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The Expected Impact of a Smoking Cessation Program for Pregnant Women on Infant Mortality among Native Americans

Marc Bulterys, MD, PhD, Hal Morgenstern, PhD,
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To quantify the expected impact of a smoking cessation program for pregnant women on infant mortality among Native Americans, we estimated the proportional reduction (impact fraction) and the absolute reduction (impact risk) in neonatal and postneonatal mortality as a result of the intervention program. The estimated attributable fraction due to maternal smoking was 16.6% of infant deaths in the Aberdeen Indian Health Service (IHS) Area, 16.2% in the Alaska IHS Area, and 5.2% in the Navajo IHS Area. Under the assumptions that 14% of the smokers participating in a smoking cessation program would quit and that the intervention would have 60% relative efficacy in preventing infant deaths attributable to smoking, the impact fraction was estimated to be 0.9% of all infant deaths in the Aberdeen Area, 1.0% in the Alaska Area, and 0.3% in the Navajo Area. Under the "best" model assumptions (28% cessation rate and 90% relative efficacy), 2.6% of all infant deaths, 3.7% of postneonatal deaths, and 1.2% of neonatal deaths would be prevented by a smoking cessation program in the Aberdeen Area. When applied to 1984–1986 infant mortality data, the impact risk per 100,000 live births under the "best" model assumptions was 10 neonatal deaths and 41 postneonatal deaths in the Aberdeen Area, 10 neonatal and 34 postneonatal deaths in Alaska, and 2 neonatal and 8 postneonatal deaths in the Navajo Area. This report points to the need to develop effective smoking cessation programs for Native Americans, targeted in particular to women of reproductive age. [Am J Prev Med 1990; 6:267–73]

From 1955 through 1985, the Native-American infant mortality rate fell 84% from 62.7 to 9.8 per 1,000 live births (1983–1985) and is now below the infant mortality rate in the general U.S. population (10.8 per 1,000 live births in 1984).[1,2] While the neonatal mortality rate among Native Americans was 34% below the U.S. average (4.6 versus 7.0 per 1,000 live births), the postneonatal mortality rate continued to be higher (5.3 versus 3.8 per 1,000 live births).[2,3] These figures obscure the large differences in Native-American neonatal, postneonatal, and infant mortality rates within geographic areas of the Indian Health Service (IHS).[4–6] For instance, the postneonatal mortality rate varied between 2.9 and 14.6 per 1,000 live births for different IHS areas.[4]

Discussions regarding the high postneonatal mortality rate among Native Americans have stressed the poor socioeconomic conditions that many Native-American families experience and the related problems of unemployment, alcoholism, and family disorganization.[4,7] The Indian Health Service has emphasized the need to focus on living conditions and on access to and use of medical care to further reduce postneonatal mortality among Native Americans.[1,8] Maternal cigarette smoking during pregnancy has been shown in other ethnic groups to be independently associated with a higher risk of postneonatal death.[9,10] This may result in part from passive inhalation of smoke after birth.

The prevalence of cigarette smoking is exceptionally high among Northern Plains Indians and Alaska Natives.[11] The purpose of this report is to

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estimate the impact of a smoking cessation program for pregnant women on infant mortality among Native Americans in two areas with a high prevalence of smoking (Aberdeen and Alaska IHS Areas) and in one low-prevalence area, the Navajo IHS Area. The Aberdeen IHS Area serves Indians, mainly Sioux, in North Dakota, South Dakota, Nebraska, and Iowa. The Navajo IHS Area is in Arizona, New Mexico, and Utah.

METHODS

Using selected results from previous studies and analytic methods described in the epidemiologic literature,[12–15] we estimated three impact measures for each IHS area. These measures reflect the expected adequacy[13] of a smoking cessation program for pregnant women in reducing the risk of neonatal and postneonatal mortality. The first measure, called the impact fraction[13,14] (or intervention impact[15]), is the proportional reduction in risk that would be expected from an intervention program designed to stop cigarette smoking during pregnancy. The second measure, called the impact risk (or preventable risk[15]), is the absolute reduction in risk that would be expected from the intervention. Suppose, for example, that the net effect of a smoking cessation program were to reduce the risk of infant mortality in the target population from 1.6% to 1.4% of all live births. The impact risk would be (1.6% − 1.4%) = 0.2%, and the impact fraction would be 0.2/1.6 = 0.125 or 12.5%. Our approach for calculating these measures in practice is to estimate the impact fraction first (to be described below); then we multiply this estimate by the preintervention risk to obtain the impact risk. The third impact measure is the number of infant deaths that we would expect to prevent (i.e., the impact number), which is estimated by multiplying the impact risk by the total number of live births in each area during a three-year period (1984–1986). The impact fraction is calculated by obtaining the product of three estimated parameters: (1) the attributable fraction in the total population of live births; (2) the success rate of the program in inducing pregnant smokers to quit; and (3) the relative efficacy of quitting on the risk of infant mortality.

Attributable Fraction

The attributable (or etiologic) fraction is the proportion of all infant deaths that is attributable to the effect of smoking during pregnancy.[12–15] The calculation of this measure was based on two other estimates: the effect (risk ratio) of smoking on infant mortality, and the prevalence of cigarette smoking among pregnant Native-American women. Risk-ratio estimates for both neonatal and postneonatal mortality were based on the results of a study of 306,000 live births among white Missouri residents between 1979 and 1983.[10,16] After adjusting for maternal age, educational level, marital status, and parity, the estimated risk ratio was 1.17 (95% confidence interval = 1.05–1.30) for neonatal mortality and 1.61 (95% confidence interval = 1.41–1.85) for postneonatal mortality.[16]

Although data are limited on smoking behavior among pregnant Native-American women, we were able to approximate this parameter from several studies,[11,17–20] including unpublished findings from a household survey of Cheyenne River Sioux Indians and a survey of pregnant women at the IHS Hospital in Rapid City. The estimated prevalence of maternal smoking during pregnancy was 50% among Native Americans in the Aberdeen and Alaska IHS Areas and 13% in the Navajo Area.

Success Rate

We estimated the success rate of the intervention program by multiplying the proportion of pregnant smokers who are expected to participate (participation rate) by the proportion of participants who are expected to quit smoking (the cessation rate). The participation rate was approximated by the proportion of pregnant women who received prenatal care during the first trimester (1981–1983).[5] Since increased availability and use of prenatal care has been a priority within the Indian Health Service in recent years,[8] we assumed that 25% of the remaining women would also be reached. Thus, we estimated that 62.3% of the pregnant women who smoke during pregnancy in the Aberdeen Area, 73.0% in the Alaska Area, and 64.6% in the Navajo Area could be enrolled in a smoking cessation program during the first four months of their pregnancies. On the basis of a randomized trial of low-cost, self-help smoking cessation methods in public-health maternity clinics,[21] we estimated the cessation rate to be 14%. Since a more costly, multicomponent smoking cessation program for pregnant women might achieve a higher cessation rate,[22,23] we also specified another value for this parameter—28%. Thus, two values for the success rate were used for each area; for example, these were 0.623(0.14) = 0.087 and 0.623(0.28) = 0.174 for the Aberdeen Area.

Relative Efficacy

Relative efficacy (called efficacy by Browner[15]) is the expected reduction in mortality risk for infants of smoking mothers who quit, divided by the risk difference for maternal smoking (i.e., the maximum possible risk reduction). Thus, 100% relative efficacy means that the postintervention risk among infants of mothers who quit smoking is equal to the risk among infants of mothers who never smoked during pregnancy. Unfortunately, there is not enough information available to specify precisely the relative efficacy of a smoking cessation program during pregnancy in reducing infant deaths attributable to maternal smoking. In the absence of this knowledge, we used two values for this parameter—60% and 90%.

RESULTS

The estimated attributable fraction due to maternal smoking was 7.8% for neonatal deaths and 23.4% for postneonatal deaths in the Aberdeen and Alaska Areas (Table 1). Overall, 16.6% of infant deaths in the Aberdeen Area and 16.2% in the Alaska Area were attributable to maternal smoking. In the Navajo Area, the attributable fraction was estimated to be 2.2% for neonatal deaths, 7.3% for postneonatal deaths, and 5.2% for total infant deaths (Table 1).

To estimate the public-health impact on Native-American infant mortality of a widespread smoking cessation program for pregnant women, we applied several estimates of success rate and relative efficacy to the above results. Under the assumptions that 14% of the smokers participating in the program would quit and that the intervention would have 60% relative efficacy in preventing infant deaths attributable to smoking, we estimated the impact fraction to be 0.9% of all infant deaths in the Aberdeen Area, 1.0% in the Alaska Area, and 0.3% in the Navajo Area (Table 2). Under the "best" set of assumed conditions (28% cessation rate and 90% relative efficacy), 2.6% of all infant deaths, 3.7% of postneonatal deaths, and 1.2% of neonatal deaths would be prevented by a smoking cessation program in the Aberdeen Area. For Alaska, the impact fractions were slightly higher because of the greater expected enrollment of pregnant women in a smoking cessation program. Among the Navajo Indians, 0.9% of all infant deaths would be prevented under the same circumstances (see Table 2).

When applied to the IHS area-specific 1984–1986 infant mortality data, the impact risk per 100,000 live births under the "best" model assumptions was 10 neonatal deaths and 41 postneonatal deaths in the Aberdeen Area, 10 neonatal and 34 postneonatal deaths in Alaska, and 2 neonatal and 8 postneonatal

Table 1. Estimated attributable fraction and attributable number due to maternal smoking for neonatal, postneonatal, and total infant mortality (1984–1986), by IHS Area

	Aberdeen IHS Area	Alaska IHS Area	Navajo IHS Area
Number of live births	7,849	8,087	16,389
Neonatal mortality			
Number of deaths	67	54	77
Neonatal mortality rate[a]	8.5	6.7	4.7
Attributable fraction	0.078	0.078	0.022
Attributable number	5	4	2
Postneonatal mortality			
Number of deaths	88	64	109
Postneonatal mortality rate[a]	11.2	7.9	6.7
Attributable fraction	0.234	0.234	0.073
Attributable number	21	15	8
Infant mortality			
Number of deaths	155	118	186
Infant mortality rate[a]	19.7	14.6	11.4
Attributable fraction	0.166	0.162	0.052
Attributable number	26	19	10

Attributable fraction = the proportion of infant deaths in the population that is attributable to smoking; attributable number = the number of infant deaths in the population that is attributable to smoking.
[a]Per 1,000 live births.

Table 2. Estimated impact of a smoking cessation program on neonatal, postneonatal, and total infant mortality (1984–1986), by IHS Area

			Neonatal deaths		Postneonatal deaths		Infant deaths		
IHS Area	Success rate	Relative efficacy	Impact fraction	Impact risk[a]	Impact fraction	Impact risk[a]	Impact fraction	Impact risk[a]	Impact number
Aberdeen	0.087	0.6	0.0041	3.5	0.0122	13.7	0.0087	17.1	1
	0.087	0.9	0.0061	5.2	0.0183	20.5	0.0130	25.6	2
	0.174	0.6	0.0081	6.9	0.0244	27.3	0.0174	34.2	3
	0.174	0.9	0.0122	10.4	0.0366	41.0	0.0260	51.3	4
Alaska	0.102	0.6	0.0048	3.2	0.0143	11.3	0.0099	14.5	1
	0.102	0.9	0.0072	4.8	0.0215	17.0	0.0149	21.8	2
	0.204	0.6	0.0096	6.4	0.0286	22.6	0.0198	28.9	2
	0.204	0.9	0.0143	9.6	0.0430	34.0	0.0298	43.5	4
Navajo	0.091	0.6	0.0012	0.6	0.0040	2.7	0.0028	3.2	1
	0.091	0.9	0.0018	0.9	0.0060	4.0	0.0043	4.9	1
	0.182	0.6	0.0024	1.1	0.0080	5.4	0.0057	6.5	1
	0.182	0.9	0.0036	1.7	0.0120	8.0	0.0085	9.7	2

Refer to the Methods section for definitions of impact fraction, impact risk, and impact number.
[a]Per 100,000 live births.

deaths in the Navajo Area (Table 2). Based on the number of Native-American live births in each area from 1984 to 1986, the "best" intervention program could have saved approximately four infant lives in the Aberdeen Area, four in the Alaska Area, and two in the Navajo Area during this three-year period. If we assume that only 14% of the smoking women would quit as a result of the intervention program, the impact number in each area would be halved (Table 2).

DISCUSSION

The conversion of epidemiologic evidence into meaningful public-health measures that reflect the expected impact of a primary prevention program has certain limitations.[13] Several key assumptions were required for estimating the impact fraction of a smoking cessation program for pregnant women on Native-American infant mortality.

First, we assumed that the effect of maternal smoking during pregnancy on neonatal and postneonatal mortality among Native Americans would be equal to the adjusted relative risks for smoking found among whites in Missouri.[16] In the absence of any published study on the effect of smoking on Native-American infant mortality, we had to rely on estimates from studies in other ethnic groups. Fortunately, these estimates appear remarkably homogeneous.[24] A higher risk of postneonatal death associated with maternal smoking during pregnancy (relative risk = 2.5) was demonstrated even among the Maori people in New Zealand.[25] Our confidence in the relative-risk estimates was further enhanced by a number of studies of the association between smoking and various adverse pregnancy outcomes in which the investigators were able to control for a wide variety of maternal characteristics.[26–31] In none of these studies was the relative risk for maternal smoking reduced appreciably by adjusting for these covariates. We used the relative-risk estimates of the study by Malloy et al.[16] in our calculations because it is by far the largest published study of the effect of maternal smoking on infant mortality. Furthermore, similar results have been reported by a number of other investigators.[24] Thus, we believe that the results of Malloy et al. provide the best available estimates of the effect of maternal smoking on infant mortality, which appear to be generalizable across ethnic groups.

Second, we assumed that the relative efficacy of the intervention in reducing infant mortality would lie between our two estimates (0.6 and 0.9). Indeed, there is some evidence to suggest that 100% intervention efficacy may not hold in practice,[32–34] but no randomized clinical trial has evaluated the impact of a smoking cessation program on subsequent infant mortality. The efficacy of smoking cessation in reducing the risk of low birthweight, on the other hand, has been fairly well established.[22,35] The estimated benefits of the program will depend critically on its ability to get women to quit smoking early in pregnancy, or even before they get pregnant, and on their determination not to resume smoking after birth.

Third, we assumed that the cessation rate among smokers participating in the intervention program would be equal to the rate in other populations, in particular, pregnant women visiting public-health maternity clinics.[21,36] There is some evidence to suggest, for example, that the beneficial effect of an intervention on smoking cessation may depend on the amount of smoking before the intervention,[37–39] level of education,[39,40] and the number of problems experienced by women early in pregnancy, such as high blood pressure and urinary-tract infection.[38] Other factors unique to Native-American women may affect the likelihood that they will quit smoking as a result of health education, but to our knowledge, this has not been studied.

Fourth, we ignored possible modification of the effect of maternal smoking on neonatal and postneonatal mortality by the timing of prenatal care, and thus the probability of enrollment in the intervention program. Almost 20% of all Native-American women in the Aberdeen and Navajo Areas and 10% in the Alaska Area did not receive prenatal care until the third trimester of pregnancy or received none at all.[5] If the effect of smoking on infant mortality would be more pronounced among these women, then the potential impact of an antismoking intervention, targeting women early in pregnancy, would be lower than calculated here. Smokers may also be less likely to seek out prenatal care than nonsmokers.[41]

Another important issue is that the effect of cigarette smoking is dose-dependent. In the Missouri study, 39% of white smoking mothers smoked one pack or more a day. Native-American smokers in the Aberdeen and Alaska Areas may smoke more than that.[11,17] Therefore, the attributable fractions may have been underestimates for these areas. Few Navajo Indians, on the other hand, smoke, and those who do smoke relatively little.[19,20] This would lead to fewer deaths attributable to smoking among the Navajos, but the intervention impact, calculated in this report, may not be exaggerated because smoking is considered unacceptable behavior by many Navajos.[42] As a result, a smoking cessation program during pregnancy may be much more successful in Navajo Indian society.

The two most common causes of infant death attributable in part to maternal smoking are respiratory disease and sudden infant death syndrome (SIDS).[16] We assumed that there will be no significant secular trends in the distribution of other risk factors that modify the effect of smoking on these causes of death. By restricting our methodologic approach to infant mortality, we most likely underestimated the full potential benefits of an antismoking intervention to the mother and infant.[43–46] Most troubling, perhaps, is the growing body of evidence suggesting that maternal smoking during pregnancy has long-term effects on children, including intellectual and emotional development.[47–49]

Few investigators have distinguished between the effects of maternal smoking during pregnancy and passive inhalation of smoke by infants after birth. Possibly, postneonatal deaths may be related more to "passive smoking" than to maternal smoking during pregnancy.[16] This issue deserves further research. Respiratory morbidity in infancy appears independently associated with both maternal smoking during pregnancy and, to a lesser extent, passive smoking in infancy.[50] Cessation of smoking by fathers and other household members may therefore decrease infant mortality and morbidity further.

During the past 20 years, the prevalence of smoking among women has declined much more slowly than among men.[51,52] Although firm conclusions must await further research, there is an urgent need for aggressive efforts to fully educate women about the risks associated with smoking.[43] The prevalence of cigarette smoking is exceptionally high among Native-American women in the northern United States, Alaska, and Canada.[11,53,54] Since many Native Americans view tobacco as a medicinal agent in addition to its social use,[55,56] it is important to evaluate smoking cessation programs to determine which methods are most successful among Native Americans. The IHS has recently launched a strong initiative to make nonsmoking the social norm by eliminating smoking in all of its health facilities.[8,11] As suggested in this report, smoking cessation methods aimed at a large proportion of pregnant Native-American women may have an impact on infant mortality, especially in areas with a high prevalence of habitual smoking. Among Northern Plains Indians and Alaska Natives, such a program can be expected to reduce infant mortality by a maximum of about 3% or equivalently, about 50 infant deaths per 100,000 live births. Considering the multifactorial nature of infant mortality, this is a substantial reduction. Postneonatal mortality will be affected most. Among Southwestern Indians, special care should be taken to counteract a surge in the popularity of tobacco. In the long run, programs aimed at Native-American children and adolescents in elementary and secondary schools may prove to be most effective by preventing the initiation of smoking.[57]

The methodology described in this paper, although fairly straightforward, has been sparsely used in the public-health arena. This is reflected in the paucity of attempts to estimate the potential impact of various risk-factor modification programs on adverse pregnancy outcomes. Similar to cost-effectiveness analysis for medical practices, the methodology described forces one to be explicit about beliefs and assumptions that underlie health planning and decision-making.[58] We therefore recommend its broader use in determining optimal preventive strategies.

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