and revised the manuscript; and both authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Address correspondence to Robert L. Wagmiller, PhD, Department of Sociology, 754 Gladfelter Hall, Temple University, Philadelphia, PA 19122. E-mail: robert.wagmiller@temple.edu

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**WHAT'S KNOWN ON THIS SUBJECT:** A decline in obesity prevalence among 2- to 5-year-old children in the United States was recently reported. This decline may be a product of changes in the population composition or a consequence of changes between individual- or family-level factors.

**WHAT THIS STUDY ADDS:** We used regression decomposition techniques to identify the sources of this decline. The obesity rate was lower in 2011–2012 compared with 2003–2004 mainly because older children were more likely to be obese than younger children in 2003–2004 but not in 2011–2012.

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Childhood obesity trends have been studied and analyzed extensively.[1–5] A decline in the prevalence of obesity among 2- to 5-year-old children in the United States was reported recently, indicating that the obesity rate decreased from 13.9% in 2003–2004 to 8.4% in 2011–2012.[6] In the current study, we used regression decomposition techniques to identify the sources of this decline. The decline in the obesity rate for young children between 2003–2004 and 2011–2012 may be due to changes over time in the population composition of children. For example, several studies reported that poverty and race/ethnicity are associated with childhood obesity,[7–9] so a decrease in the poverty rate or changes in the racial/ethnic composition of children may lead to a decline in obesity. However, the decline may be a result of changes in how strongly individual- and family-level factors (including poverty or a child's racial/ethnic background) are associated with childhood obesity.

We used data from the NHANES from 2003–2004 and 2011–2012 and regression decomposition techniques[10–12] to partition the decline in obesity for 2- to 5-year-old children into change resulting from (1) variations in the demographic, economic, and health characteristics of children over this period (ie, changes in population composition) and (2) alterations in the association between demographic, economic, and health factors and obesity status (ie, changes in associations).

## FACTORS AFFECTING CHILDHOOD OBESITY

A variety of factors are associated with childhood obesity. These factors generally fall into 3 interrelated domains: demographic and economic characteristics, health characteristics, and characteristics associated with children's activity.

### Demographic and Economic Characteristics

Previous studies have found that girls are at greater risk of being obese than boys,[13] and gender differences vary by race/ethnicity.[14–19] Preadolescent Hispanic immigrant children weigh more than children born in the United States,[20–23] and ethnic-minority immigrant children are at higher risk of childhood obesity than comparable native-born children.[24–26] Obesity rates increase as children grow older,[15] and age is the single largest predictor of obesity in children.[27] Economic characteristics are also associated with childhood obesity. For example, obesity rates are higher for children growing up in poor families and families with low incomes than for children from higher-income families.[19,28–33]

### Health Characteristics

The lifestyle patterns of mothers and their children are also related to childhood obesity. Health factors begin to influence obesity risk in utero[34] and continue throughout infancy and childhood.[35] Extremes of birth weight, either high or low, increase the risk of obesity in children.[34,36–38] Mothers' cigarette smoking in the first trimester of pregnancy doubles the risk of obesity among children at age 3,[39] and that risk continues to increase with age.[40] Maternal breastfeeding practices,[41] mothers' nutritional choices,[25,28,30] and children's energy intake[1] also increase their risk of being obese.

### Characteristics Associated With Children's Activity

Children's lifestyle patterns influence their risk of being obese in additional ways. Children who watch more television are more likely to be overweight than those who watch less,[42–44] and a recent meta-analysis indicates that media use is linked to obesity in children.[45] Children who frequently eat meals outside the home,[46] play computer games,[47] and are physically inactive[48] also are more likely to have an increased BMI.

### Other Factors

Many other factors are associated with childhood obesity. For example, children whose families experience food insufficiency eat fewer fruits and vegetables and more energy-dense foods,[49–53] leading to higher obesity rates. In addition, demographic shifts have resulted in significant changes in the prevalence of childhood obesity.[29,54] Societal changes that promote inactivity and food consumption contribute to childhood obesity.[55–58] Varying cultural norms[22] in feeding practices[59] are also associated with children's weight, although this relationship can be confounded by education and economics.[22,25] And obesity can "spread" through social networks.[60–62]

## POTENTIAL MECHANISMS OF CHANGE IN THE RATE OF EARLY CHILDHOOD OBESITY

Two principal mechanisms underlie change across cohorts in the obesity rate, and it is likely that both have contributed to the recent decline in early childhood obesity. First, the relationship between individual/family characteristics and obesity can weaken over time. For example, numerous studies have found that immigrant children to the United States are at significantly greater risk of obesity than are native-born children.[20,22,24] If the positive association between immigration status and obesity risk weakens, the obesity rate will decline.[10,11] Second, the obesity rate may change because the economic, demographic, or health composition of the population of children changes. For example, if more recent cohorts of children include fewer immigrants, the obesity rate will decline.[63,64]

## METHODS

### Data

Our analyses are based on 2 waves (2003–2004 and 2011–2012) of the NHANES, a cross-sectional survey of the civilian, noninstitutionalized US population.[65] We used these data because of the recent report citing a decline in obesity among 2- to 5-year-olds between 2003–2004 and 2011–2012.[6] NHANES uses a complex, multistage probability sampling design, with oversampling of smaller racial/ethnic subgroups. The sample was restricted to 2- to 5-year-olds with a completed body measurement component of the survey. Analyses were estimated by using the sampling weights to account for differences in the chances of selection and nonresponse. The total sample sizes for our analyses were 926 children in 2003–2004 (498 girls and 428 boys) and 974 children in 2011–2012 (482 girls and 492 boys), for a total of 1900 children.

### Analytic Strategy

We used the Blinder-Oaxaca regression decomposition technique to identify the sources of change in the rate of early childhood obesity between 2003–2004 and 2011–2012. The idea behind this technique is that the decline in the obesity rate can be divided into 2 components.[66–68] The first component captures the contribution of changes in the regression coefficients for the 2003–2004 and 2011–2012 survey waves. The second component captures the contribution of changes in the population composition of children between 2003–2004 and 2011–2012.

The first step in partitioning change into these 2 components is to estimate separate regression equations for 2003–2004 and 2011–2012. In the second step, the estimated coefficients and intercept from each of these regression equations, and the sample means for the covariates for each wave, are used to compute 2 counterfactuals. The first counterfactual quantifies how the obesity rate would have changed if the regression coefficients and intercept changed as they did between 2003–2004 and 2011–2012 but the population composition did not change (ie, the means of the covariates in 2011–2012 were the same as they had been in 2003–2004). The second counterfactual quantifies how the obesity rate would have changed if the population composition changed as it did between 2003–2004 and 2011–2012 but the regression coefficients did not change (ie, the regressions coefficients for 2003–2004 and 2011–2012 were the same). The value of the first counterfactual represents the contribution of differences in the regression coefficients and intercepts between waves (ie, changes in associations) to the decline in the obesity rate, and the value of the second counterfactual represents the contribution of differences in the mean levels of the covariates between waves (ie, changes in population composition) to the decline in the obesity rate.

In addition to estimating the overall contribution of these 2 components of change, the Blinder-Oaxaca regression decomposition technique may be used to estimate the contributions of individual variables to change. However, in the traditional Blinder-Oaxaca regression decomposition approach, the estimated contribution of individual variables can be erroneous.[69] Consequently, we used a modified Blinder-Oaxaca regression decomposition approach recently proposed by Kim[12] that produces correct estimates of the contributions of individual variables. This procedure allowed us to identify those factors contributing to the decline in the obesity rate and to quantify the extent to which changes in the composition of cohorts, as opposed to changes in the associations between child/family characteristics and obesity, led to the decline. (For a more technical discussion of the Blinder-Oaxaca regression decomposition technique, see refs 12, 66–68.)

### Measures

#### *Dependent Variable*

The outcome in this study is a dichotomous variable indicating whether the child is obese. Standardized weight and height measures were used to calculate age- and gender-specific BMI percentiles, according to the 2000 Centers for Disease Control and Prevention growth charts.[70,71] Children were classified as obese if they had a gender- and age-specific BMI percentile ≥95, according to criteria established by the International Task Force on Obesity.[72]

#### *Independent Variables*

We included covariates to represent children's demographic, economic, and health characteristics. Demographic measures include variables representing a child's age, racial/ethnic background, and gender. We included 1 economic characteristic of the child's family: parents' income. Health characteristics included the following: mother's smoking status while pregnant, mother's breastfeeding practices, child's daily energy intake, child's weight at birth, the number of hours the child spends watching television or using the computer, the child's level of physical activity, and the number of times the child eats out during the week. The models presented include all covariates.

## RESULTS

### Changes in Children's Weight Status Between 2003–2004 and 2011–2012

Tables 1, 2, and 3 display weighted means and SEs for children's weight

**TABLE 1** Weighted Means or Percentages and SEs of Early Childhood: Children Ages 2 to 5 Years: 2003–2004 and 2011–2012 NHANES

| | Overall | | | | | |
|---|---|---|---|---|---|---|
| | Pooled ($N$ = 1900) | | 2003–2004 ($N$ = 926) | | 2011–2012 ($N$ = 974) | |
| Variable | Mean or % | SE | Mean or % | SE | Mean or % | SE |
| BMI category | | | | | | |
| Normal weight | 0.73 | 0.02 | 0.70 | 0.02 | 0.75 | 0.02 |
| Overweight | 0.14 | 0.02 | 0.12 | 0.02 | 0.15 | 0.02 |
| Obese | 0.10* | 0.01 | 0.13 | 0.02 | 0.07 | 0.01 |
| Child demographic and family economic characteristics | | | | | | |
| Age, y | 3.53 | 0.04 | 3.58 | 0.05 | 3.50 | 0.06 |
| Gender | | | | | | |
| Male | 0.50 | 0.02 | 0.50 | 0.02 | 0.49 | 0.03 |
| Race | | | | | | |
| White | 0.57 | 0.04 | 0.61 | 0.04 | 0.54 | 0.06 |
| Black | 0.14 | 0.02 | 0.14 | 0.02 | 0.13 | 0.03 |
| Hispanic | 0.22 | 0.03 | 0.19 | 0.03 | 0.24 | 0.05 |
| Other | 0.07 | 0.01 | 0.06 | 0.02 | 0.08 | 0.02 |
| Household income (in thousands), $ | 61.32* | 2.93 | 55.34 | 3.60 | 65.17 | 4.18 |
| Child health characteristics | | | | | | |
| Mother's smoking status while pregnant | | | | | | |
| Smoker | 0.14* | 0.02 | 0.20 | 0.04 | 0.10 | 0.02 |
| Nonsmoker | 0.86* | 0.02 | 0.80 | 0.04 | 0.90 | 0.02 |
| Mother's breastfeeding practices | | | | | | |
| Mother breastfed child | 0.74** | 0.02 | 0.67 | 0.04 | 0.79 | 0.03 |
| Mother did not breastfeed child | 0.26** | 0.02 | 0.33 | 0.04 | 0.21 | 0.03 |
| Child daily energy intake, kcal | 1637.46*** | 17.51 | 1707.13 | 22.87 | 1577.24 | 24.62 |
| Child birth weight | | | | | | |
| <5 lbs | 0.12 | 0.02 | 0.12 | 0.02 | 0.12 | 0.02 |
| 6–8 lbs | 0.80 | 0.02 | 0.78 | 0.02 | 0.82 | 0.03 |
| ≥9 lbs | 0.08 | 0.02 | 0.10 | 0.02 | 0.06 | 0.02 |
| Child activities | | | | | | |
| Number of hours child watched TV /videos or used computer last month | | | | | | |
| 0–3 h | 0.70** | 0.02 | 0.62 | 0.03 | 0.74 | 0.02 |
| ≥3 h | 0.30 | 0.02 | 0.38 | 0.03 | 0.26 | 0.02 |
| Child physical activity last week | | | | | | |
| ≤2 d | 0.06*** | 0.01 | 0.10 | 0.02 | 0.04 | 0.01 |
| 3–4 d | 0.11 | 0.02 | 0.11 | 0.03 | 0.11 | 0.02 |
| ≥5 d | 0.83** | 0.02 | 0.80 | 0.03 | 0.86 | 0.02 |
| Child eating out behavior last week | | | | | | |
| 0 d | 0 19*** | 0.02 | 0.07 | 0.02 | 0.27 | 0.02 |
| 1–5 d | 0.77*** | 0.02 | 0.92 | 0.01 | 0.66 | 0.04 |
| >5 d | 0.04** | 0.01 | 0.01 | 0.01 | 0.07 | 0.02 |

TV, television. Asterisks indicate significant change between 2003–2004 and 2011–2012 evaluated by using 2-tailed independent-means $t$ test of intercohort differences. *P < .05, **$P$ < .01, ***P < .001.

status and for the covariates by survey wave (2003–2004 and 2011–2012), both overall (Table 1) and separately for girls (Table 2) and boys (Table 3). Between 2003–2004 and 2011–2012, the percentage of normal-weight children increased from 70% to 75% and the percentage of obese children decreased from 13% to 7% ($P$ = .02). It is likely that our estimates are lower than the recently reported reduction in children's obesity of 13.9% to 8.4%[6] because of methodologic differences, such as cutoff points used. Between 2003–2004 and 2001–2012, the obesity rate decreased from 10% to 6% for girls and from 16% to 8% for boys. Boys were significantly less likely to be obese in 2011–2012 than in 2003–2004 ($P$ = .03).

## Compositional Changes in Children's and Families' Characteristics Between 2003–2004 and 2011–2012

The decline in obesity may be a consequence of changes in the composition of the 2003–2004 and 2011–2012 cohorts of children. Mean family income in inflation-adjusted dollars increased significantly between 2003–2004 and 2011–2012 ($P$ = .05), but the demographic composition of children (age, gender, race/ethnicity) did not change. The health characteristics of children changed between waves and may have influenced the decline in obesity. In 2011–2012, compared with 2003–2004, fewer mothers smoked while pregnant (20% vs 10%, $P$ = .02), more mothers breastfed (79% vs 67%, $P$ = .01), children had lower energy intakes (97.73 vs 109.64 kcal, $P$ < .001),

**TABLE 2** Weighted Means and SEs of Early Childhood Obesity Rates for Girls: Children Ages 2 to 5 Years: 2003–2004 and 2011–2012 NHANES

| | Pooled ($N$ = 980) | | 2003—2004 ($N$ = 498) | | 2011–2012 ($N$ = 482) | |
|---|---|---|---|---|---|---|
| Variable | Mean or % | SE | Mean or % | SE | Mean or % | SE |
| BMI category | | | | | | |
| Normal weight | 0.73 | 0.02 | 0.70 | 0.02 | 0.76 | 0.04 |
| Overweight | 0.14 | 0.02 | 0.14 | 0.03 | 0.14 | 0.03 |
| Obese | 0.08 | 0.02 | 0.10 | 0.02 | 0.06 | 0.02 |
| Child demographic and family economic characteristics | | | | | | |
| Age, y | 3.56 | 0.06 | 3.58 | 0.08 | 3.54 | 0.08 |
| Gender | | | | | | |
| Male | — | — | — | — | — | — |
| Race | | | | | | |
| White | 0.57 | 0.04 | 0.61 | 0.04 | 0.55 | 0.06 |
| Black | 0.13 | 0.02 | 0.13 | 0.03 | 0.13 | 0.03 |
| Hispanic | 0.21 | 0.03 | 0.19 | 0.03 | 0.22 | 0.05 |
| Other | 0.09 | 0.02 | 0.07 | 0.03 | 0.10 | 0.02 |
| Household income (in thousands), $ | 63.89 | 3.47 | 58.15 | 4.45 | 67.57 | 4.77 |
| Child health characteristics | | | | | | |
| Mother's smoking status while pregnant | | | | | | |
| Smoker | 0.13* | 0.02 | 0.18 | 0.04 | 0.10 | 0.02 |
| Nonsmoker | 0.87* | 0.02 | 0.82 | 0.04 | 0.90 | 0.02 |
| Mother's breastfeeding practices | | | | | | |
| Mother Breastfed child | 0.75* | 0.03 | 0.70 | 0.05 | 0.79 | 0.04 |
| Mother did not breastfeed child | 0.25* | 0.03 | 0.30 | 0.05 | 0.21 | 0.04 |
| Child daily energy intake, kcal | 1618.28*** | 29.17 | 1726.47 | 44.76 | 1525.43 | 33.64 |
| Child birth weight | | | | | | |
| <5 lbs | 0.14 | 0.02 | 0.15 | 0.04 | 0.13 | 0.03 |
| 6–8 lbs | 0.81 | 0.02 | 0.77 | 0.03 | 0.84 | 0.02 |
| ≥9 lbs | 0.04** | 0.01 | 0.08 | 0.02 | 0.02 | 0.01 |
| Child activities | | | | | | |
| Number of hours child watched TV /videos or used computer last month | | | | | | |
| 0–3 h | 0.72 | 0.03 | 0.68 | 0.04 | 0.75 | 0.03 |
| ≥3 h | 0.28 | 0.03 | 0.32 | 0.04 | 0.25 | 0.03 |
| Child physical activity last week | | | | | | |
| ≤2 d | 0.08** | 0.01 | 0.13 | 0.03 | 0.05 | 0.01 |
| 3–4 d | 0.09 | 0.02 | 0.12 | 0.03 | 0.08 | 0.01 |
| ≥5 d | 0.83** | 0.02 | 0.75 | 0.04 | 0.88 | 0.02 |
| Child eating out behavior last week | | | | | | |
| 0 d | 0.21*** | 0.02 | 0.07 | 0.02 | 0.29 | 0.03 |
| 1–5 d | 0.74*** | 0.03 | 0.91 | 0.02 | 0.65 | 0.04 |
| >5 d | 0.04 | 0.02 | 0.02 | 0.01 | 0.06 | 0.02 |

TV, television; —, present for male as model stratified by gender. Asterisks indicate significant change between 2003–2004 and 2011–2012 evaluated by using 2-tailed independent-means $t$ test of intercohort differences. *$P$ < .05, ***$P$ < .001, **$P$ < .01.

fewer girls had extreme birth weights ($P$ < .01), and children spent less time in sedentary activities ($P$ = .01), more time in physical activities ($P$ = .01), and less time eating out ($P$ < .001).

## Changes in the Associations Between Children's and Families' Characteristics and Obesity Between 2003–2004 and 2011–2012

Obesity may have also declined because the associations between child/family characteristics and childhood obesity changed. Table 4 displays the estimated coefficients from weighted ordinary least squares models regressing a binary indicator of obesity on selected children's, parents', and families' characteristics for the 2003–2004 and 2011–2012 survey waves and for girls and boys. The coefficients represent the change in the probability of being obese attributable to that particular characteristic.

The associations between age/birth weight and obesity changed significantly between the 2003–2004 and 2011–2012 waves. In 2003–2004, the probability of being obese increased by ∼0.05 for each 1-year increase in age ($P$ = .003). In 2011–2012, a 1-year increase in age was associated with a statistically insignificant growth of 0.01 in the probability of obesity ($P$ = .27). The association between age and obesity was stronger for boys than for girls in both 2003–2004 (boys = 0.08, girls = 0.02; $P \leq .002$) and 2011–2012 (boys = 0.03, girls = −0.00; $P$ = .04). The probability of obesity for children who weighed >9 pounds at birth, relative to children who weighed <5 pounds at birth ($P$ = .02), declined sharply between survey waves.

The associations between obesity and a host of factors (eg, children's other demographic and family

**TABLE 3** Weighted Means and SEs of Early Childhood Obesity Rates for Boys: Children Ages 2 to 5 Years: 2003–2004 and 2011–2012 NHANES

| | Pooled ($N$ = 920) | | 2003–2004 ($N$ = 428) | | 2011–2012 ($N$ = 492) | |
|---|---|---|---|---|---|---|
| Variable | Mean or % | SE | Mean or % | SE | Mean or % | SE |
| BMI category | | | | | | |
| Normal weight | 0.73 | 0.02 | 0.70 | 0.03 | 0.74 | 0.02 |
| Overweight | 0.14 | 0.02 | 0.10 | 0.03 | 0.16 | 0.02 |
| Obese | 0.11* | 0.02 | 0.16 | 0.03 | 0.08 | 0.02 |
| Child demographic and family economic characteristics | | | | | | |
| Age, y | 3.50 | 0.05 | 3.58 | 0.08 | 3.46 | 0.06 |
| Gender | | | | | | |
| Male | — | — | — | — | — | — |
| Race | | | | | | |
| White | 0.57 | 0.04 | 0.62 | 0.05 | 0.54 | 0.06 |
| Black | 0.14 | 0.02 | 0.15 | 0.02 | 0.14 | 0.03 |
| Hispanic | 0.23 | 0.03 | 0.19 | 0.04 | 0.26 | 0.05 |
| Other | 0.06 | 0.01 | 0.05 | 0.02 | 0.06 | 0.02 |
| Household income (in thousands), $ | 58.68 | 3.32 | 52.58 | 3.25 | 62.68 | 5.10 |
| Child health characteristics | | | | | | |
| Mother's smoking status while pregnant | | | | | | |
| Smoker | 0.15* | 0.02 | 0.21 | 0.04 | 0.11 | 0.03 |
| Nonsmoker | 0.85* | 0.02 | 0.79 | 0.04 | 0.89 | 0.03 |
| Mother's breastfeeding practices | | | | | | |
| Mother breastfed child | 0.73** | 0.03 | 0.64 | 0.05 | 0.78 | 0.03 |
| Mother did not breastfeed child | 0.27** | 0.03 | 0.36 | 0.05 | 0.22 | 0.03 |
| Child daily energy intake, kcal | 1656.09 | 21.43 | 1688.49 | 24.57 | 1627.89 | 33.97 |
| Child birth weight | | | | | | |
| <5 lbs | 0.10 | 0.02 | 0.09 | 0.03 | 0.11 | 0.03 |
| 6–8 lbs | 0.78 | 0.03 | 0.79 | 0.03 | 0.78 | 0.04 |
| >9 lbs | 0.11 | 0.02 | 0.12 | 0.02 | 0.10 | 0.03 |
| Child activities | | | | | | |
| Number of hours child watched TV/videos or used computer last month | | | | | | |
| 0–3 h | 0.67** | 0.02 | 0.57 | 0.03 | 0.74 | 0.03 |
| >3 h | 0.33** | 0.02 | 0.43 | 0.03 | 0.26 | 0.03 |
| Child physical activity last week | | | | | | |
| ≤2 d | 0.04** | 0.01 | 0.07 | 0.02 | 0.03 | 0.01 |
| 3–4 d | 0.12 | 0.02 | 0.09 | 0.03 | 0.14 | 0.03 |
| ≥5 d | 0.84 | 0.02 | 0.84 | 0.03 | 0.84 | 0.03 |
| Child eating out behavior last week | | | | | | |
| 0 d | 0.18*** | 0.02 | 0.07 | 0.02 | 0.25 | 0.03 |
| 1–5 d | 0.78*** | 0.02 | 0.92 | 0.02 | 0.68 | 0.03 |
| >5 d | 0.05** | 0.01 | 0.01 | 0.00 | 0.07 | 0.02 |

TV, television. Asterisks indicate significant change between 2003–2004 and 2011–2012 evaluated by using 2-tailed independent-means $t$ test of intercohort differences. *$P < .05$, **$P < .01$, ***$P < .001$.

economic characteristics, their other health characteristics, and their level of activity) were generally modest and did not change significantly between 2003–2004 and 2011–2012. The association between race/ethnicity and obesity was also generally modest and did not lessen significantly between the 2003–2004 and 2011–2012 waves. Hispanic girls (β = 0.13, $P$ = .001) and boys (β = 0.17, $P < .001$) were more likely to be obese than white children, whereas African-American children were not. The association between physical activity and obesity was small and largely unchanged between the 2003–2004 and 2011–2012 waves. Overall, the association between sedentary activities and early childhood obesity was negligible in both 2003–2004 and 2011–2012.

However, patterns of association for boys and girls differed notably. For boys, but not girls, the associations between family income and obesity and between energy intake and obesity weakened between the 2003–2004 and 2011–2012 waves. For girls, but not boys, the positive relationship between watching more television and videos or using the computer more and obesity decreased between 2003–2004 and 2011–2012.

Although the estimated coefficients for most child/family characteristics were unchanged between the 2003–2004 and 2011–2012 waves, the decline in obesity may be attributable to the few important changes we observed in the association between child/family characteristics and obesity. Most important, the strong positive association between a child's age and the risk of obesity declined substantially between the 2003–2004 and 2011–2012 waves to the point

**TABLE 4** Weighted OLS Regression Estimates of Early Childhood Obesity Rates Overall and for Boys and Girls, by Survey Year: Children Ages 2 to 5 Years, 2003–2004 and 2011–2012 NHANES

| | Overall | | | Girls | | | Boys | | |
|---|---|---|---|---|---|---|---|---|---|
| Variable | 2003–2004 (*N* = 926) | 2011–2012 (*N* = 974) | *P* for diff | 2003–2004 (*N* = 498) | 2011–2012 (*N* = 482) | *P* for diff | 2003–2004 (*N* = 428) | 2011–2012 (*N* = 492) | *P* for diff |
| Child demographic and family economic characteristics | | | | | | | | | |
| Age | 0.05** | 0.01 | 0.04* | 0.02 | −0.00 | 0.34 | 0.08** | 0.03* | 0.13 |
| | (0.02) | (0.01) | | (0.01) | (0.00) | | (0.03) | (0.02) | |
| Gender (reference: female) | | | | | | | | | |
| Male | 0.05 | 0.01 | 0.37 | — | — | — | — | — | — |
| | (0.02) | (0.03) | | | | | | | |
| Race (reference: white) | | | | | | | | | |
| Black | −0.01 | 0.04 | 0.37 | 0.04 | 0.05 | 0.98 | −0.07 | 0.07 | 0.09 |
| | (0.05) | (0.03) | | (0.05) | (0.03) | | (0.07) | (0.05) | |
| Hispanic | 0.08 | 0.14*** | 0.31 | 0.04 | 0.13** | 0.18 | 0.10 | 017*** | 0.42 |
| | (0.04) | (0.03) | | (0.06) | (0.04) | | (0.07) | (0.05) | |
| Other race | 0.02 | 0.10 | 0.35 | −0.05 | 0.17* | 0.03* | 0.08 | −0.02 | 0.41 |
| | (0.07) | (0.06) | | (0.06) | (0.08) | | (0.12) | (0.04) | |
| Household income | −0.00 | 0.00 | 0.37 | −0.00 | −0.00 | 0.78 | −0.00* | 0.00 | 0.03* |
| | (0.00) | (0.00) | | (0.00) | (0.00) | | (0.00) | (0.00) | |
| Child health characteristics | | | | | | | | | |
| Mother's smoking status while pregnant (reference: mother smoked during pregnancy) | | | | | | | | | |
| Mother did not smoke during pregnancy | −0.08 | 0.07* | 0.03* | −0.11 | 0.05 | 0.07 | −0.03 | 0.07 | 0.31 |
| | (0.06) | (0.03) | | (0.08) | (0.04) | | (0.08) | (0.06) | |
| Mother's breastfeeding practices (reference: mother breastfed child) | | | | | | | | | |
| Mother did not breastfeed child | 0.01 | 0.02 | 0.88 | −0.02 | 0.10 | 0.06 | 0.04 | −0.06 | 0.12 |
| | (0.04) | (0.03) | | (0.06) | (0.04) | | (0.05) | (0.04) | |
| Child birth weight (reference: <5 lbs) | | | | | | | | | |
| 6–8 lbs | 0.04 | −0.02 | 0.37 | 0.01 | −0.12 | 0.14 | −0.27 | 0.07 | 0.76 |
| | (0.09) | (0.06) | | (0.06) | (0.05) | | (0.15) | (0.05) | |
| >9 lbs | 0.16 | −0.07 | 0.02* | 0.09 | −0.26** | 0.00** | 0.25* | 0.05 | 0.15 |
| | (0.06) | (0.04) | | (0.09) | (0.08) | | (0.12) | (0.06) | |
| Child daily energy intake, kcal | 0.00 | −5.57 | 0.34 | −0.00 | −0.00 | 0.99 | 0.00* | −0.00 | 0.03* |
| | (0.00) | (0.00) | | (0.00) | (0.00) | | (0.00) | (0.00) | |
| Child activities | | | | | | | | | |
| Number of hours child watched TV/videos or used computer last month (reference: >3 h) | | | | | | | | | |
| Child used TV/computer <3 h | 0.02 | −0.05 | 0.15 | 0.01 | −0.11** | 0.07 | 0.02 | 0.02 | 0.95 |
| | (0.04) | (0.03) | | (0.05) | (0.04) | | (0.05) | (0.04) | |
| Child physical activity last week (reference: ≤2 d) | | | | | | | | | |
| 3–4 d | −0.11 | 0.03 | 0.18 | −0.03 | 0.01 | 0.76 | −0.27 | 0.17* | 0.01* |
| | (0.06) | (0.08) | | (0.05) | (0.11) | | (0.13) | (0.09) | |
| ≥5 d | −0.05 | 0.05 | 0.26 | 0.07 | −0.03 | 0.31 | −0.25 | 0.18*** | 0.00** |
| | (0.06) | (0.06) | | (0.05) | (0.08) | | (0.12) | (0.04) | |
| Child eating out behavior last week (reference: 0 d) | | | | | | | | | |
| 1–5 d | −0.02 | 0.01 | 0.78 | 0.03 | 0.00 | 0.70 | −0.11 | −0.18 | 0.45 |
| | (0.08) | (0.03) | | (0.05) | (0.03) | | (0.10) | (0.04) | |
| >5 d | 0.01 | 0.18 | 0.42 | −0.12 | −0.11 | 0.90 | 0.42 | 0.37* | 0.87 |
| | | (0.14) | | (0.06) | (0.06) | | (0.25) | (0.17) | |

**TABLE 4** Continued

| Variable | Overall | | | Girls | | | Boys | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2003–2004 ($N$ = 926) | 2011–2012 ($N$ = 974) | $P$ for diff | 2003–2004 ($N$ = 498) | 2011–2012 ($N$ = 482) | $P$ for diff | 2003–2004 ($N$ = 428) | 2011–2012 ($N$ = 492) | $P$ for diff |
| Intercept | −0.02 | −0.07 | | 0.03 | 0.18 | | 0.15 | −0.38** | |
| | (0.11) | (0.10) | | (0.14) | (0.14) | | (0.16) | (0.13) | |

$N$ = 1900. All models include all covariates; SEs are in parentheses. diff, difference; OLS, ordinary least squares; TV, television. ** $P < .01$, * $P < .05$, *** $P < .001$.

that, by 2011–2012, a child's age was no longer positively associated with the probability of being obese.

## Regression Decomposition

The Blinder-Oaxaca decomposition results are shown in Table 5. The table displays the unique contributions and total effect of each characteristic (children's demographic characteristics, economic circumstances, health, and physical activity) on change in the rate of obesity. The estimated contribution of each factor to compositional change and change in the coefficients is shown. If a factor is associated with a decline in obesity, the resulting estimate is positive.

## Overall Change

The obesity rate declined by 6% between the 2003–2004 and 2011–2012 waves (Table 1). The obesity rate for girls (Δ4.00) declined less than the rate for boys (Δ8.00). We can compute the overall contribution of compositional changes to change in the obesity rate by summing the compositional effects for all covariates. Computing the total compositional effect reveals that compositional changes in the population of children played a negligible role in the decline in the obesity rate, both overall and for girls and boys individually. Change in the population composition of children explained none of the decline in the obesity rate either overall (0.0%) or for girls (0.0%), and variations in the population composition of boys would have led to a slight increase in the obesity rate were it not for offsetting changes in the patterns of association between covariates and obesity (−4.6%).

## Compositions

Not only did overall compositional change explain none of the obesity decline but none of the observed changes in the demographic, economic, health, or physical activity composition of the population of children between the 2003–2004 and 2011–2012 waves contributed significantly to the decline. As discussed earlier, the population of children changed in important ways between 2003–2004 and 2011–2012. A smaller proportion of children lived in low-income households, had mothers who smoked during pregnancy, had mothers who did not breastfeed, had high daily energy intake, spent significant time involved in sedentary activities, and frequently ate out. A higher proportion of children engaged in physical activities for significant amounts of time. However, none of these compositional changes contributed to the decline in obesity overall or for either boys or girls.

## Associations

The principal factor responsible for the decline in the obesity rate is the weakening of the association between age and obesity. The obesity rate was lower in 2011–2012 than it was in 2003–2004 mainly because obesity was strongly and positively associated with age in 2003–2004 (ie, older children were more likely to be obese than younger children) but not in 2011–2012 (ie, older children were no more likely to be obese than younger children). Apart from other factors, some of which counteract the positive effect of the decline in the age slope, the weakening of the relationship between age and obesity is responsible for a 13.6% decrease in the obesity rate. For boys, the change attributable to the coefficient for age (0.16) is larger than for girls (0.08). For boys, the weakening of the association between household income and obesity between 2003–2004 and 2011–2012 also contributed to the decline in the obesity rate (0.025). The decline in obesity was not linked to changes in the estimated coefficients for race/ethnicity, extreme birth weights, daily energy intake, physical activity, or sedentary activities.

**TABLE 5** Regression Decomposition of Early Childhood Obesity Rates, Overall and for Boys and Girls: Children Ages 2 to 5 Years, 2003–2004 and 2011–2012 NHANES

| | Overall | | Girls | | Boys | |
|---|---|---|---|---|---|---|
| Variable | Association | Composition | Association | Composition | Association | Composition |
| Age | 0.136*** | 0.002 | 0.076* | 0.001 | 0.156*** | 0.002 |
| Gender | | | | | | |
| Male | −0.010 | 0.001 | — | — | — | — |
| Female | 0.010 | 0.000 | — | — | — | — |
| [Σ gender effect] | [0.000] | [0.001] | — | — | — | — |
| Race | | | | | | |
| White | 0.008 | −0.003 | 0.011 | −0.003 | 0.011 | −0.004 |
| Black | −0.002 | 0.000 | 0.019 | 0.000 | −0.025 | 0.004 |
| Hispanic | −0.004 | 0.001 | −0.008 | 0.000 | −0.001 | −0.029 |
| Other race | −0.007 | 0.001 | −0.023 | 0.008 | 0.015 | 0.023 |
| [Σ race effect] | [−0.005] | [−0.001] | [−0.001] | [0.004] | [0.000] | [−0.005] |
| Household income | 0.018* | −0.020 | 0.004 | −0.010 | 0.025* | −0.024 |
| Mother's smoking status while pregnant | | | | | | |
| Mother smoked during pregnancy | 0.012 | 0.006 | 0.016 | 0.004 | 0.011 | 0.001 |
| Mother did not smoke during pregnancy | −0.017 | 0.001 | −0.018 | 0.001 | −0.011 | 0.000 |
| [Σ maternal smoking effect] | [−0.006] | [0.007] | [−0.002] | [0.005] | [0.000] | [0.001] |
| Mother's breastfeeding practices | | | | | | |
| Mother breastfed child | 0.002 | 0.001 | 0.074 | −0.001 | −0.024 | 0.001 |
| Mother did not breastfeed child | −0.001 | 0.001 | −0.005 | 0.000 | 0.024 | 0.002 |
| [Σ breastfeeding effect] | [0.001] | [0.002] | [0.070] | [-0.001] | [0.000] | [0.003] |
| Child birth weight | | | | | | |
| <5 lbs | −0.009 | 0.000 | −0.020 | 0.000 | 0.001 | 0.001 |
| 6–8 lbs | −0.002 | 0.000 | 0.015 | 0.000 | −0.018 | 0.000 |
| ≥9 lbs | 0.008 | 0.004 | 0.005 | 0.004 | 0.018 | −0.002 |
| [Σ birth weight effect] | [−0.003] | [0.004] | [0.000] | [0.004] | [0.001] | [0.000] |
| Child daily energy intake, kcal | −0.003 | 0.005 | 0.000 | −0.003 | −0.004 | 0.008 |
| Number of hours child watched TV/videos or used computer last month | | | | | | |
| 0–3 h | −0.015 | −0.001 | −0.028 | −0.001 | 0.001 | −0.001 |
| ≥3 h | 0.018 | −0.001 | 0.028 | 0.000 | −0.001 | −0.001 |
| [Σ electronics effect] | [0.003] | [−0.002] | [0.000] | [−0.001] | [0.000] | [−0.002] |
| Child physical activity last week | | | | | | |
| Physical activity ≤2 d | 0.004 | 0.005 | −0.004 | −0.006 | 0.016 | 0.018 |
| Physical activity 3–4 d | −0.005 | 0.000 | −0.011 | 0.000 | −0.002 | 0.000 |
| Physical activity ≥5 d | −0.004 | 0.000 | 0.015 | −0.001 | −0.014 | 0.001 |
| [Σ physical activity effect] | [−0.005] | [0.005] | [0.000] | [−0.007] | [0.000] | [0.018] |
| Child eating out frequency in an average week | | | | | | |
| 0 d | 0.007 | −0.002 | −0.005 | 0.003 | 0.017 | −0.009 |
| 1–5 d | 0.000 | −0.001 | 0.006 | 0.004 | −0.023 | −0.016 |
| >5 d | −0.007 | −0.001 | −0.001 | 0.001 | 0.006 | −0.022 |
| [Σ eating out effect] | [0.000] | [−0.003] | [0.000] | [0.008] | [0.000] | [−0.047] |
| Intercept | −0.022 | | −0.097 | | 0.302 | |

Σ, sum effect; TV, television. ***$P < .001$, *$P < .05$.

## DISCUSSION

Childhood obesity has more than doubled since the early1980s.[73] Between 2003–2004 and 2011–2012, childhood obesity unexpectedly declined from ∼13% to 7%. Obesity declined more sharply for boys (−8%) than it did for girls (−4%), although rates remained higher for boys (8% vs 6%). In this study, we used regression decomposition techniques[10–12] and data from the 2003–2004 and 2011–2012 NHANES to investigate the sources of this decline. This approach allowed us to partition total change in the obesity rates over this period overall, and for girls and boys separately, into the part due to changes in the demographic, economic, health, and physical activity characteristics of the population of children and the part attributed to changes in the association between these characteristics and obesity.

Both the population composition and the association between child/family characteristics and obesity changed between 2003–2004 and 2011–2012. In 2011–2012, fewer children had a low household income, a mother who smoked during pregnancy, a mother who did not breastfeed, and high daily energy intake, and the typical child spent more time engaged in physical activity and less time involved in sedentary activities and ate outside the home less frequently. For girls, a smaller proportion

had extreme birth weights. The association of most characteristics of children's demographic, economic, health, and physical activity factors with obesity did not change significantly between 2003–2004 and 2011–2012. Nonetheless, several important changes in the association between child/family characteristics and obesity did occur over the study period. Most notably, the strong positive association between children's age and their risk of obesity declined substantially. The associations between race/ethnicity (overall), extreme birth weights (overall), family economic characteristics (overall), daily energy intake (overall), physical activity (for boys), and sedentary activities (for girls) also changed.

In 2003–2004, the probability of being obese was positively and significantly associated with age, both overall and for boys. By contrast, in 2011–2012, obesity was not associated with age, either overall or for boys or girls. Excluding other factors, the overall obesity rate decreased by 13.6% because older children were more likely to be obese than younger children in 2003–2004. However, in 2011–2012, older children were not more likely to be obese than younger children. For boys, the weakening association between household income and obesity also contributed to the decline in obesity (−2.5%). Thus, the sharp decline in the obesity rate is almost exclusively a consequence of the weakening of the positive association between age and obesity over the period of the study.

Our findings have important implications for understanding the factors that influence childhood obesity. Changes in the population composition of children and changes in the association of key demographic (race/ethnicity), health (children's birth weight, maternal smoking during pregnancy, maternal breastfeeding practices), and children's activity (television/video viewing and computer use, physical activity, frequency of eating out) characteristics with obesity contributed little to the decline in obesity. However, this may, at least in part, reflect the rudimentary nature of the measures available in the NHANES for several key concepts in our analysis (eg, children's sedentary and physical activities). Moreover, the weak impact that well-established predictors of childhood obesity had on change in the obesity rate over this period indicates that the decline in obesity may, at least in part, be a consequence of sampling error or random fluctuation in the obesity rate over time.

The fact that older children were more likely to be obese than younger children in 2003–2004, but not in 2011–2012, has further implications. If the association between age and obesity we observed for this cohort of 2- to 5-year-olds in 2011–2012 persists for subsequent cohorts of young children, the obesity rate for young children will remain at or near the lower rate observed in 2011–2012. Even more promising, if this association between age and obesity persists as these children advance into middle and late childhood, sizable reductions in obesity rates at later stages of childhood can be expected, as well as significant declines in the overall rate of childhood obesity over time.

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# Association Between Age and Obesity Over Time

Ashley Wendell Kranjac and Robert L. Wagmiller

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# Association Between Age and Obesity Over Time

Ashley Wendell Kranjac and Robert L. Wagmiller

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