Estimated Potential Improvement in Birth Outcomes Resulting from Reductions in Maternal Smoking and Obesity

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Introduction

The health of newborns and infants is influenced by characteristics of the mothers. Many of these maternal characteristics, such as genetics, race, and age, cannot be changed. Two factors that can be changed are maternal weight and tobacco use. The purpose of this analysis is to estimate the proportion of poor birth outcomes that could be avoided if all women who gave birth were not obese and did not smoke.

Methods

The data used in this analysis were resident live births in Florida in 2008. These births were linked to infant deaths in instances where the infant died before one year of age. The birth outcomes of interest were low birth weight (LBW) defined as birth weight below 2500 grams, preterm birth (PTB) defined as birth before 37 weeks gestation according to the clinical estimate of gestational age on the birth record, small for gestational age (SGA) defined as births in the lower 10% of birth weights for a given gestational age measured in weeks, and infant mortality (IM) defined as death before one year of age. There were 230,813 birth records in the data file before excluding 659 (0.3%) records with unknown values for outcome variables, leaving 230,154 records for the analysis.

In this analysis population attributable fractions (PAF) are used to estimate the improvement that could be made in birth outcomes if the risk factor of interest was eliminated. For example, the LBW rate for infants born to women who smoke is higher than the LBW rate for infants born to non-smokers. If all of the women who smoked had quit smoking before they became pregnant, the LBW rate for their infants could be expected to be as low as the rate for the non-smokers and there would be fewer LBW infants. The PAF is the estimated proportion of LBW infants that would be avoided if none of the mothers smoked.

In terms of the standard 2 by 2 table below:

Risk Factor	LBW	Not LBW
Smoker	a	b
Non-Smoker	c	d

There are (a+b) infants exposed to the risk factor, maternal smoking, and (c+d) infants not exposed to the risk factor. The LBW rate for persons with the risk factor is: r_s=a / (a+b) and the LBW rate for persons without the risk factor is: r_n=c / (c+d). If the (a+b) exposed infants were not exposed to the risk factor they could be expected to have the same LBW rate as the infants represented by (c+d) who are not exposed to the risk factor. This would be r_n x (a+b) which would be less than a, assuming the risk factor is associated with greater risk of disease. The difference between a and [(a+b) x r_n] is the number of LBW infants attributable to the risk factor. The formula is: AC = (r_s – r_n) x (a+b), where AC stands for attributable cases. Theoretically, there would be AC fewer disease cases if the risk factor were eliminated. To calculate the proportion of LBW infants that are attributable to the risk factor, the AC is divided by the number of persons with the disease which is (a+c). This is the PAF and the formula is: PAF = AC / (a+c).

The standard deviations for PAFs were calculated using formula (1) below developed by Walter [1]. The standard deviation of the PAFs were then used with Formula (2) to calculate the 95% confidence intervals for the PAFs.

(1) SD_{af} = squareroot {ct[ad(t-c)+bc^2] / [(a+c)^3(c+d)^3] }

Where a, b, c, and d are as defined in the 2 x 2 table above and t = a+b+c+d.

(2) PAF 95% CI = PAF $\pm$ (1.96 x SD_{af})

Where 1.96 is the Z value for 95% confidence intervals from a standard normal distribution table.

The standard 2x2 table above represents a relationship between the risk factor and the condition of interest. This relationship is often confounded by other variables that are associated with both the risk factor and the condition. In the example above, smoking is associated with increased risk of LBW. However, smokers are also more likely to have lower education levels which are also associated with increased risk of LBW. This raises the question; how much of the increased risk of LBW is associated with the smoking and how much of the increase is a result of the fact that smokers tend to be less educated than non-smokers. In this case the relationship between smoking and risk of LBW is said to be confounded by the relationship between smoking, education level and risk of LBW.

There are well developed and widely used methods to control for confounding and perhaps the most widely used methods are based on generalized linear models (glm). Logistic regression is one of the glm models. These methods yield odds ratios and risk ratios that are adjusted for confounding. Confidence intervals for the adjusted odds ratios and adjusted risk ratios are also produced using glm methods.

In this analysis glm methods were used with bootstrapping techniques to control for confounding and obtain the adjusted PAFs. Bootstrapping is a re-sampling technique and was implemented by drawing 1,000 samples of size 230,154 from the data file of 230,154 births. Since the sampling was done with replacement, each sample of 230,154 will be slightly different from the sample frame file of 230,154 records. Some records in the sample frame may be in the sample more than once and some records may not be in the sample. Logistic regression was used to compute a formula for the probability of LBW using the data in each sample. The logistic equation included terms for each of the potential confounding variables. This equation was then applied to every record in the sample after setting all smoking status variables in the sample to zero to indicate non-smoker. In effect, this changed all of the smokers in the sample to non-smokers and then computed their probability of LBW as if they were non-smokers. This is essentially the method described by Kooperberg and Petitti [2]. These probabilities were then summed to obtain the estimated LBW births that would occur in the absence of smoking. The difference between this sum and the sum of the LBW births in the sample was the estimated LBW births attributable to smoking. This was then used to compute the PAF using the formula PAF = attributable LBW births / total LBW births. This was done for each of the 1,000 samples to obtain 1,000 PAFs. These were then used to compute the standard deviation of the 1,000 PAFs which was then used with formula (2) to obtain the 95% CI for the PAF. This method was also used with the obesity risk factor and also with the combination of smoking and/or obesity. The PAF for smoking and/or obesity provides an estimate of the effect of eliminating both smoking and obesity.

Results

Table 1 shows the prevalence of smoking and obesity for the births in the analysis. 8.2% of the infants were born to mothers who were identified as smokers on the on the birth record and 19.0% of the infants were born to mothers who's body mass index (BMI) was 30 or greater, based on height and weight information on the birth record.

In Tables 2 and 3 the percentages of the four birth outcomes are given for smokers versus non-smokers (Table 2) and obese versus non-obese mothers (Table 3). Infants born to mothers who smoked have higher percentages for all four of the poor birth outcomes listed in Table 2. In Table 3, infants born to obese mothers have higher percentages for PTB and IM but lower percentages for LBW and SGA. This indicates that maternal obesity is protective for LBW and SGA.

Tables 4 and 5 show the adjusted and unadjusted risk ratios for smoking (Table 4) and obesity (Table 5) for the four birth outcomes. The covariates used in the adjusting were: maternal age, race, marital status, no prenatal care, father's name not present, smoking status, Medicaid payment source, and interactions between race and father's name not present, and race and late prenatal care initiation. For example, the adjusted risk ratio for IM associated with smoking (Table 4) is 1.39. This means that after adjusting for the covariates, infants born to women who smoke are 1.39 times as likely to die before reaching age one. Another way to say this is they are 39% more likely to die before age one. The corresponding unadjusted risk ratio is 1.53 and since this is higher than the adjusted risk ratio of 1.39, some of the increased risk reflected by the 1.53 is a result of the associations between smoking, the covariates and IM.

As shown by the 95% confidence intervals, all of the adjusted risk ratios in Table 4 are statistically significant at the alpha 0.05 level. This indicates that maternal smoking is statistically significantly associated with increased risk for all four of the poor birth outcomes. In contrast, Table 5 shows that maternal obesity is associated with increased risk for PTB and IM and decreased risk for LBW and SGA. As indicated by the 95%

confidence intervals, all of these results are also statistically significant at the alpha 0.05 level.

Tables 6 and 7 give the PAFs for smoking (Table 6) and obesity (Table 7). For example, in Table 6 the adjusted PAF for IM is 3.4%. This means an estimated 3.4% of the IM could have been avoided if none of the women who gave birth in 2008 smoked. This PAF is adjusted for: maternal age, race, marital status, no prenatal care, father's name not present, smoking status, Medicaid payment source, and interactions between race and father's name not present, and race and late prenatal care initiation.

In Table 7, the PAFs for obesity are positive for PTB and IM but negative for LBW and SGA. Since the PAFs are the proportion of outcomes that would be avoided if obesity were eliminated, the negative PAFs mean the outcomes would increase if obesity were eliminated. This is consistent with Table 5 which indicated that maternal obesity is protective for LBW and SGA.

Table 8 reflects a scenario where both maternal smoking and obesity are eliminated. The PAFs in this table show the estimated reduction in the outcomes if all women who gave birth were not obese and did not smoke. For example the adjusted AF for IM in Table 8 is 8.5%. This means IM would have been reduced by an estimated 8.5% if none of the women who gave birth in 2008 smoked or were obese.

In summary, an estimated 3.4% of infant deaths could be avoided if smoking were eliminated among women who gave birth, an estimated 5.2% of infant deaths could be avoided if all women who gave birth were not obese and an estimated 8.5% of infant deaths could be avoided if both factors were eliminated.

Discussion

The major finding of this analysis is a substantial number of infant deaths could be avoided by reducing smoking and obesity among women who give birth. In 2009 there were 1,525 infant deaths in Florida and the infant death rate was 6.9 infant deaths per 1000 births. If eliminating smoking reduced infant deaths by 3.4% (the PAF for smoking) there would have been 52 fewer infant deaths and the rate would have been 6.7. Using the PAF for obesity of 5.2%, there would have been 79 fewer infant deaths for a rate of 6.5. For smoking and obesity combined the reduction would have been 130 fewer infant deaths and a rate of 6.3. As explained in the methods section, these estimates are adjusted for the influence of the associations with several other factors.

As mentioned in the introduction the purpose of this analysis was to estimate the proportion of poor birth outcomes that could be avoided if all women who gave birth were not obese and did not smoke. It has been established that a woman's health prior to her pregnancy can greatly affect the birth outcome as well as the woman's health status after birth. Obesity and smoking are individual factors that may be influenced by a health care provider conducting preconceptual health screening and counseling at each medical encounter. It is important that healthcare providers empower women to make healthy choices and informed decisions. Florida's *1999-2008 Florida Pregnancy-Related Mortality Report: Why are Florida Mothers Continuing to Die?* reported, " Women classified as obese Class III (BMI of 40.0 or more) or considered morbidly obese had nine times the risk of pregnancy-related death than women with normal weight." [5]

There are several limitations to this analysis. One limitation is smoking is underreported on the birth records. In an analysis of birth record data compared to survey data from PRAMS projects in 24 states, Allen et al found that using both sources increased the smoking percentage from 10.4% based on birth record data alone, to 15.1% using both sources [3]. The maternal height and weight data on the birth records are also influenced by reporting bias. In a study that compared directly measured values from the Women, Infants, and Children (WIC) Program to Florida birth certificate data, Park et al found the birth record data to be 76.4% sensitive for obesity (BMI $\geq$ 30) [4]. Based on this, the birth records correctly identify an estimated 76.4% of the obese women as obese and incorrectly identify an estimated 23.6% of the obese women as not obese. Similar limitations may also apply to the other variables used in this analysis.

Another limitation is the potential that some relevant confounders were not used in the adjustments. For example, income data were not available in the data set so it could not be used in the adjustments for potential confounders. If income level does act as confounder in the relationship between smoking and LBW, for example, then part of the PAF for smoking is actually associated with income level.

In conclusion, as with any analysis, there are limitations, but based on the results of this analysis, it is evident that a substantial number of poor birth outcomes could be avoided if all women who gave birth did not smoke and achieved a BMI under 30 before they became pregnant.

Table 1

Florida Resident Births in 2008 Linked to Infant Deaths

	Births	% of Births
Smoke - yes	18953	8.2%
Smoke - no	211201	91.8%
Total	230154	100.0%
Obese (BMI 30+)	43833	19.0%
Not obese	186321	81.0%
Total	230154	100.0%
Smoke - no, not obese	171098	74.3%
Smoke - no, and obese	40103	17.4%
Smoke - yes, not obese	15223	6.6%
Smoke - yes, and obese	3730	1.6%
Total	230154	100.0%

Table 2

Florida Resident Births in 2008 Linked to Infant Deaths
Birth Outcomes by Maternal Smoking Status

Birth Outcome	Outcome Percentage for Smokers	Outcome Percentage for Non-Smokers	Outcome Percentage For All
Low birth weight	12.1%	8.4%	8.7%
Preterm birth	12.1%	10.9%	11.0%
Small for gest. age	15.8%	9.3%	9.8%
Infant death	0.87%	0.57%	0.59%

Table 3

Florida Resident Births in 2008 Linked to Infant Deaths
Birth Outcomes by Maternal Obesity Status

Birth Outcome	Outcome Percentage for Obese Mothers	Outcome Percentage for Non-Obese Mothers	Outcome Percentage For All
Low birth weight	8.3%	8.7%	8.7%
Preterm birth	12.1%	10.8%	11.0%
Small for gest. age	7.8%	10.3%	9.8%
Infant death	0.74%	0.56%	0.59%

Table 4

Florida Resident Births in 2008 Linked to Infant Deaths
Risk Ratios for Maternal Smoking by Birth Outcome

Birth Outcome	Adjusted* Risk Ratio	95% Confidence Interval Lower	95% Confidence Interval Upper	Unadjusted Risk Ratio	95% Confidence Interval Lower	95% Confidence Interval Upper
Low birth weight	1.44	1.38	1.50	1.44	1.39	1.50
Preterm birth	1.15	1.11	1.20	1.14	1.09	1.18
Small for gest. age	1.64	1.58	1.71	1.70	1.64	1.76
Infant death	1.39	1.18	1.65	1.53	1.30	1.80

***Adjusted for maternal age, race, marital status, no prenatal care, father's name not present, smoking status, Medicaid payment source, and interactions between race and father's name not present, and race and late prenatal care initiation**

Table 5

Table 5

Florida Resident Births in 2008 Linked to Infant Deaths
Risk Ratios for Maternal Obesity by Birth Outcome

Birth Outcome	Adjusted* Risk Ratio	95% Confidence Interval Lower	95% Confidence Interval Upper	Unadjusted Risk Ratio	95% Confidence Interval Lower	95% Confidence Interval Upper
Low birth weight	0.88	0.85	0.92	0.95	0.92	0.98
Preterm birth	1.08	1.04	1.11	1.12	1.09	1.15
Small for gest. age	0.69	0.66	0.71	0.76	0.73	0.79
Infant death	1.28	1.12	1.47	1.32	1.17	1.49

***Adjusted for maternal age, race, marital status, no prenatal care, father's name not present, smoking status, Medicaid payment source, and interactions between race and father's name not present, and race and late prenatal care initiation**

Table 6

Florida Resident Births in 2008 Linked to Infant Deaths
Maternal Smoking Attributable Fraction

Outcome	Adjusted* Population Attributable Fraction (PAF)	95% Confidence Interval		Un-Adjusted* Population Attributable Fraction (PAF)	95% Confidence Interval	
		Lower	Upper		Lower	Upper
Low Birth Weight	3.5%	3.0%	3.9%	3.5%	3.1%	4.0%
Preterm Birth	1.2%	0.8%	1.6%	1.1%	0.7%	1.5%
Small for Gestational Age	5.2%	4.8%	5.7%	5.4%	5.0%	5.9%
Infant Death	3.4%	1.5%	5.2%	4.2%	2.3%	6.0%

***Adjusted for maternal age, race marital status, no prenatal care, father's name not present, smoking status, Medicaid payment source, and interactions between race and father's name not present, and race and late prenatal care initiation**

Table 7

Florida Resident Births in 2008 Linked to Infant Deaths
Maternal Obesity Attributable Fraction

Outcome	Adjusted* Population Attributable Fraction (PAF)	95% Confidence Interval		Un-Adjusted* Population Attributable Fraction (PAF)	95% Confidence Interval	
		Lower	Upper		Lower	Upper
Low Birth Weight	-2.3%	-3.0%	-1.7%	-0.9%	-1.6%	-0.3%
Preterm Birth	1.5%	0.9%	2.2%	2.2%	1.6%	2.8%
Small for Gestational Age	-7.0%	-7.6%	-6.4%	-4.8%	-5.4%	-4.3%
Infant Death	5.2%	2.4%	8.1%	5.7%	3.0%	8.5%

***Adjusted for maternal age, race marital status, no prenatal care, father's name not present, smoking status, Medicaid payment source, and interactions between race and father's name not present, and race and late prenatal care initiation**

Table 8

Florida Resident Births in 2008 Linked to Infant Deaths
Maternal Obesity or Smoking Attributable Fraction

Outcome	Adjusted* Population Attributable Fraction (PAF)	95% Confidence Interval Lower	95% Confidence Interval Upper	Un-Adjusted* Population Attributable Fraction (PAF)	95% Confidence Interval Lower	95% Confidence Interval Upper
Low Birth Weight	1.2%	0.4%	2.0%	3.2%	2.4%	4.0%
Preterm Birth	2.7%	2.0%	3.4%	3.7%	3.0%	4.4%
Small for Gestational Age	-1.5%	-2.2%	-0.7%	1.1%	0.4%	1.9%
Infant Death	8.5%	5.2%	11.8%	10.6%	7.3%	14.0%

***Adjusted for maternal age, race marital status, no prenatal care, father's name not present, smoking status, Medicaid payment source, and**
interactions between race and father's name not present, and race and late prenatal care initiation

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