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Research Article

Effect of Smoking Reduction on Birth Weight: Benefits of Temporarily Quitting Smoking and Smoking Less

Abstract

Objectives: To assess the benefits of smoking cessation beyond measuring success as completely quitting smoking. To consider time-specific and dose-dependent smoking cessation as important harm reduction measures during pregnancy.

Methods: Cross-sectional study quantified the independent effects of a longitudinal-type measure of maternal smoking prior to, and during pregnancy on baby's birth weight, using Pennsylvania 2011 birth certificates data on 90,702 live singleton term births. Multivariate linear regression modeling was performed.

Results: Maternal smoking status: Among the 22% of mothers who smoked pre-pregnancy, during pregnancy 53% continued to smoke throughout, 28% completely quit, and 18% partially quit. Adjusted birth weight: Compared to babies born to non-smokers, on average, mothers who: 1) Smoked pre-pregnancy and during all trimesters had the lowest birth weight babies (166g less). 2) Didn't smoke pre-pregnancy but smoked during pregnancy had the second lowest birth weight babies (133g less). 3) Smoked pre-pregnancy but partially quit during pregnancy had the third lowest birth weight babies (66g less). 4) Smoked pre-pregnancy but completely quit during pregnancy had babies with similar birth weights. 5) Mothers who self-designated as Black race had babies weighing 148 g less. Birth weights were 5g less for every cigarette smoked/day during the last trimester.

Conclusions: This large population-based study's comprehensive analytical approach contributes to a data-driven strategy that expands the benefits of smoking cessation to include smoking reduction. These data support continual quit smoking attempts as a means of harm reduction, documented by the benefits of temporarily quitting smoking (time-specific effect) and smoking less (dose effect).

Introduction

It is well established that smoking cigarettes during pregnancy is a significant public health problem as it's a major risk predictor of infant mortality, childhood morbidity and mortality, and carries substantial medical costs related to preterm birth, intrauterine growth retardation and reduced birth weight [1-18]. According to the Centers for Disease Control and Prevention (CDC) 2011 Pregnancy Risk Assessment and Monitoring System (PRAMS) approximately 10% of women reported smoking during the last trimester, and only 55% of women who smoked three months before pregnancy, quit during pregnancy [19]. Hence, smoking cessation interventions during pregnancy is an important public health strategy. That is, smoking cessation is not only beneficial in preventing the development of tobacco-related diseases in smokers, and in non-smokers exposed to secondhand smoke, but also in babies

who are especially vulnerable to intrauterine exposure when mothers smoke during pregnancy [1].

However, studies of the effect of smoking during pregnancy on low birth weight are typically small cohort studies with insufficient power due to the small sample size, or large cross-sectional studies that lack data for important potential explanatory health risk factors [2-4,7-10,12]. Conclusions derived from such studies may have introduced bias regarding the effect of smoking on low birth weight due to inadequate control of potential cofounders such as age, pre-pregnancy weight, psychological stress and anxiety, racial/ethnic origin, and socio-economic status (e.g. income, education, insurance status) or its risk factor correlates (e.g., height, caloric intake, and sexually transmitted diseases) [6]. When considering the effectiveness of smoking cessation, in addition to completely quitting smoking without relapse, temporarily quitting or

smoking less are additional important indicators of harm reduction [1], especially for pregnant women [20,21]. The effect of maternal smoking during pregnancy on babies' health outcomes should not be limited to ever smoking because associations related to the timing of smoking would be missed [22].

It is also noteworthy, that earlier population-based studies of the association between smoking and birth weight using 1989 U.S. standard of certificate of live births had considerable limitations [5,23-26]. The 2003 revised U.S. birth certificate added many pertinent items to better address the gap in knowledge regarding the consequences of smoking (timing and amount) independent of other health risk factors. The following are relevant data when performing a systematic comprehensive evaluation of the effect of smoking: mother's pre-pregnancy body mass index (BMI), tobacco use three months prior to pregnancy, and during three trimesters of pregnancy, receipt of food from the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) during pregnancy, source of payment for the delivery, maternal morbidities and others [27].

The objective of our study was to facilitate the incorporation of science into public health practice and policy to positively affect the health and well-being of pregnant women and their babies by assessing the benefits of smoking cessation beyond only measuring success as completely quitting smoking. This important harm reduction approach assessed temporarily quitting (time-specific effect) and smoking less (dose-dependent effect). Our study quantified the simultaneous effect of multiple factors on baby's birth weight, with a focus on the longitudinal-type main exposure of maternal smoking prior to, and during pregnancy. We evaluated the independent association between smoking status (i.e., pre-pregnancy and during pregnancy) and birth weight for all Pennsylvania residents' live term singleton births. We hypothesized that a reduction in maternal smoking, in the amount of cigarettes smoked and/or the timing of temporarily quitting smoking can be beneficial for the baby's health.

Methods

Study population

This cross-sectional study assessed Pennsylvania 2011 birth certificate data for all 90,702 live singleton term births born to resident mothers with the following information: birth weight, smoking status, mother's age, mother's height, mother's pre-pregnancy weight and weight at birth, mother's race and ethnicity, mother's education level, child's gender, estimated gestational age, and mother's pre-pregnancy and gestational diabetes and hypertension status, mother's WIC assistant information and number of prenatal visit.

Description of outcome (dependent variable)

Birth weight was based on the baby's weight measured in grams and recorded on the birth certificates.

Description of main exposure (independent variable)

The longitudinal-type dose of smoking was defined as the number of cigarettes smoked/day at 3 months before pregnancy, and during the 1st trimester, 2nd trimester, and 3rd trimester of pregnancy. Smoking information from the birth certificate was also used to define the longitudinal-type timing of smoking as follows:

Never smoker: Pre-pregnancy non-smoker (mother did not smoke 3 months before pregnancy) and never smoked in the 1st, 2nd, and 3rd trimester of pregnancy.

Did not smoke pre-pregnancy but smoked during pregnancy: Mother did not smoke 3 months before pregnancy but smoked in 1st, 2nd, and/or 3rd trimester of pregnancy.

Smoked pre-pregnancy and during pregnancy: Mother smoked 3 months before pregnancy and smoked during the 1st, 2nd, and 3rd trimester of pregnancy.

Smoked pre-pregnancy but partially quit during pregnancy: Mother smoked 3 months before pregnancy but did not smoke in one or two periods during 1st, 2nd, or 3rd trimester.

Smoked pre-pregnancy but completely quit during pregnancy: Mother smoked 3 months before pregnancy but did not smoke anytime during pregnancy.

Description of other explanatory factors (independent variables)

See Table 1 for description of 17 other explanatory variables. The only factor that is not clearly delineated in Table 1 is the infection present or treated during pregnancy which is defined as the mother having or being treated for any of the following diseases: gonorrhea, syphilis, herpes simplex virus, chlamydia, hepatitis B or hepatitis C infection during pregnancy (Yes/No).

Statistical analyses

Descriptive analysis – Number, percent, and average birth weight by timing of smoking, baby's gender, mother's age group, mother's marital status, mother's education level, mother's race, mother's ethnicity, primary payor, diabetes pre-pregnancy and during pregnancy, hypertension pre-pregnancy and during pregnancy, infection present/treated during pregnancy, previous pre-term birth, parity (nulliparous), and mother received WIC food assistance were calculated. The dose of smoking was calculated as the average number of cigarettes smoked/day during the 3rd trimester, along with the average length of pregnancy, average number of prenatal care visits and average mother's weight gain during pregnancy.

Multivariate linear regression model – Birth weight was modeled as the dependent variable or outcome measure. The independent variables included in the model building steps are delineated as categorical or continuous variables as depicted in Table 1. The statistical package SAS version 9.3 (SAS Institute, Cary, NC) was used for the analysis. SAS stepwise variable selection determined the significant variables that remained in the model. A p-value of <0.05 was considered statistically significant.



Table 1: Descriptive summary of maternal and baby characteristics and birth weight: Pennsylvanian 2011 term births Average Birth Weight by Maternal and Baby Characteristics

Timing of smoking	Smoked pre-pregnancy (22%)	Smoked during all of pregnancy	10,441 (53.4%)	3,192	<.0001
		Partially quit during pregnancy	3,607 (18.4%)	3,362	
		Completely quit during pregnancy	5,511 (28.2%)	3,458	
	Pre-pregnancy non-smoker (78%)	Non-smoker during pregnancy	70,979 (99.8%)	3,445	
		Smoked during pregnancy	164 (0.2%)	3,256	
Baby's gender	Girl		44,491 (49.1%)	3,345	<.0001
	Boy		46,211 (50.9%)	3,479	
Maternal age at delivery (years)	<18		1,740 (1.9%)	3,276	<.0001
	18-34		75,942 (83.7%)	3,407	
	35-40		11,562 (12.7%)	3,471	
	≥41		1,458 (1.6%)	3,428	
Maternal pre-pregnancy BMI category	Obese (BMI ≥30)		19,923 (22.0%)	3,485	<.0001
	Overweight (BMI between 25 and 29.9).		21,270 (23.5%)	3,456	
	Underweight (BMI <18.5)		3,569 (3.9%)	3,192	
	Normal (BMI between 18.5 and 24.9)		45,940 (50.6%)	3,378	
Marital status at delivery	Not married		34,117 (37.6%)	3,320	<.0001
	Married		56,585 (62.4%)	3,469	
Mother's education level	Some college or higher		57,525 (63.4%)	3,449	<.0001
	High school graduate/GED		22,093 (24.4%)	3,357	
	Less than high school graduate		11,084 (12.2%)	3,338	
Mother's self-designated race	American Indian or Alaska Native		141 (0.2%)	3,405	<.0001
	Asian/Pacific Islander		3,458 (3.8%)	3,284	
	Black		12,771 (14.1%)	3,260	
	White		74,332 (81.9%)	3,445	
Mother's ethnicity	Non-Hispanic		88,131 (97.2%)	3,414	<.0001
	Hispanic		2,571 (2.8%)	3,361	
Primary payor for delivery	Medicaid		25,903 (28.6%)	3,314	<.0001
	Other/Unknown		3,763 (4.1%)	3,363	
	Self-pay		4,289 (4.7%)	3,517	
	Private insurance		56,747 (62.6%)	3,453	
Diabetes (pre- or during pregnancy)	No		85,826 (94.6%)	3,409	<.0001
	Yes		4,876 (5.4%)	3,488	
Hypertension (pre- or during pregnancy)	No		85,724 (94.5%)	3,417	<.0001
	Yes		4,978 (5.5%)	3,337	
Previous pre-term birth	No		88,122 (97.2%)	3,417	<.0001
	Yes		2,580 (2.8%)	3,273	
Parity (nulliparous)	No		52,827 (58.2%)	3,446	<.0001
	Yes		37,875 (41.8%)	3,366	
Infection during pregnancy	No		86,419 (95.3%)	3,417	<.0001
	Yes		4,283 (4.7%)	3,327	
Mother on WIC during pregnancy	No		58,249 (64.2%)	3,454	<.0001
	Yes		32,453 (35.8%)	3,339	

Average Values for Maternal Characteristics

Number of cigarettes smoked/day during pre-pregnancy	19,559 (21.5%)	15.2
Number of cigarettes smoked/day during 1 st trimester	13,791 (15.2%)	11.2
Number of cigarettes smoked/day during 2 nd trimester	11,514 (12.3%)	9.2
Number of cigarettes smoked/day during 3 rd trimester	10,982 (12.1%)	8.3
Length of pregnancy (obstetric estimate of gestation in weeks)	90,702 (100%)	39.1
Number of prenatal care visits	90,702 (100%)	10.7
Mother's weight gain during pregnancy (pounds)	90,702 (100%)	32.0

Abbreviations: BMI, body mass index; WIC, federal special supplemental nutrition program for women, infant and children; GED, general educational development.

Results

Descriptive summary

The overall average birth weight was 3,413g for all 90,702 babies. Prior to pregnancy, most mothers were non-smokers (78%). As depicted in Table 1, among the mothers who smoked prior to their pregnancy, 53% continued to smoke throughout pregnancy, 28% completely quit smoking during pregnancy, and 18% partially quit smoking during pregnancy. A very small proportion of mothers (0.2%) did not smoke before pregnancy but smoked in at least one trimester. The average birth weight for babies born to mothers who were continual non-smokers was 3,445g, while babies born to mothers who smoked before and throughout their pregnancy had the lowest birth weight (3,192g), which is a 7.3% reduction. Nearly 22% of mothers smoked 3 months pre-pregnancy and the average number of cigarettes smoked/day was 15.2. About 15% of mothers smoked in the 1st trimester and the average number of cigarettes smoked/day was 11.2. More than 12% of mothers smoked in the 2nd trimester and the average number of cigarettes smoked/day was 9.2. About 12% of mothers smoked in the 3rd trimester and the average number of cigarettes smoked/day was about 8.3.

Multivariate linear model

Next, as depicted in Table 2, we report the adjusted birth weight which simultaneously takes into account all the factors in model. Infection present/treated during pregnancy, maternal age, mother received WIC food assistance, number of cigarettes smoked pre-pregnancy, number of cigarettes smoked during 1st and 2nd trimester were not statistically significant so these variables did not remain in the final model.

Mothers who were non-smokers were the reference group used for comparison. Mothers who smoked pre-pregnancy and during all trimesters had the lowest adjusted birth weight babies (166g less). Mothers who didn't smoke pre-pregnancy but smoked during pregnancy had the second lowest birth weight babies (133g less). Mothers who smoked pre-pregnancy but partially quit smoking during one or two trimesters had the third lowest birth weight babies (66g less). Adjusted birth weights were not statistically different for babies born to mothers who were non-smokers or smoked pre-pregnancy but completely quit during pregnancy (only 7g less). Each cigarette that mothers smoked/day during the 3rd trimester was associated with an additional 5g reduction in birth weight. Whereas, mothers smoked on average 8.3 cigarettes/day during the last trimester, this translates to an additional 42g reduction in birth weight. So, on average the baby would be 166g plus 42g for a total 208g heavier if the mother smoked pre-pregnancy and completely quit during pregnancy. This depicts the independent effects of complete smoking cessation for mothers who smoked prior to pregnancy, instead of the average 208g smaller baby if the mother smoked prior to and continued to smoke during all of pregnancy, the baby was only 7g smaller if the mother completely quit during pregnancy.

On average the adjusted birth weight for baby girls was 130g less than that for baby boys. Mothers who were obese prior

to pregnancy had babies that were 189g heavier than mothers with normal BMI, while being overweight was associated with 88g heavier babies, and being underweight was associated with 111g smaller babies. Babies born to unmarried mothers were 30g lighter than babies born to married mothers. Mothers with at least some college had 24g heavier babies than mothers who had not finished high school. Babies born to Black and Asian/Pacific Islander mothers were 148g and 126g less, respectively, than babies born to white mothers. Babies born to Non-Hispanic mothers were 39g heavier than babies born to Hispanic mothers. Babies born to mothers with Medicaid insurance as principal source of payment for the delivery were 93g less than those babies born to mothers who self-paid as the principal source of payment for their delivery.

Babies born to mothers with diabetes or gestational diabetes were 107g heavier than babies born to mothers without diabetes or gestational diabetes. Babies born to mothers with hypertension or gestational hypertension were 55g less than babies born to mothers without hypertension.

Each week that gestational age increased beyond 37 weeks is associated with 142g increase in adjusted birth weight. For each pound weight gain during pregnancy the birth weight increased 6g. With an average 32 pound weight gain during pregnancy (see Table 1), this translates to 192g increase in birth weight. Interestingly, each additional prenatal care visit was independently associated with a 3g increase in birth weight. Previous preterm birth was associated with 77g less in birth weight and nulliparous was associated with 137g less in birth weight, after simultaneously taking into account all these factors.

Discussion

This large population-based study provides strong evidence confirming the detrimental effects of smoking during pregnancy on birth weight, and indicates that partially quitting reduces the harm caused by smoking. Specifically, we report on the dose-dependent effect (e.g., reduction in the number of cigarettes smoked/day) and time-specific effect (quitting smoking prior to the 3rd trimester). After simultaneously taking into account baby's gender, pre-pregnancy BMI, marital status, mother's weight gain during pregnancy, race/ethnicity, social-economic status, health risk factors including infection during pregnancy, diabetes, hypertension and other explanatory factors, babies born to mothers who smoked pre-pregnancy but completely quit during pregnancy were only 7g lighter than babies born to mothers who were non-smokers (not statistically significant nor clinically significant).

Our results strongly support the benefits of smoking cessation for women of child-bearing age who might become pregnant, because when they do not smoke during pregnancy they could have healthy birth weight babies, similar to women who were non-smokers [28–30]. However, due to the addictive nature of smoking, comprehensive smoking cessation programs incorporate a wide-range of strategies [1], including psychosocial motivational behavioral counselling [29], and pharmacological interventions [31]. Tobacco control strategies



Table 2: Multivariate model of association between maternal characteristics and birth weight

Variable		Coefficient	p-value	
Timing of smoking	Smoked pre-pregnancy	Smoked during all of pregnancy	-166	<.0001
		Partially quit during pregnancy	-66	<.0001
		Completely quit during pregnancy	-7	0.2293
	Pre-pregnancy non-smoker	Non-smoker during pregnancy	0	-
		Smoked during pregnancy	-133	<.0001
Baby's gender	Girl	-130	<.0001	
	Boy	0	-	
Maternal pre-pregnancy BMI category	Obese (BMI ≥30)	189	<.0001	
	Overweight (BMI between 25 and 29.9)	88	<.0001	
	Underweight (BMI <18.5)	-111	<.0001	
	Normal (BMI between 18.5 and 24.9)	0	-	
Marital status at delivery	Not married	-30	<.0001	
	Married	0	-	
Mother's education level	Some college or higher	24	<.0001	
	High school graduate/GED	2	0.6469	
	Less than high school graduate	0	-	
Mother's self-designated race	American Indian or Alaska Native	-3	0.9250	
	Asian/Pacific Islander	-126	<.0001	
	Black	-148	<.0001	
	White	0	-	
Mother's ethnicity	Non-Hispanic	39	<.0001	
	Hispanic	0	-	
Primary payor for delivery	Medicaid	-30	<.0001	
	Other/Unknown	-18	0.0087	
	Self-pay	63	<.0001	
	Private insurance	0	-	
Diabetes (Pre- or during Pregnancy)	No	0	-	
	Yes	107	<.0001	
Hypertension (Pre- or during Pregnancy)	No	0	-	
	Yes	-55	<.0001	
Previous pre-term birth	No	77	<.0001	
	Yes	0	-	
Parity (nulliparous)	No	137	<.0001	
	Yes	0	-	
For each cigarette smoked/day during 3 rd trimester		-5	<.0001	
Length of pregnancy (weeks)		142	<.0001	
Number of prenatal care visits		3	<.0001	
Mother's weight gain during pregnancy (pound)		6	<.0001	

Abbreviations: BMI, body mass index; GED, general educational development.

generally focus on complete smoking cessation and relapse prevention. Using this measure, we found 28% of mothers who smoked prior to their pregnancy completely quit during their pregnancy. Additionally, we found 18% of mothers who smoked pre-pregnancy partially quit smoking during their pregnancy, improving their babies' birth weight. These data support the positive effect of smoking reduction programs that promote continual quit smoking attempts as a means of harm reduction.

The interesting finding, regarding the public health importance of smoking cessation programs, is that these data support the benefit of partially quitting smoking, as a means of harm reduction. That is, if completely quitting smoking during

pregnancy is deemed to be too difficult [32], but the mother quit smoking during the 3rd trimester, the adjusted average birth weight was only 66g less than for babies born to mothers who were non-smokers. This is an increase of 100g birth weight than if they continued to smoke throughout the pregnancy. In addition, each cigarette smoked/day during the 3rd trimester is associated with 5g additional lower birth weight. Hence, these data indicate how important it is for mothers who cannot quit smoking completely during pregnancy, to at least quit in the last trimester, so as not to have the worst birth weight outcomes.

Furthermore, the effect of mothers' smoking status on

their babies birth weight is evident in the finding that not smoking pre-pregnancy but smoking during pregnancy was almost as unhealthy for their baby, as measured by the health outcome of birth weight (133g less), as always smoking (166g less). On average, mothers who always smoked had babies that weighed 208g less (166g less related to the time-specific effect of always smoking + 42g less related to the dose-dependent effect of smoking 8.3 cigarettes/day x 5g less/cigarette) than babies born to mothers who were non-smokers.

After simultaneously taking into account 16 statistically significant factors, the harmful effect of smoking on birth weight is documented by means of a more precise quantitative measurement that is especially relevant when educating women smokers. Although quitting smoking completely during pregnancy yields the greatest benefit on birth weight, our study provides evidence that quitting smoking at any time point can be beneficial, especially during the last trimester. This is a strong indication that continual quit smoking attempts that reduce the number of cigarettes smoked (dose-dependent) and/or the timing (time-specific) of smoking should be considered as a means of harm reduction.

This study has several limitations. First, the smoking information was self-reported, and it is well established that people under-report their smoking history. For example, one study reported overall 8% of smokers denied smoking, but up to 68% of certain age, race/ethnicity, gender smokers denied smoking [33]. On the other hand, self-reported birth certificate prenatal smoking status and number of cigarettes smoked/day have recently been validated via cotinine [34], supporting our use of these data. In addition, this misclassification bias due to under-reporting of smoking status will underestimate the true effect of cigarette smoking on birth weight. Secondly, exposure to second-hand smoke in the household is not collected on birth certificates, thus, while the mother may not smoke or quit, she may be exposed to second-hand smoke when others in the household smoke [7]. Furthermore, even though we addressed most of the factors raised in World Health Organization's methodological assessment and meta-analysis report on determinants of low birth weight [6], there are other factors, such as, stress, illicit drugs use and alcohol consumption that could not be evaluated using birth certificate. Some of the effect of smoking on birth weight may be exemplified by concurrent use of alcohol and/or illicit drugs [26]. The small number of mothers who did not smoke pre-pregnancy and smoked during pregnancy could be explained by stress and other factors.

We believe the strengths of our study design far outweigh the aforementioned limitations. First of all, due to the complexities related to differentiating between low birth weight and small for gestational age [35], our study is restricted to term births. In addition, using data collected via the 2003 revised birth certificate form we were able to address several limitations of previous studies of the association between birth weight and smoking by simultaneously taking into account some of the risk factors for low birth weight that were not collected in previous birth certificate format. Thus, the harm-reduction

findings of this large population-based study are generalizable to all pregnant smokers. More specifically, the results reported herein regarding the effect of diabetes, hypertension, race, maternal education level, newborn gender, and prenatal care were consistent with other studies [5,7,24-26]. In addition, our findings are consistent with a recent report that two-thirds of the total adverse smoking impact on birth weight occurs in the second trimester and beyond, and decreasing the amount of cigarettes smoked improves birth weight [36]. The incorporation of the scientific evidence presented herein into the evaluation component of smoking cessation public health programs to expand our knowledge of the benefits of smoking reduction via temporarily quitting smoking and smoking less, to expand health education and health promotion practices and policies.

Conclusions

As smoking during pregnancy is clearly associated with lower birth weight, effective smoking cessation programs could significantly improve birth weight outcomes. However, it is not a simple matter to overcome the challenges to quit smoking, due to the addictive and withdrawal properties of nicotine. Mothers who smoke pre-pregnancy should quit. Continual quit smoking attempts should be considered to be a means of harm reduction, documented by the benefits of temporarily quitting smoking (time-specific effect) and smoking less (dose effect), related to improved birth weight.

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