Association of maternal smoking with overweight at age 3 y in American Indian children\(^1\)-\(^3\)

Alexandra K Adams, Heather E Harvey, and Ronald J Prince

ABSTRACT

Background: Prevalence rates of overweight are higher among American Indian children than among any other ethnic group, but little research has explored contributing influences.

Objective: The objective was to determine the prevalence and predictors of body mass index (BMI; in kg/m\(^2\)) ≥ 85th percentile in American Indian children in Wisconsin.

Design: A retrospective analysis was conducted with linked pediatric and pregnancy nutrition surveillance systems and birth records from 1997 through 2001. Participants were American Indian mothers and children (aged 0–3 y) who were participating in the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) operated by the Food and Nutrition Service Area comprising the states of Minnesota, Wisconsin, and Michigan (5). However, little research has been conducted on the prevalence or predictors of obesity among American Indians in this area. Because of the inherent difficulty of treating overweight and obesity and because of the link of overweight and obesity to adult disease, it is imperative that preventive measures are employed (6, 7).

Previous research on contributors to childhood obesity focused primarily on older children and white children and identified genetic, neonatal, environmental, and lifestyle factors related to overweight. These included sex (8-11), race (11), maternal BMI (8-10, 12), paternal BMI (8, 12), gestational diabetes (13, 14), smoking during pregnancy (12, 15, 16), birth weight (8, 10, 12, 17), breastfeeding (16-19), television watching in h/d (11, 12), sleep in h/d (8, 12), rate of weight gain during the first 6 mo of life (10), and family socioeconomic status (11, 16).

To examine some of these factors in a younger and underrepresented American Indian population, this study used linked data from 5 y of Wisconsin Pediatric Nutrition Surveillance System (PedNSS), Pregnancy Nutrition Surveillance System (PNSS), and birth records to identify predictors of overweight in American Indian children at age 3 y. Maternal and child predictors included were birth weight, breastfeeding, maternal prepregnancy body mass index (BMI; in kg/m\(^2\)), family income, maternal weight change during pregnancy, smoking, and education. This information will help in the design and evaluation of community-based obesity prevention programs in American Indian tribes in Wisconsin.

SUBJECTS AND METHODS

Subjects

The Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) operated by the Food and Nutrition

\(^1\) From the Department of Family Medicine, University of Wisconsin–Madison, Madison, WI.
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\(^3\) Reprints not available. Address correspondence to AK Adams, Department of Family Medicine, University of Wisconsin–Madison, 777 South Mills Street, Madison, WI 53715. E-mail: alex.adams@fammed.wisc.edu.

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Service of the US Department of Agriculture collects information on maternal prenatal and postnatal characteristics and demographics and also performs child growth and nutrition measurements from birth to age 5 y. These data, along with Head Start and maternal and child health data, are reported to the Centers for Disease Control and Prevention (CDC) by the states and stored as 2 data sets, the PNSS and the PedNSS. In Wisconsin, only WIC data are reported to the CDC. These data sets offer an opportunity to look at familial and environmental determinants of overweight in children from lower socioeconomic environments. WIC serves 48% of American Indian infants and children and 65% of American Indian women (20).

The PedNSS and PNSS data sets were obtained from the CDC for all Wisconsin records for the years 1997 through 2001. In Wisconsin, PedNSS data are collected by local WIC clinics, amalgamated, and submitted monthly to the CDC. Information on child growth, nutrition, and general health is included. The PNSS data set contains information on maternal factors related to gestational and postnatal health. Permission for the use of Wisconsin PedNSS and PNSS data was obtained from the Bureau of Family and Community Health, Division of Public Health, Wisconsin Department of Health and Family Services. Birth records for all American Indian births from 1997 through 2001 were obtained from the Bureau of Health Information, Division of Health Care Financing, Wisconsin Department of Health and Family Services. These records included demographic and birth data for both the mother and the child. For the purposes of this study, mothers were identified as American Indian if they self-selected “American Indian” on any of the PedNSS, PNSS, or birth records. In addition, children were identified as American Indian if one or both parents self-selected the child as “American Indian” on the birth record.

Procedures followed were in accordance with the ethical standards of the institutional committee on human experimentation. Approval was obtained from the state WIC office and the University of Wisconsin Institutional Review Board.

An employee of the Wisconsin Department of Health and Family Services matched mothers’ PNSS and children’s PedNSS records to birth records. We obtained 1649 PNSS maternal records and 21,525 American Indian PedNSS records (representing unique child visits; there were multiple visits per child) for children between the ages of 0 and 60 mo. A total of 6769 mother-child pairs were identified as American Indian; ID, identification.

Procedures followed were in accordance with the ethical standards of the institutional committee on human experimentation. Approval was obtained from the state WIC office and the University of Wisconsin Institutional Review Board.

Maternal predictor variables analyzed (n = 252, unless otherwise noted) were age (in years), prepregnancy BMI (n = 226), weight change (kg gained or lost) during pregnancy (n = 239), smoking before pregnancy (no. of cigarettes/d), smoking at initial WIC visit (no. of cigarettes/d), smoking at first postpartum visit (no. of cigarettes/d), education (no. of years), and income (n = 242). At the initial WIC visit, maternal height was measured to the nearest 1/8 inch (0.31 cm) while the subject was not wearing underclothes or light clothing at routine visits. At the same time, height was measured to the nearest 1/8 inch (0.31 cm) while the subject was not wearing shoes (23). Large-for-gestational-age status was defined as >4000 g and small-for-gestational-age status was defined as <2500 g at birth.

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Child predictor variables (n = 252, unless otherwise noted) were birth weight (g), birth length (cm), sex, clinical gestational age (no. of weeks), and breastfeeding (no. of days/wk) (n = 192).
Breastfeeding was reduced to a bivariate measure of ever breastfed (yes or no) if the child was breastfed for ≥ 1 d. Other variables were the changes in weight and height from birth to 36 mo, expressed as percentages of increase.

**Statistical analysis**

The relations among maternal and child predictor variables and risk of overweight and overweight at 36 mo were examined by using zero-order Pearson’s correlations. Predictor variables with significant correlations at $P < 0.05$ were combined in a binary logistic regression model of risk of overweight and overweight at 36 mo. Results are reported as odds ratios and 95% CIs. Change in WFL $z$ scores (birth to 36 mo) comparing children of non-WIC and WIC mothers was examined by using a two-way repeated-measures analysis of variance (ANOVA) with time (birth or 36 mo) as a within-group factor and smoking or non-smoking as a between-group factor. Differences in the percentage change in height and weight were tested with univariate ANOVAs. Analyses were performed with SPSS software (version 12; SPSS Inc., Chicago, IL).

**RESULTS**

Seventy-three percent of mothers who were matched to children (ie, enrolled in WIC) were single, and 40.6% smoked during pregnancy. The average length of education was 12.1 y. In a comparison of matched WIC mothers with non-WIC mothers who had birth records, chi-square analysis found that the WIC mothers were more likely than were the non-WIC mothers to be single (73.0% and 41.0%, respectively; $P < 0.001$), to have smoked during their pregnancy (40.6% and 29.9%, respectively; $P < 0.001$), and to have less education (12.1 and 12.6 y, respectively; $P < 0.001$). A comparison of the characteristics of our final sample, ie, mothers who were not enrolled in WIC, and those of the larger sample of matched WIC American Indian mother-child pairs, is shown in Table 1. There were no significant mean differences in predictor variables between our final sample of 252 mother-child pairs and other American Indian mother-child pairs enrolled in WIC ($n = 3015$).

Of the children from the 252 mother-child pairs analyzed, 22.2% of 3 y olds were overweight, and an additional 18.7% were at risk of overweight. Most children had a normal birth weight, but 18.7% of children were LGA. Of the mothers, 54.0% ever breastfed, and 42.5% smoked during pregnancy. Most (57.9%) mothers were either overweight or obese before pregnancy (Table 1).

Child and mother characteristics that showed significant intercorrelations were entered simultaneously into a binary logistic regression model predicting BMI ≥ 85th percentile at 36 mo. Only smoking at initial WIC visit (odds ratio (OR): 2.16; 95% CI: 1.05, 4.47) was significant predictor of children at risk of overweight or overweight at age 3, although birthweight (OR: 1.82; 95% CI: 0.09, 3.71) and ever breastfed (OR: 0.53; 95% CI: 0.26, 1.06) tended toward significance (Table 2).

Children were divided into birth weight sextiles to examine the relative size of effects across birth weights. Children with higher birth weights had higher WFL $z$ scores at 36 mo, and this was seen across all birth weight groups when 2-way repeated measures ANOVA was performed ($P < 0.01$). For all birth weight groups except small-for-gestational-age children, change in WFL $z$ scores at 36 mo was positive. LGA children had WFL $z$ scores ≥
1 SD above those of other children of similar age and same sex at 36 mo.

Overall, the mean increase in WFL z score increase from birth to 36 mo was significantly (P = 0.009) more pronounced in children of mothers who smoked (1.33) than in children of mothers who did not smoke (0.88). These children of smokers were significantly smaller at birth, but, at 36 mo, they were significantly larger than were the children of nonsmoking mothers, independent of birth weight, as indicated by the significant difference in the increase in z score between the 2 groups of children (P = 0.009; Figure 2). This relation was also found at multiple time points between birth and 36 mo when a subset of children with ≥6 measurements was analyzed (n = 183; P = 0.035).

Changes in WFL can be based on either a relatively greater increase in weight or a relatively slower increase in length. Birth weights were significantly higher in the nonsmoking group (3460 and 3622 g, respectively; P = 0.05), but birth lengths did not differ significantly between the 2 groups of children (50.4 and 50.8 cm, respectively), which indicated that the lower WFL z scores at birth in children of smokers were due to lower relative weight and not to greater relative length. When changes in WFL z scores were considered relative to changes in weight and height by using univariate ANOVAs, only the mean percentage change in weight differed significantly between the children of smokers and those of nonsmokers (Figure 3 and Figure 4), which indicated that the larger increase in the WFL z score of children of smoking mothers was due to relatively greater increases in weight and not to slower increases in height. In addition, birth weight was negatively correlated with mean percentage change in both weight and height (Figures 3 and 4).

We also examined the association of postnatal smoking (women who began smoking after delivery) on child weight at age 36 mo. Prenatal and postnatal smoking correlated highly (r = 0.80). However, when we compared child growth between children of postnatal smokers and children of nonsmokers, no significant differences were found.

DISCUSSION

This retrospective analysis of linked PedNSS, PNSS, and birth record data for Wisconsin American Indians documented high rates of overweight risk status and overweight at age 3 y. Maternal smoking was a significant predictor of overweight risk status

<table>
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<tr>
<th>Predictors of BMI ≥ 85th percentile at age 36 mo</th>
<th>OR</th>
<th>95% CI</th>
<th>P</th>
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<tr>
<td>Smoked at initial WIC visit</td>
<td>2.16</td>
<td>1.05, 4.47</td>
<td>0.04</td>
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<tr>
<td>Birth weight</td>
<td>1.82</td>
<td>0.90, 3.71</td>
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<td>Maternal age</td>
<td>0.98</td>
<td>0.92, 1.04</td>
<td>0.49</td>
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<td>Maternal education</td>
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<td>0.82, 1.77</td>
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<td>1.00, 1.00</td>
<td>0.87</td>
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<tr>
<td>Maternal prepregnancy BMI (in kg/m²)</td>
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<td>0.98, 1.10</td>
<td>0.19</td>
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<tr>
<td>Ever breastfed</td>
<td>0.53</td>
<td>0.26, 1.06</td>
<td>0.07</td>
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1 n = 161. WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

FIGURE 2. Mean (±SE) changes in weight-for-length z score of children of nonsmoking and smoking mothers between 2 time points, birth and 36 mo (n = 252). z Score change × time interaction was significant, P = 0.009 (repeated-measures ANOVA).

FIGURE 3. Mean percentage change in weight from birth to 36 mo by birth weight group and mother’s smoking status at initial Women, Infants, and Children visit (n = 252). Birth weight group main effect, P < 0.001; maternal smoking effect, P = 0.024; group × smoking interaction, NS (ANOVA).

FIGURE 4. Mean percentage change in height from birth to 36 mo by birth weight group and mother’s smoking status at initial Women, Infants, and Children visit (n = 252). Birth weight group main effect, P < 0.001; maternal smoking effect, P = 0.714; group × smoking interaction, NS (ANOVA).
and overweight. Children of mothers who smoked during pregnancy showed significantly greater rates of weight gain than did children of nonsmokers, which resulted in significantly greater increases in WFL z score between birth and age 3 y.

In our study population, 22.2% of children were at risk of overweight and 18.7% were overweight. These rates are higher than those of overweight reported nationally for 3-y-old American Indian WIC participants—14.4% (20). Moreover, 18.7% of the children in the sample in the current study were LGA, whereas national American Indian and Wisconsin all-race proportions are 11.3% and 8.7%, respectively (1). This high rate of LGA is especially troubling, given the correlation between birth weight and later BMI seen in this study and in others. Rates of breastfeeding were comparable to reported all-race national and state rates of 52.5% and 55.0%, respectively, but were slightly below national rates of 59% for American Indians participating in WIC (25).

In our population, children of mothers who smoked at the initial WIC visit were almost twice as likely as children of nonsmokers to have a BMI ≥ 85th percentile at age 36 mo. The increased overweight risk and incidence of overweight among children of smokers seen in our study was similar to, if not slightly higher than, that seen in other populations (15, 26-28). However, because of the nature of our data, we were not able to establish a dose-dependent relation for smoking as seen in studies by Power and Jeffers (26) and von Kries et al (15).

The prevalence of maternal smoking during pregnancy seen in the current study is higher than that reported in other studies (15, 26, 27, 29, 30). However, our data corresponded to those from a recent report indicating that 40% of Wisconsin American Indian mothers smoked during pregnancy (28). Mothers enrolled in WIC were significantly more likely to have smoked during pregnancy than were mothers not enrolled in WIC. This agrees with national trends for WIC or lower-income mothers (24, 25).

In the current study, we used smoking status at initial WIC visit to establish whether the mother smoked during pregnancy. Almost half (48.4%) of the mothers who visit WIC do so within the first trimester of their pregnancy, and 39.8% visit WIC during the second trimester (24). By using smoking at initial WIC visit, we captured both mothers who smoked throughout the pregnancy and mothers who smoked during the first part of their pregnancy and quit thereafter. Toschke et al (31) showed an equal effect of smoking in the first trimester only and of smoking throughout pregnancy on overweight at age 5–6 y.

Children of mothers who smoked during pregnancy were, on average, 160 g smaller at birth than were children of nonsmoking mothers, which is consistent with findings of other studies (26). In our sample, however, the children of mothers who smoked were not shorter at birth than were the children of nonsmokers, and this finding is at odds with the literature. Furthermore, the children of mothers who smoked during pregnancy did not show any significant differences from the children of nonsmoking others in height at 36 mo, whereas other studies found that the children of smokers were shorter than the children of nonsmokers at ages 2 and 7 y (31, 32). Nevertheless, these results agree with other studies that showed no significant difference in height at age 3 y after adjustment for maternal, environmental, and birth characteristics (33–35). The lower birth weights of infants of mothers who smoked is important because studies have shown both a greater risk of morbidity in obese persons who were small at birth than in those with a normal birth weight (36) and a greater number of risk factors for adult disease in children who displayed “catch-up” growth between ages 1 and 2 y (34). Paradoxically, other studies show that lower birth weights are correlated with lower BMIs, which suggests that the decreased birth weight of children of smokers may attenuate the magnitude of their later overweight (37).

Our results remained robust after we considered several additional variables, including size at birth and the mother’s prepregnancy weight. The significance of a relation between maternal smoking and child overweight at age 3 y, independent of these factors, suggests mechanisms separate from growth restriction through which smoking affects early childhood growth. Mechanisms relating to alterations in the fetal environment that affect endocrine balance or metabolic functions or the mechanisms of the direct effect of nicotine on brain development have been put forth by others (15, 31, 38).

The correlation of smoking with weight gain from birth to 36 mo, independent of birth weight, could also be explained by lifestyle factors that correlate with smoking—eg, poor nutritional choices and reduced physical activity—and promote weight gain. However, we did not see an association between maternal postnatal smoking and child overweight at age 3 y. Thus, the association between maternal smoking and later growth may be due to the in utero effect of smoking and not to other variables that may be associated with smoking. Toschke et al (31) postulated that smoking in early pregnancy has a direct metabolic effect on the offspring, whereas later smoking may be a marker for other lifestyle factors.

Similar to studies in other populations (8, 10, 39), the current study did not find a significant effect of breastfeeding on overweight at age 3 y. A reason for this may be that the percentage of mothers who exclusively breastfed was not comparable between our study and other studies that showed an association (17, 18). Alternatively, the effects of breastfeeding may not become apparent until later childhood. For example, Bergmann et al (16) showed a protective effect of breastfeeding on overweight at age 6 y, but not at age 3 y.

Limitations of the current study included the large reduction in number of subjects because of nonmatching and missing data. The greatest loss of mother-child pairs was due to the requirement of WIC visits until age 36 mo. It is possible that mothers who remained in WIC long enough to be included differed in some way (eg, nutritional status) that would affect child growth, but none of the relevant measures we examined reflected such differences. An additional obstacle was the standards for collecting PedNSS and PNSS data, which are geared toward easy reporting by WIC personnel rather than toward scientific analysis. Also lacking were data on paternal smoking, which was correlated to child overweight in another study (40). Finally, key differences were noted between WIC and non-WIC participants. However, when differences were considered in more detail, income, education, maternal weight gain, and age did not correlate with the change in WFL z score. This suggests that the relation between smoking and change in WFL z score is independent of these factors and may hold true in a non-WIC population.

To our knowledge, this is the first study to show a relation between smoking in pregnancy and later overweight in American Indian children. Given the limitations and potential biases inherent in retrospective analysis, prospective cohort studies would be an ideal next step in evaluating the suggested relation between...
smoking and overweight. Our results have important implications for health care and point to the need for targeted interventions to reduce smoking in pregnant women and women of childbearing age. A similar message should be communicated at the initial WIC visit and at subsequent WIC visits throughout a pregnancy.

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AKA obtained study funding, established the study concept and design, acquired data, supervised the execution of the study, reviewed and revised the manuscript, and provided critical intellectual content. HEW contributed to the study concept and design, provided administrative support throughout the study, and wrote the manuscript draft. RJP provided statistical expertise and analyzed and interpreted data, revised the manuscript, and provided critical intellectual content.

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