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RESEARCH ARTICLE

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Does it matter when I quit? Could I just cut down some? Links between trimester-specific smoking amount, preterm birth, and low birth weight

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Abstract

Background: Substantial evidence demonstrates the harms of pregnancy smoking. Due to the need for very large data sets, less data exist to inform decisions about when quitting should occur, or whether a certain amount of reduction is beneficial.

Objectives: Our goal was to examine the effect of timing and amount of pregnancy smoking on low birth weight (LBW) and preterm birth (PTB).

Methods: Data for 3 years of registered births in Tennessee were available and included standard birth certificate information.

Results: Of 241,616 women, 15.7% smoked at conception, and those who quit as early as the first trimester had significantly increased adjusted odds of LBW (27%) and PTB (14%) compared to nonsmokers, with this effect largely driven by smoking 10+ cigarettes per day. Smoking into the second trimester but quitting prior to the third also predicted increases in LBW and PTB compared to both not smoking at all and smoking only in the first trimester. Smoking to delivery predicted a 2.8-fold increased likelihood of LBW, and a 2.1-fold increased rate of PTB. Any level of smoking after the first trimester substantially increased the odds of poor outcomes compared to both nonsmoking and smoking only in the first trimester.

Conclusions: Findings suggest that to avoid LBW or PTB, pregnant smokers should be advised that quitting completely by the end of the first trimester is important, and that continuing to smoke even <5 cigarettes per day after that point substantially increases the potential for of adverse outcomes.

KEYWORDS

birth weight, pregnancy smoking, preterm birth

1 | BACKGROUND

The leading cause of preventable disease and death in the United States is cigarette smoking (Centers for Disease Control and Prevention [CDC], 2017). Smoking cigarettes is harmful to the human body, including during pregnancy. Although significant evidence exists concerning the dangers of smoking, in 2016 7.2% of pregnant women reported cigarette use during pregnancy (Drake, Driscoll, & Mathews, 2018). Smoking tobacco cigarettes during pregnancy can increase risk for poor pregnancy and birth outcomes, including intrauterine growth

restriction, low birth weight (LBW), and preterm birth (PTB) (Bernstein et al., 2005; Blatt, Moore, Chen, Van Hook, & DeFranco, 2015; Mccowan et al., 2009).

It would be most advantageous for pregnant women to never smoke cigarettes, or cease cigarette smoking upon being aware of their pregnancy. However, even with established interventions, it can be extremely difficult for routine smokers to quit or reduce their amount of smoking (Hajek et al., 2001). Understanding the potential role of the amount and timing of prenatal cigarette exposure could be informative for developing more effective prevention resources, intervention programs, and clinical healthcare decisions. Therefore, it is important to investigate smoking cessation and reduction patterns during different trimesters of pregnancy and how they may impact the occurrence of adverse birth outcomes.

Smoking further into pregnancy increases risk for PTB and LBW, with studies demonstrating greater risk the longer smoking continues (Moore, Blatt, Chen, Van Hook, & De Franco, 2016; Xaverius, O'Reily, Li, Flick, & Arnold, 2019; Yan & Groothuis, 2015). However, evidence is mixed regarding the point in pregnancy at which cessation no longer negates the risk of poor birth outcomes. For example, several studies have suggested that by quitting by the end of the first trimester, there is no significantly increased risk for LBW (Yan & Groothuis, 2015), PTB (Moore et al., 2016), or fetal growth restriction (Blatt et al., 2015). However, a recent population based study showed that even smoking only in the first trimester significantly increased the risk of LBW by 26% (Xaverius et al., 2019). Additionally, inconsistencies in findings across studies exist when examining dose–response effects on these birth outcomes, which may have impacted the inconsistent findings related to timing of exposure. For example, a recent study suggested that pregnant women who struggled to quit smoking and continued throughout their pregnancy still avoided significantly increased risk of LBW, as long as they reduced to fewer than 6 cigarettes per day (Kataoka et al., 2018). However, another study found that increased risk for PTB is evident for pregnant women who smoked as few as 1–9 cigarettes per day and quit smoking by the end of the first trimester (Soneji & Beltrán-Sánchez, 2019). Clearly, additional large sample research that considers both amount and timing of exposure, is needed.

According to the CDC, Tennessee ranks fifth in cigarette smoking prevalence in the United States at 20.7%, with rates in pregnancy exceeding 25% in many areas of the state (Bailey & Jones Cole, 2009; CDC, 2018). Therefore, utilizing statewide data from Tennessee provides a large sample that will provide enough statistical power for detailed examination of specific amounts and patterns of smoking during pregnancy, and how they might differentially predict birth outcomes. The current study had two major objectives. First, we sought to examine whether quitting smoking at various points in pregnancy differentially reduced the odds of experiencing LBW and PTB. The second objective was to examine how the number of cigarettes smoked per day, along with cigarette timing exposure, might additionally influence the likelihood of experiencing LBW and PTB.

2 | METHODS

2.1 | Participants

Potential study participants were all women who had a registered birth in Tennessee during a 3-year period from 2012 to 2014. The final sample included 241,616 singleton births with complete birth certificate data, which represented more than 99% of singleton deliveries in Tennessee during that time. As is often done in studies of this type, twins and higher order multiples were necessarily excluded due to potential differences in both birth weight and gestational age at delivery irrespective of study factors.

2.2 | Procedures

For this retrospective, population-based study, a de-identified birth certificate data file was obtained from the State of Tennessee Department of Health. Data had been entered and validated according to standard procedures established by the U.S. CDC. Data were imported into and analyzed using IBM SPSS version 24.0. Procedures for the current investigation were approved by the Tennessee Department of Health Institutional Review Board (IRB), and the Medical IRB at the university where the requesting investigator had a faculty appointment.

2.3 | Variables

All variables were constructed from standard Tennessee Birth Certificate fields. The primary predictors, pregnancy smoking timing and amount, were developed from maternal reported information of amount of smoking, in average number of cigarettes per day, in each trimester and at delivery. The smoking timing variable had four levels: no smoking at any point in pregnancy, smoking during the first trimester only, smoking into the second trimester but no smoking after 28 weeks, and smoking through to delivery (for 99% of births this meant smoking occurred in the third trimester, but for the small number

of births that occurred in the second trimester, if smoking was still occurring at delivery they were classified as smoking through to delivery rather than just smoking through the second trimester). Smoking amount was represented by three separate variables: number of cigarettes smoked per day in the first trimester, number of cigarettes smoked per day in the second trimester, and number of cigarettes smoked per day in the third trimester or at delivery. These amount variables were analyzed as categorical: 0 cigarettes, at least 1 per week but less than 5 per day, 5–9 cigarettes per day, and 10 or more cigarettes per day. For women whose reported smoking amount varied across trimesters (less than 10% of our sample), number of cigarettes was averaged across trimesters for final amount classification purposes.

The primary outcomes, LBW and PTB, were constructed from the birth certificate fields for birth weight and gestational age at delivery. Newborns were considered LBW if they weighed less than 2,500 g at delivery and preterm if they were born prior to 37 weeks gestation (whether spontaneously or as a result of a medically indicated induction). Additional background information was collected from the birth certificates for purposes of sample description and control for confounding. Variables included maternal age (in years), race/ethnicity, and education (represented as an 8-group variable, with 1 indicating less than eighth grade to 8 representing a graduate or professional degree). Also available were whether or not the mother qualified for federal Women, Infants, and Children Nutrition Program (WIC) benefits and number of prenatal care visits completed. Finally, infant sex was also abstracted.

2.4 | Data analysis

Smokers and nonsmokers were compared on background factors via *t* tests and chi-square analysis. Based on prior research that has identified significant confounders and covariates in the relationship between pregnancy smoking and birth outcomes, all variables listed in Table 1 were considered as potential control variables in subsequent analyses. The relationships between timing and amount of smoking as predictors, and presence or absence of LBW and PTB as outcomes, were analyzed utilizing logistic regression analysis. Significant control variables were entered stepwise, followed by entry of timing and amount variables on the final step. Odds ratios from these analyses compared the odds of LBW and PTB for specific timing and amount of smoking exposure groups against nonsmokers. Follow-up analyses compared women who continued to smoke beyond the first trimester with women who entered pregnancy smoking any amount but quit by the end of the first trimester.

3 | RESULTS

3.1 | Participant demographics

The final sample included 241,616 births during the study period. Differences between nonsmokers ($N = 203{,}641$) and smokers ($N = 37{,}975$) are shown in Table 1. Nonsmokers and smokers differed on seven key background factors, with women who reported smoking during pregnancy significantly younger, more likely to be White, less likely to be married, have lower education, be receiving WIC benefits, having had fewer prenatal visits, and more likely to have had a male child than women who reported not smoking.

3.2 | Low birth weight

Overall, 21,708 (9.0%) of the births were LBW. Smoking later into pregnancy consistently increased the odds of experiencing LBW when compared to no smoking.

TABLE 1 Background differences by pregnancy smoking status

	Nonsmoker ($n = 203{,}641$)	Smoker ($n = 37{,}975$)	t/χ^2	*p*-Value
Maternal age (years)	27.3 (5.8)	25.5 (5.2)	59.0	<.001
Maternal race (% White)	64.4%	86.0%	6,762.9	<.001
Maternal marital status (% married)	60.2%	33.1%	9,523.4	<.001
Maternal education[a]	4.2 (1.7)	3.2 (1.0)	167.4	<.001
Receiving WIC benefits (%)[b]	44.1%	69.2%	8,077.9	<.001
Number of prenatal visits	11.1 (4.0)	10.5 (4.5)	26.9	<.001
Child gender (% male)	51.1%	51.7%	4.1	.042

[a]An 8-point scale ranging from 1 = eighth grade or less to 8 = graduate or professional degree;
[b]federal Women, Infants, and Children Nutrition (WIC) program

Logistic regression analyses revealed that after controlling for confounders and covariates, pregnant women who quit smoking by the end of their first trimester were 27% more likely than nonsmokers to experience LBW. Additionally, pregnant women who did not quit smoking until the end of their second trimester more than doubled their likelihood of experiencing LBW compared to nonsmokers. Finally, expectant mothers who smoked through to delivery had a 179% increased rate of LBW compared to nonsmokers (see Table 2).

Further analyses were conducted to examine the potential additional role of amount of smoking exposure on trimester-specific exposure findings. Pregnant women who smoked fewer than 10 cigarettes per day and quit smoking by the end of their first trimester did not differ in their likelihood of experiencing LBW compared to nonsmokers after controlling for significant confounders. However, pregnant women who smoked 10 or more cigarettes per day, even if they quit smoking by the end of their first trimester, had a 33% increased

TABLE 2 Increased risk of low birth weight and preterm birth associated with amount and timing of pregnancy smoking in specific trimesters compared to nonsmokers

	Adjusted[a] odds (95% CI) of low birth weight	Adjusted[a] odds (95% CI) of preterm birth
Smoking any amount		
Began pregnancy smoking, smoked during the first trimester only	1.27 (1.15, 1.41)	1.14 (1.03, 1.25)
Began pregnancy smoking, smoked in the second trimester, quit by 28 weeks	2.20 (1.97, 2.45)	1.68 (1.51, 1.87)
Began pregnancy smoking, smoked through delivery	2.79 (2.72, 2.87)	2.12 (2.08, 2.17)
Specific smoking amounts		
Smoking <5 cigarettes/day, quit by end of first trimester	1.15 (.96, 1.39)	1.04 (.88, 1.23)
Smoking 5–9 cigarettes/day, quit by end of first trimester	1.10 (.87, 1.38)	1.02 (.82, 1.25)
Smoking 10 + cigarettes/day, quit by end of first trimester	1.33 (1.09, 1.62)	1.22 (1.03, 1.47)
Smoking <5 cigarettes/day, quit by end of second trimester	1.80 (1.49, 2.18)	1.43 (1.19, 1.72)
Smoking 5–9 cigarettes/day, quit by end of second trimester	2.27 (1.84, 2.81)	1.90 (1.56, 2.32)
Smoking 10 + cigarettes/day, quit by end of second trimester	2.76 (2.25, 3.37)	1.99 (1.63, 2.43)
Smoking <5 cigarettes/day, smoked through delivery	2.68 (2.55, 2.82)	2.17 (2.08, 2.27)
Smoking 5–9 cigarettes/day, smoked through delivery	2.73 (2.60, 2.87)	2.13 (2.03, 2.21)
Smoking 10 + cigarettes/day, smoked through delivery	2.87 (2.75, 2.99)	2.11 (2.04, 2.18)

Abbreviation: CI, confidence interval.

[a]Adjusted for maternal age, education, marital status, and race, receipt of WIC benefits, number of prenatal visits, and infant gender.

TABLE 3 Increased risk of low birth weight and preterm birth associated with amount and timing of pregnancy smoking in specific trimesters compared to women who began pregnancy smoking but quit by the end of the first trimester

	Adjusted[a] odds (95% CI) of low birth weight	Adjusted[a] odds (95% CI) of preterm birth
Smoking any amount		
Began pregnancy smoking, quit by end of second trimester	1.71 (1.48, 1.98)	1.47 (1.28, 1.69)
Began pregnancy smoking, smoked through delivery	1.83 (1.70, 1.98)	1.46 (1.37, 1.57)
Specific smoking amounts		
Smoking <5 cigarettes/day, quit by end of second trimester	1.52 (1.22, 1.89)	1.31 (1.05, 1.62)
Smoking 5–9 cigarettes/day, quit by end of second trimester	1.87 (1.47, 2.37)	1.72 (1.38, 2.17)
Smoking 10 + cigarettes/day, quit by end of second trimester	2.22 (1.76, 2.81)	1.82 (1.44, 2.27)
Smoking <5 cigarettes/day, smoked through delivery	1.88 (1.70, 2.09)	1.55 (1.42, 1.70)
Smoking 5–9 cigarettes/day, smoked through delivery	1.88 (1.70, 2.09)	1.51 (1.38, 1.65)
Smoking 10 + cigarettes/day, smoked through delivery	1.95 (1.77, 2.16)	1.49 (1.37, 1.82)

Abbreviation: CI, confidence interval.

[a]Adjusted for maternal age, education, marital status, and race, receipt of WIC benefits, number of prenatal visits, and infant gender.

likelihood of experiencing LBW compared to nonsmokers. After the first trimester, any smoking regardless of the amount increased the odds of experiencing LBW compared to nonsmokers, with those smoking even fewer than 5 cigarettes per day into the second trimester experiencing an 80% increased likelihood of LBW. Those who smoked 10 or more cigarettes per day through to delivery had nearly a threefold increase in LBW rates (see Table 2).

The final set of analyses compared women who continued to smoke with women who smoked any amount early in pregnancy but quit by the end of the first trimester. The pattern of results was similar to comparisons with nonsmokers. Compared to those who quit in the first trimester, women who continued to smoke into the second trimester had a 71% increased likelihood of low birth weight, while those who smoked the entire pregnancy had an 83% increased odds of LBW. Examination of amount of continued smoking revealed a dose–response relationship, with greater amounts of smoking associated with increased rates of LBW. At the highest level examined, continuing to smoke 10 or more cigarettes per day increased the likelihood of LBW twofold or more compared to quitting by the end of the first trimester (Table 3).

3.3 | Preterm birth

Overall, 26,392 (10.9%) of the births were preterm. Similar to the findings for LBW, smoking later into pregnancy consistently increased the odds of experiencing PTB compared to not smoking at all. Logistic regression analyses controlling for significant background differences revealed that pregnant women who quit smoking by the end of their first trimester had a small but significantly increased odds of PTB when compared to nonsmokers. However, those who smoked into the second trimester but quit by 28 weeks had a 68% increased likelihood of PTB, while those who smoked through to delivery had a more than twofold increased odds (see Table 2).

Similar to the findings for LBW, pregnant women who smoked fewer than 10 cigarettes per day and quit smoking by the end of their first trimester did not differ significantly in the likelihood of experiencing PTB compared to nonsmokers. Pregnant women who smoked

10 or more cigarettes per day, even if they quit smoking by the end of their first trimester, had a 22% increased likelihood of experiencing PTB compared to nonsmokers. After the first trimester, any amount of smoking led to increased odds of experiencing PTB compared to nonsmokers, with those smoking 10 or more cigarettes through to delivery more than twice as likely as nonsmokers to experience PTB (see Table 2).

The final set of analyses compared women who continued to smoke with women who smoked any amount early in pregnancy but quit by the end of the first trimester. The pattern of results was similar to comparisons with nonsmokers. Compared to those who quit in the first trimester, women who continued to smoke into the second trimester had a 71% increased rate of low birth weight, while those who smoked the entire pregnancy had an 83% increased odds of LBW. Examination of amount of continued smoking revealed a dose–response relationship, with greater amounts of smoking increasing the risk of LBW. At the highest level examined, continuing to smoke 10 or more cigarettes per day increased the likelihood of LBW twofold or more compared to quitting by the end of the first trimester (Table 3).

4 | COMMENT

4.1 | Principal findings, strengths of the study, and interpretation

Our study assessed the relationship between trimester specific smoking and both LBW and PTB, accounting for other risk factors. Our hypothesis was that women who report smoking longer into their pregnancy, as well as more cigarettes per day would be more likely to experience LBW and PTB compared to nonsmokers and to those who quit early in pregnancy. This hypothesis was largely supported. We discovered that smoking any amount of cigarettes past the first trimester significantly increased the odds of experiencing LBW and PTB when compared to both nonsmokers and those who quit smoking early in pregnancy. Our study additionally aimed to take the initial analyses one step further by also accounting for the number of cigarettes smoked per day. Our results suggest that pregnant women who smoke nine or fewer cigarettes per day and quit smoking by the end of their first trimester do not have a significantly increased likelihood of experiencing LBW or PTB compared to nonsmokers. However, even if expectant mothers quit smoking by the end of their first trimester, but averaged 10 or more cigarettes per day, they are at increased odds of experiencing LBW and PTB compared to nonsmokers. Similarly, any amount of smoking beyond the first trimester substantially increased the likelihood of LBW and PTB compared to both nonsmokers and those who quit smoking in the first trimester, with the odds increasing with the number of cigarettes smoked. These results emphasize that it is important for those who smoke prior to pregnancy to quit completely as soon as possible, but definitely by the end of their first trimester. Additionally, women who begin pregnancy as smokers should be provided support to reduce their amount of smoking to no more than 9 cigarettes per day, with the ultimate goal of quitting. Our study suggests that following these guidelines will increase the rates of optimal birth outcomes, similar to those for nonsmokers, especially with respect to LBW and PTB.

Our initial analyses, which did not take into account amount of cigarette smoking, indicated that smoking just in the first trimester increases the odds of LBW and PTB, similar to the findings of Xaverius et al. (2019). However, additional analyses in the current study revealed that the increased rates for first trimester only smokers were likely driven by the subset of pregnant women who smoked 10 or more cigarettes per day. A recent similar study by Soneji and Beltrán-Sánchez (2019) used national U.S. birth certificate data to assess temporal cigarette cessation patterns and the risk of experiencing PTB. Similar to our study, they found that increased amount of smoking and smoking later in pregnancy were associated with increased odds of PTB in a dose response fashion. However, in their sample, which did not analyze <5 cigarettes per day separately from <10 cigarettes per day, a significant 16% increased risk for PTB was associated with first trimester smoking <10 cigarettes per day. It is unclear why our findings differ from these, but could be a result of PTB and LBW rates in our sample being much higher than national averages. Thus, in our higher risk population, other risk factors may have a stronger influence on birth outcomes at low levels of pregnancy smoking, and suggest that any smoking in the first trimester could increase the risk of adverse birth outcomes in lower risk populations. This is supported by the findings of Moore et al. (2016), who analyzed statewide birth certificate data from Ohio with similarly high rates of PTB and LBW, and did not find a significantly increased risk of fetal growth restriction for smoking only in the first trimester. Taken together, all three studies highlight the importance of quitting smoking as early as possible in pregnancy, but for those unable to quit encouraging a significant and steady reduction of the number of cigarettes smoked per day will increase the chances for optimal birth outcomes.

When looking at LBW and PTB outcomes, we found the magnitude of the odds was consistently larger for LBW compared to PTB, suggesting smoking during

pregnancy produces higher risk for LBW compared to PTB. This is consistent with many previous studies that have demonstrated smoking in pregnancy has a greater impact on decreasing growth than shortening gestation (Chiolero, Bovet, & Paccaud, 2005; Jaddoe et al., 2008; Ko et al., 2014). It remains to be seen whether the effects described in the current study generalize to other birth or longer term outcomes beyond LBW and PTB.

4.2 | Limitations of the data

The current study is not without limitations. As occurs in most studies that use large population-based datasets, this study was retrospective and limited by the availability of data. While we experienced almost no missing data, we were limited in the data available and by any possible errors in data that were collected for individual and surveillance purposes rather than specifically for research. This could certainly have introduced error into the data and findings. This also resulted in us being unable to link subsequent births by the same mother, leading to some unknown level of dependence of observations in our study. This further meant that we were unable to control for additional potential differences between study groups. Past research has shown that women who smoke during pregnancy differ from those who do not on many sociodemographic factors, for which we were able to control in this study. However, it is also possible that the study groups differed on medical and lifestyle factors (beyond prenatal care engagement, which was available) for which we were unable to control, and could have increased the magnitude of the differences identified. These effects were likely mitigated in the comparisons against women who quit smoking early in pregnancy, however, as all women included in those analyses were smokers. Similarly, we did not have information about the possible impact of nicotine replacement therapy (NRT) on outcomes for women who might have been trying to quit. While this had the potential to impact outcomes, it should be noted that during the study period, use of NRT during pregnancy was not widespread in the study region, with data from our own centers indicating fewer than 1% of pregnant women using any form of NRT. Additionally, information about smoking was collected via self-report. Thus, social desirability responding could have led some smoking respondents to deny use, or underreport the amount they smoked. Similarly, being asked to reflect on smoking amounts up to 9 months ago could have been impacted by recall bias, introducing further error into the data, along with a decreased precision that resulted from averaging amount of smoking across trimesters for the small percentage of women whose smoking amount changed over time. The patterns of relationships identified in this study that are both consistent with previous work and demonstrate a clear dose–response gradient, are evidence, however, that methodological error may have been minimal.

5 | CONCLUSIONS

The current study provides further evidence of the adverse birth outcomes that can result from pregnancies complicated by smoking. Findings are also important to inform clinical care and individual decisions in pregnancy. While low levels of smoking early in pregnancy may not significantly increase the risk of LBW and PTB in higher risks populations, it is clear that pregnant women should be advised to quit smoking completely as early in pregnancy as possible, ideally prior to conception but definitely in the first trimester, to increase the chances for optimal birth outcomes.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the State of Tennessee. Restrictions apply to the availability of these data, which were used with permission for this study. Data are available by contacting the authors with the permission of the State of Tennessee.

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