Sudden Infant Death Syndrome and Smoking in the United States and Sweden

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The association between sudden infant death syndrome (SIDS) and maternal smoking was compared between the United States and Sweden—two countries with different health care and social support programs and degrees of sociocultural heterogeneity. For 1990–1991 among the five US race/ethnic groups studied, SIDS rates ranged from a high of 3.0 infant deaths per 1,000 live births for American Indians to a low of 0.8 for Hispanics and Asian and Pacific Islanders. The SIDS rate for Sweden (using 1983–1992 data) was 0.9. The strong association between maternal smoking and SIDS persisted after controlling for maternal age and live birth order. Adjusted odds ratios ranged from 1.6 to 2.5 for mothers who smoked 1–9 cigarettes per day during pregnancy (compared with nonsmokers) and from 2.3 to 3.8 for mothers who smoked 10 or more cigarettes per day during pregnancy. Although birth weight had a strong independent effect on SIDS, the addition of birth weight to the models lowered the odds ratios for maternal smoking only slightly, suggesting that the effect of smoking on SIDS is not mediated through birth weight. SIDS rates increased with the amount smoked for all US race/ethnic groups and for Sweden. Smoking is one of the most important preventable risk factors for SIDS, and smoking prevention/intervention programs have the potential to substantially lower SIDS rates in the United States and Sweden and presumably elsewhere as well. Am J Epidemiol 1997;146:249–57.

Sudden infant death syndrome (SIDS) is the leading cause of postneonatal mortality in most developed countries, including the United States and Sweden (1, 2). SIDS is probably not a single disease entity but rather a complex of factors that together lead to death; different combinations of factors are important in individual cases (3–5). Many factors have been identified as increasing the risk of SIDS, including low maternal age (5–7), high live birth order (5–7), prone sleep position (8, 9), maternal smoking during pregnancy (2, 10–14), and (possibly) passive smoke exposure of the infant after birth (10, 11).

The large differences in SIDS rates between race/ethnic groups in the United States have presented persistent challenges to researchers and policy makers. Moreover, the overall SIDS rate is higher in the United States than in several other developed countries, including Sweden. Sweden and the United States also differ in terms of health care, social support programs, and sociocultural heterogeneity. In Sweden, routine prenatal and infant medical care is free, and more than 95 percent of pregnant women attend antenatal care before the 15th week of pregnancy (15). In 1994, 14 percent of American children did not have health insurance (16), and 20 percent of American mothers did not begin prenatal care in the first trimester of pregnancy (17). These percentages are substantially higher for US black, American Indian, and Hispanic populations (16, 17).

The prevalence of risk factors for SIDS, such as low maternal age, multiparity, and maternal smoking, also differs between race/ethnic groups within the United States as well as between the United States and Sweden. Sweden and the United States are among the few countries that have national population-based data sets available to examine the relation between SIDS and these risk factors. This study compares the relation between SIDS and maternal smoking for Sweden and five different US race/ethnic groups. The comparison
of the different US race/ethnic groups with Sweden may provide clues as to the roles of identified SIDS risk factors in different sociocultural and health care delivery settings.

MATERIALS AND METHODS

US data

The newly available, national linked birth/infant death data sets (linked files) for the 1990 and 1991 birth cohorts were used for the US portion of the analysis (18). In these files, the death certificate was linked to the corresponding birth certificate for each infant who died in the United States. The linked files represent the first national US data set containing the complete "population" of SIDS cases together with data on maternal smoking and other risk factors.

Information on maternal smoking is from the birth certificate and refers to smoking at any time during the pregnancy. Although data on maternal smoking first became available for 1989 with the 1989 revision of the US Standard Certificate of Birth, item completeness is much lower for the 1989 data in part because of delays in some states in implementing the new birth certificate. Therefore, the combined 1990-1991 data were selected for study. Forty-five states and the District of Columbia reported data on maternal smoking on the 1990 and 1991 birth certificates. Five states (California, Indiana, New York, Oklahoma, and South Dakota) that did not include an item on maternal smoking are excluded from the analysis. The 45 states and Washington, DC, included about 80 percent of the non-Hispanic white births, 82 percent of the non-Hispanic black births, and 75 percent of American Indian births, but only 50 percent of the Hispanic and Asian and Pacific Islander births in the United States. Therefore, caution should be used in extrapolating the results from this study to states that did not report maternal smoking.

Swedish data

The Swedish data are from the Swedish Medical Birth Register from 1983 through 1992. The Birth Register receives prospectively collected comprehensive information on more than 99 percent of all births in Sweden (19). Starting with the first antenatal visit, antenatal, obstetric, and pediatric data are recorded on standardized records that are forwarded to the Birth Register. Information regarding smoking is collected at the first prenatal visit. All births and deaths are validated each year against another population register through individual record linkage using the mother’s and infant’s unique personal identification numbers. The Birth Register also includes information about all infant deaths, through individual record linkage with the Cause of Death Register.

Statistical methods

For both the United States and Sweden, the analysis was restricted to singleton infants. SIDS was defined as death under one year of age with the underlying cause of death coded to International Classification of Diseases, Ninth Revision, code 798.0 or International Classification of Diseases, Eighth Revision, code 795 and age of death between 7 and 364 days. Multivariate logistic regression was used to examine the risk of SIDS mortality among 1-week survivors by maternal smoking status during pregnancy. Smoking status was divided into nonsmoker (non-daily smoker), moderate smoker (1-9 cigarettes per day), and heavy smoker (10 or more cigarettes per day). Maternal age, live birth order, and infant birth weight were also included in the models. The parameters in the logistic model were estimated by the maximum likelihood method using the LOGLISTIC procedure of SAS, version 6 (SAS Institute, Inc., Cary, North Carolina). Records with missing data were excluded from the multivariate analysis.

Logistic regression models were examined separately for Sweden and for each of five US race/ethnic groups: non-Hispanic white, non-Hispanic black, Hispanic, American Indian, and Asian and Pacific Islander. Maternal age was restricted to 10-44 years for non-Hispanic white, non-Hispanic black, Hispanic, and American Indian models, as there were insufficient numbers of SIDS deaths to compute odds ratios for the 45- to 49-year-old age group. For Swedish and US Asian and Pacific Islanders, maternal age was restricted to 15-44 years, because of insufficient numbers of events for the 10- to 15- and 45- to 49-year age groups. For the Swedish data, it was necessary to use a longer time period (1983-1992) to obtain enough SIDS cases. Year of birth was therefore initially included as a covariate in the analyses of the Swedish data, but as this did not change the results for the other factors, year of birth was excluded in the final model.

For all groups except non-Hispanic white infants, logistic regression analysis was performed on the complete population of infants. For the non-Hispanic white group, 100 percent of the infant deaths and a 25 percent random sample of the survivors were included in the model since it was impractical and costly (in terms of computer processing time) to perform a logistic regression analysis on all 4 million records. The models were weighted and the weights normalized to the sample size, leading to a sample size for the multivariate model of just under 1 million cases. For each population group, three multivariate logistic regression models were run: model 1, unadjusted; model...
Two combined US models were also examined. The first shows unadjusted odds ratios for SIDS for the five US race/ethnic groups, while the second shows odds ratios for race/ethnic groups after adjustment for maternal smoking, maternal age, live birth order, and birth weight. For the combined models, 100 percent of the infant deaths and a 20 percent random sample of the survivors were included. The models were weighted and the weights normalized to the sample size, producing a sample size of about 1.2 million records.

RESULTS

The proportion of mothers who smoked during pregnancy varied widely among the different population groups, ranging from a low of 5–6 percent for US Asian and Pacific Islander and Hispanic mothers to a high of 27 percent for Swedish mothers (figure 1; table 1). However, the amount smoked varied considerably among the different groups. For non-Hispanic white women, more than three fourths of the women who smoked during pregnancy smoked 10 or more cigarettes per day compared with less than 40 percent for Sweden.

The six population groups studied also varied considerably according to maternal age, live birth order, and birth weight. The percentage of births to teenagers ranged from 3 percent for Swedish mothers to 25 percent for non-Hispanic black mothers. For American Indian mothers, nearly one fourth of births were fourth or higher order births compared with 7–8 percent for non-Hispanic white and Swedish mothers. The proportion of non-Hispanic black infants with low birth weight (<2,500 g) was 11.5 percent, more than twice as high as for any other population group.

SIDS rates varied substantially among the different population groups. American Indians had the highest rate at 3.0 SIDS deaths at 7–364 days of age per 1,000 singleton, 1-week survivors, followed by 2.2 for non-Hispanic blacks, 1.1 for non-Hispanic whites, 0.9 for Swedes, and 0.8 for Hispanics and Asian and Pacific Islanders (table 2). SIDS rates were highest for teenage mothers and lowest for mothers in their thirties and forties, although small numbers of SIDS deaths made this comparison somewhat problematic for the Asian and Pacific Islander and American Indian groups. Rates were lowest for first births and highest for fourth or higher order births. Rates were also higher for low birth weight infants than for infants born at birth weights of 2,500 g or more. Rates were higher for very low birth weight infants (<1,500 g) than for moderately low birth weight infants (1,500–2,499 g) for all population groups studied, except for Sweden, where the SIDS rate for very low birth weight infants is based on only eight infant deaths.

The results of the multivariate logistic regression analysis are shown in table 3. Odds ratios for SIDS and smoking are shown unadjusted for other factors (model 1), adjusted for maternal age and live birth order (model 2), and adjusted for maternal age, live birth order, and birth weight (model 3). For all population groups, SIDS risks were significantly higher for smokers than for nonsmokers, and SIDS risks rose with the number of cigarettes smoked per day. Unadjusted odds ratios for the different population groups ranged from 1.7 to 3.0 for mothers who smoked 1–9 cigarettes per day and from 2.4 to 4.4 for mothers who smoked 10 or more cigarettes per day. After controlling for maternal age and live birth order, odds ratios

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<th>Smoking status</th>
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<th>Non-Hispanic black</th>
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<th>American Indian</th>
<th>Asian and</th>
<th>Pacific Islander</th>
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<td></td>
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<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
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<td>787,264</td>
<td>19.9</td>
<td>147,239</td>
<td>14.5</td>
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<td>≥10 cigarettes/day</td>
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<td>&lt;1,500</td>
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<td>3.9</td>
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<tr>
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<td>3,126</td>
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<td>1,094</td>
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* Excludes data from California, Indiana, New York, Oklahoma, and South Dakota, which did not report maternal smoking on the birth certificate.
† Not stated responses are excluded from the calculation of percentages.

<table>
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<tr>
<th>Smoking status</th>
<th>Non-Hispanic white</th>
<th>Non-Hispanic black</th>
<th>Hispanic</th>
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<th>Asian and Pacific Islander</th>
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<td>Rate</td>
<td>No.</td>
<td>Rate</td>
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<td>Total</td>
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<td>Smoker</td>
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<td>1–9 cigarettes/day</td>
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<td>401</td>
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<td>0.8</td>
<td>0</td>
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</table>

* Rates are per 1,000 live births in specified group. Rates based on small numbers of deaths are statistically unreliable.

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<td>Non-smoker</td>
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<td>1.0</td>
</tr>
<tr>
<td>1–9 cigarettes/day</td>
<td>1.7 (1.5–2.1)*</td>
<td>3.0 (2.4–3.6)</td>
</tr>
<tr>
<td>≥10 cigarettes/day</td>
<td>3.2 (2.7–3.8)</td>
<td>3.7 (3.3–4.2)</td>
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<tr>
<td><strong>Model 2 (adjusted for maternal smoking, maternal age, and live birth order)</strong></td>
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</tr>
<tr>
<td>1–9 cigarettes/day</td>
<td>1.6 (1.3–1.9)</td>
<td>2.4 (1.9–3.0)</td>
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<td>2.8 (2.4–3.3)</td>
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<td>10–14</td>
<td>9.1 (3.7–22.6)</td>
<td>5.1 (3.5–7.4)</td>
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<tr>
<td>15–19</td>
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<td>3.4 (2.8–4.1)</td>
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<td>20–24</td>
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<td>40–44</td>
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<td>0.4 (0.3–0.5)</td>
<td>0.5 (0.4–0.5)</td>
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<td>≥2</td>
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</tr>
<tr>
<td>Smoking status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-smoker</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>1–9 cigarettes/day</td>
<td>1.5 (1.3–1.8)</td>
<td>2.3 (1.9–2.8)</td>
</tr>
<tr>
<td>≥10 cigarettes/day</td>
<td>2.7 (2.3–3.1)</td>
<td>2.6 (2.3–3.0)</td>
</tr>
<tr>
<td>Birth weight (g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1,000</td>
<td>2.3 (1.1–4.6)</td>
<td>3.0 (1.9–4.6)</td>
</tr>
<tr>
<td>1,500–2,499</td>
<td>2.4 (1.9–3.2)</td>
<td>2.6 (2.2–3.2)</td>
</tr>
<tr>
<td>≥2,500</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

* Numbers in parentheses, 95% confidence interval.
† Odds ratios for maternal age and live birth order differed little from those in model 2 and are not shown to save space.

The effects of maternal age and live birth order on SIDS risks were remarkably consistent across the race/ethnic groups studied (model 2). For mothers aged 15–19 years, the risk of an infant’s dying of SIDS was 2.4–3.8 times higher than for mothers in the 25- to 29-year age group. This was true for all race/ethnic groups except Asian and Pacific Islanders, where, perhaps due to small numbers of SIDS deaths, no clear relation with maternal age could be discerned. Higher birth order infants also experienced a substantially elevated risk of SIDS death (table 3).

In order to investigate whether birth weight was in the causal pathway of the smoking-related increased risk ratios for heavy versus light smokers, but overlapping confidence intervals argue for caution in inferring such a relation.
risk of SIDS, birth weight was included as an independent variable in model 3. Although birth weight had a strong independent effect on SIDS mortality, the addition of birth weight to the models lowered the odds ratios for maternal smoking only slightly for all population groups. The odds ratios for maternal age and live birth order remained essentially unchanged after controlling for birth weight (data not shown).

To assess the extent to which differences in the distribution of risk factors for SIDS can explain observed differences in SIDS rates between various US race/ethnic groups, we next examined SIDS risks after controlling for these factors (table 4). For non-Hispanic blacks, the odds ratio was reduced from 1.9 in the unadjusted model to 1.6 after controlling for the effects of the covariates. For American Indians, the odds ratio decreased from 2.7 to 1.9. For American Indians and non-Hispanic blacks, a higher percentage of births was to high-risk women as regards maternal age and live birth order (and birth weight for non-Hispanic blacks). Adjustment for these factors may have played a greater role than adjustment for smoking in reducing the odds ratios for these groups. Hispanics continued to have a substantially lower risk of SIDS even after controlling for covariates. However, for Asian and Pacific Islanders, their low unadjusted risk disappeared after controlling for the covariates, although the confidence intervals for both included the null value.

**DISCUSSION**

SIDS rates varied from 0.8 to 3.0 within the five race/ethnic groups in the United States and in Sweden. In all populations, the risk of SIDS increased with amount smoked, higher live birth order, and birth weight and decreased with older maternal age. Maternal smoking is an important risk factor for SIDS that remained strong even after controlling for maternal age, birth order, and birth weight. This was true for all six population groups studied, despite cultural, socioeconomic, and health care differences among groups. Ethnic differences in SIDS rates within the United States were only partially explained by differences in the prevalence of these risk factors.

Of the six population groups studied, Hispanics, Asian and Pacific Islanders, and Swedes had the lowest SIDS rates, but they also experienced the largest increase in SIDS risk by amount smoked per day. Among groups with the highest SIDS rates, i.e., American Indians and non-Hispanic blacks, the dose-related risk of increase of smoking on SIDS was less impressive. In populations with high baseline SIDS rates, other factors not measured in this study (such as infant sleep position, breastfeeding, or other socioeconomic or environmental differences) may be operating to keep SIDS rates high and may have lessened the relative effect of maternal smoking. The high odds ratio for American Indians after adjustment for available covariates clearly suggests the presence of other factors in explaining the high SIDS rates for this group (20–23). Still, the fact that excess risk for American Indians and American blacks decreased substantially after adjusting for available covariates suggests that intervention programs designed to decrease the proportion of high-risk births and to lower smoking prevalence might prevent a substantial number of SIDS deaths for these groups.

Socioeconomic factors (other than maternal age and race/ethnicity) were not included in the present analysis but may have accounted for some of the residual differences in SIDS risk among the race/ethnic groups, particularly for American Indians and blacks, who are more likely to be socioeconomic disadvantaged (24). However, the association of SIDS with socioeconomic status remains controversial. While many studies have found an association between SIDS and socioeconomic status (5, 7), others have found the association to be attenuated after carefully controlling for other factors, including maternal smoking (13, 25). Besides being a potential risk factor, low socioeconomic status may also be regarded as a risk marker for other risk factors, such as nonmarital childbearing, unwanted pregnancy, lack of health insurance, crowded and substandard housing conditions, formula feeding, and maternal smoking. Future research should help to clarify to what extent the elevated SIDS risks for American Indians and blacks are mediated through increased rates of socially related risk factors.

For Asian and Pacific Islanders, the low unadjusted SIDS risk (compared with the risk for non-Hispanic whites) disappeared after adjustment for covariates.

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<table>
<thead>
<tr>
<th>Race/Ethnic Group</th>
<th>Unadjusted (n = 1,218,516)</th>
<th>95% Confidence Interval</th>
<th>Adjusted* (n = 1,156,385)</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Hispanic white</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Non-Hispanic black</td>
<td>1.9</td>
<td>1.7-2.2</td>
<td>1.6</td>
<td>1.4-1.8</td>
</tr>
<tr>
<td>Hispanic</td>
<td>0.7</td>
<td>0.6-0.9</td>
<td>0.7</td>
<td>0.6-0.9</td>
</tr>
<tr>
<td>American Indian</td>
<td>2.7</td>
<td>1.9-3.8</td>
<td>1.9</td>
<td>1.3-2.7</td>
</tr>
<tr>
<td>Asian and Pacific Islander</td>
<td>0.7</td>
<td>0.5-1.1</td>
<td>1.1</td>
<td>0.7-1.6</td>
</tr>
</tbody>
</table>

* Adjusted for the effects of maternal smoking, maternal age, parity, and birth weight. † OR, odds ratio; 95% CI, 95% confidence interval.
This seems to suggest that the lower SIDS rates for Asian and Pacific Islanders may be due primarily to their more favorable population profile as regards smoking, maternal age, live birth order, and birth weight, rather than to genuine differences in baseline SIDS incidence. However, the wide confidence interval, due to small numbers of SIDS deaths for the Asian and Pacific Islander group, argues for caution in interpreting these data. For Hispanics, however, the risk of SIDS was significantly lower than that for non-Hispanic whites even after adjustment for covariates, suggesting that further study of Hispanic-origin populations may provide important clues to reducing SIDS risks. However, the estimates for the Hispanic and Asian and Pacific Islander groups must be regarded as preliminary because only 50 percent of the total US births to these groups are represented.

Despite the strong relation between SIDS and birth weight, the addition of birth weight to the models lowered the odds ratios for maternal smoking only slightly (table 4). This finding seems to suggest that the effect of smoking on SIDS mortality operates largely independently of birth weight. These findings are consistent with the results of Malloy et al. (26), who found that birth weight had little impact on the relation between SIDS and maternal smoking after controlling for live birth order, maternal age, maternal education, and marital status.

The strengths of the current study lie in the large population-based data sets on which it is based, which allow us to compute covariate-adjusted SIDS risks for Sweden and five different race/ethnic groups in the United States. Limitations include concerns about the quality of smoking data on the birth certificate. A North Carolina study found that the smoking status reported on the birth certificate agreed with the smoking status in the medical record for 96.6 percent of cases (27). A Tennessee study, conducted in the first year of adding the smoking question to the birth certificate and using a different methodology, found more evidence of underreporting of maternal smoking on the birth certificate (28). Underreporting could lead to underestimates of the odds ratios for SIDS and maternal smoking, since some smokers would be included in the nonsmoking group, leading to artificially elevated SIDS risks for nonsmokers. Moreover, it was not possible from these data to examine the effects of changes in maternal smoking status during the course of the pregnancy or the effects of other potential confounders, such as crowded housing conditions, breastfeeding, and infant sleep position.

Although the purpose of this study was to examine the relation between maternal smoking during pregnancy and SIDS, postnatal exposure of infants to environmental tobacco smoke cannot be ruled out as a contributing factor, since infants of women who smoke during pregnancy are also more likely to be exposed to passive smoking in the home (primarily from the mother). In one of the few studies that examined the timing of tobacco exposure during and after pregnancy, Schoendorf and Kiely (10) found that both prenatal and postnatal smoke exposures were important risk factors for SIDS. However, in a recent meta-analysis, DiFranza and Lew (12) concluded that, while evidence was sufficient to document the effect of maternal smoking during pregnancy on SIDS, it was insufficient to draw definite conclusions about the effect of postnatal passive smoke exposure.

In conclusion, smoking as a risk factor for SIDS seems to transcend issues of race/ethnicity and nationality. In all six population groups studied, the strong relation between SIDS and smoking persists after adjustment for maternal age, live birth order, and birth weight. The associations appear strikingly similar among the different population groups studied, suggesting a universality of causes and effects. Smoking must be viewed as one of the most important preventable risk factors for SIDS. Public health interventions that focus on smoking cessation among pregnant women, and more particularly on primary smoking prevention efforts among teenage girls, may lead to a substantial decrease in SIDS not only in the United States and Sweden but presumably elsewhere as well.

REFERENCES


SIDS and Smoking in the United States and Sweden