Costs of smoking during pregnancy: development of the Maternal and Child Health Smoking Attributable Mortality, Morbidity and Economic Costs (MCHSAMMEC) software

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Abstract
The development and availability is described of new, user friendly software, the Maternal and Child Health Smoking Attributable Mortality, Morbidity and Economic Costs (MCHSAMMEC), that will allow states and other entities to estimate pregnancy related, smoking attributable costs for their population. The methodology underlying the MCHSAMMEC software, including calculations used in the prevalence based analysis of smoking attributable mortality and costs of infant neonatal care, are described, along with design and data management features and possible applications of the software for policy and program development at various levels of the health care system.

Keywords: smoking; pregnancy; costs

It is clear that, for the general population in the USA, there is excess morbidity and mortality attributable to smoking. Unfortunately, although considerable progress has been made in measuring the health care costs of smoking that occur in the long run, less is known about the smoking attributable costs that occur when pregnant women smoke. The causal association between maternal smoking and maternal morbidity, infant mortality, and infant morbidity is well established. In 1997, 11% to 23.9% of pregnant women in the USA reported smoking throughout their pregnancy. As now constructed, women were classified as smokers if they indicated that they were still smoking during the third trimester of pregnancy, and self reports of smoking during pregnancy on smoking status during the last three months of pregnancy Monitoring System (PRAMS) question (Suppl III):iii12–iii15)

Methods
MCHSAMMEC, as now constructed, performs a prevalence based analysis of smoking attributable mortality and costs of infant neonatal care. Calculation of each of the impact measures relies on the estimate of a smoking attributable fraction (SAF) derived from either a relative risk approach or a multivariate analysis. The use of multivariate analysis to derive the SAF for direct health care costs differs from the attributable risk approach used in the original SAMMEC.

SAF DERIVATION
The SAF, which is the proportion of cases or deaths that can be regarded as causally linked to cigarette smoking, also represents the proportion by which the outcome would be reduced if exposure to cigarette smoking was eliminated. In our estimates of neonatal costs, or SAFs, exposure includes only active maternal smoking throughout pregnancy. Using responses to the Pregnancy Risk Assessment Monitoring System (PRAMS) question on smoking status during the last three months of pregnancy, and self reports of smoking status during pregnancy from the birth certificate, women were classified as smokers if they indicated that they were still smoking during the third trimester of pregnancy or if they used tobacco during pregnancy. As now constructed, the outcomes in MCHSAMMEC include infant mortality, percentage of infants with low birth weight, birth weight in grams, probability of admission to the neonatal intensive care unit (NICU), number of infant hospi-
Costs of smoking during pregnancy

where: \( p_0 \) = percentage of pregnant current smokers; and \( RR_1 \) = relative risk of maternal smoking

The attributable risk approach described above has been set to their actual value in \( x' \) and to zero in \( x^* \).

The numerator of this expression is the aggregate smoking attributable birth weight in grams, probability of admission to the NICU, and number of infant hospital days (for example, infant length of stay), depending on the coefficients used. For example, it is the difference in expected birth weight given actual in utero smoke exposure and the expected birth weight given no exposure. The actual dollar value of the expense SAF is based on all inpatient health care expenses per night incurred over the infant’s full stay. A weighted average of the NICU expenses per night and the non-NICU expenses per night is used.

The regressions underlying the SAFs were estimated with 1995 data from the PRAMS, an ongoing surveillance project of the CDC. In 1995, 13 states (Alabama, Alaska, California, Florida, Georgia, Indiana, Maine, Michigan, New York (excluding New York City), Oklahoma, South Carolina, Washington, and West Virginia) and the District of Columbia participated in PRAMS. The data are generated so as to be representative of all live births in each state although there is state-specific oversampling of certain low income and racial groups. Sample weights are provided with the data. PRAMS data on approximately 25,000 live births in the participating states and the District of Columbia were used.

In addition to PRAMS, a secondary data set available to the CDC from the MedStat Corporation is used to estimate the average number of NICU nights incurred by newborns and to attach average health care expenses to NICU and non-NICU nursery nights. The data set is a subset of birth records drawn from the MarketScan© database of commercially insured health care claims. It contains data pooled from MarketScan's employer/payer customers. The database contains detailed information on services administered and payments made for each service, including


direct and indirect costs (for example, lost wages) are also not included at this time.

IMPACT MEASURES: INFANT MORTALITY

Traditionally, derivation of an SAF is based on the following formula, which uses relative risk estimates for smoking related conditions and the prevalence of smoking in the population (here, a pregnant population):

\[ SAF = \left[ \frac{[p_0 + p_1(RR_1)] - 1}{[p_0 + p_1(RR_1)]} \right] \]

where: \( p_0 \) = percentage of pregnant current nonsmokers; \( p_1 \) = percentage of pregnant current smokers; and \( RR_1 \) = relative risk of outcome for pregnant current smokers relative to pregnant current non-smokers.

For infant mortality, the SAF is derived from pediatric conditions (for example, sudden infant death syndrome) resulting in infant death (less than 1 year of age). Again, in estimating these deaths, smoking prevalence refers only to active maternal smoking. For the selected infant conditions, smoking attributable infant mortality is calculated as follows:

smoking attributable infant deaths \( = \) total infant deaths \( \times \) SAF

The relative risks for infant mortality due to smoking during pregnancy used in deriving this SAF are currently being updated by a review of the literature and estimated by meta-analysis where appropriate.

Methodological details regarding the updated relative risks will be documented and appropriately referenced in the discussion portion of the software (see Design Features section).

IMPACT MEASURES: SMOKING ATTRIBUTABLE DIRECT HEALTH CARE COSTS

The attributable risk approach described above also applies SAFs to corresponding health care expenditures to derive smoking attributable health care costs. This approach, however, does not account for the complex interactions of factors that determine actual costs incurred by individual smokers (for example, smoker's race, age) or isolate the effects of smoking from other factors, such as alcohol abuse. For example, we do not have estimates of how changing smoking behaviour might change other risk behaviours during pregnancy. Furthermore, we do not know how these behaviours affect the outcomes of interest, birth weight, probability of NICU admission, and infant length of stay either individually or in combination. This approach also does not allow for differences in the costs of a given outcome such as low birth weight for infants of smokers and non-smokers. The multivariate approach corrects for some of these problems and is used here to derive smoking attributable health care costs for MCHSAM-MEC. It is also being used to update the overall SAMMEC 4.0 model and software.

Regression models were used to estimate the relation of maternal smoking to probability of NICU admission and to length of stay for the infant. Based on these regressions, the formula for the SAF is:

\[ \Sigma_w[exp(x^*b)/\{1 + exp(x^*b)\}] - \Sigma_w[exp(x'b)/\{1 + exp(x'\beta)\}] \]

\[(1 + exp(x'\beta))exp(x'b)\]

where \( I \) indexes individuals; \( w \) is the observation weight, \( x \) is the estimated vector of coefficients for the probability equation; and \( \beta \) is the estimated coefficient vector for the log expense equation. The values of the smoking variable(s) have been set to their actual value in \( x^* \) and to zero in \( x' \).

The regressions underlying the SAFs were estimated with 1995 data from the PRAMS, an ongoing surveillance project of the CDC. In 1995, 13 states (Alabama, Alaska, California, Florida, Georgia, Indiana, Maine, Michigan, New York (excluding New York City), Oklahoma, South Carolina, Washington, and West Virginia) and the District of Columbia participated in PRAMS. The data are generated so as to be representative of all live births in each state although there is state-specific oversampling of certain low income and racial groups. Sample weights are provided with the data. PRAMS data on approximately 25,000 live births in the participating states and the District of Columbia were used.

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Table 1 Sample neonatal health care cost smoking attributable fraction: MCHSAMMEC

<table>
<thead>
<tr>
<th>States selected:</th>
<th>Alabama and Missouri and North Carolina and Wyoming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>&lt; 18 or 18–34 or &gt;34</td>
</tr>
<tr>
<td>Education</td>
<td>No high school graduate or high school graduate, or some college or college graduate</td>
</tr>
<tr>
<td>Insurance</td>
<td>Private or Medicaid or other public or none</td>
</tr>
<tr>
<td>Marital status</td>
<td>Married or unmarried</td>
</tr>
<tr>
<td>Prenatal care</td>
<td>None or 1st trimester or 2nd trimester or 3rd trimester</td>
</tr>
<tr>
<td>Race</td>
<td>White or African American or other</td>
</tr>
<tr>
<td>Observations</td>
<td>241015 Number of observations matching selections above</td>
</tr>
<tr>
<td>Smoking prevalence:</td>
<td>16.43% Smoking prevalence in selected population</td>
</tr>
<tr>
<td>SA expenditures:</td>
<td>$28.48 M Smoking attributable expenditures in selected population</td>
</tr>
<tr>
<td>Total expenditures:</td>
<td>$1.029 B Total expenditures in selected populations</td>
</tr>
<tr>
<td>SAF among smokers:</td>
<td>15.22% Smoking attributable fraction of expenditures for smokers in selected population</td>
</tr>
<tr>
<td>Overall SAF:</td>
<td>2.77% Overall smoking attributable fraction of expenditures in selected population</td>
</tr>
<tr>
<td>User adjusted statistics:</td>
<td></td>
</tr>
<tr>
<td>User’s smoking prevalence:</td>
<td>30.0% Smoking prevalence in user’s population</td>
</tr>
<tr>
<td>User adjusted overall SAF:</td>
<td>5.05% Smoking attributable fraction of expenditures adjusted for user’s prevalence</td>
</tr>
</tbody>
</table>

Data are for illustration purposes only. M, million; B, billion.
DATA OUTPUT

For each measure, SAMMEC 4.0 produces a menu of report tables and, in some cases, charts that may be accessed on screen and, optionally, printed or saved to files on the user’s computer. The attributable mortality reports available in the MCHSAMMVEC module include tables detailing smoking prevalence, relative risk, mortality, and SAFs and smoking attributable mortality. The neonatal health care cost reports include the SAF table (table 1) and the smoking attributable expenditures table which provides both total and smoking attributable expenditures.

Discussion

Although there have been numerous studies of the increased risk of certain clinical outcomes associated with smoking during pregnancy, only a few studies have tried to estimate some of the costs related to smoking during pregnancy. A recent issue of Morbidity and Mortality Weekly Report provided the first national estimates of pregnancy related costs attributable to smoking.

The MCHSAMMVEC estimates may be used in a number of ways to influence policy and program initiatives. Estimates of health care costs due to smoking during pregnancy are informative to employers who self insure, insurance companies, and managed care organisations. The magnitude of these costs is also important for public programs such as Medicaid, which now covers a large proportion of pregnant women and children. State Medicaid directors can use estimates of direct health care costs and of cost savings associated with smoking cessation to encourage increased coverage of smoking cessation counselling for pregnant women. They could also be used to argue for directing tobacco settlement dollars into the promotion and implementation of smoking cessation programs for pregnant women. Managed care entities may use estimates of cost savings as they consider initiating or expanding programs in prenatal smoking cessation. It is also possible to use MCHSAMMVEC estimates to explore the relative cost effectiveness of various interventions and services offered during the prenatal period.

Users of the MCHSAMMVEC estimates should recognize the effect of several limitations. As noted, maternal costs, indirect costs, and infant costs beyond the neonatal period are not yet included. Without these costs, MCHSAMMVEC underestimates the true costs associated with smoking during pregnancy. Efforts are currently under way to estimate infant costs beyond the costs of delivery as well as those occurring for children exposed to smoke.

The relation between resource utilization and smoking behaviour, and hence the SAFs, is based on 1995 data from PRAMS. Although PRAMS includes questions on demographics, health status, smoking history, obstetric history, and pregnancy outcomes, it does not include information on pregnancy and childbirth costs. However, there are questions about the length of stay, and whether the infant was admitted to an NICU. In the absence of cost data, these variables can serve as reasonable proxies for resource utilisation and cost.

Because MCHSAMMVEC derives expenditure estimates based on the 1996 Market Scan® database, users must supply their own expenditure data to obtain user specific dollar estimates. Otherwise, given variations in insurance service coverage and payment rates as well as inflation over time, the dollar estimates derived from the software will not reflect actual costs for that user.

Summary

SAMMEC 4.0 and its MCHSAMMVEC module provide, for the first time, an opportunity for state and other policy and program directors to generate estimates of costs attributable to smoking during pregnancy. The software allows specification of various populations, subsets of populations, smoking prevalence, and expenditure data while maintaining default values for users who may not have this information for their state or organisation. Furthermore, MCHSAMMVEC allows users to compare their costs with costs in other states or relevant populations. The utility of MCHSAMMVEC will be further enhanced when infant costs beyond the costs of delivery and maternal costs are included.

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5 Adams EK, Miller V. Development of the maternal and child health (MCH) smoking attributable morbidity, mortality and economic cost (SAMMVEC) model. Final report to the Robert Wood Johnson Foundation (under grant 022247), May 1999.