Individual and Social Influences on Cigarette Smoking During Pregnancy

Alexandra Noel Houston-Ludlam

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Individual and Social Influences on Cigarette Smoking During Pregnancy
by
Alexandra Noel Houston-Ludlam

A dissertation presented to
Washington University in St. Louis
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of Doctor of Philosophy

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Alexandra Houston-Ludlam

Washington University in St. Louis

May 2023
Dedicated to Aiden and Ezra—my sun, my moon, and all my stars.
ABSTRACT OF THE DISSERTATION

Individual and Social Influences on Cigarette Smoking During Pregnancy

by

Alexandra Houston-Ludlam

Doctor of Philosophy in Biology and Biomedical Sciences
Human and Statistical Genetics
Washington University in St. Louis, 2023

Professor Andrew C. Heath, Chair
Professor Kathleen K. Bucholz, Co-Chair

Population-level trends on sociodemographic risk factors for cigarette smoking during pregnancy (SDP) and outcomes for offspring exposed to maternal SDP are well established. However, the more complex task of understanding individual risk-prediction, including differences by maternal race/ethnicity, and its clinical application, remains incomplete. Characterizing the relative influence of environmental and individual characteristics as risk or protective factors for continued SDP is a necessary next step for informing individual- and public health-level interventions to produce successful smoking cessation prior to pregnancy, substantially reducing smoking-related mortality in child-bearing people. In this dissertation, I wanted to explore how multiple levels of influence, from individual, to family, to neighborhood, interact to confer risk or protection for SDP. First, I used a population-level birth cohort from state birth records of first births including geocoded maternal address at time of childbirth to compare individual and neighborhood level sociodemographics as risk and protective influences for SDP. I found important social influences on cigarette smoking during first pregnancy—marital status,
reproductive partner acknowledgement of paternity, and census tract-level SDP rate. Moreover, there were differences in risk factors by maternal race/ethnicity, in particular, among Black/African Americans, where SDP was higher in tracts with a greater proportion of white non-Hispanic residents. To examine how clinical factors, namely nicotine dependence, modulate risk for SDP, I used research data from a well-characterized like-sex female twin pair sample, connected to birth records for children born to the twin participants. I found that lifetime heaviness of nicotine dependence contributed as much risk to SDP as maternal sociodemographics at time of childbirth; however, the contribution of nicotine dependence to SDP risk was diminished at high levels of sociodemographic risk. These findings were limited to white non-Hispanic participants, as there was insufficient sample size from Black/African American participants. Finally, I wanted to use findings from administrative data to inform research design and address the needs of historically excluded populations, considering protective as well as risk factors. I wanted to identify protective factors for SDP among women who identify as American Indian or Alaska Native, as most existing research either excludes Native women, or only identifies higher rates of smoking, including SDP, without considering risk and protective factors. I conducted a pilot data collection from ten women recruited from birth records to examine the roles of positive racial identity, engagement with traditional tobacco use, and social influence by reproductive partner and cohabitants during pregnancy that might be associated with SDP. While I did not achieve a sufficient sample size for statistical analysis, I identified ways future work could explore these questions, including by working with a specific Tribe or Nation to address their questions about pregnancy and perinatal health and/or partnering with Tribal Epidemiology Centers to improve recruitment opportunities.
Chapter 1: Introduction

1.1 Epidemiology of Cigarette Smoking

1.1.1 History of Cigarette Smoking in the United States

Cigarettes emerged as a form of tobacco consumption in the early 1800s in the United States. Manufacturing advances increased availability and decreased prices of cigarettes in the 1860s and 1870s, elevating their popularity. Cultural attitudes around tobacco and cigarette consumption were in flux as cigarette availability increased. Morally motivated anti-smoking messaging dominated the late 1800s and early 1900s, followed by a huge shift towards widespread cultural acceptance, illustrated by cigarettes being provided to every servicemember in World War I (Cummings & Proctor, 2014; Smith & Malone, 2009). Cigarette smoking among women also began to rise in the 1920s, coinciding with increased tobacco marketing towards women and the previously mentioned societal shifts (Amos & Haglund, 2000; Giovino, 2002). The US population smoking rate rose steeply across the first half of the twentieth century, reaching a peak of 47% in 1953 (Roper & Roper, 1953). In the early 1900s, physicians noticed rapidly increasing rates of lung cancer, which had previously been a rare diagnosis. Evidence for a link between lung cancer and cigarette consumption emerged as early as the 1920s and continued to grow over the next several decades (Doll et al., 1994; Wynder & Graham, 1950). Due to efforts of the tobacco industry to combat this messaging, public acceptance of cigarette smoking remained high. Even among physicians, there was low confidence in the reports of cigarettes being associated with health harms (Cummings & Proctor, 2014; Mahaney, 1994)
Public perception shifted with publication of the Surgeon General’s report of 1964, which named cigarette smoking as a cause of lung cancer, laryngeal cancer, and chronic bronchitis (United States, 1964). Following this report, concerted efforts were made to reduce onset of smoking among never smokers and support established smokers in quitting. These efforts included health warnings on cigarette packaging, limitations on cigarette advertising in media, commissioning annual reports on the health effects of smoking, disseminating research findings, promoting antismoking messaging, and supporting state and community programs to reduce tobacco use. Reductions in the population smoking rate is lauded as one of the most successful public health campaigns (United States, 2014). While much work has gone in to developing and identifying the effective components of tobacco control efforts, this success can largely be distilled down to influencing social norms around tobacco use, which then influences population smoking rates (Cummings, 2016). Despite these achievements, tobacco related morbidity and mortality remains high, both globally and in the United States.

1.1.2 Current Trends in Cigarette Smoking in the United States

General Population

Currently, in the United States, the use of any tobacco product among adults is 20.8%, and the cigarette smoking rate is 14.0% (Cornelius et al., 2020). However, rates of smoking are highly variable when subgroups are considered. Cigarette smoking is higher among males; white non-Hispanic, Black non-Hispanic, and American Indian/Alaska Native non-Hispanic Americans compared to Hispanic and Asian non-Hispanic Americans; GED recipients versus those with high school diploma; unmarried individuals; those with annual income below $30,000; those who identify as Lesbian, Gay, or Bisexual; Medicaid insurance recipients; those with a disability;
those with symptoms of any mental illness; and military members (Cornelius et al., 2020; Drope et al., 2018; Jamal et al., 2016; Snell et al., 2021). Smoking rates vary by state, the highest being West Virginia at 25.2% (95% Confidence Interval 23.6-26.8%), and the lowest being Utah at 9.0% (95% Confidence Interval 8.3-9.7%; (Office on Smoking and Health, 2020)). Changes in smoking over time also vary by state, with some states showing greater declines among Black, Hispanic, and Other non-white adults compared to white non-Hispanic adults (Indiana, Idaho, Virginia, Wisconsin), possibly due to differences in local tobacco control and other public health policy (Mills et al., 2021). Thus, while huge strides have been made in reducing the population smoking rate, these reductions have not happened equally across subgroups. These differences are important to consider as tobacco control interventions and smoking cessation/harm reduction treatments are developed and implemented to achieve equitable reductions in tobacco-related harm.

**Pregnancy**

The cigarette smoking rate among women of reproductive age, ages 15-44, hovers around 21% (Kurti et al., 2018; Lopez et al., 2018). For cigarette smoking during pregnancy (SDP), marked by smoking beyond the first trimester, the rate is noticeably lower, at 6.5% (Drake et al., 2018), but still above the Healthy People 2030 goal of 4.3% (Office of Disease Prevention and Health Promotion [ODPHP], n.d.). As with the general population, SDP rates can be highly variable when considering differences by subgroups. There is high geographic variation in SDP rate at the state level. In 2016, the lowest rate was 1.6% in California and highest at 25.1% in West Virginia, like trends seen among non-pregnant adult smokers (Drake et al., 2018). Moreover, reports have identified lack of reduction, or even increases, in SDP for people with
depression history, living in rural areas, and with lower income and years of education completed (Goodwin et al., 2017; Nighbor et al., 2018; Scherman et al., 2018; Tong et al., 2013).

Additionally, longitudinal smoking patterns differ by age and between racial/ethnic groups (Curtin & Matthews, 2016). Pregnancy is associated with higher rates of smoking for adolescents, but for reductions in smoking for adults (Ellickson et al., 2001; McDermott et al., 2009). Moreover, initiation of cigarette use generally occurs later (18-20 years) for Black/African American smokers, yet Black/African American adults show higher rates of smoking on average (Trinidad et al., 2004). Given the intersection of initiation of smoking and reproductive age, this relationship results in lower rates of SDP among Black/African American gestational parents compared to white non-Hispanic gestational parents (Mumford et al., 2014). There are also well-established racial/ethnic differences in smoking patterns in pregnancy, with higher rates among white non-Hispanics and Native Americans, and lower rates among African Americans, Asians, and Hispanics (Dukes et al., 2017; Li et al., 2018; Mumford et al., 2014). Many populations who have higher rates of smoking also have higher rates of SDP, both highlighting how existing interventions are not serving these populations well and illustrating a compounding of the disproportionate burdens of tobacco-related harms among these groups.

1.1.3 Electronic Nicotine Delivery Systems

Electronic Nicotine Delivery Systems include many different devices, including electronic cigarettes or “e-cigarettes,” that heat an “e-liquid” to create an inhalable aerosol (Food and Drug Administration, 2020). There is an ongoing debate whether e-cigarettes and related devices can be implemented as a harm reduction tool in achieving cessation from smoking
combustible cigarettes (Hartmann-Boyce, McRobbie, et al., 2021; United States, 2020). When people who exclusively smoke combustible cigarettes switch to using e-cigarettes exclusively, there are reductions in combustible cigarette use and biomarkers associated with harms from cigarette smoking (Dai & Khan, 2020; Hartmann-Boyce, McRobbie, et al., 2021; National Academies of Sciences et al., 2018; Stokes et al., 2021). However, the e-cigarettes are commonly used in conjunction with other combustible tobacco products, youth have high rates of e-cigarettes use and transition to combustible tobacco product use, and the long-term effects of e-cigarette use are unknown (Gentzke et al., 2020; Hair et al., 2021; Hartmann-Boyce, McRobbie, et al., 2021; Kwon et al., 2021; Mayer et al., 2020; National Academies of Sciences et al., 2018; Osibogun et al., 2020; Patnode et al., 2021). How to make e-cigarettes available as a harm reduction intervention for established smokers, but prevent onset of smoking among youth, is central to the ongoing controversy of the role of e-cigarettes in the tobacco control and policy arena (Franck et al., 2016; Hartmann-Boyce, McRobbie, et al., 2021; Jenssen & Walley, 2019).

This debate is extended in the context of pregnancy, where it is unclear whether using e-cigarettes constitutes harm reduction. The high rates of co-use of e-cigarettes and combustible tobacco products holds true for people who smoke during pregnancy—up to 39% of pregnant people who smoke cigarettes reported also using e-cigarettes, consistent with rates of co-use in the general population (Liu et al., 2019; Mayer et al., 2020). There is not a clear consensus on whether e-cigarettes should be recommended to pregnant people who use other tobacco products as a harm reduction option (Campbell et al., 2020; Gould et al., 2020).
1.2 Health Effects of Cigarette Smoking

After decades of research, many health consequences have been linked to cigarette consumption. These health consequences are due to a variety of compounds found in cigarettes. The effects of nicotine, carbon monoxide, heavy metals, and organic compounds have all been linked to tobacco-related health consequences.

1.2.1 Compounds of Cigarettes Involved in Health Effects

Nicotine

Nicotine is the compound responsible for the rewarding properties of tobacco products, thus is the primary cause for dependence and addiction (United States, 2014). Nicotine is metabolized by the liver, mainly by CYP2A6, UDP-glucuronosyltransferase, and flavin-containing monooxygenase, into its primary metabolites, cotinine, norcotinine, nornicotine, and trans-3’-Hydroxycotinine (Benowitz et al., 2009; Benowitz & Jacob, 1994; Cashman et al., 1992; United States, 2014). Nicotine acts on nicotinic acetylcholine receptors (nAChRs), which are present throughout the human body, including most nervous system tissue. In the brain, nicotine-mediated nAChR activation results in nonspecific release of most neurotransmitters (United States, 2014). Both positive and negative reinforcement mechanisms drive continued nicotine seeking in the context of nicotine dependence. Positive reinforcement of nicotine use is mediated by dopamine release in the ventral tegmental area and related downstream effects (De Biasi & Dani, 2011; Di Chiara & Imperato, 1988). Negative reinforcement of nicotine use is mediated through somatic and affective withdrawal symptoms (De Biasi & Salas, 2008). Withdrawal symptoms include irritability, anxiety, depression, increased appetite, impatience,
insomnia, and restlessness, codified in the DSM-5 as Nicotine Withdrawal Syndrome (Baker et al., 2012; McLaughlin et al., 2015).

Nicotine has widespread influence on the negative health consequences of smoking. Nicotine plays a prominent role in the development and maintenance of cancer. There is limited, and mixed, evidence whether nicotine itself can directly cause DNA or chromosomal damage, thus leading to cancer formation, despite cigarette smoke condensate having known genotoxicity (Chen et al., 2008; Sanner & Grimsrud, 2015). In lung tissue, nicotine-mediated signaling promotes many tumor-promoting cell reactions, including evasion of apoptosis, aberrant proliferation, development of pro-tumor extracellular environments, and metastasization (Cardinale et al., 2012; Carlisle et al., 2007; Catassi et al., 2008; CDC et al., 2010; Dasgupta & Chellappan, 2006; Egleton et al., 2009; Maneckjee & Minna, 1990; United States, 2014). More broadly, nicotine promotes pathological angiogenesis, which not only is important for tumor survival, but may relate to nicotine’s role in the pathophysiology of other tobacco-associated health consequences (Lee & Cooke, 2012). Nicotine has immunomodulatory effects, both directly, and via activation of the sympathetic nervous system (United States, 2014). Directly, nicotine blunts the typical response of antigen-mediated activation of B and T lymphocytes, leading to immunosuppression (Geng et al., 1995; Geng et al., 1996).

Nicotine directly activates the sympathetic nervous system, which leads to coronary vasoconstriction, increased heart rate, increased blood pressure, and increased myocardial contractility, all of which increase stress on the cardiovascular system (Benowitz, 2003). Nicotine’s role in elevated cardiovascular risk includes increased risk of acute ischemic events (e.g. myocardial infarction, stroke) and acceleration of atherogenesis. While it is sometimes
difficult to separate the specific effects of nicotine from the effects of cigarette smoking on cardiovascular risk, the evidence supports a unique role of nicotine contributing to cardiovascular risk via increased cardiac remodeling, incidence of fatal arrhythmias, and insulin resistance (Benowitz & Burbank, 2016; Jensen et al., 2012; Wu et al., 2015).

While smoking and nicotine are purported to positively influence aspects of cognitive function, it is unclear whether the reported effects are a true elevation from baseline or an alleviation of nicotine withdrawal symptoms. Importantly, the tobacco industry has promoted and funded research regarding the cognitive enhancing effects of nicotine and the role of nicotine in alleviating symptoms of mental illness (Cataldo et al., 2010; Prochaska et al., 2008; Turner & Spilich, 1997). There is mixed evidence on whether nicotine improves cognitive function in healthy smokers and non-smokers (Heishman et al., 2010). Nicotine administration has been evaluated as a potential therapy for conditions marked by cognitive decline, including Alzheimer’s, Parkinson’s, Attention-deficit/hyperactivity disorder (ADHD), and Schizophrenia. While nicotine administration has been linked to some cognitive benefit in the context of Alzheimer’s, the evidence is mixed, and current research favors nicotine derivatives and other nicotinic acetylcholine receptor agonists for potential application as a therapeutic for Alzheimer’s (Alhowail, 2021; Hoskin et al., 2019; Hsu et al., 2018; López-Arrieta & Sanz, 2001; Newhouse et al., 2012). Interestingly, there is strong and consistent evidence that smokers show a reduced risk for Parkinson’s Disease, but studies of nicotine as treatment for symptoms of Parkinson’s Disease have had mixed results (Acharya & Kim, 2021; Ritz et al., 2007; Tizabi et al., 2021; Wirdefeldt et al., 2011). For ADHD, there is limited evidence that nicotine alleviates symptoms; however, there may be improvements in behavioral inhibition, delay aversion, and
recognition memory in laboratory settings (Gehricke et al., 2009; Gehricke et al., 2006). While there is high comorbidity of smoking and Schizophrenia and evidence that nicotine-mediated changes in neurochemistry could ameliorate symptoms of Schizophrenia and antipsychotic medication side effects, no reliable studies exist of exclusive nicotine administration for Schizophrenia symptoms (Acharya & Kim, 2021; López-Arrieta & Sanz, 2001; Potter et al., 2014; Punnoose & Belgamwar, 2006).

**Carbon Monoxide**

Carbon monoxide (CO) is present in inhaled cigarette smoke and easily absorbed. CO binds to hemoglobin, with an over 200-fold greater affinity than oxygen, resulting in reduced capacity for oxygen transport and tissue hypoxia (Blumenthal, 2001). Tissues with higher oxygen requirements, such as the heart and brain, are especially vulnerable to hypoxic damage. CO is implicated in the mechanism of smoking-related cardiovascular disease, including coronary heart disease and stroke (Benowitz, 2003; CDC et al., 2010; Lippi et al., 2012). Testing the CO levels in expired air is a common and effective way to determine cigarette and cigar smoking status over the previous 8–24-hour period. CO testing is commonly used in research settings to biochemically-verify self-reported smoking status, and CO monitoring as a method of biomarker feedback may be a way to supplement existing smoking cessation interventions (Benowitz et al., 2020; Clair et al., 2019; Goldstein et al., 2018; Krishnan et al., 2019).

**Additional Compounds**

In addition to nicotine and carbon monoxide, there are a host of other toxic and carcinogenic compounds present in cigarette smoke. Prominent among this list include tobacco-
specific nitrosamines, which are potent carcinogens, heavy metals, including lead and cadmium, and a variety of other organic compounds (CDC et al., 2010; Fowles & Dybing, 2003; Talhout et al., 2011). Whether and how these compounds play a mechanistic role in tobacco-related morbidity and mortality is an ongoing area of research (CDC et al., 2010).

### 1.2.2 Health Effects in General Population

Cigarette smoking is associated with high morbidity and mortality and remains a leading modifiable risk factor for disease (Gakidou et al., 2017; Jha et al., 2013). Since the 1964 Surgeon General’s report identifying cigarette smoking’s role in lung cancer and chronic bronchitis, the list of conditions to which smoking is associated or causally related continues to grow (United States, 1964). The most prominent causes of smoking-related mortality are cardiovascular disease, lung cancer, and chronic obstructive pulmonary disease (World Health Organization, 2021). Smoking also increases risk for asthma, acute and chronic respiratory problems, increased susceptibility to infectious disease, infertility, dental disease, diabetes, macular degeneration, reduced bone density and associated increased fracture risk, peptic ulcer disease, and most forms of cancer (United States, 2014). Achieving maintained smoking cessation by age 35 is associated with reduction of mortality risks to the same level as never-smokers, while continuing to smoke beyond age 55 is associated with 10 years of life lost (Jha et al., 2013).

### 1.2.3 Health Effects in Pregnancy

Nicotine metabolism increases in pregnancy, potentially due to estrogen- and/or progesterone-mediated increased CYP2A6 activity, reaching a peak metabolism across second and third trimesters, and quickly declining within the first month postpartum (Benowitz et al.,
The health effects associated with SDP are mostly thought to be due to nicotine and carbon monoxide, both of which cross the placental barrier. Nicotine has the greatest negative impact on the fetus in the third trimester of pregnancy, and the fetus has a disproportionately higher exposure to nicotine levels than the gestational parent (Fried & O’Connell, 1987; Holbrook, 2016; Luck et al., 1985). Carbon monoxide reduces oxygen delivery for the gestational parent, also leading to reduced oxygen transport to the fetus and hypoxia (Diamanti et al., 2019).

Achieving permanent smoking cessation by the time of first pregnancy would substantially reduce maternal smoking-related mortality risk for associated cancers, cardiovascular disease, and other conditions, as previously described (Jha et al., 2013). Specific to pregnancy, gestational parent SDP is an important modifiable risk factor for several important birth outcomes. These include infant mortality, infant low birth weight, prematurity, and early lung dysfunction (Cnattingius, 2004; Diamanti et al., 2019; Flenady et al., 2011). Distal outcomes associated with SDP include impaired cognitive ability, chronic respiratory issues, structural brain changes, and psychiatric phenotypes, especially hyperactive/impulsive symptoms (Diamanti et al., 2019; El Marroun et al., 2016; Huizink & Mulder, 2006; Knopik et al., 2016; Palmer et al., 2016; Tager et al., 1983).

1.3 Smoking Cessation

1.3.1 Individual Treatments
The main treatments to support smoking cessation in the United States include behavioral therapy, nicotine replacement therapy, and two pharmacological therapies—varenicline and bupropion.

**Behavioral Treatments**

Behavioral treatments focus on providing information on how to quit and advice to quit smoking. Most components of behavioral treatment are highly variable, including who provides an intervention (healthcare professional, trained peer/lay person, written pamphlets), how often the intervention is provided and duration of the sessions (a single session of a few minutes to ongoing sessions involving several hours of provider-delivered intervention), format of treatment (individual versus group, in-person versus video versus electronic communication), theoretical underpinnings of treatment approach, and other components like romantic partner/support person involvement and financial incentives for biochemically-verified smoking abstinence (Hartmann-Boyce, Livingstone-Banks, et al., 2021). The most effective components of behavioral interventions include counselling and financial incentives for successful abstinence from smoking (Hartmann-Boyce, Livingstone-Banks, et al., 2021). Other effective components of behavioral interventions include text message-based delivery, tailored content to individuals, motivational content, intervention delivered by a lay person/peer, and email/audio recording intervention delivery (Hartmann-Boyce, Livingstone-Banks, et al., 2021). Despite the variability, behavioral treatments for smoking cessation are highly effective (Hartmann-Boyce, Livingstone-Banks, et al., 2021). However, less than a third of people use evidence-based therapies, including behavioral treatments, to aid their smoking cessation attempts (Babb et al., 2017). Marginalized and disadvantaged individuals are especially lacking sufficient coverage for evidenced based
therapies, which contributes to lower smoking cessation rates and higher tobacco-related disease burden (Brose et al., 2018; DiGiulio et al., 2020; Kock et al., 2019).

**Nicotine Replacement Therapy**

Nicotine replacement therapy involves using a skin patch, gum, lozenge, inhaler, oral or nasal spray containing nicotine to replace nicotine intake from cigarettes or other tobacco products (Hartmann-Boyce et al., 2018). Nicotine replacement therapy is an effective way to manage symptoms associated with nicotine withdrawal, with the goal of increasing chance of smoking cessation (Fiore et al., 1994; Silagy et al., 1994; West & Shiffman, 2001). All forms of nicotine replacement therapy allow nicotine to be absorbed at a rate slower than nicotine availability from cigarettes (Hartmann-Boyce et al., 2018; Henningfield et al., 2005). Using combination therapy, with both a fast acting (e.g. gum, lozenge) therapy and the nicotine patch, is more effective than monotherapy (Lindson et al., 2019). Typically, nicotine replacement therapy is dosed in a stepwise fashion, so that the highest dose of nicotine is given early in a smoking cessation attempt, and the nicotine dose is reduced, along the course of weeks, until it is no longer desired or needed (Clinical Practice Guideline Treating Tobacco et al., 2008). In the United States, skin patches, gum, and lozenges are available over-the-counter to people aged 18 and older, while nasal sprays and inhalers require a prescription (Food and Drug Administration, 2017). Through a mix of private health insurance, public health insurance, and state and community funded programs, most nicotine replacement therapy is available at free or reduced cost; however, financial and procedural barriers still prevent maximum utilization of these benefits (Cornelius et al., 2020; Tibuakuu et al., 2019; United States, 2014).

**Pharmacological Treatments**
Varenicline and bupropion are the two approved pharmacological treatments available in the United States. There is emerging evidence for other pharmacotherapies, including cytisine and nortriptyline, but neither are approved as smoking cessation treatments in the United States (Cahill et al., 2013). Varenicline is a partial agonist of the α4β2 nicotinic acetylcholine receptor, which prevents full activation of the receptor by nicotine, thereby reducing nicotine mediated reward signaling while attenuating some effects of nicotine withdrawal (Rollema et al., 2007). Bupropion is a selective noradrenergic reuptake inhibitor and selective dopamine reuptake inhibitor originally developed as an antidepressant and was later found to be an effective smoking cessation treatment (Ascher et al., 1995; Hurt et al., 1997). Prescription pharmacotherapies are consistently shown to be most effective for smoking cessation compared to over-the-counter therapies, and varenicline is more effective than bupropion (Anthenelli et al., 2016; Leone et al., 2020). However, there is still low uptake and utilization of prescription pharmacotherapies and other evidence-based smoking cessation methods (Babb et al., 2017; Caraballo et al., 2017; Patnode et al., 2021; Tibuakuu et al., 2019).

1.3.2 Tobacco Control Policies

Tobacco control policies are population-focused programs and legislation aimed at reducing initiation of smoking, promoting successful smoking cessation, and reducing secondhand smoke exposure. Increasing taxes on cigarettes, consistently found to be the most successful tobacco control policy, is effective at reducing cigarette consumption and smoking prevalence (Feirman et al., 2017; Hoffman & Tan, 2015; Mojtabai et al., 2019). Clean indoor air laws (“smoking bans”), which prohibit smoking in designated public areas, have been highly effective at promoting better health. These laws are associated with reduced smoking prevalence.
and consumption, higher rates of cessation attempts, and higher rates of voluntary smoke free homes (Becker et al., 2017; Cheng et al., 2011; Cheng et al., 2017; Hoffman & Tan, 2015; Mayne et al., 2018; Mojtabai et al., 2019). Increasing the age at which it is legal to purchase tobacco products is an effective way to reduce smoking among adolescents and young adults, leading to the 2019 legislation raising the United States federal minimum age for sale of tobacco products from 18 to 21 years (Dobbs et al., 2021; Food and Drug Administration, 2021; Friedman & Wu, 2020; Institute of Medicine, 2015; Kessel Schneider et al., 2016). Restricting or prohibiting flavored tobacco products is an important legislative tool for reducing smoking, especially among youth, Black/African Americans, and low-income Americans (Chaiton et al., 2019; Combs et al., 2020; Mills et al., 2018). Mass media campaigns attempt to reach a large segment of a given population to increase successful smoking cessation and prevent relapse and onset of smoking among non-smokers. Mass media campaigns have positive impacts on smoking cessation, are cost effective, and are most useful when coupled with other tobacco control strategies (Bala et al., 2017; Durkin et al., 2012; Feirman et al., 2017). Relatedly, including graphic and/or large warning labels on tobacco products is associated with increased cessation resource seeking and reductions in tobacco consumption (Hammond, 2011; Noar et al., 2016). Restricting or banning tobacco promotions or advertising is a highly effective method of reducing onset of smoking (Emery et al., 1999; Feirman et al., 2017).

As with other efforts to reduce smoking and increase cessation, improvements gained through tobacco control policies have not happened equitably (Brown et al., 2014; Center for Public Health Systems Science et al., 2016; Centers for Disease Prevention and Control et al., 2018). An important way to improve equity around tobacco control interventions are policies
limiting tobacco retailer density, or how many places sell tobacco within a given area (e.g. Shareck et al., 2018). To be most equitable, policies should include specific provisions to require minimum spacing between outlets, exclude sales around schools and other “child spaces,” and set specific requirements about the density of retailers within the jurisdiction of the legislation (Caryl et al., 2020; Combs et al., 2020; Ribisl et al., 2017). Implementing pricing and promotion regulation is vital for health equity, given a longstanding history of disproportionate advertising and promotion campaigns targeting youth, Black/African Americans, and low-income neighborhoods (Mills et al., 2018). Implementation of multiple tobacco control strategies, such as heightened age restrictions, increases in taxes, and mass media evidence-based smoking cessation campaigns, results in greater improvements in smoking related outcomes compared to implementing one strategy alone (Combs et al., 2020; Mojtabai et al., 2020).

1.3.3 Smoking Cessation in Pregnancy

There are higher rates of smoking cessation in pregnancy, reports ranging from 24-39%, compared to the general population annual smoking cessation rate of 7.4%, (Babb et al., 2017; Moore et al., 2016; Soneji & Beltrán-Sánchez, 2019). However, there are very high rates of postpartum relapse, with up to 70% of people who quit during pregnancy resuming cigarette use by one year postpartum (Carmichael & Ahluwalia, 2000; Fingerhut et al., 1990). However, some people can maintain long term abstinence following quitting during pregnancy (Rattan et al., 2013).

Due to limitations in the evidence base for safety of non-nicotine-based treatments for smoking cessation in pregnancy, current clinical guidelines recommend first using behavioral
interventions to support cessation attempts and advise nicotine replacement therapy only as an 
add-on support if behavioral interventions do not achieve the desired result (Chamberlain et al.,
2017; Claire et al., 2020; Diamanti et al., 2019; Patnode et al., 2021). Nicotine replacement 
therapy is considered safer than continued smoking, despite known toxic effects of nicotine to 
the fetus, because it results in less nicotine exposure compared to combustible cigarettes (Blanc 
et al., 2021; Campbell et al., 2020; Claire et al., 2020; Hickson et al., 2019). Nicotine 
replacement therapy is effective at increasing smoking cessation rates; however, there is low 
adherence, attributed to increased nicotine metabolism rates in pregnancy (Claire et al., 2020; 
Diamanti et al., 2019). There are no guidelines for the use of bupropion or varenicline in 
pregnancy due to a paucity of data (Claire et al., 2020). However, recent surveillance data 
suggests there are no increases in adverse birth outcomes associated with bupropion use, and 
lower risk of adverse birth outcomes with varenicline use compared to no medication use in 
pregnancy (Tran et al., 2020).

1.4 Influences on Smoking During Pregnancy

Cigarette use during pregnancy is an important modifiable risk factor for negative health 
consequences for the gestational parent and their offspring. Characterizing influential individual, 
sociodemographic, and environmental characteristics that inform reasons for failure of successful 
smoking cessation by pregnancy is important for improving intervention efforts. Some risk 
factors for smoking during pregnancy are common risk factors for smoking in the general 
population, and some are unique to the pregnancy and perinatal context. The following text will 
focus on risk influences for SDP.
1.4.1 Individual Influences

There are important individual-level characteristics that inform risk for continued SDP. A longer smoking history, greater number of cigarettes smoked, higher levels of nicotine dependence, and higher number of previously unsuccessful quit attempts all increase risk for smoking during pregnancy (Agrawal et al., 2008; Houston-Ludlam et al., 2019; Riaz et al., 2018). Younger age, less educational attainment, lower income, higher number of previous pregnancies, and receiving publicly funded and/or insufficient prenatal care are commonly cited risk factors for SDP (Boucher & Konkle, 2016; Riaz et al., 2018; Schneider & Schütz, 2008). These factors can also predict engagement with cessation services in pregnancy (Scheuermann et al., 2017). In the general population, there are strong associations between mood disorders, stress, and childhood trauma and elevated smoking rates. Most of the research investigating links between mental health and SDP focus on outcomes among exposed children; however, maternal depression and adverse childhood experiences stand out as important risk factors for SDP (Blalock et al., 2005; Racine et al., 2021).

1.4.2 Social and Geographic Influences

Some of the previously mentioned individual characteristics have important social components to their effect. For example, while higher rates of SDP are reported among some racial/ethnic minorities, the social-level component of this finding is racism and discrimination. Race-related stress is a risk factor for prenatal smoking and SDP for Black/African American women (Fernander et al., 2010; Nguyen et al., 2012). Public insurance and inadequate prenatal care are often considered individual level factors, but the health care provider plays a role in this
effect. Health care providers are vital to promoting smoking cessation, including during pregnancy; however, reports consistently show that providers feel ill-equipped to provide cessation services, lack time in visits to address smoking cessation, and have low rates of referral to cessation services and prescription of nicotine replacement therapy (Campbell et al., 2020; Fiore et al., 2007; Flemming et al., 2016; Gould et al., 2020).

Social influence, for example, via friend and reproductive partner smoking status during pregnancy, also confers individual risk for SDP and postpartum relapse (Homish et al., 2012; Nguyen et al., 2012; Scheffers-van Schayck et al., 2019; Waldron et al., 2017). Providers want to include partner support and partner cessation within patient quit attempts (Fergie et al., 2019), and treatments are being designed to address smoking cessation for the partner dyad (e.g. Meghea et al., 2018). These changes are important, as partners have higher rates of continued smoking and no reductions in amount smoked, which are risk factors for the pregnant patient continuing to smoke and secondhand smoke exposure for parents and offspring (Román-Gálvez et al., 2018; Schneider & Schütz, 2008; Shawe et al., 2019). Even brief interventions, like referral and provision of a short course of nicotine replacement therapy, improves partner quit rates (Luk et al., 2021). Addressing both parties in the reproductive dyad is vital for improving smoking cessation and secondhand smoke exposure for pregnant people and their offspring.

Broader social context, including neighborhood social class, neighborhood racial segregation, and county-level social capital, confers additional risk for SDP beyond individual factors (Bell et al., 2007; Pickett et al., 2002; Shoff & Yang, 2013). Addressing changes in social supports and networks surrounding initiation and maintenance of smoking cessation is an important component of treatment necessary to increase success.
Larger-scale social context also plays an important role in smoking cessation in pregnancy. Using information about neighborhood/geographic influences is important when considering which interventions to implement and how to implement them—from individual to community to policy (Gootjes et al., 2019). As increased tobacco retailer density is related to increased SDP rates (Hall et al., 2019), implementing tobacco control policies like limiting tobacco retailer density or proximity to one another could be an effective strategy to help reduce SDP. Moreover, targeting tobacco retailer density, proximity, and marketing is an important strategy to promote health equity in reducing tobacco-related health consequences (Center for Public Health Systems Science et al., 2016; Centers for Disease Prevention and Control et al., 2018).

Permeating all levels of social influence on SDP is the intersection with gender, as women are distilled down to their role as reproducer and a related focus of the effect of SDP on the exposed fetus (Chamberlain et al., 2017; Healton et al., 2009). An unintended consequence of strong anti-smoking messaging is that people already experiencing additional hardships then experience an additional layer of judgement, effectively adding another barrier to smoking cessation rather than motivating it (Chamberlain et al., 2017; Ebert & Fahy, 2007; Flemming et al., 2015; Graham, 1976). Ensuring that individual and population level interventions acknowledge the role of stressors and socioeconomic disadvantage, promote maternal health, direct messaging to both parents about effects of smoking on children, and promote the positive effects of quitting can ensure greater equity while promoting smoking cessation (Flemming et al., 2015; Gould et al., 2020; Healton et al., 2009; Klein et al., 2020).
1.5 Outstanding Questions in the Field

Extensive literature exists predicting which individuals will become smokers and on the effects of cigarette smoking during pregnancy on exposed offspring. Yet, few studies prospectively predict, by race/ethnicity, in a way that can be translated to clinical practice, which smokers successfully quit prior to or during the first trimester of pregnancy, despite the public health significance of this risk-behavior. Achieving permanent smoking cessation by first pregnancy benefits maternal health, reducing later-life smoking associated health burdens (Jha et al., 2013) and benefits child and family health by reducing exposure in utero and secondhand smoke exposure in early life. Rather than focusing solely on individuals, as though insulated from community or environmental influence, or treating patients merely as their demographics and census tract, the work I present in this dissertation integrates multiple levels of influence (individual, family, neighborhood, etc.) to predict risk for SDP.

This dissertation will focus on two overarching questions:

What is the interplay of sociodemographics, neighborhood influences, and individual and family-of-origin effects on conferring risk for cigarette smoking during pregnancy?

How to use findings from administrative data to inform research design and address the needs of historically excluded populations?
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Chapter 2: Marital status, partner acknowledgment of paternity, and neighborhood influences on smoking during first pregnancy: findings across race/ethnicity in linked administrative and census data

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This study was designed by ANHL, KKB, ACH, with input from AGC. Analyses were designed and completed by ANHL, except for the American Community Survey Microdata analyses, conducted by MW, with input from ACH, KKB, ML, and VVM. ANHL drafted the first version of the manuscript, tables, and figures. All authors contributed to and approved the final manuscript.

2.1 Introduction

In 2016, the estimated prevalence of any cigarette use in pregnancy in the United States was 7.2% (Drake et al., 2018), much higher than the Healthy People 2020 goal of reduction to 1.4% (U.S. Department of Health and Human Services). Although striking, national estimates have the potential to obscure the wide geographic variation in cigarette smoking during pregnancy (SDP) rate at the state level. In 2016, California was lowest at 1.6%, Missouri was 5\textsuperscript{th} highest at 15.2%, and West Virginia was highest at 25.1% (Drake et al., 2018), all of which are likely underestimates due to underreporting. SDP has well-documented negative health effects for those who smoke and their offspring (Cnattingius, 2004; Crume, 2019; Dietz et al., 2010; Flenady et al., 2011; McEvoy & Spindel, 2017; Tager et al., 1983). Additionally, since most people who smoke during first pregnancy are young (Riaz et al., 2018), successful and permanent cessation by first pregnancy would achieve an important reduction in tobacco-related morbidity and mortality (Jha et al., 2013).

Despite a broad general literature on predictors of SDP (Boucher & Konkle, 2016; Riaz et al., 2018), the literature is underdeveloped in several key domains. There is minimal work examining cultural differences and consistency of risk factors across different race/ethnic groups (Dukes et al., 2017). While recent work, especially in the context of cessation interventions, has
examined the role of the reproductive dyad, this is often limited to traditional classifications of ‘married’ or ‘unmarried and cohabiting’ versus non-cohabiting (Riaz et al., 2018), without considering absentee (‘disengaged’) versus engaged non-cohabiting reproductive partners (cf. Hummer & Hamilton, 2010). While there is increasing recognition of the importance of social and systemic determinants of health, the varying influences of neighborhood environment by race/ethnicity are often ignored. Lastly, most existing research is not equipped to examine the potential confounding of individual and neighborhood sociodemographic influences. By using either relatively small research samples or summary data at the population-level, the existing literature’s ability to achieve individual-level prediction that includes geographic influences is limited. Understanding individual risk prediction, including differences by race/ethnicity, is necessary for policy and therapeutic interventions to achieve greater and more equitable reductions in SDP for all.

To achieve a better understanding of individual risk prediction, we cross-link two forms of administrative data, individual-level state birth record data and associated census-tract American Community Survey data (GeoLytics, version 7.9). This ensures sufficiently large sample sizes to highlight important differences between Black/African Americans and white non-Hispanics and to show trends for other historically excluded US minority groups, including Native Americans. This report examines whether social influences associated with both residential neighborhood SDP rate and reproductive partner relationship (marital status and reproductive partner acknowledgement of paternity), after adjusting for other aspects of maternal and residential neighborhood sociodemographics, play an important role in assessing individual-level risk for smoking during first pregnancy.
2.2 Materials and Methods

2.2.1 Analysis Sample

In this population-cohort study, all non-adopted singleton first births in Missouri, for birth years 2010-17, were extracted from birth records, after agreement and data release from the Missouri Department of Health and Senior Services. Records about biological parents of adoptees could not be accessed due to Missouri state law. Maternal residential address was standardized (SmartyList, version 8.2.6, SmartyStreets) and geocoded to census tract using 2010 Census tract boundaries (GeoLytics, version 7.9). The success rate for geocoding ranged from 87.1% for white non-Hispanics (WNH), to 95.2% for Black/African Americans (AA), reflecting AA urban concentration in the state and lower success rate in geocoding rural route and similar rural addresses. The total sample, after exclusions for missing data (eTable 2.1), included 139,732 white non-Hispanics, 27,455 Black/African Americans, 7,973 Hispanics (H), 5,027 Asians (AS) and 2,707 Native Americans (NA). There were no exclusions for pregnancy outcome. This study received ethical approval from the Washington University Family and Population Research Center Review Board, Washington University Institutional Review Board, and Missouri Department of Health and Senior Services Ethical Review Board.

2.2.2 Measures

Birth Record Variable Coding

Beginning in 2010, maternal race/ethnicity was coded on the birth record to allow for multiracial/multiethnic identity. The variables were recoded in our analyses in the following manner: Ethnicity: if mother_hisp_other, mother_mexican, mother_puerto_rican, or
mother_cuban were yes, then Hispanic was coded as yes. Otherwise, observations were coded as non-Hispanic. Race: First, race was collapsed from 14 variables into four variables, white, Black/African American, Native American, and Asian. A small number coded as ‘Other’ were set to missing. White: if mother_white equaled yes, than white was coded yes. African American: if mother_black was coded as yes, then Black/African American was coded as yes. Native American: if mother_indian was coded as yes, than Native American was coded as yes. Asian: if mother_chinese, mother_filipino, mother_guamanian, mother_hawaiian, mother_japanese, mother_korean, mother_other_asian, mother_pacific_island, mother_samoan, mother_viet, or mother_asian_indian were coded as yes, than Asian was coded as yes. In order to not double count observations for mothers with a multiracial identity, mothers were counted as belonging to a single race/ethnicity category in the following order: Native American, Hispanic, Black/African American, Asian, then white, non-Hispanic.

**Maternal variables**

Missouri adopted the standard long-form birth certificate 2003 revision, published by the Centers for Disease Control and Prevention (CDC), in 2010. Variables extracted from birth record data included child birth year, maternal age, years of education completed, marital status, presence/absence of name of reproductive partner, number of living children, number of deceased children, race/ethnicity, and cigarette quantity smoked during the three months prior to pregnancy and during each trimester of pregnancy. According to CDC protocol, birth record report of smoking during pregnancy is obtained from medical records or physician report first, and if these sources are unavailable, then it is based on maternal self-report (National Center for Health Statistics, 1987). The presence/absence of the reproductive partner name indicates whether the partner signed an ‘affidavit of paternity’ either at the time of childbirth or, less
commonly, subsequently. Births were counted as first births if maternal record indicated zero living and zero deceased children at time of index childbirth. Smoking was recoded as a binary variable indicating whether the gestational parent smoked in the second and/or third trimesters.

**Birth Record-Sociodemographic Risk Score (SRS)**

We followed the Imbens and Rubin (2015) approach to propensity score estimation. As discussed in text, analyses were conducted separately for each race/ethnic group. The first step was to enter main effects into the model. Main effects entered into the model based on existing literature were: maternal age (continuous), maternal marital status and reproductive partner status (3 dummy variables: unmarried, paternity Acknowledged; unmarried, paternity unacknowledged; married, paternity acknowledged [reference group]; married, paternity unacknowledged), maternal years education completed (dummy variables: ≤ 8 years, 9-12 years, 13-15 years, 16 years, 17+ years), pre-pregnancy BMI coded into WHO categories (dummy variables: Underweight (<18.5), Normal (18.5-24.9), Overweight (25.0-29.9), Obese(≥ 30.0)). In the second step, additional variables were allowed to enter stepwise into the model and were retained using a generous threshold (p<0.35): maternal birth place (mother born in-state, mother born in United States, but not in-state, mother born outside of United States), maternal age², and child birth year. We considered a stepwise approach acceptable because of the very large sample sizes involved. In the third step, all pairwise interactions were tested for possible inclusion in the final model to achieve best model fit, except age² and the dummy variable for unknown maternal birth place in cases when they had already been entered in step two. Interactions were retained if they reached nominal significance (Likelihood Ratio Statistic change>2.71, ~p<0.1). Models were tested iteratively, so all pairwise interactions were tested in separate models for one iteration,
using a stepwise procedure with entry criterion p<0.35 and retention criterion p<0.95. The interaction with the greatest Likelihood Ratio Statistic change was retained, so long as it was greater than 2.71 and met the retention criterion. All pairwise interactions, except for any already retained, were tested again for possible inclusion. This process was repeated until no interactions showed a Likelihood Ratio Statistic change > 2.71. Interaction terms involving age were especially common. Model fit statistics can be found in eTable 2.2.

Interactions retained for white, non-Hispanics (33): 1) age² 2) age*unmarried, paternity unacknowledged 3) age*unmarried, paternity acknowledged 4) unmarried, paternity acknowledged*< 9 years education 5) age*16 years education 6) unmarried, paternity acknowledged*16 years education 7) unmarried, paternity unacknowledged*obese 8) age*17+ years education 9) unmarried, paternity unacknowledged*birth year 10) age*birth year 11) age*underweight 12) unmarried, paternity acknowledged*obese 13) age*13-15 years education 14) unmarried, paternity unacknowledged*< 9 years education 15) unmarried, paternity unacknowledged*13-15 years education 16) unmarried, paternity acknowledged*16 years education 17) unmarried, paternity unacknowledged*16 years education 18) married, paternity acknowledged*17+ years education 19) 16 years education*overweight 20) unmarried, paternity acknowledged*17+ years education 21) age*< 9 years education 22) 16 years education*obese 23) married, paternity unacknowledged*< 9 years education 24) age*obese 25) 13-15 years education*obese 26) married, paternity unacknowledged*obese 27) age* married, paternity unacknowledged 28) 17+ years education*obese 29) unmarried, paternity acknowledged*birth year 30) unmarried, paternity unacknowledged*underweight 31) < 9 years education*birth year 32) 16 years education*birth year 33) married, paternity unacknowledged*birth year.
Interactions retained for Black/African Americans (12): 1) age^2 2) age*unmarried, paternity unacknowledged 3) age*overweight 4) age*obese 5) 13-15 years education*obese 6) age*16 years education 7) obese*birth year 8) age*13-15 years education 9) married, paternity acknowledged*13-15 years education 10) married, paternity acknowledged*17+years education 11) married, paternity acknowledged*< 9 years education 12) married, paternity unacknowledged*birth year.

Interactions retained for Native Americans (10): 1) age^2 2) age*unmarried, paternity unacknowledged 3) overweight*birth year 4) age*unmarried, paternity acknowledged 5) unmarried, paternity acknowledged*mother US (not Missouri) born 6) age*mother US (not Missouri) born 7) age*overweight 8) < 9 years education*mother US (not Missouri) born 9) unmarried, paternity unacknowledged*obese 10) birth year*mother US (not Missouri) born.

Interactions retained for Hispanics (10): 1) age^2 2) birth year*mother US (not Missouri) born 3) < 9 years education*mother US (not Missouri) born 4) unmarried, paternity unacknowledged*underweight 5) age*birth year 6) age*obese 7) < 9 years education*underweight 8) 13-15 years education*birth year 9) underweight*mother US (not Missouri) born 10) married, paternity unacknowledged*birth year

Interactions retained for Asians (10): 1) age*overweight 2) age*16 years education 3) unmarried, paternity acknowledged*underweight 4) age*13-15 years education 5) age^2 6) age*< 9 years education 7) unmarried, paternity unacknowledged*16 years education 8) unmarried, paternity acknowledged*mother not US born 9) married, paternity unacknowledged*birth year 10) overweight*birth year
Census tract variables

The American Community Survey is an annual survey, conducted by the US Census Bureau, of 3.5 million households, assessing social, economic, housing, and demographic domains, with census tract-level data aggregated over five years to protect confidentiality (United States Census Bureau, 2017). American Community Survey 2012-16 variables were selected covering domains of census tract-level education, family structure, family income and wealth, poverty and socioeconomic distress, percent residents Black/African American, and population density as a measure of urban/rural status. Each variable was ranked and ranks were recoded to create a seven-point ordinal scale with distribution 10%/10%/20%/20%/20%/10%/10% in order to satisfy state requirements for confidentiality protection. These selected variables were reduced to two correlated factors, with interfactor correlation 0.31, by unweighted principal factor analysis (Table 2.1): a tract socioeconomic advantage-disadvantage factor (F1) and a tract rural white – urban mixed-race factor (F2). Factor scores were then ranked and recoded as quintiles to preserve confidentiality.

Birth records for all non-adopted births in state, 2005-2016, not limited to singleton nor to first births, were used to calculate census tract five-year trailing aggregate rates of SDP (ctSDP). This variable was recoded as missing for any tract with fewer than 25 births over a five-year period to protect confidentiality. Births in 2010 used census tract SDP data for 2005-9; births in 2011 used 2006-10 data, and so on. Since the analysis sample only included first births, and the census tract-level SDP rates are trailing, the index pregnancy for analysis is never included in its respective trailing window. Tracts were ranked for five-year SDP rates, separately for each birth year, and ranks recoded to quintiles.
American Community Survey (ACS)-Census tract-level characteristics

American Community Survey variables were selected under a Family Capital framework (Bourdieu, 1986), broadly covering domains including education, wealth indicators, family structure, economic distress, and other sociodemographics. Census tract-level variables were recoded into ordinal seven-level categories, containing approximately 10%/10%/20%/20%/10%/10% of the distribution, respectively. This step is necessary to protect confidentiality and aid reproducibility. Reporting results based on these quantiles prevents individuals from being identified based on individual and neighborhood sociodemographics. By comparing quantiled, versus raw, versions of the variables, future research using quantiled variables can be compared more easily to the present results. Polychoric correlations were run for all variables extracted. Variables with inherent dependencies (e.g. occupational measures requiring a certain educational level) were excluded from the analysis. An exploratory principal factor analysis was used for data-reduction, with two factors extracted based on standard eigenvalues >1 criterion. Census tracts were ranked on the factors and recoded into a five-level ordinal variable representing quintiles of the distribution to protect confidentiality and aid reproducibility, as described above. Factors were linked to birth record data via census tract. Interfactor correlation was 0.31, and factor loadings are shown in eTable 2.3.

American Community Survey Microdata

In a separate follow-up analysis, we examined data drawn from the American Community Survey (ACS) 2013-2017 microdata (Ruggles et al., 2020). ACS variables FERTYR (whether a female participant had given birth within the last 12 months), MARST (six-level
variable of marital status: Married, spouse present; Married, spouse absent; Separated; Divorced; Widowed; Never married/single), AGE, SEX, ELDCH (age of eldest child residing with participant, including step-, adopted, and biological children), and RACE, were downloaded. We used these variables to identify gestational parents aged 22-23, by race, who have given birth in previous 12 months, whose child resides with mother, by marital status, and whether they were cohabitating with their reproductive partner one year following childbirth.

2.2.3 Statistical Analysis

Analyses were conducted separately for each race/ethnic group because of the strong racial separation in the state, with ~50% of AA births but < 2% of WNH births occurring in census tracts falling in the top decile for percent residents AA. A multi-level logistic regression model, taking into account clustering of births within a given census tract, was fit to predict maternal SDP as a joint function of maternal birth record variables, including a quadratic term for age, census tract ACS factors, and five-year census tract SDP rate, separately for each race/ethnic group. To provide robust evidence for census tract-level effects, an additional logistic regression model was estimated using only maternal birth record variables, with comprehensive testing for interactive effects (G Imbens & D Rubin, 2015) to generate a ‘sociodemographic’ risk score. See eTable 2.2 for model summary statistics. The risk score was recoded to quintiles, and then used as a control variable in a multi-level model predicting SDP as a function of census tract variables. Given smaller numbers of births for all groups except WNH and AA, results for some analyses for other race/ethnic groups are presented only in supplementary tables. To examine assumptions regarding presence or lack of paternity acknowledgement, we compared current marital status and cohabitation with romantic partner patterns in ACS 2013-2017.
microdata described above. All analyses were run in SAS 9.2 and figures were generated in Stata 15.1.

2.3 Results

2.3.1 Maternal predictors

Prevalence of smoking during first pregnancy was 12.7% (WNH), 6.8% (AA), 19.5% (Native American, NA), 4.7% (Hispanic, H), and 2.8% (Asian, AS). Comparing SDP to non-SDP births, we observe, for SDP births (eTable 2.3): younger age (except for AA); less frequently married and more frequently unmarried, and especially unmarried with no paternity acknowledgement by reproductive partner; and lower educational level. Residential census tract characteristics showed increasing individual SDP rates with greater socioeconomic disadvantage, greater rural/white population, and lesser proportion of AA residents (eTable 2.4). SDP rate in Black/African Americans was inversely related to the proportion of AA residents in the tract: comparing across quintiles for increasing proportion of Black/African American residents, SDP rate was 15%, 11.1%, 10.7%, 8.0%, and 6.1%, respectively. Figure 2.1 shows, separately for white non-Hispanics and Black/African Americans, model-based predicted probabilities of maternal smoking during pregnancy, as a joint function of maternal age at childbirth, educational level, and relationship with reproductive partner (marital status and reproductive partner paternity acknowledgement), estimated under the full model including interaction terms. See eFigure 2.1 for other race/ethnic groups. Key findings are (i) expected risk differences by educational level; (ii) generally quadratic form of the relationship with age within educational levels; (iii) consistent risk differences at every age and educational level, as a function of marital status/paternity acknowledgement; and (iv) consistently lower SDP rate in AAs, particularly at
lower educational levels. Table 2.2 shows, separately by maternal race/ethnicity, Odds Ratios from a multi-level logistic regression for SDP associations with marital status/paternity acknowledgement under a model including the quadratic effect of age and main effects of other maternal characteristics, both unadjusted and adjusted for neighborhood sociodemographics and SDP rate. Full model results unadjusted (eTable 2.5) and adjusted (eTable 2.6) for census tract ACS factor quintiles and five-year SDP rate quintiles are shown separately. In models unadjusted for census tract characteristics, there is a consistent ranking of SDP rate, in every race/ethnicity, with married, paternity acknowledged < unmarried, acknowledged < unmarried, unacknowledged < married, unacknowledged, the latter hypothesized to be cases of marital breakdown during pregnancy. Odds ratios are reduced only minimally, if at all, after adjustment for census tract characteristics. There are substantial differences by race/ethnicity in proportions of people by reproductive partner relationship type, and substantial differences in median age at first childbirth and percent with any college education for marrieds versus unmarieds. However, median ages for unmarried/unacknowledged (WNH 21; AA 20) and unmarried/acknowledged (WNH 21, AA 20) are very similar, with great consistency for all groups except Asians (eTable 2.7). Differences in percent reporting any college education are also modest (unmarried/unacknowledged: WNH 36%, AA 35%; unmarried/acknowledged: WNH 44%, AA 47%).

To examine whether our assumption about presence or absence of paternity acknowledgement potentially reflected partner support/abandonment effects, rather than cohabitation effects, we consulted American Community Survey 2013-2017 microdata. We identified gestational parents living with eldest child less than age 12 months, currently aged 22-23, to examine their current marital status and cohabitation with romantic partner. For WNH
gestational parents, (N=6,408) approximate cohabitation rates with spouse/romantic partner in
the year following childbirth of oldest child were: married, 93%; separated, 16%; divorced, 39%;
ever married/single, 40%. For AA gestational parents (N=1,434), the approximate cohabitation
rates were: married, 76%; separated/divorced, 10%; never married/single, 14%. The much lower
rate of cohabitation by AA compared to WNH single/never married gestational parents, but very
consistent risk differences for pregnancies of unmarried with named versus unnamed partner,
cautions against assuming equivalence between presence/absence of paternity acknowledgement
and cohabitation/non-cohabitation during the pregnancy.

2.3.2 Census Tract Predictors

Figure 2.2 shows the Odds Ratios for the effect of quintiles of ctSDP on individual SDP
risk, adjusted for both maternal sociodemographic risk score and ACS factor scores, for WNH
and AA. See eFigure 2.2 for results for other race/ethnic groups and eTable 2.8 for detailed
results by race/ethnicity. In both WNH and AA, there is a progressive increase in risk with
increasing five-year rate of ctSDP, with this effect more pronounced in AA (e.g. for top quintile
compared to lowest quintile, WNH: OR=1.75, 95% CI 1.57-1.94; AA: OR=2.67, 95%CI 2.03-
3.52). Risk differences as a function of census tract disadvantage (F1) are modest in both WNH
and AA (highest quintile ORs: WNH 1.49 [1.34-1.66]; AA 1.23 [0.90-1.89]), with no significant
association in AAs. Risk differences as a function of rural-white/urban-mixed race (F2) are
minimal in WNH, but more pronounced in AA, with risk being highest in the most rural-white
quintile and lowest in the most urban-mixed race quintile. Table 2.3 compares selected
sociodemographic characteristics of the highest quintile for ctSDP versus pooled remaining
quintiles. A more comprehensive selection of sociodemographic variables for comparison is
shown in eTable 2.9. For AA, the high-risk quintile is characterized by a reduced proportion of AA residents (33% vs 57%). For AA, indicators of poverty and economic resources (e.g. median household income, unemployment rate, %homes receiving public assistance, %children living in poverty) were similar between the lowest 80% of tracts for ctSDP (low-risk) and highest 20% of census tracts for ctSDP (high-risk) tracts. However, for other maternal race/ethnicities, there were marked differences between low and high-risk tracts, with lower poverty and higher economic resources in low-risk tracts compared to higher poverty and fewer economic resources in high-risk tracts.

2.4 Discussion

2.4.1 Summary

This report uses a US Midwest state, with consistently high SDP rates, lowest cigarette taxes, few enacted tobacco control policies, yet permissive policies for researcher data access, to improve characterization of two social influences on smoking during first pregnancy: residential census tract-level SDP prevalence and relationship with reproductive partner (marital status and whether paternity was acknowledged). Cross-linking birth record maternal sociodemographic data with census tract American Community Survey sociodemographic data and aggregated five-year census tract rates of smoking during pregnancy provided convergent support for an important role of social influences on smoking during pregnancy. These methods allowed improved statistical control for potentially confounding neighborhood characteristics when predicting SDP risk from individual maternal variables.

2.4.2 Census Tract Predictors
At the census tract level, five-year census tract SDP rates remained significantly predictive of SDP risk, even after adjustment for effects of sociodemographic characteristics of individuals at the time of childbirth and for the effects of census tract sociodemographic disadvantage and urban-rural characteristics. Census tract rate differences, after adjustment for maternal sociodemographics, likely stem from many origins, including a broad spectrum of differences in local taxes, local policy, tobacco retail outlet proximity, and availability and quality of health care (Center for Public Health Systems Science, 2016; Centers for Disease Control and Prevention, 2015; Hall et al., 2019). The association of SDP with increasing census tract rates of SDP was stronger in Black/African Americans than in white non-Hispanics, consistent with important influences of risk-behaviors of other census tract residents, though other interpretations cannot be excluded. Noticeably, the characteristics of the highest risk census tracts for census tract smoking during pregnancy rate were starkly different between white non-Hispanics versus Black/African Americans. For high-risk tracts, white non-Hispanics showed the expected pattern of increased socioeconomic disadvantage, while the high-risk tracts in which Black/African Americans resided were primarily characterized by an increased percent of white non-Hispanic residents and unchanged levels of socioeconomic disadvantage. This is consistent with an important social risk influence, where Black/African Americans who live near white non-Hispanics, who have higher rates of smoking during pregnancy, are themselves more likely to smoke during pregnancy than Black/African Americans living in neighborhoods that are more segregated. Alternatively, Black/African Americans living in predominantly white neighborhoods may experience greater levels of discrimination and racism, making it harder to achieve smoking cessation by early pregnancy (Berger & Sanyai, 2015; Gravlee, 2009; Sims et al., 2016; Tomfohr et al., 2016).
2.4.3 Individual Predictors

For individual risk characteristics, we found that, in addition to the anticipated risk differences in unmarried versus married people, lack of reproductive partner legal acknowledgement of paternity was associated with clear differences in likelihood of individual SDP across the distribution of maternal age and educational level. After adjustment for other maternal and for census tract risk factors, there was a clear ordering of risk, consistent across all race/ethnic groups: risk was lowest for married with paternity acknowledgement, somewhat greater for unmarried with paternity acknowledgement, substantially elevated for unmarried with no paternity acknowledgment, and highest for married with no paternity acknowledgement. Acknowledgement of paternity, occurring at or after childbirth, is likely capturing aspects of the engagement versus disengagement of the reproductive partner earlier in the pregnancy, given how this effect predicts differences in SDP risk, and is not reducible to simple presence/absence of cohabitation. Several considerations support this interpretation. The risk differences associated with presence/absence of paternity acknowledgement were observed consistently across race/ethnic groups. This persists despite marked differences in partner cohabitation rates, as inferred from American Community Survey microdata on gestational parents with oldest child less than one year old: 14% versus 40% for Black/African Americans versus white non-Hispanics living with oldest child of age less than 12 months are cohabiting with a partner. Additionally, if cohabitation was driving this effect, one might have anticipated differences in household income for cohabitating versus non-cohabitating pregnant people to explain our findings. However, our findings were robust to adjustment for census tract sociodemographics. Also consistent with our reproductive partner engagement/disengagement hypothesis, SDP risk
is especially elevated for married persons with paternity not acknowledged: this effect is likely explained by breakdown of the relationship between reproductive partners, since, by law, being married at any time between conception and childbirth is recorded as “married” on the birth record in Missouri (Missouri Legislature, 2005). These findings not only support but also extend a broader research literature focused on pregnancy risk-behaviors (Kiernan & Pickett, 2006; Pickett et al., 2009; Riaz et al., 2018), with finer control for potential maternal and neighborhood sociodemographic confounders. Given high rates of co-use of cigarettes and alcohol and other substances in pregnancy, it seems plausible that similar risk-patterns would be observed for prenatal alcohol, marijuana and other illicit drug use during pregnancy (Desrosiers et al., 2016; Dukes et al., 2017; Frazer et al., 2019; Oga et al., 2019).

Conditional upon relationship with reproductive partner, white non-Hispanics and Black/African Americans were very similar in terms of age and educational level at first childbirth. However, except at the highest levels of maternal education, where overall rates of smoking during pregnancy were low, rates of SDP were also consistently lower across age, education, and relationship with reproductive partner in Black/African Americans compared to white non-Hispanics. Thus, in the context of known sociodemographic risk factors for smoking during pregnancy, these observed lower SDP rates among Black/African Americans suggest important resiliency factors that warrant further study.

2.4.4 Treatment and Policy Implications

Our results have clear applications for both treatment and policy interventions. Environmental and individual, including biological, influences are not independent (Bagby et al., 2019), and must be considered both jointly and uniquely, including in the context of smoking.
during pregnancy. Given the consistent effect of marital status/paternity acknowledgement on SDP risk, addressing both parties in the reproductive dyad is vital for improving smoking cessation and second hand smoke exposure for pregnant people and their offspring (Fergie et al., 2019; Meghea et al., 2018; Patrick, 2019; Román-Gálvez et al., 2018; Shawe et al., 2019). This distinction between reproductive partner engagement versus cohabitation may be of translational importance, since it is likely easier to ‘nudge’ (Thaler & Sunstein, 2008) unmarried fathers into greater engagement than into cohabitation. This may also aid in minimizing alcohol, marijuana, and other illicit drug use (Desrosiers et al., 2016; Frazer et al., 2019; Oga et al., 2019). Historical census tract five-year SDP rate is a variable easily constructed and shared by every state, as it is recorded on the birth record for all states. Sharing smoking during pregnancy rates at the census tract level protects confidentiality and allows consideration of the clear geographic variation in smoking during pregnancy. Once geocoded, these data are easily combined with American Community Survey data to improve prediction of maternal SDP risk, facilitating early detection of individuals at highest risk. Implementing health equity-focused policies could be an effective strategy to increase smoking cessation prior to pregnancy. Some examples include limiting tobacco retailer density, proximity to one another, and/or regulating tobacco product promotions. These policies have the added benefit of broadly promoting health equity and reducing tobacco-related health consequences (Centers for Disease Control and Prevention, 2015; Galiatsatos et al., 2020; Ribisl et al., 2017; Rodriguez et al., 2013). Consideration of neighborhood context is important when considering which interventions to implement and how to implement them—from individual to community to policy (D'Agostino et al., 2018; Gootjes et al., 2019; Hall et al., 2019; Williams & Jackson, 2005).
2.4.5 Application of Methods beyond Smoking During Pregnancy

In this population-based cohort study, we provide evidence for the important role of social influence on cigarette use during first pregnancy, with comprehensive control for confounding variables not previously achieved in the literature. The novel methods we present for combining administrative and publicly available US Census/American Community Survey data have important applications in addiction and health research beyond this application to smoking during pregnancy. Linking geocoded research and administrative datasets to US Census data allows use of universally assessed environmental measures available, which are available for all US-based samples. Most research programs can achieve this linkage at modest additional cost. This linkage of data allows important examination of geographic and social context of many questions in addiction and health research.

2.4.6 Limitations

Administrative data analyses, as presented here, leave unanswered questions only addressable by appropriately targeted new data collection. Future research must parse out, for example, if risk differences among unmarried pregnant people as a function of presence/absence of paternity acknowledgement reflect partner conflict/abandonment effects, or partner support effects (Hummer & Hamilton, 2010), or other mechanisms. However, administrative data analyses do have the advantage of identifying with considerable precision, and therefore with reduced likelihood of false positive reporting (Ioannidis, 2005a, 2005b; Ioannidis et al., 2011), phenomena requiring targeted research follow-up. Despite the potential limitations of birth record data, including likely underreporting of smoking during pregnancy and possible
misspecification in individual cases of other variables, it is unlikely that results presented herein can be dismissed as artefacts of reporting bias. The present study does not examine co-use of tobacco and other nicotine products or other substances during pregnancy, due to either unreliable reporting of data (alcohol use during pregnancy) or no report (other substances, electronic nicotine delivery systems). Future research should examine the role of social and other influences on co-substance use during pregnancy to inform treatment and policy interventions.

2.4.7 Conclusions

The social influences of marital status/paternity acknowledgement and census tract-level smoking during pregnancy rate prove to be consistent predictors of individual-risk of smoking during first pregnancy, even after accounting robustly for individual and neighborhood-level characteristics. The magnitude of these relationships varies by maternal race/ethnicity, notably that census tract SDP rate is an especially important risk factor for Black/African Americans, despite overall lower SDP rates. For neighborhood characteristics, we observed an expected transition from high economic resources in low SDP prevalence tracts to low economic resources in high SDP prevalence tracts for all maternal races, except for Black/African Americans: the tracts in which Black/African Americans reside have stable rates of lower economic resources across the distribution of census tract SDP rate. Lastly, we provide proof-of-concept for using publicly available US Census/American Community Survey in conjunction with administrative data. These methods can be extended to any US based administrative or primary research sample, with modest additional cost, to examine important social and neighborhood context of other questions in addiction and health research.
2.5 Abbreviations

AA: Black/African American
ACS: American Community Survey
AS: Asian
CDC: Centers for Disease Control and Prevention
ctSDP: census tract-level cigarette smoking during pregnancy rate
F1: Factor 1 (from American Community Survey variables)
F2: Factor 2 (from American Community Survey variables)
H: Hispanic
NA: Native American
SDP: cigarette smoking during pregnancy
WNH: white non-Hispanic

2.6 References


Center for Public Health Systems Science. (2016). Point-of-Sale Report to the Nation: Realizing the Power of States and Communities to Change the Tobacco Retail and Policy Landscape. St. Louis, MO: Center for Public Health Systems Science at the Brown School at Washington University in St. Louis and the National Cancer Institute, State and Community Tobacco Control Research Initiative


Health Coaching to Improve Periconceptional Nutrition and Lifestyle in Women: Survey in a Large Urban Municipality in the Netherlands. *JMIR Mhealth Uhealth*, 7(4), e11664. [https://doi.org/10.2196/11664](https://doi.org/10.2196/11664)


Ioannidis, J. P. (2005b). Why most published research findings are false. *PLoS Med*, 2(8), e124. [https://doi.org/10.1371/journal.pmed.0020124](https://doi.org/10.1371/journal.pmed.0020124)


Table 2.1. Factor structure of American Community Survey 2012-2016 Missouri census tract data.

<table>
<thead>
<tr>
<th>Factor 1</th>
<th>Factor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Educational level adults 25+</td>
<td>-92</td>
</tr>
<tr>
<td>Median individual income (in 2016 $)</td>
<td>-93</td>
</tr>
<tr>
<td>Median household income (in 2016 $)</td>
<td>-91</td>
</tr>
<tr>
<td>% households with investment income</td>
<td>-70</td>
</tr>
<tr>
<td>% children in poverty</td>
<td>80</td>
</tr>
<tr>
<td>% households with no vehicle</td>
<td>56</td>
</tr>
<tr>
<td>% women 18-44 without health insurance</td>
<td>76</td>
</tr>
<tr>
<td>% in owner-occupied housing</td>
<td>-45</td>
</tr>
<tr>
<td>Labor force unemployment rate</td>
<td>64</td>
</tr>
<tr>
<td>% households receiving public assistance</td>
<td>90</td>
</tr>
<tr>
<td>% housing units vacant</td>
<td>72</td>
</tr>
<tr>
<td>% children living with married parents</td>
<td>-60</td>
</tr>
<tr>
<td>% ever married now separated/divorced</td>
<td>62</td>
</tr>
<tr>
<td>% population African American</td>
<td>8</td>
</tr>
<tr>
<td>% population Hispanic</td>
<td>-9</td>
</tr>
<tr>
<td>% agricultural workers</td>
<td>29</td>
</tr>
<tr>
<td>% children in single parent families</td>
<td>51</td>
</tr>
<tr>
<td>% children living with unmarried parents</td>
<td>42</td>
</tr>
<tr>
<td>% householders living with grandchildren</td>
<td>44</td>
</tr>
<tr>
<td>Population density</td>
<td>-28</td>
</tr>
<tr>
<td>Interfactor correlation</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Factor loadings (x100) under an oblique PROMAX rotation.
Table 2.2. Maternal sociodemographics at childbirth recorded on birth record predict smoking during pregnancy, by maternal race/ethnicity, births 2010-2017.

<table>
<thead>
<tr>
<th>Maternal Race/Ethnicity</th>
<th>white, non-Hispanic</th>
<th>Black / African American</th>
<th>Native American</th>
<th>Hispanic</th>
<th>Asian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal Marital Status</td>
<td>Unadjusted</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married, Paternity Acknowledged(^a)</td>
<td>-</td>
<td>0.58 [0.47, 0.73]</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Unmarried, Paternity Acknowledged(^b)</td>
<td>3.17 [3.03, 3.32]</td>
<td>-</td>
<td>1.98 [1.50, 2.25 [1.63, 4.94 [3.07, 7.94]]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unmarried, Paternity Unacknowledged</td>
<td>4.64 [4.39, 4.90]</td>
<td>1.52 [1.37, 1.68]</td>
<td>2.47 [1.81, 3.16 [2.21, 6.84 [3.91, 11.99]]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married, Paternity Unacknowledged</td>
<td>5.46 [4.61, 6.46]</td>
<td>3.75 [2.28, 6.16]</td>
<td>7.83 [2.99, 23.11 [4.01, 133.23]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal Marital Status</td>
<td>Adjusted</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married, Paternity Acknowledged(^a)</td>
<td>-</td>
<td>0.54 [0.43, 0.68]</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Unmarried, Paternity Acknowledged(^b)</td>
<td>3.15 [3.01, 3.30]</td>
<td>-</td>
<td>2.00 [1.51, 2.42 [1.75, 5.21 [3.19, 8.50]]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) Referent for white non-Hispanics, Native Americans, Hispanics, Asians. \(^b\) Referent for Black/African Americans. See eTable 5 and eTable 6 for results from the full model.

Table 2. Odds Ratios and 95% Confidence Intervals from multi-level logistic regressions predicting maternal smoking during pregnancy from maternal sociodemographics on the birth record, unadjusted and adjusted for ACS-derived census tract sociodemographics and census tract-level five-year smoking during pregnancy rate for birth years 2010-2017. Full results for both models presented in eTable 5 (unadjusted) and eTable 6 (adjusted).
Table 2.3. Census tract characteristics from American Community Survey data, 2012-2016, for census tracts with lowest four quintiles (0-80ile) vs highest quintile (81-100ile) five-year census tract-level smoking during pregnancy rate, by maternal race/ethnicity.

<table>
<thead>
<tr>
<th></th>
<th>0-80ile census tract SDP rate</th>
<th>81-100ile census tract SDP rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>white non-Hispanic</td>
<td>Black/ African American</td>
</tr>
<tr>
<td>Population density (persons/km²)</td>
<td>N=107374</td>
<td>N=25055</td>
</tr>
<tr>
<td>% Black / African American residents</td>
<td>8.37</td>
<td>56.55</td>
</tr>
<tr>
<td>% residents with Bachelor’s degree or higher</td>
<td>32.76</td>
<td>22.50</td>
</tr>
<tr>
<td>% residents with any college education</td>
<td>63.34</td>
<td>55.83</td>
</tr>
<tr>
<td>Median household income ($)</td>
<td>59,711</td>
<td>39,981</td>
</tr>
<tr>
<td>Income to Poverty ratio&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.85</td>
<td>1.65</td>
</tr>
<tr>
<td>Unemployment rate (%)</td>
<td>5.38</td>
<td>11.82</td>
</tr>
<tr>
<td>% children living in poverty</td>
<td>15.07</td>
<td>34.83</td>
</tr>
<tr>
<td>Value of housing units ($)</td>
<td>162,386</td>
<td>106,184</td>
</tr>
<tr>
<td>% housing units vacant</td>
<td>10.64</td>
<td>22.08</td>
</tr>
<tr>
<td>% children living in married, two-parent households</td>
<td>72.91</td>
<td>42.90</td>
</tr>
<tr>
<td>% ever married, now separated/divorced</td>
<td>19.80</td>
<td>34.78</td>
</tr>
</tbody>
</table>

All statistics reported represent means. <sup>a</sup>The total family income divided by the poverty threshold is called the Ratio of Income to Poverty (US Census Bureau, 2019). [https://www.census.gov/topics/income-poverty/poverty/guidance/poverty-measures.html](https://www.census.gov/topics/income-poverty/poverty/guidance/poverty-measures.html)
<table>
<thead>
<tr>
<th>Maternal Race/Ethnicity</th>
<th>white, non-Hispanic</th>
<th>Black/African American</th>
<th>Native American</th>
<th>Hispanic</th>
<th>Asian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>N=163,222</td>
<td>N=31,257</td>
<td>N=3,221</td>
<td>N=9,763*</td>
<td>N=7,220</td>
</tr>
<tr>
<td>Smoking During Pregnancy</td>
<td>831 (0.51)</td>
<td>433 (1.39)</td>
<td>20 (0.62)</td>
<td>92 (0.94)</td>
<td>64 (0.89)</td>
</tr>
<tr>
<td>Age</td>
<td>4 (0.00)</td>
<td>3 (0.01)</td>
<td>1 (0.03)</td>
<td>2 (0.02)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Census Tract Assignment</td>
<td>21113 (12.94)</td>
<td>1491 (4.77)</td>
<td>405 (12.57)</td>
<td>875 (8.96)</td>
<td>595 (8.25)</td>
</tr>
<tr>
<td>Marital Status/</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paternity Acknowledged</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>Years Education Completed</td>
<td>304 (0.19)</td>
<td>142 (0.45)</td>
<td>7 (0.22)</td>
<td>45 (0.46)</td>
<td>22 (0.30)</td>
</tr>
<tr>
<td>Pre-Pregnancy BMI</td>
<td>1257 (0.77)</td>
<td>639 (2.04)</td>
<td>25 (0.78)</td>
<td>373 (3.82)</td>
<td>117 (1.62)</td>
</tr>
<tr>
<td>Maternal Birth Placeb</td>
<td>2952 (1.81)</td>
<td>1239 (3.96)</td>
<td>39 (1.21)</td>
<td>2953 (30.25)</td>
<td>4300 (59.56)</td>
</tr>
</tbody>
</table>

No data on year of childbirth were missing. *1,023 of 215,690 (0.47%) birth records were missing maternal Hispanicity. Observations missing maternal ethnicity were excluded from these data.

b Observations with missing (missing or not coded) maternal birth place were included using a dummy variable for missingness.
**eTable 2.2. Sociodemographic risk score model final statistics.**

<table>
<thead>
<tr>
<th>Maternal Race/Ethnicity</th>
<th>AIC</th>
<th>c statistic</th>
<th># interactions retained</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Initial, Age&lt;sup&gt;2,b&lt;/sup&gt;</td>
<td>Final Risk Score&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>white, non-Hispanic</td>
<td>86006.40</td>
<td>85314.38</td>
<td>84769.51</td>
</tr>
<tr>
<td>Black/African American</td>
<td>12917.51</td>
<td>12633.64</td>
<td>12629.40</td>
</tr>
<tr>
<td>Native American</td>
<td>2441.98</td>
<td>2387.74</td>
<td>2377.09</td>
</tr>
<tr>
<td>Hispanic</td>
<td>2898.94</td>
<td>2692.06</td>
<td>2663.20</td>
</tr>
<tr>
<td>Asian</td>
<td>1063.54</td>
<td>1006.98</td>
<td>1028.91</td>
</tr>
</tbody>
</table>

<sup>a</sup> A priori main effects plus main effects that entered in stepwise selection; <sup>b</sup> Initial model, plus a quadratic term for maternal age; <sup>c</sup> Initial model, plus stepwise main effects, plus interactions retained according to Imbens and Rubin approach for estimating the propensity score.
**eTable 2.3. Maternal sociodemographic characteristics at first childbirth as recorded on birth record, by maternal race/ethnicity, 2010-2017.**

<table>
<thead>
<tr>
<th>Maternal Race/Ethnicity</th>
<th>white, non-Hispanic</th>
<th>Black/African American</th>
<th>Native American</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SDP</td>
<td>No SDP</td>
<td>SDP</td>
</tr>
<tr>
<td>N=17,718</td>
<td>23.07 (4.74)</td>
<td>25.96 (5.37)</td>
<td>23.09 (4.59)</td>
</tr>
<tr>
<td>Age Mean (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married, Paternity Acknowledged</td>
<td>20.29</td>
<td>63.62</td>
<td>5.38</td>
</tr>
<tr>
<td>Unmarried, Paternity Acknowledged</td>
<td>53.98</td>
<td>27.67</td>
<td>38.73</td>
</tr>
<tr>
<td>Unmarried, Paternity Unacknowledged</td>
<td>24.33</td>
<td>8.36</td>
<td>54.60</td>
</tr>
<tr>
<td>Married, Paternity Unacknowledged</td>
<td>1.41</td>
<td>0.35</td>
<td>1.29</td>
</tr>
<tr>
<td>Years Education Completed (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 8 years</td>
<td>1.68</td>
<td>0.85</td>
<td>1.45</td>
</tr>
<tr>
<td>9-12 years</td>
<td>67.54</td>
<td>26.17</td>
<td>70.68</td>
</tr>
<tr>
<td>13-15 years</td>
<td>27.36</td>
<td>31.45</td>
<td>26.79</td>
</tr>
<tr>
<td>16 years</td>
<td>2.84</td>
<td>26.72</td>
<td>0.97</td>
</tr>
<tr>
<td>17+ years</td>
<td>0.58</td>
<td>14.80</td>
<td>0.11</td>
</tr>
<tr>
<td>Pre-Pregnancy BMI (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight</td>
<td>8.65</td>
<td>4.20</td>
<td>5.11</td>
</tr>
<tr>
<td>Normal</td>
<td>46.15</td>
<td>51.50</td>
<td>42.28</td>
</tr>
<tr>
<td>Overweight</td>
<td>21.69</td>
<td>22.87</td>
<td>22.91</td>
</tr>
<tr>
<td>Obese</td>
<td>23.57</td>
<td>21.43</td>
<td>29.69</td>
</tr>
<tr>
<td>Maternal Birth Place (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-State (Missouri)</td>
<td>72.42</td>
<td>67.07</td>
<td>78.32</td>
</tr>
<tr>
<td>United States, not Missouri</td>
<td>20.41</td>
<td>25.56</td>
<td>17.81</td>
</tr>
<tr>
<td>Outside United States</td>
<td>6.33</td>
<td>5.45</td>
<td>3.23</td>
</tr>
<tr>
<td>Unknown/not coded</td>
<td>0.84</td>
<td>1.93</td>
<td>0.65</td>
</tr>
<tr>
<td>Maternal Race/Ethnicity</td>
<td>Hispanic SDP</td>
<td>Hispanic No SDP</td>
<td>Asian SDP</td>
</tr>
<tr>
<td>-------------------------</td>
<td>--------------</td>
<td>-----------------</td>
<td>-----------</td>
</tr>
<tr>
<td></td>
<td>N=371</td>
<td>N=7,602</td>
<td>N=139</td>
</tr>
<tr>
<td>Age Mean (SD)</td>
<td>22.41 (4.55)</td>
<td>23.47 (5.39)</td>
<td>24.65 (5.70)</td>
</tr>
<tr>
<td>Maternal Marital Status (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married, Paternity Acknowledged</td>
<td>15.63</td>
<td>37.95</td>
<td>23.74</td>
</tr>
<tr>
<td>Unmarried, Paternity Acknowledged</td>
<td>54.72</td>
<td>44.36</td>
<td>51.08</td>
</tr>
<tr>
<td>Unmarried, Paternity Unacknowledged</td>
<td>29.11</td>
<td>17.19</td>
<td>23.74</td>
</tr>
<tr>
<td>Married, Paternity Unacknowledged</td>
<td>0.54</td>
<td>0.50</td>
<td>1.44</td>
</tr>
<tr>
<td>Years Education Completed (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 8 years</td>
<td>3.50</td>
<td>6.04</td>
<td>3.60</td>
</tr>
<tr>
<td>9-12 years</td>
<td>72.24</td>
<td>53.00</td>
<td>54.68</td>
</tr>
<tr>
<td>13-15 years</td>
<td>22.10</td>
<td>26.65</td>
<td>32.37</td>
</tr>
<tr>
<td>16 years</td>
<td>1.61</td>
<td>10.08</td>
<td>8.63</td>
</tr>
<tr>
<td>17+ years</td>
<td>0.54</td>
<td>4.24</td>
<td>0.72</td>
</tr>
<tr>
<td>Pre-Pregnancy BMI (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight</td>
<td>4.58</td>
<td>4.43</td>
<td>10.07</td>
</tr>
<tr>
<td>Normal</td>
<td>46.63</td>
<td>50.50</td>
<td>46.76</td>
</tr>
<tr>
<td>Overweight</td>
<td>26.95</td>
<td>24.55</td>
<td>21.58</td>
</tr>
<tr>
<td>Obese</td>
<td>21.83</td>
<td>20.52</td>
<td>21.58</td>
</tr>
<tr>
<td>Maternal Birth Place (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-State (Missouri)</td>
<td>41.78</td>
<td>21.53</td>
<td>35.97</td>
</tr>
<tr>
<td>United States, not Missouri</td>
<td>34.50</td>
<td>36.66</td>
<td>30.22</td>
</tr>
<tr>
<td>Outside United States</td>
<td>19.14</td>
<td>14.81</td>
<td>8.63</td>
</tr>
<tr>
<td>Unknown/not coded</td>
<td>4.59</td>
<td>26.99</td>
<td>25.18</td>
</tr>
</tbody>
</table>
eTable 2.4. Unadjusted sample smoking during pregnancy prevalence, by American Community Survey neighborhood characteristics, and by maternal race/ethnicity, 2010-2017.

<table>
<thead>
<tr>
<th></th>
<th>Factor 1: Socioeconomic Disadvantage</th>
<th>Factor 2: Population Density</th>
<th>% Residents Black/African American</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low 0-20 21-40 41-60 61-80 81-100</td>
<td>Low 0-20 21-40 41-60 61-80 81-100</td>
<td>Low 0-20 21-40 41-60 61-80 81-100</td>
</tr>
<tr>
<td>Black/African</td>
<td>High 4.92 5.32 5.39 7.39 7.44</td>
<td>High 17.37 12.37 10.67 6.43 6.03</td>
<td>High 14.93 11.06 10.66 7.98 6.05</td>
</tr>
<tr>
<td>American</td>
<td>Native American</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>Low 9.07 18.81 20.89 23.66 21.42</td>
<td>Low 25.00 22.85 18.06 19.34 14.84</td>
<td>Low 21.97 23.49 22.41 18.88 12.56</td>
</tr>
<tr>
<td>Hispanic</td>
<td>High 3.54 4.87 5.51 4.84 4.30</td>
<td>High 7.53 6.28 4.52 4.26 3.68</td>
<td>High 7.50 6.61 3.83 4.47 3.61</td>
</tr>
<tr>
<td>Asian</td>
<td>Low 1.12 2.91 3.14 4.65 5.17</td>
<td>Low 8.45 3.54 2.18 2.40 2.86</td>
<td>Low 5.20 3.61 2.72 2.43 2.40</td>
</tr>
</tbody>
</table>
**eTable 2.5. Maternal sociodemographics at childbirth recorded on birth record predict smoking during pregnancy, by maternal race/ethnicity, unadjusted for ACS-derived census tract sociodemographics and five-year census tract-level smoking during pregnancy rate, births 2010-2017.**

<table>
<thead>
<tr>
<th>Maternal race</th>
<th>white, non-Hispanic</th>
<th>Black/African American</th>
<th>Native American</th>
<th>Hispanic</th>
<th>Asian</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.38 [1.34, 1.42]</td>
<td>1.83 [1.68, 2.00]</td>
<td>1.68 [1.40, 2.01]</td>
<td>1.54 [1.27, 1.87]</td>
<td>1.12 [0.86, 1.45]</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>1.00 [0.99, 1.00]</td>
<td>0.99 [0.99, 0.99]</td>
<td>0.99 [0.99, 1.00]</td>
<td>0.99 [0.99, 1.00]</td>
<td>1.00 [0.99, 1.00]</td>
</tr>
<tr>
<td><strong>Maternal Marital Status</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married, Paternity Acknowledged</td>
<td>-</td>
<td>0.58 [0.47, 0.73]</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Married, Paternity Unacknowledged</td>
<td>5.46 [4.61, 6.46]</td>
<td>3.75 [2.28, 6.16]</td>
<td>7.83 [2.99, 20.52]</td>
<td>1.83 [0.42, 8.00]</td>
<td>23.11 [4.01, 133.23]</td>
</tr>
<tr>
<td><strong>Years Education Completed</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 8 years</td>
<td>1.11 [0.97, 1.27]</td>
<td>1.82 [1.19, 2.78]</td>
<td>1.60 [0.78, 3.30]</td>
<td>0.68 [0.38, 1.22]</td>
<td>1.26 [0.47, 3.38]</td>
</tr>
<tr>
<td>9-12 years (Referent)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13-15 years</td>
<td>0.35 [0.34, 0.37]</td>
<td>0.36 [0.33, 0.41]</td>
<td>0.27 [0.21, 0.35]</td>
<td>0.45 [0.34, 0.60]</td>
<td>0.58 [0.39, 0.89]</td>
</tr>
<tr>
<td>16 years</td>
<td>0.06 [0.05, 0.06]</td>
<td>0.06 [0.04, 0.09]</td>
<td>0.07 [0.03, 0.13]</td>
<td>0.09 [0.04, 0.21]</td>
<td>0.19 [0.10, 0.38]</td>
</tr>
<tr>
<td>17 years</td>
<td>0.02 [0.02, 0.03]</td>
<td>0.03 [0.01, 0.12]</td>
<td>0.02 [0.003, 0.17]</td>
<td>0.08 [0.02, 0.33]</td>
<td>0.03 [0.004, 0.20]</td>
</tr>
<tr>
<td><strong>Pre-Pregnancy BMI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight</td>
<td>1.47 [1.38, 1.57]</td>
<td>0.97 [0.77, 1.21]</td>
<td>1.52 [1.04, 2.20]</td>
<td>0.95 [0.56, 1.59]</td>
<td>1.36 [0.73, 2.51]</td>
</tr>
<tr>
<td>Normal (Referent)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Overweight</td>
<td>1.04 [0.99, 1.09]</td>
<td>0.94 [0.82, 1.06]</td>
<td>0.86 [0.65, 1.13]</td>
<td>1.13 [0.87, 1.47]</td>
<td>1.54 [0.97, 2.44]</td>
</tr>
<tr>
<td>Obese</td>
<td>1.07 [1.02, 1.11]</td>
<td>0.89 [0.79, 1.01]</td>
<td>0.94 [0.73, 1.22]</td>
<td>0.88 [0.66, 1.17]</td>
<td>1.98 [1.23, 3.20]</td>
</tr>
<tr>
<td><strong>Maternal Birth Place</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-state (Missouri; Referent)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>US Born, not in-state</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Not US Born</td>
<td>1.07 [0.99, 1.14]</td>
<td>-</td>
<td>0.84 [0.67, 1.05]</td>
<td>0.48 [0.37, 0.62]</td>
<td>0.45 [0.28, 0.72]</td>
</tr>
<tr>
<td>Unknown</td>
<td>0.62 [0.52, 0.74]</td>
<td>0.17 [0.10, 0.31]</td>
<td>0.31 [0.09, 1.09]</td>
<td>0.07 [0.04, 0.11]</td>
<td>0.26 [0.16, 0.43]</td>
</tr>
<tr>
<td>Child Birth Year</td>
<td>0.93 [0.93, 0.94]</td>
<td>0.93 [0.91, 0.95]</td>
<td>0.93 [0.89, 0.97]</td>
<td>0.99 [0.94, 1.03]</td>
<td>0.92 [0.85, 1.00]</td>
</tr>
</tbody>
</table>

*Beta coefficient for age: WNH 0.32, AA 0.61, NA 0.52, H 0.43, AS 0.11; B Beta coefficient for age: WNH -0.01, AA -0.01, NA -0.01, H -0.01, AS -0.002; C Referent for white non-Hispanics, Native Americans, Hispanics, Asians; D Referent for African Americans; E “Married” on the birth record includes someone who was married at anytime during their pregnancy until childbirth, which includes people who experienced a divorce between becoming pregnant and giving birth; F Beta coefficient for birth year: WNH -0.07, AA -0.08, NA -0.07, H -0.01, AS -0.08; G did not enter stepwise selection.
Table 2.6. Maternal sociodemographics at childbirth recorded on birth record predict smoking during pregnancy, by maternal race/ethnicity, adjusted for ACS-derived census tract sociodemographics and five-year census tract-level smoking during pregnancy rate, births 2010-2017.

<table>
<thead>
<tr>
<th>Maternal race</th>
<th>white, non-Hispanic</th>
<th>Black/African American</th>
<th>Native American</th>
<th>Hispanic</th>
<th>Asian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.40 [1.36, 1.44]</td>
<td>1.86 [1.71, 2.03]</td>
<td>1.73 [1.44, 2.08]</td>
<td>1.53 [1.26, 1.87]</td>
<td>1.13 [0.87, 1.46]</td>
</tr>
<tr>
<td>Age&lt;sup&gt;2,b&lt;/sup&gt;</td>
<td>1.00 [0.99, 1.00]</td>
<td>0.99 [0.99, 0.99]</td>
<td>0.99 [0.99, 0.99]</td>
<td>0.99 [0.99, 1.00]</td>
<td>1.00 [0.99, 1.00]</td>
</tr>
</tbody>
</table>

### Maternal Marital Status

<table>
<thead>
<tr>
<th>Maternal Marital Status</th>
<th>Married, Paternity Acknowledged&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Unmarried, Paternity Acknowledged&lt;sup&gt;d&lt;/sup&gt;</th>
<th>Unmarried, Paternity Unacknowledged</th>
<th>Married, Paternity Unacknowledged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Hispanic</td>
<td>1.00 [0.99, 1.00]</td>
<td>2.00 [1.51, 2.66]</td>
<td>2.80 [2.03, 3.84]</td>
<td>10.38 [4.09, 26.36]</td>
</tr>
<tr>
<td>Black/African American</td>
<td>1.86 [1.71, 2.03]</td>
<td>2.42 [1.75, 3.36]</td>
<td>3.58 [2.49, 5.15]</td>
<td>1.80 [0.40, 8.20]</td>
</tr>
<tr>
<td>Native American</td>
<td>1.73 [1.44, 2.08]</td>
<td>5.21 [3.19, 8.50]</td>
<td>7.84 [4.39, 14.01]</td>
<td>7.68 [1.49, 39.52]</td>
</tr>
<tr>
<td>Hispanic</td>
<td>1.53 [1.26, 1.87]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>1.13 [0.87, 1.46]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Years Education Completed

<table>
<thead>
<tr>
<th>Years</th>
<th>Less than 8 years</th>
<th>9-12 years (Referent)</th>
<th>13-15 years</th>
<th>16 years</th>
<th>17 years</th>
<th>Pre-Pregnancy BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.08 [0.94, 1.24]</td>
<td></td>
<td>1.69 [1.10, 2.60]</td>
<td>1.84 [0.93, 3.66]</td>
<td>0.88 [0.50, 1.54]</td>
<td>1.36 [0.49, 3.81]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.46 [1.36, 1.56]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.98 [0.78, 1.22]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.56 [1.06, 2.28]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.96 [0.57, 1.59]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.34 [0.71, 2.53]</td>
</tr>
</tbody>
</table>

### Maternal Birth Place

<table>
<thead>
<tr>
<th>Maternal Birth Place</th>
<th>In-state (Missouri)</th>
<th>US Born, not Missouri</th>
<th>Not US Born</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>White</td>
<td>-</td>
<td>-</td>
<td>1.03 [0.96, 1.11]</td>
<td>0.68 [0.57, 0.81]</td>
</tr>
<tr>
<td>Non-Hispanic</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.17 [0.10, 0.31]</td>
</tr>
<tr>
<td>Black/African American</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.34 [0.09, 1.22]</td>
</tr>
<tr>
<td>Native American</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.07 [0.04, 0.12]</td>
</tr>
<tr>
<td>Hispanic</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.28 [0.17, 0.48]</td>
</tr>
<tr>
<td>Asian</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Child Birth Year<sup>e</sup>

| Child Birth Year<sup>e</sup> | 0.93 [0.92, 0.94] | 0.91 [0.89, 0.93] | 0.93 [0.89, 0.98] |

<sup>a</sup> Beta coefficient for age: WNH 0.33, AA 0.62, NA 0.55, H 0.43, AS 0.12; <sup>b</sup> Beta coefficient for age<sup>2</sup>: WNH -0.01, AA -0.01, NA -0.01, H -0.01, AS -0.001; <sup>c</sup> Referent for white non-Hispanics, Native Americans, Hispanics, Asians; <sup>d</sup> Referent for African Americans; <sup>e</sup> Beta coefficient for birth year: WNH -0.07, AA -0.09, NA -0.07, H -0.03, AS -0.08; ' did not enter stepwise selection into model.
### eTable 2.7. Maternal median age at reproduction and percent college education as a function of relationship at childbirth with reproductive partner and race/ethnicity: births 2010-2017.

<table>
<thead>
<tr>
<th>Relationship with Reproductive Partner</th>
<th>Age at Reproduction</th>
<th>% Any College Education</th>
<th>Age at Reproduction</th>
<th>% Any College Education</th>
<th>Age at Reproduction</th>
<th>% Any College Education</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Median (IQR)</td>
<td></td>
<td>N</td>
<td>Median (IQR)</td>
<td></td>
</tr>
<tr>
<td>white, non-Hispanic</td>
<td>14632</td>
<td>21 (19-24)</td>
<td>36.35</td>
<td>43577</td>
<td>21 (19-25)</td>
<td>44.37</td>
</tr>
<tr>
<td>Black/African American</td>
<td>12085</td>
<td>20 (19-23)</td>
<td>34.85</td>
<td>12487</td>
<td>21 (19-24)</td>
<td>46.65</td>
</tr>
<tr>
<td>Native American</td>
<td>606</td>
<td>20 (18-24)</td>
<td>35.15</td>
<td>1149</td>
<td>21 (19-24)</td>
<td>38.73</td>
</tr>
<tr>
<td>Hispanic</td>
<td>1442</td>
<td>20 (18-23)</td>
<td>22.19</td>
<td>3607</td>
<td>21 (19-24)</td>
<td>29.30</td>
</tr>
<tr>
<td>Asian</td>
<td>287</td>
<td>23 (19-28)</td>
<td>47.04</td>
<td>804</td>
<td>24 (20-28)</td>
<td>52.36</td>
</tr>
<tr>
<td></td>
<td>Socioeconomic advantage</td>
<td>Socioeconomic disadvantage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------------</td>
<td>-----------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low population density / ctSDP</td>
<td>High population density / ctSDP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-20ile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-40ile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41-60ile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>61-80ile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>81-100ile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>white non-Hispanic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 1: ACS Factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor 1</td>
<td>-</td>
<td>1.35 [1.25, 1.45]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor 2</td>
<td>1.39 [1.28, 1.51]</td>
<td>1.25 [1.16, 1.35]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 2: Five-year aggregate census tract rate of smoking during pregnancy</td>
<td>-</td>
<td>1.59 [1.47, 1.72]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 3: Combined</td>
<td>-</td>
<td>1.87 [1.73, 2.02]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Black/African American</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 1: ACS Factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor 1</td>
<td>-</td>
<td>1.11 [1.03, 1.21]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor 2</td>
<td>1.15 [1.06, 1.26]</td>
<td>1.07 [0.99, 1.15]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ctSDP</td>
<td>-</td>
<td>1.40 [1.27, 1.54]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ctSDP</td>
<td>-</td>
<td>1.57 [1.42, 1.73]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Native American</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 1: ACS Factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor 1</td>
<td>-</td>
<td>1.04 [0.77, 1.40]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor 2</td>
<td>2.80 [1.78, 4.42]</td>
<td>2.60 [1.96, 3.44]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ctSDP</td>
<td>-</td>
<td>1.72 [1.37, 2.15]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

80
## eTable 2.8. Prediction of smoking during pregnancy using neighborhood-level variables by multi-level logistic regression, adjusted for maternal sociodemographics at time of childbirth, continued.

<table>
<thead>
<tr>
<th></th>
<th>Socioeconomic advantage</th>
<th>Socioeconomic disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-20ile</td>
<td>21-40ile</td>
</tr>
<tr>
<td></td>
<td>20ile</td>
<td>40ile</td>
</tr>
<tr>
<td>Hispanic</td>
<td>Low population density / ctSDP</td>
<td></td>
</tr>
<tr>
<td>Model 1: ACS Factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factor 1&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td>1.20 [0.76, 1.88]</td>
</tr>
<tr>
<td>Factor 2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.13 [1.30, 3.49]</td>
<td>2.03 [1.34, 3.07]</td>
</tr>
<tr>
<td>ctSDP</td>
<td>Model 2: ctSDP</td>
<td></td>
</tr>
<tr>
<td>Factor 1</td>
<td></td>
<td>0.94 [0.58, 1.54]</td>
</tr>
<tr>
<td>Factor 2</td>
<td>1.34 [0.80, 2.25]</td>
<td>1.38 [0.90, 2.12]</td>
</tr>
<tr>
<td>ctSDP</td>
<td>Model 3: Combined</td>
<td></td>
</tr>
<tr>
<td>Factor 1</td>
<td></td>
<td>1.03 [0.62, 1.72]</td>
</tr>
<tr>
<td>Asian</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 1: ACS Factors</td>
<td></td>
<td>1.65 [0.88, 3.09]</td>
</tr>
<tr>
<td>Factor 2</td>
<td>2.35 [1.03, 5.33]</td>
<td>1.24 [0.64, 2.42]</td>
</tr>
<tr>
<td>ctSDP</td>
<td>Model 2: ctSDP</td>
<td></td>
</tr>
<tr>
<td>Factor 1</td>
<td></td>
<td>0.96 [0.53, 1.74]</td>
</tr>
<tr>
<td>Factor 2</td>
<td>1.55 [0.61, 3.95]</td>
<td>0.98 [0.48, 2.00]</td>
</tr>
<tr>
<td>ctSDP</td>
<td>Model 3: Combined</td>
<td></td>
</tr>
<tr>
<td>Factor 1</td>
<td></td>
<td>1.70 [0.86, 3.37]</td>
</tr>
<tr>
<td>Factor 2</td>
<td>1.55 [0.61, 3.95]</td>
<td>0.98 [0.48, 2.00]</td>
</tr>
<tr>
<td>ctSDP</td>
<td></td>
<td>0.83 [0.44, 1.58]</td>
</tr>
</tbody>
</table>

<sup>a</sup> Factor 1: scaled from socioeconomic disadvantage to socioeconomic advantage; <sup>b</sup> scaled from rural / low mixed race population to urban / high mixed race population.
### Table 2.9.
Census tract characteristics from American Community Survey data, 2012-2016, for census tracts with lowest four quintiles (0-80ile) vs highest quintile (81-100ile) five-year census tract-level smoking during pregnancy rate, by maternal race/ethnicity.

<table>
<thead>
<tr>
<th></th>
<th>0-80ile census tract SDP rate</th>
<th>81-100ile census tract SDP rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>white non-Hispanic</td>
<td>Black/African American</td>
</tr>
<tr>
<td>N=107374</td>
<td>N=25055</td>
<td>N=2042</td>
</tr>
<tr>
<td>* Population density (persons/km²)</td>
<td>846.50</td>
<td>1559.90</td>
</tr>
<tr>
<td>* % Black / African American residents</td>
<td>8.37</td>
<td>56.55</td>
</tr>
<tr>
<td>% American Indian / Alaska Native residents</td>
<td>1.21</td>
<td>1.29</td>
</tr>
<tr>
<td>* % Hispanic residents</td>
<td>4.08</td>
<td>4.50</td>
</tr>
<tr>
<td>% born in-state</td>
<td>65.27</td>
<td>68.82</td>
</tr>
<tr>
<td>* % residents with Bachelor’s degree or higher</td>
<td>32.76</td>
<td>22.50</td>
</tr>
<tr>
<td>* % residents with any college education</td>
<td>63.34</td>
<td>55.83</td>
</tr>
<tr>
<td>Median male full-time income ($)</td>
<td>51,080</td>
<td>39,862</td>
</tr>
<tr>
<td>Median female full-time income ($)</td>
<td>38,816</td>
<td>33,795</td>
</tr>
<tr>
<td>* Median household income ($)</td>
<td>59,711</td>
<td>39,981</td>
</tr>
<tr>
<td>* Income to Poverty ratio*</td>
<td>1.85</td>
<td>1.65</td>
</tr>
<tr>
<td>* Unemployment rate (%)</td>
<td>5.38</td>
<td>11.82</td>
</tr>
<tr>
<td>% part-time female workers</td>
<td>39.97</td>
<td>40.87</td>
</tr>
<tr>
<td>% part-time male workers</td>
<td>29.06</td>
<td>35.62</td>
</tr>
<tr>
<td>% households receiving interest/dividend income</td>
<td>22.07</td>
<td>11.95</td>
</tr>
<tr>
<td>* % children living in poverty</td>
<td>15.07</td>
<td>34.83</td>
</tr>
<tr>
<td>% households with no vehicle</td>
<td>5.44</td>
<td>16.63</td>
</tr>
<tr>
<td>% children 6-17 without health insurance</td>
<td>5.80</td>
<td>7.76</td>
</tr>
<tr>
<td>* % women 18-44 w/o health insurance</td>
<td>14.39</td>
<td>22.59</td>
</tr>
</tbody>
</table>
Table 2.9. Census tract characteristics from American Community Survey data, 2012-2016, for census tracts with lowest four quintiles (0-80ile) vs highest quintile (81-100ile) five-year census tract-level smoking during pregnancy rate, by maternal race/ethnicity, continued.

<table>
<thead>
<tr>
<th></th>
<th>0-80ile census tract SDP rate</th>
<th>81-100ile census tract SDP rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>white non-Hispanic</td>
<td>Black/ African American</td>
</tr>
<tr>
<td></td>
<td>N=107374</td>
<td>N=25055</td>
</tr>
<tr>
<td>% agricultural workers</td>
<td>1.23</td>
<td>0.43</td>
</tr>
<tr>
<td>% professional/scientific/management workers</td>
<td>9.96</td>
<td>10.52</td>
</tr>
<tr>
<td>% Occupation: management, business, science, arts</td>
<td>38.03</td>
<td>29.21</td>
</tr>
<tr>
<td>% Occupation: service industry</td>
<td>16.53</td>
<td>24.63</td>
</tr>
<tr>
<td>% Occupation: sales and office</td>
<td>24.78</td>
<td>26.08</td>
</tr>
<tr>
<td>% Occupation: production, transportation, material moving</td>
<td>12.19</td>
<td>13.74</td>
</tr>
<tr>
<td>% Occupation: military</td>
<td>0.26</td>
<td>0.15</td>
</tr>
</tbody>
</table>

* Value of housing units ($) 162,386 106,184 136,302 128,799 183,725 104,808 80,510 101,552 96,601 102,601
Gross rent ($) 858 824 828 815 911 665 675 669 682 691
Real estate taxes ($) 1,508 946 1,342 1,172 1,340 1,238 733 1,230 1,049 1,085
Housing costs ($) 1,293 1,131 1,191 1,164 1,411 975 924 968 958 953
% living in owner-occupied housing 70.82 51.91 64.84 60.48 62.66 66.00 48.81 63.46 59.50 56.95
* % housing units vacant 10.64 22.08 13.27 16.15 10.46 19.21 23.80 20.30 22.25 19.52
% living in group quarters 6.06 20.01 2.15 2.24 2.56 3.52 4.08 3.34 2.82 5.23
% households with children 5-17 years 16.70 17.17 16.81 16.83 15.25 17.06 16.96 17.46 17.11 16.31
% children in single parent families 22.12 49.25 28.19 30.85 24.38 26.40 46.79 27.16 30.64 30.85
% children in unmar. coparent families 6.71 8.38 7.70 7.63 6.48 10.27 11.49 11.11 19.61 10.48
% children living with grandparent 6.06 10.74 7.47 7.44 5.38 8.15 10.19 8.74 7.62 8.37
* % children in married, two-parent households 72.91 42.90 65.69 63.35 70.98 64.89 42.13 63.78 60.41 60.18
<table>
<thead>
<tr>
<th></th>
<th>0-80ile census tract SDP rate</th>
<th>81-100ile census tract SDP rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>white non-Hispanic</td>
<td>Black/ African American</td>
</tr>
<tr>
<td>% children living with unmarried mother</td>
<td>N=107374</td>
<td>N=25055</td>
</tr>
<tr>
<td></td>
<td>20.05</td>
<td>49.06</td>
</tr>
<tr>
<td>% children living with unmarried father</td>
<td>N=107374</td>
<td>N=25055</td>
</tr>
<tr>
<td></td>
<td>7.04</td>
<td>8.04</td>
</tr>
<tr>
<td>% adults living with unmarried partner</td>
<td>N=107374</td>
<td>N=25055</td>
</tr>
<tr>
<td></td>
<td>6.40</td>
<td>7.00</td>
</tr>
<tr>
<td>* % ever married, now separated/div.</td>
<td>N=107374</td>
<td>N=25055</td>
</tr>
<tr>
<td></td>
<td>19.80</td>
<td>34.78</td>
</tr>
</tbody>
</table>

All statistics reported represent means. *Reported in main Table 3. *The total family income divided by the poverty threshold is called the Ratio of Income to Poverty (US Census Bureau, 2019). [https://www.census.gov/topics/income-poverty/poverty/guidance/poverty-measures.html](https://www.census.gov/topics/income-poverty/poverty/guidance/poverty-measures.html)
Figure 2.1. Predicted probability of smoking during pregnancy as a function of maternal age and years education completed, stratified by maternal race/ethnicity and marital status. Panels a-c: For white non-Hispanics, being married/having paternity acknowledgement is especially protective for smoking during pregnancy risk. Similar patterns for SDP risk are seen between both unmarried groups (panels a,b), with the protective effect of increasing years of education particularly apparent. Panels d-f: There is an overall reduction in predicted probability of SDP
for Black/African Americans compared to white non-Hispanics. However, similar patterns emerge—increasing years education completed and being married/having paternity acknowledgement both reduce SDP risk. Means for predicted probability of SDP for each maternal age x marital status/paternity acknowledgement x education level are plotted with shaded areas representing the 95% confidence interval. Any cell size < 9 was censored from the plot.
Figure 2.2. Five-year census tract-level rates of smoking during pregnancy predict individual smoking during pregnancy, adjusted for individual sociodemographics and ACS-derived census tract sociodemographics, lowest quintile census tract rate of smoking during pregnancy as referent.

- **white, non-Hispanic**
  - Odds Ratio (95% CI)
    - 0-20ile (ref): 1.00 (1.00, 1.00)
    - 21-40ile: 1.26 (1.15, 1.37)
    - 41-60ile: 1.40 (1.27, 1.54)
    - 61-80ile: 1.57 (1.42, 1.73)
    - 81-100ile: 1.75 (1.57, 1.94)

- **Black/African American**
  - Odds Ratio (95% CI)
    - 0-20ile (ref): 1.00 (1.00, 1.00)
    - 21-40ile: 1.35 (1.08, 1.68)
    - 41-60ile: 1.72 (1.37, 2.15)
    - 61-80ile: 2.02 (1.59, 2.56)
    - 81-100ile: 2.67 (2.03, 3.52)

Figure 2.2. Results from a multi-level logistic regression predicting smoking during pregnancy by five-year census tract smoking during pregnancy rates, adjusted for maternal sociodemographics and ACS-derived census tract sociodemographics for address at time of childbirth. When compared to the census tracts with lowest rates of smoking during pregnancy (0-20ile), increasing rate of census tract smoking during pregnancy increases maternal smoking during pregnancy, beyond individual and neighborhood-level influences. For white non-
Hispanics, there is a modest but consistent elevation in smoking during pregnancy with increasing census tract smoking during pregnancy rate. This effect is stronger for Black/African Americans. Error bars reflect 95% confidence intervals for Odds Ratio estimates.
eFigure 2.1. Maternal Age versus Predicted Probability of SDP, by Years Education Completed and Marital Status/Paternity Acknowledgement, for Native Americans, Hispanics, and Asians.

Panels a-c: for Native Americans, similar risk patterns are observed between both unmarried groups (panels a,b) by education level. SDP risk is reduced for the married, paternity acknowledged group (panel c).

Panels d-f: for Hispanics, there is overall low predicted risk for SDP in all groups. There is seemingly reduced SDP risk with increasing years of education completed, which is most apparent in the married, paternity acknowledged group.

Panels g-i: for Asians, there is overall
low predicted risk for SDP in all groups. There is seemingly reduced SDP risk with increasing years of education completed, which is most apparent in the married, paternity acknowledged group. Means for predicted probability of SDP for each maternal age x marital status/paternity acknowledgement x education level are plotted with shaded areas representing the 95% confidence interval. Any cell size < 9 was censored from the plot.
eFigure 2.2. Five-year census tract-level rate of smoking during pregnancy predicts individual smoking during pregnancy, adjusted for individual sociodemographics and ACS-derived census tract sociodemographics, lowest quintile census tract-level rate of smoking during pregnancy as referent.

eFigure 2.2. Results from a multi-level logistic regression predicting smoking during pregnancy by five-year census tract-level smoking during pregnancy rates, adjusted for maternal sociodemographics and ACS-derived census tract sociodemographics for address at time of childbirth. When compared to the census tracts with lowest rates of smoking during pregnancy (0-20ile), increasing rate of census tract smoking during pregnancy increases risk for maternal smoking during pregnancy, beyond individual and neighborhood-level influences. For Hispanics,
there is a consistent elevation in risk with increasing census tract smoking during pregnancy rate. This effect is stronger for African Americans. For Native Americans, there is an overall elevated risk for the highest two quintiles for SDP risk. Error bars reflect 95% confidence intervals for Odds Ratio estimates.
Chapter 3: Maternal race/ethnic differences in association between lifetime DUI history and cigarette smoking during first pregnancy

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This study was designed by ANHL, KKB, ACH, with input from VVM. Analyses were designed and completed by ANHL, with input from ACH, KKB, ML, and VVM. ANHL drafted the first
version of the manuscript, tables, and figures. All authors contributed to and approved the final manuscript.

### 3.1 Introduction

The United States’ median age of first pregnancy is 26.9 years (Martin et al., 2019), coinciding with a high risk period for alcohol and nicotine use disorders (Goodwin et al., 2013; Grant et al., 2015; Huggett et al., 2019). In the United States, 11.5% of pregnant people reported alcohol use in the past 30 days, 3.9% reported 4+ drinks on a single occasion (“binge drinking”), and 15.4% reported smoking cigarettes beyond their first trimester (Denny et al., 2019; Martin et al., 2019). Cigarette and alcohol use in pregnancy have well-established negative health consequences for pregnant people and their offspring (Gould et al., 2020; Hayes et al., 2021; Oh et al., 2020; Roerecke & Rehm, 2013), yet most existing research focuses on outcomes for offspring exposed to alcohol or tobacco in utero. Of studies to examine outcomes for pregnant people, few adequately investigated the associations between severe alcohol use and tobacco use during pregnancy. In the present analysis, we examined the history of Driving Under the Influence (DUI) as a marker of heavy alcohol use (Bender et al., 2018; McCutcheon et al., 2009). People with history of multiple DUlS have rates of AUD as high as 95% (Lapham et al., 2006; LaPlante et al., 2008). Research on alcohol use and disorder, and especially severe forms of disorder, has disproportionately focused on cisgender males, with less attention given to women and to other historically excluded populations (Meyer et al., 2019). There are important sociodemographic risk factors for substance use in pregnancy, which are often not well accounted for in the literature. In particular, if studies even include information about the
reproductive partner, it is often only in terms of the gestational parent being married/unmarried, without considering reproductive partner engagement or disengagement (Erng et al., 2020; Hummer & Hamilton, 2010; Oh et al., 2017; Riaz et al., 2018; Yang & Hall, 2019). We used population-level data from Missouri as a high-risk case study, due to high SDP rates (Drake et al., 2018), low tobacco and alcohol taxes, low financial investment in smoking cessation services (American Lung Association, 2021), and permissive policies for administrative data access for researchers. Using DUI occurrence as an index of severe alcohol problems, we examined whether lifetime DUI history is associated with SDP beyond individual and neighborhood-level characteristics, including census tract-level SDP rate.

3.2 Materials and Methods

3.2.1 Study Sample

The sample used in this study, methods used for risk score estimation, and details about variable coding have been described previously (Houston-Ludlam et al., 2020; McCutcheon et al., 2019). Briefly, though the resources of the Family and Population Research Center (FPRC) at Washington University, a population-cohort of all first, singleton births in the state of Missouri, 2010-2017, was extracted from the Missouri birth record, with approval from the Missouri Department of Health and Senior Services. The study sample was further integrated with two additional sources: 2012-2016 American Community Survey data via census tract FIPS number, and convictions for DUlIs and other alcohol-related driving offenses from the Missouri Department of Revenue via an FPRC-generated unique identifier. The physical addresses from birth records were geocoded to obtain the residential census tracts based on 2010 US Census
boundaries. DUls and related conviction records from 2000-2017 were received from the Missouri Department of Revenue. Using maternal self-reported race/ethnic identity on the birth record, we limited our analyses to white non-Hispanic (N=140,240), Black/African American (N=28,720), and Hispanic (N=8,431) gestational parents, as the total number of DUls for Asian and Native American gestational parents did not permit meaningful analysis. This study received ethical approval from the FPRC Review Board, Washington University Institutional Review Board, and Missouri Department of Health and Senior Services Ethical Review Board.

3.2.2 Birth Record

Variables extracted from birth record data included: child birth year, maternal age, years of education completed, marital status, presence/absence of name of reproductive partner (which indicates whether or not the partner completed an affidavit of paternity, typically at time of childbirth), number of living children, number of deceased children, race/ethnicity, and cigarette quantity smoked during the three months prior to pregnancy and during each trimester of pregnancy.

In addition to sociodemographic variables extracted from the birth record, an aggregate measure of smoking during pregnancy rate by census tract was created. Using birth records for all non-adopted births in state 2005-2016, trailing five-year windows were generated and linked to each birth year in the sample—e.g. for birth year 2010, the aggregate SDP rate for 2005-2009 was used, for birth year 2011 the aggregate SDP rate for 2006-2010 was used, and so on. Aggregate rates were calculated for each sample year, then converted into an ordinal variable.
representing quintiles. This variable was recoded to missing for any tracts with less than 25
births in a five-year period.

3.2.3 American Community Survey

The American Community Survey is an annual survey, conducted by the US Census
Bureau, of 3.5 million households, assessing social, economic, housing, and demographic
domains, with census tract-level data aggregated over five years to protect confidentiality
(United States Census Bureau, 2017). Variables were selected under a Family Capital framework
(Bourdieu, 1986), broadly covering domains including education, wealth, family structure,
economic distress, and other sociodemographic characteristics. Variables were reduced to two
correlated factors by unweighted principal factor analysis. The first factor represented
socioeconomic advantage-disadvantage, and the second factor represented a rural white–urban
mixed-race dimension.

3.2.4 Alcohol-related driving convictions

DUIs and related convictions were counted in driving records from 2000-2017 from
Missouri Department of Revenue. The count included outright DUI conviction, excessive blood
alcohol content (> 0.08, range 0.08-0.32, median=0.16), tampering with ignition interlock
device, and manslaughter. Excessive BAC was included because it is possible to plea bargain
DUIs for lesser conviction, given sufficient resources to hire legal help. Tampering with
interlock devices was included as they are required in the vehicles of subjects with two or more
DUIs.
3.2.5 Analysis

Descriptive statistics for maternal sociodemographics were generated. Differences in relationship status with reproductive partner and maternal age by DUI count were further examined. The main analysis was two multivariable multi-level logistic regression models, with cigarette smoking beyond first trimester on the birth record as outcome, by DUI count. The first model included maternal age and age$^2$ as covariates and was considered “unadjusted”. Based on the first model, the second “adjusted” model included maternal birth record sociodemographic risk score, ACS-derived neighborhood characteristics, and five-year census tract-level SDP rate. The multi-level regression accounts for clustering of births within census tracts. Analyses were run in SAS 9.4, and the figure was generated with Stata 15.1 (Fisher, 2018).

3.3 Results

DUI occurrence in the study sample was as follows—white non-Hispanic 1DUI 0.90%, 2+DUI 0.29%; Black/African American 1DUI 0.23%, 2+DUI 0.06%; Hispanic 1DUI 0.43%, 2+DUI 0.18%. Due to low case numbers, the 1 and 2+DUI categories were combined in all subsequent analyses for Black/African American and Hispanic pregnant persons — Black/African American 1+DUI 0.29%; Hispanic 1+DUI 0.60%. Compared to the zero alcohol-offense group, white non-Hispanic SDP rate was more than doubled in the 1 DUI group (28.7% vs 12.4%) and nearly tripled in the 2+ DUI group (33.9% vs 12.4%). Black/African American SDP rate was elevated over 5-fold in the 1+ DUI group (35.4% vs 6.4%), comparable to the SDP rate in WNH 2+DUI group, and Hispanic SDP was also elevated in the 1+ DUI group (13.7% vs 4.4%). Rates of being married with paternity acknowledgement were reduced for white non-Hispanic
Hispanic 1 and 2+ DUI and Hispanic 1+ DUI groups compared to the no-DUI group, but were not different among Black Americans.

To further examine sociodemographic differences by DUI status, we compared % of subjects with 1+ DUI by relationship with reproductive partner, and we compared the median age at reproduction by DUI count. For relationship with reproductive partner, compared to the married, named partner category, we observed an increase in incidence of DUI with being unmarried with named partner, and further increase for the unmarried, unnamed partner category for white non-Hispanic (1.72% and 1.95% vs 0.76%, respectively) and Hispanic (0.61% and 0.84% vs 0.50%, respectively) parents (Cochran-Mantel-Haenszel test of trend p<0.0001). For median age at reproduction, we observed an increase in age at reproduction for all DUI groups versus no DUI controls: white non-Hispanic 0DUI median 25 years, (interquartile range 21-29) years, 1DUI 27 (23-30) years, 2+DUI 28 (23-31) years; Black/African American 0DUI 21 (19-25) years, 1+DUI 24 (21-27) years; Hispanic 0DUI 23 (19-27) years, 1+DUI 26 (22-30) years; Cochran-Mantel-Haenszel Test of Trend p<0.0001.

A multi-level logistic regression investigated the association between individual smoking during pregnancy by DUI status, which serves as a marker for lifetime severe alcohol problems (Figure 3.1). The unadjusted model includes maternal age and age², due to the 1+DUI groups being older, on average, than the 0DUI groups. The adjusted model also includes maternal sociodemographic risk score, five-year census tract SDP rate, and ACS-derived census tract sociodemographics for address at time of childbirth. In the unadjusted models, compared to 0DUI groups, the DUI groups were significantly associated with smoking during first pregnancy:
white non-Hispanic 1DUI OR=3.61 (95% CI 3.17-4.12), 2+DUI OR=4.87 (95%CI 3.92-6.06); Black/African American 1+DUI OR=6.97 (95% CI 4.30-11.27); and Hispanic 1+DUI OR=3.88 (95% CI 1.66-9.07). In the adjusted models, we observed varying attenuation of the association between DUI and SDP: Hispanic, non-significant, 1+DUI OR=1.79 (95% CI 0.74-4.35); Black/African American, slight attenuation, 1+DUI OR=6.32 (95% CI 3.73-10.69); white non-Hispanic, some attenuation, 1DUI OR=2.22 (95% CI 1.93-2.55), 2+DUI OR=2.58 (95% CI 2.04-3.25).

3.4 Conclusions

We found that maternal lifetime DUI history, a marker of severe alcohol use, is associated with higher likelihood of having smoked during first pregnancy, even after accounting for census tract-level SDP rate and sociodemographic risks. This effect was greatest for Black/African Americans and adjusting for individual and neighborhood characteristics did not appreciably change the magnitude of the observed association. Our previous study showed differences in neighborhood characteristics between census tracts in which Black/African American gestational parents resided compared to other maternal races/ethnicities. For Black/African American gestational parents, there were overall lower economic resources in census tracts with both low and high smoking during pregnancy rates. Given this lack of variation in neighborhood characteristics, this may explain in part why adjusting for individual and neighborhood characteristics in the present report did not attenuate the association with DUI history. We observed lower proportion of Black/African Americans with 1+DUIs. There could be several contributing factors, including differences in policing in population dense versus rural
areas and severity of alcohol problems at time when DUI occurs. The association for white non-Hispanic Americans was less than for Black/African Americans. For white non-Hispanic Americans, the magnitude was reduced, but remained significant, when the model was adjusted for individual and neighborhood sociodemographics—the Odds Ratio for 2+DUI was reduced about 50%, and reduced about 40% for 1DUI. This result retained significance and remained robust in the adjusted analysis. The association for Hispanic Americans disappeared when adjusting for other sociodemographics. This study further extends our previous findings—higher rates of smoking during any pregnancy were linked to DUI status in a previous population cohort of people who gave birth in Missouri 2000-2004, after propensity score adjustment for individual, reproductive partner, and neighborhood sociodemographics (McCutcheon et al., 2019). Consistent with prior work, we also observed that being unmarried with unnamed reproductive partner on the birth record was associated with higher rates of DUI compared to both married and unmarried with named partner groups. Over 98% of pregnant people in the United States receive prenatal care during pregnancy (Martin et al., 2019), which provides an important opportunity for assessment and intervention. Our results indicate that co-assessment of alcohol and cigarette use for people of reproductive age is important to reduce substance-related morbidity and mortality for pregnant people, and their children (Oh et al., 2017).

We provide additional proof-of-concept for merging of administrative datasets to examine environmental and neighborhood contexts of questions in addiction research. Geocoding existing or future research samples, and/or administrative databases, allows direct linkage to publicly available datasets (American Community Survey) or limited access datasets (identified birth records, state Department of Revenue records for alcohol related convictions).
These methods can be achieved by most research programs at modest additional cost and are widely applicable to address important questions in addiction and health research.

Using administrative data comes with inherent limitations. For example, there is likely underreporting of cigarette use during pregnancy on the birth record, and there will be many cases where someone with severe AUD is not identified using DUIs. However, both of these issues bias against uncovering an association between DUI status and smoking behaviors during pregnancy. We do not consider additional substance use in this analysis, such as opiates or electronic nicotine delivery systems, in pregnancy or not, due to lack of availability of this information in the administrative datasets. However, we have confidence that we are capturing the vast majority of nicotine use with birth record cigarette use report, based on a recent study showing the most common pattern of e-cigarette use in women of reproductive age was co-use with combustible cigarettes (Kurti et al., 2018). The analyses presented did not include other maternal race/ethnicities, including Native American and Asian, due to low numbers of alcohol related convictions. All of these limitations highlight questions only answerable with targeted follow up data collection. For example, investigating the course of alcohol and tobacco use in relation to the timing of first pregnancy would highlight the best times to assess and refer for treatment.

3.5 References


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Figure 3.1. Results from multi-level logistic regressions investigating the association of smoking during pregnancy and recurrent DUI status, unadjusted/adjusted for maternal sociodemographics, five-year census tract smoking during pregnancy rates, and ACS-derived census tract sociodemographics for address at time of childbirth. Unadjusted model includes age and age$^2$ as covariates. For Hispanic Americans, the unadjusted model shows a significant association between 1+DUI and smoking during first pregnancy; however, this effect is non-significant when the model is adjusted for additional individual and neighborhood characteristics. For Black/African Americans, there is a robust association between 1+DUI and smoking during first pregnancy.
pregnancy, which is minimally changed when adjusted for individual and neighborhood sociodemographics. For white non-Hispanic Americans, both 1 and 2+DUI is associated with smoking during first pregnancy, and these effects remain significant when adjusted for individual and neighborhood sociodemographics.
Chapter 4: The Interaction of Sociodemographic Risk Factors and Measures of Nicotine Dependence in Predicting Maternal Smoking During Pregnancy

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The research cohort was ascertained and study protocol designed by ACH, KKB, and PAFM. The research topic of this paper was designed by ANHL, KKB, and ACH. Analyses were designed and completed by ANHL, with input from ACH and KKB. ANHL drafted the first
version of the manuscript, tables, and figures. All authors contributed to and approved the final manuscript.

4.1 Introduction

While risk and protective factors for onset of substance use and problem use are well-described, determinants of successful recovery and cessation are less clear, particularly given variability in the contexts of quit attempts (e.g. proximal stressors, major life-changing events, self-efficacy for cessation; Bolman et al., 2018; Koslovsky et al., 2018; Volz et al., 2014). Using outcomes of many users under similar conditions enables inference about risk- and protective-mechanisms in addiction persistence and desistance. Cigarette smoking during pregnancy is a useful model for identifying predictors of cessation failure because many smokers experience a common, strong incentive for cessation: pregnancy, or the anticipation of pregnancy (Practice Committee of the American Society for Reproductive Medicine, 2012).

Smoking during pregnancy prevalence ranges from 8.4%-16.5%, depending whether it is reported from surveillance data or from a U.S. nationally-representative sample (Brown et al., 2016; Curtin and Matthews, 2016). These rates exceed the Healthy People 2020 goal of reduction to 1.4% (U.S. Department of Health and Human Services). Smoking during pregnancy has been associated with newborn outcomes such as low birth weight and premature birth (Cnattingius, 2004; Dietz et al., 2010) and more distal outcomes such as chronic respiratory issues (McEvoy and Spindel, 2017; Tager et al., 1983), structural brain changes (El Marroun et al., 2016), and psychiatric phenotypes, especially hyperactive/impulsive symptoms (Knopik et al., 2016; for review see Scherman et al., 2018). Smoking during pregnancy provides a powerful
model system for examining the interplay of biological factors, such as inherited differences in nicotine dependence vulnerability (for review see Sharp and Chen, 2019), and sociodemographic factors, (for review see Chamberlain et al., 2017; Riaz et al., 2018). Given low rates of smoking cessation in pregnancy and high rates of post-partum relapse (Cnattingius, 2004), identifying early predictors of future smoking during pregnancy risk will improve early screening and intervention.

A measure’s predictive utility for smoking during pregnancy is influenced by how nicotine dependence is assessed. The nicotine dependence construct aims to assess problems associated with nicotine use that have individual and societal impact (IARC Handbooks of Cancer Prevention, 2008; Piper et al., 2006). Nicotine dependence measures commonly assess themes of difficulty quitting, experiencing problems related to use, and heaviness of use. There are global assessments, such as the Fagerström Test for Nicotine Dependence (FTND; Heatherton et al., 1991) and the Diagnostic and Statistical Manual of Mental Disorders Nicotine Dependence criteria (DSM; APA, 1994), now assessed as Tobacco Use Disorder in the most recent DSM-5 (APA, 2013), and more focused measures for identifying and defining subgroups of smokers (Piper et al., 2008), including the Nicotine Dependence Syndrome Scale (Shiffman et al., 2004) and Wisconsin Inventory of Smoking Dependence Motives (Piper et al., 2004). The six-item FTND and related Heaviness of Smoking Index (HSI; Heatherton et al., 1989), containing two FTND items, measure physical nicotine dependence. Both have been shown to predict smoking cessation outcomes (Baker et al., 2012). The DSM-IV assessment of nicotine dependence uses a medical model framework to identify “a maladaptive pattern of nicotine use, leading to clinically significant impairment or distress” (APA, 2000) and has modest ability to
predict smoking cessation outcomes, yet generally underperforms other measures (Baker et al., 2012).

Understanding the relationship between nicotine dependence, sociodemographic factors, and risk of smoking during pregnancy is arguably best achieved prospectively, since failure of smoking cessation during pregnancy may impact a participant’s evaluation of own nicotine dependence (e.g. greater likelihood of endorsement of nicotine dependence). In this report, we utilize data from a large female twin cohort, with many participants assessed prior to first pregnancy, in tandem with data from state birth records, to analyze the interplay of sociodemographic characteristics at the time of childbirth, and research assessments of nicotine dependence, in predicting smoking during pregnancy as recorded on the birth record.

4.2 Methods and Materials

4.2.1 Sample

Analyses used Missouri Adolescent Female Twin Study (MOAFTS) data, described previously (Heath et al., 2002). Briefly, a like-sex female twin pair cohort (monozygotic and dizygotic), born July 1st 1975-June 30th 1985, was ascertained from Missouri birth records. Parents (“Generation 1” – G1) and their twin daughters (“Generation 2” – G2) were recruited using a cohort-sequential design for a prospective study initially focused on the predictors and long-term outcomes of alcohol misuse in adolescent girls. Data for this report comes from the first major follow-up telephone diagnostic interview of the original target sample of twins, after G2 age 18 (G2 median age 22, range 18-28, N=3787 twins, 81.7% of the total cohort identified from birth records, 14% African American (Sartor et al., 2013). Informed consent was obtained.
Study procedures were approved by the Washington University Institutional Review Board and comply with the Declaration of Helsinki. State birth record data from 1993-2016 were used to identify children ("Generation 3"-G3) that were born to MOAFTS twins (G2). The final sample included G2 participants who were regular smokers, had given birth, and participated in the follow-up interview: a total of 1,657 births to 763 white non-Hispanic participants and 177 births to 65 Black/African American participants were identified. Rates of smoking during pregnancy in Black/African American gestational parents are lower (Mumford et al., 2014), and smoking trajectories for smoking during pregnancy differ between white and Black/African American gestational parents (De Genna et al., 2017). Due to these differences, we had insufficient power to conduct separate analyses in Black/African American gestational parents. We find it inappropriate to collapse these samples by race, given the limited sociodemographic overlap of white non-Hispanic and Black/African American twins, which would lead to predictions for cells with no data (Imbens and Rubin, 2015). Thus, we present analyses only for white non-Hispanic gestational parents.

4.2.2 Measures

Follow-up interview assessments of the G2 twins were based on the Semi-Structured Assessment of the Genetics of Alcoholism (Bucholz et al., 1994) adapted for telephone interview. This measure is an extensively validated semi-structured interview initially developed for the Collaborative Study on the Genetics of Alcoholism (Begleiter et al., 1995; Bucholz et al., 1994; Hesselbrock et al., 1999). The smoking section of the interview is based on items from the Composite International Diagnostic Interview (WHO, 1997).

Nicotine Dependence Measures from the Research Data
We adopted the commonly used definition of regular smoking recommended by the CDC: ever smoking ≥ 100 lifetime cigarettes. This definition includes ‘current’ and ‘former’ smokers at time of research interview, who are the pool of people at risk for smoking during pregnancy. The tobacco use module included assessment of the Heaviness of Smoking Index (HSI) and criteria for DSM-IV Nicotine dependence diagnosis. The HSI (Heatherton et al., 1991; Heatherton et al., 1989) is a widely used two-item measure to assess nicotine dependence containing two-items: Time-to-First-Cigarette and Cigarettes-(smoked)-Per-Day. The Heaviness of Smoking Index items were coded as follows: Time-to-First-Cigarette responses are within 5 minutes (3 points), 6-30 minutes (2 points), 31-60 minutes (1 point), and after 60 minutes (0 points). Cigarettes-Per-Day responses are 5 or fewer (0 points), 6-10 (1 point), 11-15 (2 points), 16-20 (3 points), and 21 or greater (4 points). The variables included in the present analyses include: 1) Total HSI score, as a sum of the points for each item ranging from 0-7, with higher numbers indicating more severe nicotine dependence, coded into a six-level ordinal variable corresponding to HSI scores of: 0, 1, 2, 3, 4-5, 6-7; 2) individual Time-to-First-Cigarette item and 3) individual Cigarettes-Per-Day item, coded as above.

DSM-IV-Nicotine Dependence was assessed via structured questions to capture the following items: tolerance, great deal of time using, important activities given up, smoking more than intended, difficulty quitting (experienced ≥ 2 lifetime failed quit attempts) or persistent desire to quit, withdrawal syndrome (experienced ≥ 4 symptoms within 24 hours of last cigarette use), and use despite experiencing physical or emotional health problems related to smoking. Questions assessing each symptom of the DSM-IV Nicotine Dependence diagnosis were structured based on the Composite International Diagnostic Interview. The DSM-IV symptom of
Tolerance was coded as present if a participant endorsed either i) a period of time of smoking 20 or more cigarettes per day, or ii) needing to smoke more cigarettes or a stronger form of tobacco to feel satisfied. Cigarettes smoked per day during their heaviest period of smoking were also used to code the Heaviness of Smoking Index item of Cigarettes Per Day.

The DSM-based variables used in the present analyses include: 1) A symptom count variable characterized as a six-level ordinal variable corresponding to 0, 1, 2, 3, 4, ≥ 5 symptoms; ND-sx, 2) a dichotomous variable indicating a DSM-IV-Nicotine Dependence diagnosis, by endorsing three or more symptoms; ND-dx, and 3) individual symptom level data. To reflect the DSM criterion, the two or more failed quit attempts item was combined with persistent desire to quit for the total DSM symptom score, but these two symptoms were analyzed separately for the individual symptom level analyses.

**Pregnancy Data**

Given that the experience of difficulty quitting during pregnancy could influence a participant’s endorsement of nicotine dependence symptoms, we compared prospective with retrospective prediction. Prospective prediction occurred when nicotine dependence items were assessed prior to the participant ever experiencing pregnancy. Retrospective prediction occurred when nicotine dependence assessment occurred after a participant experienced their first pregnancy. There was 98.6% concordance between self-report pregnancy history and state birth record data on childbirth. In cases of discordance, birth record data superseded self-report.

**Birth Record Data**

Missouri birth records from 1993—2016 including identifiers were obtained with permission from the state Department of Health and Senior Services and linked at the individual
level for all in-state births of G3 children to G2 MOAFTS participants. Sociodemographic
variables from the birth record were recoded when necessary for consistency across years and
used to create the sociodemographic risk score (SRS). Variables used for the SRS: maternal age,
maternal highest educational attainment, marital status, parity (yes/no indicating first born child,
due to lower rates of smoking during pregnancy for first-pregnancy compared with subsequent-
pregnancy; Meernik and Goldstein, 2015), and a dummy variable to represent a coding change
initiated by the CDC, implemented in 2010 (2010-onwards: smoking during pregnancy by
trimester; 1993-2009: dichotomous smoking at any time during pregnancy). The primary
outcome is thus smoking during pregnancy as recorded on the birth record, with cases for 2010-
onwards reflecting smoking during pregnancy beyond the first trimester.

Smoking during pregnancy (SDP) data were not obtained prior to 1992; and maternal
years of education completed, a key covariate, only from 1993. Smoking during pregnancy
(through December 31st, 2009) was recorded as “yes” or “no” for any smoking while pregnant
reported by the mother at time of childbirth. Smoking during pregnancy, beginning January 1st,
2010, was recorded as number of cigarettes smoked during the following intervals: three months
prior to pregnancy, 1st three months of pregnancy, 2nd three months of pregnancy, and third
trimester. Maternal race (through Dec 31st, 2009) was self-reported as one choice from the
following categories: White, Black/African American, American Indian/Alaska Native, Asian
Indian (Chinese, Filipino, Japanese, Korean, Vietnamese, Other Asian, Native Hawaiian,
Guamanian/Chamorro, Samoan, Other Pacific Islander, Other. Maternal race (beginning January
1st, 2010) was self-reported as selecting any of the following: White, Black/African American,
American Indian/Alaska Native, Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese,
Other Asian, Native Hawaiian, Guamanian/Chamorro, Samoan, Other Pacific Islander, Other.

Maternal marital status is recorded as “yes” or “no” for “Mother married at conception, at birth, or any time in between.” Maternal education (prior to 2007) was recorded on the Missouri birth certificate as: 0-8 years, 9-11 years, 12 years, 13-15 years, 16 years and over, and not stated. The categories beginning 2007 and later: 8th grade or less, 9th-12th grade with no diploma, high school graduate or GED completed, Some college credit but no degree, Associate degree (AA, AS), Bachelor’s degree (BA, AB, BS), Master’s degree (MA, MS), Doctorate (PhD, EdD) or Professional degree (MD, DDS, DVM, LLB, JD), and Unknown/not on birth certificate.

For data analysis purposes, birth record variables were recoded for clarity and consistency as follows. Maternal age at childbirth was coded into categories: ≤ 17 years, 18-19 years, 20-23 years, 24-26 years, 27-30 years, ≥ 31 years of age. Maternal marital status was coded into four categories: unmarried, partner not named on birth certificate; unmarried, partner named on birth certificate; married, partner not named on birth certificate; and married, partner named on birth certificate. Maternal highest educational level completed was coded into categories: ≤ 8 years, 9-12 years, 13-15 years, 16 years, 17 years. Parity was modeled as a dichotomous variable for first-born child. The change in CDC coding was coded as a dichotomous dummy variable to account for the change between recording any SDP (prior to Jan 1, 2010) versus smoking by trimester (after Jan 1, 2010). The SDP variable was coded a dichotomous variable representing any SDP—for birth records beginning Jan 1, 2010, SDP information by trimester was collapsed into any SDP, not including smoking limited to the 3 months preceding pregnancy or the first trimester of pregnancy.
4.2.3 Data Analysis

Descriptive statistics were calculated with SAS Version 9.2 (SAS Institute Inc., Cary, NC). Descriptive statistics for sample characteristics were calculated based on smoking status at time of research interview: never smokers (reported never smoking or smoking < 100 lifetime cigarettes), regular smokers (≥ 100 lifetime cigarettes) with no reports of smoking during pregnancy on the birth record, and regular smokers with ≥1 report of smoking during pregnancy on the birth record. Descriptive statistics for smoking variables were calculated on both groups of smokers. Generalizability of findings from twin cohort research data was assessed by comparing MOAFTS participants versus other non-twin gestational parents, who were born in state during the same birth years as the MOAFTS participants (1975-1985), on key sociodemographic variables.

Generation of Sociodemographic Risk Score (SRS)

Logistic regression analyses predicting smoking during pregnancy from the birth record as the primary outcome were calculated using STATA Version 15.1 (StataCorp, College Station, TX). All births were included, thus the same gestational parent could be represented on multiple records. To generate the SRS, predicted probabilities of smoking during pregnancy were estimated using logistic regression with the birth record variables, adjusted for clustered samples using the STATA robust cluster command. SRS was then sextiled for use in subsequent analyses to protect confidentiality, a requirement for working with state birth record data.

Analyses using SRS, HSI, DSM-ND

To identify which smoking variables had best utility for predicting smoking during pregnancy, individual adjusted logistic regressions were performed predicting smoking during
pregnancy from smoking characteristic separately: HSI score, HSI individual items; DSM-based ND-sx (symptom count), ND-dx (endorsement of ≥ 3 symptoms), and individual DSM-IV-Nicotine Dependence items. The HSI analyses were adjusted for SRS. The DSM-IV-Nicotine Dependence analyses were adjusted for SRS and individual HSI items to evaluate their ability to improve prediction of smoking during pregnancy beyond HSI and sociodemographic risk. Additional logistic regression models, stratified by prospective (no pregnancy by research interview) versus retrospective (experienced at least one pregnancy by time of research interview) assessment of nicotine dependence relative to first pregnancy, investigated the interaction between SRS and smoking characteristic (HSI, ND-sx) on predicting smoking during pregnancy risk.

4.3 Results

4.3.1 Sample Characteristics

Sociodemographic characteristics of never-smokers, regular smokers with no report of smoking during pregnancy, and regular smokers with report of smoking during at least one pregnancy (“pregnancy smokers”), are summarized in Table 4.1. These show the expected differences: Compared to never smokers, both groups of smokers were younger at childbirth, had completed fewer years of education, and were more likely to be unmarried, with these differences more pronounced for pregnancy smokers. For both groups of regular smokers, the endorsement rate for nicotine dependence symptoms at interview is shown in Table 4.2. Across all variables except difficulty quitting/persistent desire to quit, higher endorsement rates were seen among pregnancy smokers.
eTable 4.1 presents additional birth record sample characteristics for gestational parent and child at time of childbirth: Pregnancy smokers were, on average, younger at first childbirth. Sociodemographic variables at childbirth between MOAFTS participants and all other gestational parents, themselves born in state 1975-1985, show minimal differences (Spearman rhos <\(0.02\); eTable 4.2). For participants who experienced first pregnancy after research interview (prospective nicotine dependence assessment), children were born 7.0 years after research interview (N=593 births). For participants who had at least one pregnancy by time of research interview (retrospective nicotine dependence assessment), children were born on average 2.9 years before research interview (N=577 births) and 5.3 years after research interview (N=490 births).

4.3.2 Sociodemographic predictors of smoking during pregnancy risk

The results of fitting a multiple logistic regression predicting smoking during pregnancy are summarized in Table 4.3. Smoking during pregnancy risk is reduced in those younger than age 18 at childbirth and those who completed more years of education, with the protective effect of education particularly strong. Compared to the married, partner named reference group, smoking during pregnancy risk is elevated both by being unmarried during pregnancy and having an unnamed reproductive partner. The control variable correcting for the effects of the CDC coding change was non-significant. In a separate analysis including a dummy variable for whether first childbirth occurred before or after research interview, an increased risk in those interviewed after their first birth was noted (OR:1.82, 95% CI: [1.33, 2.49]). When comparing rates of smoking during pregnancy by birth year between the retrospective and prospective
analyses, we observe higher rates for each birth year in those who had first pregnancy by research assessment (unpublished data, available upon request).

4.3.3 Joint effects of sociodemographic risk and individual nicotine dependence measures

Spearman correlations among the nicotine dependence variables were low to modest, ranging from 0.05 to 0.34 (eTable 4.4). Table 4.4 summarizes the association between HSI measures obtained at research interview and smoking during pregnancy, controlling for sociodemographic variables (Model 1a: HSI-total score; Model 1b: HSI time-to-first-cigarette; Model 1c: HSI cigarettes-per-day); and then between DSM-IV-Nicotine Dependence measures and smoking during pregnancy, controlling for both SRS and HSI items (Model 2a: ND-sx count; Model 2b: ND-dx; Model 3, individual nicotine dependence symptoms, entered separately). The HSI items improve prediction of smoking during pregnancy risk, but the DSM symptom count (OR:1.01, 95% CI [0.92-1.13]) and binary diagnostic measures (OR:1.00, 95% CI [0.74-1.35]) show a striking lack of further improvement in prediction. Only a single DSM-based measure, reporting two or more unsuccessful efforts to quit smoking, improves prediction.

Given that past experience of failed quit attempts during pregnancy might influence responding to this item, we ran an additional model predicting smoking during pregnancy including a dichotomous variable indicating whether a participant experienced first pregnancy by time of follow-up interview, the symptom of experiencing two or more failed quit attempts, and their two-way interaction, adjusted for SRS and two HSI items, and observed a significant interaction term (OR: 1.97, 95% CI: [1.07, 3.60]), confirming our concern. Spearman correlation between HSI items was moderate (0.54), while those between HSI items and the ≥2 failed quit attempts
item were low: *time-to-first-cigarette* and ≥2 failed quit attempts (0.21) and *cigarettes-per-day* and ≥2 failed quit attempts (0.15).

Figure 4.1 summarizes predicted probability of smoking during pregnancy as a joint function of SRS (continuous) and nicotine dependence score (HSI, panels a, c; ND-sx, panels b, d), stratified by prospective (panels a, b) versus retrospective (panels c, d) prediction. The interaction between HSI and SRS was statistically significant for prospective prediction (HSI-prospective: OR: 0.39, 95% CI [0.170, 0.876]; HSI-retrospective: OR: 0.54, 95% CI [0.256, 1.15]). The interaction between ND-sx count and SRS was trend-level significant (ND-sx prospective: OR:0.40, 95% CI [0.168, 0.961], ND-sx retrospective: OR:0.64, 95% CI [0.323, 1.28]). Four major conclusions may be drawn from the figure. First, confirmation of HSI-score as a superior predictor of smoking during pregnancy risk, shown by greater separation of the smoking during pregnancy predicted probability curves as a function of level of nicotine dependence at every level of sociodemographic risk. Second, the probability curves show greatly diminished separation at high levels of sociodemographic risk, indicating that at high levels of sociodemographic risk, degree of nicotine dependence at research interview is a much weaker predictor of outcome. Third, there is broad consistency of findings regardless of whether reporting of nicotine dependence occurred after or before first childbirth (i.e. retrospectively or prospectively). Lastly, the predictive utility of nicotine dependence shows a trend towards strengthened prospective versus retrospective prediction.

### 4.4 Discussion

#### 4.4.1 Conclusions
Characterizing influential sociodemographic, individual, and environmental risk-factors for failure of smoking cessation during pregnancy is important for improving intervention efforts. We used nicotine dependence data from research cohort of female twins, combined with the birth records of children born to these twins, to investigate the predictive utility for smoking during pregnancy by proximal sociodemographic variables recorded on the birth record, nicotine dependence measured in a research setting, and their interaction. Consistent with previous research, we found that birth record data on education, marital status, age, and parity, were significant predictors of smoking during pregnancy. The best predictors of smoking during pregnancy were SRS, HSI, their two-way interaction, and a single item assessing lifetime report of failing two or more smoking cessation attempts. The DSM-IV symptom count, DSM-IV-Nicotine Dependence diagnosis, and individual DSM-IV-Nicotine Dependence items all failed to improve prediction of smoking during pregnancy when accounting for SRS and HSI items. Our ability to prospectively predict smoking during pregnancy risk from smoking characteristics was stronger than retrospective prediction.

4.4.2 Assessment of nicotine dependence in pregnancy

While both the DSM-IV-Nicotine Dependence and HSI aim to measure physiological nicotine dependence, the HSI is a shorter measure, requiring minimal resources to administer, containing the majority of the information important for predicting smoking during pregnancy. Our work is consistent with a previous report showing that prediction of late-pregnancy smoking status was best achieved by using both HSI items and failed pre-pregnancy quit attempts were associated with higher risk of late-pregnancy continued smoking (Kurti et al., 2016). This conflicts with reports from the general population, where the time-to-first-cigarette item is more
important for predicting smoking cessation (Baker et al., 2007). This present report highlights aspects of smoking behavior associated with smoking during pregnancy risk, setting the stage for improved assessment of risk and identifying at-risk individuals to target for increased cessation support. We identified three aspects of smoking behavior most important for assessing smoking during pregnancy risk—how soon one smokes their first cigarette after waking, number of cigarettes smoked per day, and history of cessation attempts/number of failed attempts. Using this information about an individual’s smoking behavior in the context of their sociodemographic status—age, years of education completed, marital status/reproductive partner support, and history of prior pregnancy and childbirth, yields important information for providers in determining smoking during pregnancy risk and indicates need for smoking cessation intervention. Importantly, given our observed strengthened prospective prediction, our results support the importance of beginning screening years in advance of first pregnancy, thus maximizing opportunities to achieve successful smoking cessation prior to pregnancy.

The predictive utility of nicotine dependence measures was substantially diminished in individuals with intermediate-high sociodemographic risk, and this result was consistent in both prospective and retrospective analyses. Since more severe dependence is associated with greater difficulty quitting, including in pregnancy (Riaz et al., 2018), this implies an important health disparities challenge: the failure to accomplish cessation for sociodemographically disadvantaged pregnant individuals, despite lower levels of nicotine dependence, which should otherwise facilitate successful quitting. Our results suggest that nicotine dependence is not the sole indicator of smoking during pregnancy risk, and for some patients, sociodemographic risk proximal to time of childbirth may explain more risk for smoking during pregnancy. In their
review, Boucher and Konkle (2016) emphasize the role of socioeconomic status, nicotine dependence, social support, culture, mental health, and access to health services as important contributors to smoking during pregnancy risk and emphasize pregnancy as an important point of contact for smoking cessation services to be delivered to patients. Less than half of patients report that their healthcare providers discourage their continued smoking during pregnancy (Hoekzema et al., 2014), despite evidence that two or more healthcare providers asking about smoking status increases odds of a past-year quit attempt and increased intention to quit in the next six months in the general population (An et al., 2008). Our results corroborate the need to address factors other than nicotine dependence as an important focus of patient-centered care and intervention efforts. In a recent analysis of the same data, we demonstrated unique risk of smoking during pregnancy associated with relationship/marital status at time of birth (Waldron et al., 2017).

4.4.3 Combining research and administrative data in health research

The analytic framework presented in this report is applicable to a broad array of health problems, where research data and administrative (e.g. birth record, driver’s license) datasets can be combined to yield important insights not achieved in analyses considering only one data type. Our analyses of phenotype-environment interaction, predicting smoking during pregnancy as a joint function of nicotine dependence and environmental risk-factors at time of pregnancy, illustrate a framework that can be extended to other questions of interaction between individual and environmental risk: identify key environmental domains to test for interaction effects on cessation failure in addiction; on continued weight gain or failure of weight-loss efforts in obesity; or on relapse/recurrence risk across a broader range of psychiatric phenotypes. Such an
approach can then be used to guide genotype-interaction analyses in genetic association data, or twin/family study data, supplementing preexisting research data with administrative data at modest cost.

4.4.4 Limitations

First, our analyses include only white non-Hispanic gestational parents due to limited numbers of Black/African American twin pairs. It is important that future research identifies both risk and protective factors for groups experiencing higher rates of smoking during pregnancy and associated risk factors (e.g. Native Americans; CDC, 2018; Curtin and Matthews, 2016). Second, while aggregate birth record data are useful for understanding predictors of smoking during pregnancy, individual cases of both false positive and, more frequently, false negative reports can be identified. While some under-reporting of smoking during pregnancy is anticipated, this does not appear to be a major problem in our data. Some age x education combinations report rates as high as 60% (e.g. white non-Hispanic gestational parents, less than high school education, giving birth in their early 20s; data available on request), compared to the 8.4% national average. Moreover, underestimation of smoking during pregnancy rates does not change observed effect estimates between smoking during pregnancy and offspring outcomes (Bakker et al., 2011). Third, while identifying individual factors associated with smoking during pregnancy risk is important for intervention efforts, this risk undoubtedly reflects an interplay of sociodemographic risks, history of exposure to neighborhoods with high rates of smoking during pregnancy, and other individual (including genetic, psychiatric history) and family-of-origin effects which may be only partially mediated through nicotine dependence. The present report does not address important aspects of social influence, either by reproductive partner, cohabitants
during pregnancy, or neighborhood rates of smoking during pregnancy. We include reproductive partner influence obliquely, by analyzing the effect of marital status, but future research would benefit from more thorough analysis of these influences and their effect on achieving successful smoking cessation by time of pregnancy. Fourth, there is relatively high rates of co-use of tobacco and other drugs, especially cannabis and alcohol, during pregnancy (Dukes et al., 2017; Oga et al., 2018). Future research should examine the roles of substance use and dependence, including, alcohol, marijuana, illicit substances, and electronic nicotine delivery systems, on risk for cigarette use during pregnancy. This would further inform how healthcare providers should use assessment of alcohol and other substance use during pregnancy to tailor risk assessment and treatment. Finally, lower levels of nicotine dependence may become more severe over time. Future work could address this by examining changes in sociodemographic risk and nicotine dependence between pregnancies and evaluate the roles of sociodemographic risk and nicotine dependence in sister-sister discordance for smoking during pregnancy.

4.6 References


APA, 2013. Diagnostic and Statistical Manual of Mental Disorders, 5th ed, Washington, DC.


Figure 4.1. Predicted probability of smoking during pregnancy as a function of sociodemographic risk score at time of pregnancy and of nicotine dependence measured either prior to or after first pregnancy.

![Graphs showing predicted probability of smoking during pregnancy as a function of sociodemographic risk score at time of pregnancy and of nicotine dependence measured either prior to or after first pregnancy.]

Figure 4.1. Interaction between Nicotine Dependence measure (Heaviness of Smoking Index score or DSM-IV-Nicotine Dependence symptom count), assessed during late teens/early twenties from research data and sociodemographic risk score, estimated using birth record data at time of childbirth, in predicting SDP. Analyses are separated by whether assessment of Nicotine
Dependence occurred before or after first pregnancy. In panels A) and C), the interaction between HSI score and sociodemographic risk score (continuous) is presented, separated by timing of first pregnancy relative to follow-up interview. In panels B) and D), the interaction between sextiled DSM ND-sx count and sociodemographic risk score (continuous) is presented, separated by timing of first pregnancy relative to follow-up interview. As sociodemographic risk increases, the importance of HSI as a predictor of future SDP is diminished. The strength of this relationship is weakened for ND-sx relative to HSI. Smoking assessment prior to first pregnancy: N = 589 births; smoking assessment after first pregnancy: N = 1048 births. (ND-sx: DSM-IV Nicotine Dependence Symptom Count; HSI: Heaviness of Smoking Index).
Table 4.1. Maternal sociodemographic characteristics at childbirth recorded on birth record.
Sample size, N, refers to number of births, since maternal characteristics could change between births.

<table>
<thead>
<tr>
<th>Smoking Status at Follow Up Interview</th>
<th>Never Smokers</th>
<th>Regular Smokers, Never SDP</th>
<th>Regular Smokers, SDP for ≥ 1 birth&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
<td>N</td>
</tr>
<tr>
<td>Maternal Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Under 18</td>
<td>28</td>
<td>1.41</td>
<td>25</td>
</tr>
<tr>
<td>18-19</td>
<td>90</td>
<td>4.54</td>
<td>44</td>
</tr>
<tr>
<td>20-23</td>
<td>291</td>
<td>14.69</td>
<td>177</td>
</tr>
<tr>
<td>24-26</td>
<td>426</td>
<td>21.50</td>
<td>130</td>
</tr>
<tr>
<td>27-30 (reference)</td>
<td>667</td>
<td>33.67</td>
<td>209</td>
</tr>
<tr>
<td>31 or greater</td>
<td>479</td>
<td>24.18</td>
<td>181</td>
</tr>
<tr>
<td>Maternal Marital Status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unmarried, Partner Unnamed</td>
<td>107</td>
<td>5.40</td>
<td>59</td>
</tr>
<tr>
<td>Unmarried, Partner Named</td>
<td>281</td>
<td>14.18</td>
<td>173</td>
</tr>
<tr>
<td>Married, Partner Named (reference)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1590</td>
<td>80.26</td>
<td>532</td>
</tr>
<tr>
<td>Married, Partner Unnamed&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2</td>
<td>0.15</td>
<td>2</td>
</tr>
<tr>
<td>Years Education Completed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 8 years</td>
<td>8</td>
<td>0.40</td>
<td>12</td>
</tr>
<tr>
<td>9-12 years (reference)</td>
<td>495</td>
<td>25.03</td>
<td>313</td>
</tr>
<tr>
<td>13-15 years</td>
<td>501</td>
<td>25.33</td>
<td>210</td>
</tr>
<tr>
<td>16 years</td>
<td>651</td>
<td>32.91</td>
<td>143</td>
</tr>
<tr>
<td>17 years</td>
<td>323</td>
<td>16.33</td>
<td>88</td>
</tr>
</tbody>
</table>

<sup>a</sup>“Regular Smoker” status (100+ cigarettes lifetime) determined at time of research follow-up interview, median age 22. SDP status determined across all birth records to a given gestational parent ascertained from birth record data.

<sup>b</sup>Since under state law a woman married at any stage during pregnancy is recorded as married, this group could include women who had already divorced their partner.
Table 4.2. Maternal smoking characteristics at research interview. Sample size N refers to number of gestational parents with history of regular smoking who have given birth in state.

<table>
<thead>
<tr>
<th>Smoking Status at Follow Up Interview</th>
<th>Regular Smokers, Never SDP(^a)</th>
<th>Regular Smokers, SDP for (\geq 1) birth(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heaviness of Smoking Index (HSI) Score</td>
<td>N = 391</td>
<td>%</td>
</tr>
<tr>
<td>0</td>
<td>86</td>
<td>21.99</td>
</tr>
<tr>
<td>1</td>
<td>71</td>
<td>18.16</td>
</tr>
<tr>
<td>2</td>
<td>65</td>
<td>16.62</td>
</tr>
<tr>
<td>3</td>
<td>53</td>
<td>13.55</td>
</tr>
<tr>
<td>4</td>
<td>37</td>
<td>9.46</td>
</tr>
<tr>
<td>5</td>
<td>33</td>
<td>8.44</td>
</tr>
<tr>
<td>6</td>
<td>32</td>
<td>8.18</td>
</tr>
<tr>
<td>7</td>
<td>14</td>
<td>3.58</td>
</tr>
<tr>
<td>HSI: Cigarettes Per Day</td>
<td>N = 391</td>
<td>%</td>
</tr>
<tr>
<td>1-5</td>
<td>108</td>
<td>27.62</td>
</tr>
<tr>
<td>6-10</td>
<td>109</td>
<td>27.88</td>
</tr>
<tr>
<td>10-15</td>
<td>70</td>
<td>17.90</td>
</tr>
<tr>
<td>16-19</td>
<td>48</td>
<td>12.28</td>
</tr>
<tr>
<td>20+</td>
<td>56</td>
<td>14.32</td>
</tr>
<tr>
<td>HSI: Time to First Cigarette</td>
<td>N = 394</td>
<td>%</td>
</tr>
<tr>
<td>&gt;60 minutes</td>
<td>203</td>
<td>51.52</td>
</tr>
<tr>
<td>31-60 minutes</td>
<td>70</td>
<td>17.77</td>
</tr>
<tr>
<td>6-30 minutes</td>
<td>87</td>
<td>22.08</td>
</tr>
<tr>
<td>(\leq 5) minutes</td>
<td>34</td>
<td>8.63</td>
</tr>
<tr>
<td>DSM IV Nicotine Dependence</td>
<td>N = 391</td>
<td>%</td>
</tr>
<tr>
<td>Symptom Count</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>38</td>
<td>9.64</td>
</tr>
<tr>
<td>1</td>
<td>95</td>
<td>24.11</td>
</tr>
<tr>
<td>2</td>
<td>94</td>
<td>23.86</td>
</tr>
<tr>
<td>3</td>
<td>62</td>
<td>15.74</td>
</tr>
<tr>
<td>4</td>
<td>61</td>
<td>15.48</td>
</tr>
<tr>
<td>(\geq 5)</td>
<td>44</td>
<td>11.17</td>
</tr>
<tr>
<td>Diagnosis ((\geq 3) Symptoms)</td>
<td>158</td>
<td>40.10</td>
</tr>
<tr>
<td>DSM IV Nicotine Dependence Symptoms</td>
<td>N = 391</td>
<td>%</td>
</tr>
<tr>
<td>Tolerance</td>
<td>150</td>
<td>38.07</td>
</tr>
<tr>
<td>Great Deal of Time Using</td>
<td>91</td>
<td>23.10</td>
</tr>
<tr>
<td>Important Activities Given Up</td>
<td>19</td>
<td>4.82</td>
</tr>
<tr>
<td>Smoke More Than Intended</td>
<td>168</td>
<td>42.64</td>
</tr>
<tr>
<td>Difficulty Quitting/Persistent Desire To Quit</td>
<td>321</td>
<td>81.47</td>
</tr>
<tr>
<td>≥ Two Failed Quit Attempts</td>
<td>171</td>
<td>43.40</td>
</tr>
<tr>
<td>Withdrawal Syndrome (≥ 4 Symptoms)</td>
<td>134</td>
<td>34.01</td>
</tr>
<tr>
<td>Use Despite Physical/Emotional Problems</td>
<td>67</td>
<td>17.01</td>
</tr>
</tbody>
</table>

*a“Regular Smoker” status (100+ cigarettes lifetime) determined at time of research follow-up interview, median age 22. SDP status determined across all birth records to a given gestational parent ascertained from birth record data.*
Table 4.3. Prediction of smoking during pregnancy using sociodemographic variables at time of childbirth analyzed with logistic regression.

<table>
<thead>
<tr>
<th>Maternal Age (years)</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 18</td>
<td>0.46</td>
<td>0.23</td>
</tr>
<tr>
<td>18-19</td>
<td>0.80</td>
<td>0.49</td>
</tr>
<tr>
<td>20-23</td>
<td>0.82</td>
<td>0.56</td>
</tr>
<tr>
<td>24-26</td>
<td>0.94</td>
<td>0.66</td>
</tr>
<tr>
<td>27-30 (reference)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>31 or greater</td>
<td>0.85</td>
<td>0.56</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maternal Marital Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Married, Partner Named (reference) - - -</td>
</tr>
<tr>
<td>Married, Partner Unnamed</td>
</tr>
<tr>
<td>Unmarried, Partner Named</td>
</tr>
<tr>
<td>Unmarried, Partner Unnamed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maternal Educational Attainment (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 8</td>
</tr>
<tr>
<td>9-12 (reference)</td>
</tr>
<tr>
<td>13-15</td>
</tr>
<tr>
<td>16</td>
</tr>
<tr>
<td>17</td>
</tr>
</tbody>
</table>

| CDC Coding Change (dummy variable)         | 1.09 | 0.71 | 1.68 |
| First Born Child (yes/no)                  | 0.79 | 0.62 | 1.00 |
Table 4.4. Comparison of the ability of smoking characteristics from research data to predict smoking during pregnancy beyond sociodemographic variables at time of childbirth analyzed with logistic regression.

<table>
<thead>
<tr>
<th>Model</th>
<th>Heaviness of Smoking Index&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>Heaviness of Smoking Index Score</td>
<td>1.51</td>
<td>1.36</td>
</tr>
<tr>
<td>1b</td>
<td>Heaviness of Smoking Index Score</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Time To First Cigarette</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 60 minutes (reference)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>31-60 minutes</td>
<td>2.39</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>6-30 minutes</td>
<td>2.72</td>
<td>1.84</td>
</tr>
<tr>
<td></td>
<td>≤ 5 minutes</td>
<td>6.05</td>
<td>3.87</td>
</tr>
<tr>
<td>1c</td>
<td>Cigarettes Per Day</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1-5 (reference)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6-10</td>
<td>3.27</td>
<td>1.83</td>
</tr>
<tr>
<td></td>
<td>11-15</td>
<td>4.18</td>
<td>2.31</td>
</tr>
<tr>
<td></td>
<td>16-20</td>
<td>4.83</td>
<td>2.51</td>
</tr>
<tr>
<td></td>
<td>≥ 21</td>
<td>7.73</td>
<td>4.29</td>
</tr>
<tr>
<td>2</td>
<td>DSM IV Nicotine Dependence&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2a</td>
<td>Symptom Count</td>
<td>1.01</td>
<td>0.92</td>
</tr>
<tr>
<td>2b</td>
<td>Diagnosis (≥ 3 Symptoms)</td>
<td>1.00</td>
<td>0.74</td>
</tr>
<tr>
<td>3</td>
<td>DSM IV Nicotine Dependence Symptoms</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tolerance</td>
<td>1.01</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>Great Deal of Time Using</td>
<td>0.86</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>Important Activities Given Up</td>
<td>0.92</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>Smoke More Than Intended</td>
<td>1.36</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Difficulty Quitting/Persistent Desire To Quit</td>
<td>1.04</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>≥ Two Failed Quit Attempts</td>
<td>1.37</td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td>Withdrawal Syndrome (≥ 4 Symptoms)</td>
<td>0.80</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
<td>Use Despite Physical/Emotional Problems</td>
<td>1.03</td>
<td>0.75</td>
</tr>
</tbody>
</table>

<sup>a</sup> Heaviness of Smoking Index analyses were run as three separate logistic regression models adjusted for sociodemographic risk score at time of childbirth ascertained from birth record data.
DSM-IV-Nicotine Dependence analyses were run as separate logistic regression models per variable listed, adjusted for sociodemographic risk score and the individual Heaviness of Smoking Index Items (Time to First Cigarette and Cigarettes Per Day).
Table 4.1. Sample characteristics at childbirth recorded on birth record.

<table>
<thead>
<tr>
<th>Smoking Status at Follow Up Interview Median Age 22</th>
<th>Never Smokers</th>
<th>Regular Smokers, Never SDP</th>
<th>Regular Smokers, SDP for ≥ 1 birth</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mother Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Mothers</td>
<td>N = 953</td>
<td>N = 396</td>
<td>N = 369</td>
</tr>
<tr>
<td>Median Age at Follow Up Interview</td>
<td>21</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Median Age at Childbirth</td>
<td>27</td>
<td>26</td>
<td>23</td>
</tr>
<tr>
<td>Median Age at First Childbirth&lt;sup&gt;a&lt;/sup&gt;</td>
<td>26.5</td>
<td>26</td>
<td>21</td>
</tr>
<tr>
<td>Median Age at Most Recent Childbirth&lt;sup&gt;b&lt;/sup&gt;</td>
<td>28</td>
<td>27</td>
<td>26</td>
</tr>
<tr>
<td><strong>Child Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median Number of Children Born</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Child Median Birth Year</td>
<td>2009</td>
<td>2007</td>
<td>2005</td>
</tr>
<tr>
<td>First Child Median Birth Year</td>
<td>2007</td>
<td>2005</td>
<td>2002</td>
</tr>
<tr>
<td>Most Recent Child Median Birth Year&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2011</td>
<td>2009</td>
<td>2008</td>
</tr>
<tr>
<td>Child Sex (% male)</td>
<td>52.04</td>
<td>50.00</td>
<td>51.39</td>
</tr>
</tbody>
</table>

<sup>a</sup> Sample size for this characteristic: Never Smokers N=738; Regular Smokers, Never SDP N=303; Regular Smokers, SDP for ≥ 1 birth N=224

<sup>b</sup> For families with more than one child: Sample size for this characteristic: Never Smokers N=124; Regular Smokers, Never SDP N=58; Regular Smokers, SDP for ≥ 1 birth N=80

<sup>c</sup> For families with more than one child
eTable 4.2. Comparison of sociodemographic variables between births to research participants (MOAFTS participants) versus births to individuals themselves born in Missouri 1975-1985.

<table>
<thead>
<tr>
<th>Variable</th>
<th>MOAFTS Participants</th>
<th>MO-Born Mothers</th>
<th>Spearman’s rho</th>
<th>S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth Year (modal)</td>
<td>2009</td>
<td>2006</td>
<td>0.018</td>
<td>0.0016</td>
</tr>
<tr>
<td>Years Education Completed: 9 – 12 years (%)</td>
<td>38.80</td>
<td>45.64</td>
<td>0.014</td>
<td>0.0017</td>
</tr>
<tr>
<td>Age at Childbirth: 27 – 30 years (%)</td>
<td>31.80</td>
<td>24.55</td>
<td>0.014</td>
<td>0.0015</td>
</tr>
<tr>
<td>Marital Status: Married, Named Partner (%)</td>
<td>65.51</td>
<td>64.70</td>
<td>0.002</td>
<td>0.0016</td>
</tr>
<tr>
<td>Smoked During Pregnancy (%)</td>
<td>18.63</td>
<td>21.96</td>
<td>-0.006</td>
<td>0.0015</td>
</tr>
</tbody>
</table>
Table 4.3. Spearman correlations between nicotine dependence variables.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>HSI Score</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>HSI TTF</td>
<td>0.83</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>HSI CPD</td>
<td>0.90</td>
<td>0.54</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>ND-dx</td>
<td>0.35</td>
<td>0.31</td>
<td>0.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>ND-sx</td>
<td>0.46</td>
<td>0.41</td>
<td>0.41</td>
<td>0.84</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Tolerance</td>
<td>0.57</td>
<td>0.43</td>
<td>0.56</td>
<td>0.52</td>
<td>0.63</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Time</td>
<td>0.22</td>
<td>0.20</td>
<td>0.20</td>
<td>0.44</td>
<td>0.53</td>
<td>0.23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Act. Give Up</td>
<td>0.11</td>
<td>0.15</td>
<td>0.07</td>
<td>0.25</td>
<td>0.31</td>
<td>0.16</td>
<td>0.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Smoke More</td>
<td>0.22</td>
<td>0.23</td>
<td>0.18</td>
<td>0.60</td>
<td>0.67</td>
<td>0.23</td>
<td>0.34</td>
<td>0.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Difficult Quit</td>
<td>0.06</td>
<td>0.05</td>
<td>0.06</td>
<td>0.34</td>
<td>0.46</td>
<td>0.14</td>
<td>0.10</td>
<td>0.07</td>
<td>0.23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>WD</td>
<td>0.30</td>
<td>0.29</td>
<td>0.23</td>
<td>0.51</td>
<td>0.62</td>
<td>0.30</td>
<td>0.18</td>
<td>0.17</td>
<td>0.29</td>
<td>0.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>Use with problems</td>
<td>0.22</td>
<td>0.20</td>
<td>0.18</td>
<td>0.40</td>
<td>0.50</td>
<td>0.24</td>
<td>0.14</td>
<td>0.13</td>
<td>0.19</td>
<td>0.12</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>2+ failed QA</td>
<td>0.20</td>
<td>0.22</td>
<td>0.15</td>
<td>0.42</td>
<td>0.47</td>
<td>0.16</td>
<td>0.13</td>
<td>0.28</td>
<td>0.52</td>
<td>0.26</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>14.</td>
<td>Tolerance (qual)</td>
<td>0.33</td>
<td>0.31</td>
<td>0.28</td>
<td>0.47</td>
<td>0.57</td>
<td>0.80</td>
<td>0.21</td>
<td>0.16</td>
<td>0.26</td>
<td>0.26</td>
<td>0.25</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Physical/Emotional Problems; 13. 2+ failed QA: two or more failed quit attempts, lifetime; 14. Tolerance (qual): Tolerance symptom recoded using only the qualitative item. To reflect the DSM criterion, the two or more failed quit attempts item (13) was combined with persistent desire to quit (10) for the total DSM symptom score (5), but these two symptoms were analyzed separately for the individual symptom level analyses.
Chapter 5: Identifying Protective Factors for Smoking During Pregnancy Among Indigenous Women

5.1 Introduction

5.1.1 Smoking During Pregnancy Trends Among American Indians/Alaska Natives

Cigarette smoking during pregnancy (SDP) has been associated with a host of short- and long-term negative health outcomes for exposed offspring, in addition to the well documented adverse health effects for the gestational parent (Cnattingius, 2004; Diamanti et al., 2019; Gakidou et al., 2017; Jha et al., 2013; Palmer et al., 2016; Tager et al., 1983). For AI/AN gestational parents, the SDP rate is 19.5% for first births in Missouri and across the United States for all births it is 15.17% (Azagba et al., 2020; Cornelius et al., 2020; Houston-Ludlam et al., 2020), rates that are higher compared to other races/ethnicities. Moreover, smoking cessation interventions that show efficacy in other ethnic minority groups do not significantly improve quit rates for Indigenous women (Chamberlain et al., 2017). However, when appropriately adjusting for known sociodemographic risk factors for SDP, smoking rates before and during pregnancy were similar for American Indian and white women, and American Indian women were more likely to smoke fewer cigarettes and to quit during pregnancy (Specker et al., 2018). Thus, it is important that research continues to identify important social influences, regional differences, and protective factors for SDP among Indigenous communities.
5.1.2 The Role of Resiliency and Protective Factors for Smoking During Pregnancy in Indigenous Communities

It is important to note that AI/AN communities have experienced unique hardships distinct from other minority and/or marginalized groups. To quickly condense a wide body of literature, there is demonstrated contribution of historical (intergenerational) trauma experienced by colonized Indigenous peoples to health morbidity and mortality. Historical trauma has been characterized as both a description of lived experiences and posited as a cause for poor health outcomes (Evans-Campbell, 2008). This trauma includes governments removing Indigenous peoples from their homelands, outlawing their cultural traditions and language, and forcibly removing children from their homes and stripping familial connections (L Kirmayer et al., 2003). However, the resiliency of these communities considering this intergenerational trauma has often been overlooked in research focusing only on risk mechanisms and rates of poor health outcomes.

Positive racial/ethnic identity and engagement with cultural practices have been shown to be protective against poor health outcomes among many Indigenous groups across life stages (Gonzales et al., 2021; LJ Kirmayer et al., 2003; Les Whitbeck et al., 2004; Oré et al., 2016; Reinschmidt et al., 2016; Wexler et al., 2020). Some, but not all, Indigenous communities use the word “tobacco” to refer to the traditional herbs and medicines that have an important role in cultural and spiritual practices. This traditional tobacco use, in its many forms, is distinct from consumption of commercial cigarettes. Daley and colleagues found that among male and female AI/AN adult smokers, engaging with traditional tobacco use was associated with more days of
abstinence during quit attempts for cessation of commercial tobacco use (Daley et al., 2011). However, to our knowledge, the role of racial identity and engagement in traditional tobacco use has not been examined in the context of SDP in AI/AN women.

The present study aims to improve ability to predict SDP for AI/AN women by including, in addition to sociodemographic data from birth records, the individual factors of nicotine dependence, engagement with traditional/ceremonial use of tobacco, racial identity, history of problems related to alcohol use for self and biological father of their child, and smoking behaviors of those they lived with during pregnancy.

5.2 Methods

5.2.1 Participants

Birth Record Ascertainment and Recruitment

Participants were recruited via a stratified random sample from identified Missouri birth records, with permission from the Missouri Department of Health and Senior Services. First, records were cross-referenced with the death record, to remove any potential participants who themselves and/or whose child is now deceased, to avoid undue burden on the respondent and to comply with Missouri Department of Health and Senior Services procedures for using vital records data. There were a total of 836 people eligible for this study, based on the following criteria: listed as biological mother to child(ren) born in Missouri during 2015-2017, maternal race/ethnicity includes American Indian/Alaska Native (AI/AN), and by smoking status recorded on birth record—controls will report smoking in the 3 months preceding pregnancy on the birth
record, and report not smoking beyond the 1st trimester of pregnancy; cases will report smoking in the 3 months preceding pregnancy and continued smoking into the 2nd and 3rd trimester.

From the total eligible pool of participants, Family and Population Research Center staff released a random sample of 240 participants to recruit to the study. Once these potential subjects were identified, current contact information was obtained using standard public and commercial databases. Of 240 participants, 145 were located, 27 provided verbal consent and were screened, and 11 were eligible to participate. Participants were enrolled by phone and participated via telephone interview after providing informed verbal consent, following a protocol approved by the Washington University Institutional Review Board, The Family and Population Research Center Review Board, and Missouri Department of Health and Human Services Institutional Review Board. Eligible participants who completed the full study interview received a $50 gift card to Amazon, Target, or Walmart.

In similar studies previously conducted by our working group, recruiting women with a history of DUI conviction, it took an average of 25-35 phone calls to recruit one participant to the study (Bender et al., 2018; McCutcheon & Bucholz, in prep). For the present study, I completed 794 phone calls and sent 207 recruitment letters, averaging 79 phone calls per completed interview. Due to this unexpectedly high labor burden for recruitment, the study closed to recruitment after reaching 10 completed interviews.

5.2.2 Measures

Telephone Screening
After providing verbal consent to participate, participants were asked questions to determine their eligibility for the study. Cases met the following inclusion criteria: biological mother of at least one currently living child, born in Missouri 2015-2017, following a singleton pregnancy; report smoking during at least one singleton pregnancy during 2015-2017; report smoking after knowing they were pregnant during a singleton pregnancy in 2015-2017; endorse American Indian/Alaska Native racial identity; report smoking at least 100 lifetime cigarettes. Controls met the following inclusion criteria: biological mother of at least one currently living child, born in Missouri 2015-2017, following a singleton pregnancy; report not smoking after knowing they were pregnant during all pregnancies in 2015-2017; report not smoking after knowing they were pregnant during any other pregnancies; endorse American Indian/Alaska Native racial identity; report smoking at least 100 lifetime cigarettes. Exclusion criteria were: not a biological mother to at least one child born in Missouri during 2015-2017; only had pregnancies with multiples during 2015-2017; decline to answer smoking during pregnancy questions; did not endorse American Indian/Alaska Native racial identity or declined to answer racial identity question; cannot complete interview in English; did not report smoking at least 100 lifetime cigarettes.

**Study Interview**

Once participants provided consent and were deemed eligible to participate, they completed the study phone interview. Cases and controls received the same interview, except for one additional section completed by cases. The interview included a demographics, contact information, and residential history questionnaire; Mother and Baby Health questionnaire about
pregnancy and early postpartum health of mother and child (Pregnancy Risk Assessment Monitoring System, 2009 / PHENX Toolkit); Lifetime nicotine / tobacco use history, including lifetime Heaviness of Smoking Index and Electronic Nicotine Delivery Systems (ENDS) product use (Abuse et al., 2020; Bucholz et al., 1994; Heatherton et al., 1991; Heatherton et al., 1989); Traditional Tobacco Use questionnaire, which asked about traditional/ceremonial tobacco use outside of commercial cigarette use (adapted from Daley et al., 2011); Cohabitant cigarette use, Reproductive partner cigarette and alcohol use, and participant alcohol use, including lifetime problems associated with alcohol use, and largest number of drinks consumed during lifetime and during pregnancy (adapted from Bucholz et al., 1994); and the Multigroup Ethnic Identity Measure (MEIM; Phinney, 1992 / PHENX Toolkit). Cases were also administered the Heaviness of Smoking Index for their smoking habits during pregnancy (Bucholz et al., 1994; Heatherton et al., 1991; Heatherton et al., 1989).

The Heaviness of Smoking Index is a two-question measure to assess nicotine dependence, which asks how many cigarettes one smokes per day, and how soon after waking one smokes their first cigarette. The total scores range from 0-7, with 0 indicating the lowest level of nicotine dependence, and 7 the highest. The MEIM measures both cognitive and affective components of conceptualization of, interaction with, and reaction to one’s ethnic identity/identities. There are three scores that can be calculated from answers: A total score, and two related factors underlying this measure—the first being a measure of ethnic identity search, and the second being a measure of affirmation, belonging, and commitment. Scores are calculated by averaging item values and range from 1-4.
Study Newsletter

Participants were asked to opt-in to receive a newsletter summarizing the study and findings. All participants opted to receive the newsletter. The newsletter is included in the appendix.

5.2.3 Analysis

Descriptive statistics were calculated for available data while preserving confidentiality using SAS 9.4.

5.3 Results

5.3.1 Demographics

Six cases and four control participants completed the interview. Participants mostly identified with more than one race/ethnic identity (9/10), had more than one child by time of interview (7/10), and all received prenatal care by the end of the first trimester of their pregnancy.

5.3.2 Substance Use

Most participants had at least tried an electronic nicotine delivery system (“e-cigarette”) at least once (8/10). Of the eight people who had tried an e-cigarette, three used them at least some days during the month before the study interview. For cases, the mean pregnancy Heaviness of Smoking Index (HSI) score was 0.5, lower than the mean lifetime HSI score of 3.3 for all participants. Of the 8/10 who were lifetime smokers, the biological father’s lifetime HSI score was similar to that of participants’, at 3.3. Biological fathers’ smoking status during
participants’ pregnancies was known for 6/8 biological fathers, and one third (2/6) of the biological fathers of participants’ children quit smoking cigarettes for seven days or longer during participants’ pregnancies. Most participants lived with someone else who smoked cigarettes during their pregnancy (7/10). Participants reported that 4/9 biological fathers had either had periods of “excessive” alcohol consumption or problems related to alcohol use. For largest number of drinks consumed in a 24-hour period in their lifetime, participants reported a mean of 10.8, with range from 5-20 drinks.

5.3.3 Traditional Tobacco Use

Participants were asked about their use of tobacco for “traditional” or “ceremonial” purposes, outside of commercial cigarette use. Two participants reported using tobacco in this manner during their lifetimes.

5.3.4 Racial Identity

The mean and standard deviation for the three different subscales of the Multigroup Ethnic Identity Measure are as follows: total score mean 2.9 (SD 0.3), ethnic identity search 2.6 (0.4), and affirmation, belonging, and commitment 3.1 (0.4), similar to a study comparing Native American adolescents who lived on a reservation in California to those who do not live on a reservation, with mean 3.0 (SD 0.63) for non-reservation dwelling and mean 3.05 (0.65) for reservation-dwelling Native Americans (Schweigman et al., 2011).
5.4 Discussion

This study was a pilot data collection aimed at identifying protective factors for cigarette smoking during pregnancy among Native women. It also serves as an example for how findings in administrative data can be used to design follow up research studies. Recruitment for this sample proved to be more difficult than anticipated based on prior studies recruiting from the birth record.

A major shift in recruitment strategy is required for future work. Ideally, researchers should develop a research project in partnership with a specific Tribe or Nation and prioritizing the questions they want to answer for their community (Poitra et al., 2021). Alternatively, collaboration with Tribal Epidemiology Centers inform future research partnerships and study design changes.

5.5 References


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Healthy Pregnancy Study Findings

Message from Study Coordinator

Dear Study Participants,

I would like to sincerely thank you for participating in our study of women's health behaviors during pregnancy. I am incredibly thankful for your time and willingness to share your story. I value the information you provided about yourself and those around you; I could not have completed this project without your help! In addition to helping us answer our original research questions, your answers inspired us to change the way we think about conducting future research projects. In this newsletter, I'm excited to share with you a summary of our research study findings and related resources which you may find helpful.

Sincerely,

Alexandra Houston-Ludlam, BS
Principal Investigator, MD-PhD Candidate
Washington University School of Medicine in St. Louis
About the Research Study

The purpose of this research study was to gather information on how health behaviors and racial identity influence experiences with pregnancy and childbirth. In particular, we wanted to hear from women who identify as American Indian or Alaska Native. Previous research studies have historically focused on men, and even when women were included, Native women were often excluded. Our long term goal from our research is to improve health and wellness by time of early pregnancy, including reducing harms associated with commercial tobacco use.

Native communities are vibrant, diverse, and resilient. Being connected to community, through traditions and language, has positive impacts on health and wellness. This study aimed to focus on some positive influences on having a healthy pregnancy, like having a positive experience with one's racial identity and engaging with traditional tobacco use.

While we hoped to interview more women for this study, we ran into some unanticipated challenges with completing interviews. We will use what we learned from this project to improve how we go about future research projects. We hope you find this summary newsletter interesting!

About Study Participants

Most people identified with more than one racial/ethnic identity

7 participants had more than one child

3 participants had 1 child

About the findings

We have included what we found in the study, while also protecting the privacy of individual participants.

Throughout the newsletter, we highlight resources you may be interested in for more information.

U.S. Department of Education Parent Sites

https://www2.ed.gov/parents/landing.jhtml
Links to education materials and resources for all ages.
Pregnancies

100% of participants received 1st trimester prenatal care

All participants who responded to our question about the timing of prenatal care had their first prenatal appointment within the first trimester of their pregnancy.

Starting prenatal care in the first trimester, and having regular visits, helps develop a relationship between patient and provider. It also helps identify any problems early, so any needed treatment can be provided quickly.

E-Cigarette Use

One of the health behaviors we wanted to learn more about in this study was cigarette and e-cigarette use.

As e-cigarettes and other “electronic nicotine delivery system” products are relatively new, we don’t have a good understanding of their long term effects. The Centers for Disease Control and Prevention guidelines say that for non-pregnant adults who smoke tobacco products, switching to exclusively using e-cigarettes may reduce harms associated with smoking.

8 of 10 participants had tried e-cigarettes at least once

Of the 8 people who tried an e-cigarette, 3 used them at least some days during the month before the study interview.

Resources

Office on Women’s Health information about prenatal care:
https://www.womenshealth.gov/a-z-topics/prenatal-care

ParentLink Warm Line
https://education.missouri.edu/parentlink/warmline/
1-800-552-8522 (confidential, toll-free)
Hours 8 AM-10 PM M-F
12 noon-5 PM Sat-Sun.

Information and resources for parents and caregivers who have questions about parenting practices, including development, discipline, and stress management.

Centers for Disease Control and Prevention: E-cigarettes
https://www.cdc.gov/tobacco/basic_information/e-cigarettes/index.htm
Cigarette Use

We wanted to know about our participants’ lifetime use of cigarettes. One factor that can affect success of quitting smoking or not is Nicotine Dependence. One way to measure this is a score called the “Heaviness of Smoking Index.” This score is based on how many cigarettes someone smokes per day, and how soon after they wake up they smoke their first cigarette. The lowest score is 0, the highest is 7. Here are the averages of scores from the study:

Participants’ During Pregnancy

![Graph showing participants' highest lifetime Nicotine Dependence scores during pregnancy.]

Participant’s Highest Lifetime

![Graph showing participant’s highest lifetime Nicotine Dependence scores.]

Participant’s Child’s Biological Father’s Highest Lifetime

![Graph showing participant’s child’s biological father’s highest lifetime Nicotine Dependence scores.]

Social Influences on Smoking in Pregnancy

People find it easier to quit smoking when they have support from the people they live with and romantic partners.

Seven participants lived with someone else who smoked cigarettes during their pregnancy

33%

One third of participants’ children’s biological fathers quit smoking for seven days or longer during participant’s pregnancies
Traditional Tobacco Use

For Native Americans, “traditional” or “ceremonial” tobacco use is a practice involving tobacco that is different from smoking commercial cigarettes. Traditions/protocols vary between tribes and Nations. In this study, we wanted to know if engaging with traditional/ceremonial tobacco use was connected to healthier pregnancies. From the limited number of completed interviews, we can’t say if there is a connection or not. However, other researchers reported that engaging with traditional tobacco use is associated with more days without smoking cigarettes among adults who are trying to quit smoking commercial cigarettes.

Two participants reported traditional or ceremonial tobacco use.

Racial/Ethnic Identity

Racial and Ethnic identity has many different meanings to people. In our study, we think about ethnic identity as having two parts. First, as having a sense of commitment and belonging to one’s ethnic group(s). The second part is about someone’s process of exploring, learning about, and becoming involved with their ethnic group(s). We wanted to know how people’s sense of belonging with, attachment to, and involvement with their Native identity influenced their pregnancies. Some examples of having a positive ethnic identity would be feeling like you “agree” or “strongly agree” with the following statements.

Commitment/Belonging

“I have a clear sense of my ethnic background and what it means for me.”

“I feel a strong attachment towards my own ethnic group.”

Search/Learning/Involvement

“I have spent time trying to find out more about my ethnic group, such as its history, traditions, and customs.”

“I participate in cultural practices of my own group, such as special food, music, or customs.”

Resources

Traditional Tobacco Information and Resources

https://keepitsacred.itcmi.org/
tobacco-and-tradition/
traditional-tobacco-use/

All Nations Breath of Life—Smoking Cessation Treatment for American Indians

https://www.anbl.org/#

The researchers who reported that traditional tobacco use was related to more smoke free days during a quit attempt.

“All of Us”

https://sites.wustl.edu/allofus/

A local group of researchers, in partnership with the National Institutes of Health, are working to create a diverse national registry of research participants to reduce health disparities. See this website for information on how to enroll.
About the Study Coordinator

My name is Alexandra Houston-Ludlam, and I am a biracial Métis and white MD-PhD student at Washington University in St. Louis. This project was one part of my doctoral dissertation, which I have worked on for the last four years. I chose to study cigarette smoking during pregnancy for my graduate work. I am especially interested in how social influences, whether from family, friends, romantic partner, or neighborhood, affect someone’s ability to quit cigarette smoking by time of early pregnancy. As a Native woman, I want to elevate Native perspectives in all aspects of research—from design to reporting of research findings. Part of this is including diverse perspectives in research data collection so what researchers learn can lead to advances for all people.
Chapter 6: Synthesis and Future Directions

6.1 Summary

The goal of this dissertation was to identify predictors of cigarette smoking during pregnancy (SDP) at the individual level to inform clinical practice. I was especially interested in how social influences confer risk or protection for SDP, and how predictors may differ by maternal race and ethnicity.

In my study investigating predictors in a state population cohort of first births, I identified that multiple levels of social influence affect risk for smoking during pregnancy. Relationship with reproductive partner, measured as marital status and whether the reproductive partner acknowledged paternity, and census tract-level SDP rate, both predicted individual smoking during first pregnancy. Being unmarried and lack of reproductive partner legal acknowledgement of paternity both increased likelihood of individual SDP across maternal age and education levels. These effects were consistent across maternal race/ethnicity. At the census tract level, five-year census tract SDP rate predicted individual SDP risk, after adjustments for both individual and census tract sociodemographics at time of childbirth. The association of individual SDP with increasing census tract SDP rate was stronger for Black/African Americans than for white non-Hispanic Americans. However, rates of SDP were consistently and significantly lower across age, education, and relationship with reproductive partner in Black/African Americans compared to white non-Hispanic Americans, suggesting important resiliency factors that should be studied further.
In a related study of the same birth cohort, I investigated the association between DUI conviction incidence, a marker of lifetime severe alcohol use, and smoking during first pregnancy. Conviction for one or more DUls was associated with increased odds of smoking during first pregnancy. Adjusting for individual and neighborhood characteristics at time of childbirth attenuated this effect for white non-Hispanic American gestational parents, while the effect remained strongest and unchanged with adjustment for Black/African American gestational parents. The significant association was not robust to adjustment for sociodemographics for Hispanic gestational parents.

To understand how nicotine dependence relates to SDP risk, I conducted a study merging research data from a female like-sex twin pair birth cohort with birth records for children born to the twin participants, focusing on white non-Hispanic participants. Research participants provided information on their lifetime tobacco use and continuous measure of nicotine dependence symptoms in early adulthood, and sociodemographic information at time of childbirth was obtained from linked birth records. Sociodemographic risk and nicotine dependence in early adulthood both predicted SDP, with a significant interaction. At low levels of sociodemographic risk, increasing severity of nicotine dependence explained increases in SDP risk. At high levels of sociodemographic risk, however, SDP risk remained high across all levels of nicotine dependence, regardless of severity.

Finally, I used findings from administrative data analyses to inform design of new data collection to explore potential protective factors for SDP among Indigenous women. While the
full sample needed for the planned analysis was not recruited, the design and recruitment experience provided useful information for improving future work.

6.2 Future Directions

There are several important avenues to explore with further work. These include health disparities, upstream social influences including tobacco control policy, health care provider-level influences, and additional individual level factors.

When considering health disparities, in particular racial/ethnic health disparities, a few overarching ideas should guide future work. A working definition of “health disparities” is that one social group, who experiences social disadvantage, also experiences a disproportionate burden of health morbidity and mortality (Palmer et al., 2019). I consider race a “rough proxy for a range of underlying causal factors (socioeconomic status, cultural elements, and genes), and as an indicator of risk for mechanisms tied to the social stratification of people in a race-conscious society” (Doll et al., 2018). Keeping these ideas in mind, I believe future work on health disparities must prioritize identifying protective and resiliency factors for SDP. By focusing on protective and resiliency factors, research findings become more directly informative on how to improve health and wellbeing, rather than being confined to reporting high rates of poor outcomes. This positive framing of messaging is an important shift, especially when it comes to reporting research results back to the community. Relatedly, future work should consider how studies work to uphold or dismantle existing power structures. Laura Nader’s idea of studying “up the anthropologist,” which encourages academics to study “up” power structures instead of “down” them, can also inform future work on smoking during pregnancy (Nader, 1972). An
individual who does or does not smoke during pregnancy is influenced by many power structures above them. Looking “up” this power structure shifts focus from patients to individual healthcare providers, healthcare systems, insurance companies, healthcare policy and regulation, broader public health policy, and the governments who create and enforce this policy.

Larger scale studies should add focus on upstream levels of social determinants of health. In this dissertation, and most existing research, the emphasis is on “midstream” and “downstream” determinants of health, like education, neighborhood, health care access and provision, and individual risk behaviors (Palmer et al., 2019). “Upstream” social determinants of health permeate all of these lower-level influences, including government, the social and economic policies the government implements, and how these are influenced by racism and discrimination (Palmer et al., 2019). Applied to smoking during pregnancy, this process can start with studying tobacco control policy—e.g. where it is implemented, how it is enforced, and intended and unintended consequences of policy implementation. However, tobacco control policy does not exist in a vacuum, so it is necessary to consider how the interplay of the large-scale influence of governance and policy ultimately affect conditions that are associated with, and may lead to, health disparities. This might involve a study of multiple U.S. states, across time, measuring various types of tobacco control policy, other public health initiatives, education, economic indicators, health insurance coverage, and healthcare provider density/access, and look at the interplay between these large-scale influences on health disparities broadly, and how policy changes work together to alleviate or exacerbate SDP among other health conditions. One way to make this type of work more achievable is to use universal measures of social factors, such as those available in US Census/American Community Survey.
data, which reduce assessment variability and allow comparison of analyses between geographic
regions.

One important influence that was not considered in this dissertation is the role of
healthcare, especially individual provider-level influences. There are several ways future studies
could consider healthcare provider-level influences. One method could be using GIS-informed
approaches to examine the interplay among healthcare provider density variation, as a proxy for
healthcare access, and other geographic/neighborhood influences described in this dissertation.
Additionally, including provider and patient level information, through health insurance claims
and/or electronic health record data, could be useful in identifying providers and regions in need
of additional support for provision of evidenced-based smoking cessation interventions,
including in pregnancy.

Some research questions need to be asked and answered with new data collection. For
example, I identified that relationship with reproductive partner, and particularly the
differentiation of risk linked to whether paternity was acknowledged or not, was an important
influence on SDP risk; however, only new data collection can answer whether this is due to
partner support effects (protection) or partner conflict/abandonment effect (risk), a combination,
or through some other mechanism. I identified that lifetime severity of nicotine dependence was
an important predictor of SDP risk, and that there was a significant interaction with
sociodemographic risk at time of childbirth. However, this work was limited to only white non-
Hispanic participants. Future work should examine the role of smoking history and nicotine
dependence and how it relates to SDP risk among other maternal race/ethnicities, since
longitudinal smoking patterns and degree of nicotine dependence vary by race/ethnicity (Dukes et al., 2017).

The pilot study presented in this dissertation was an attempt to use findings from population-level data to inform new data collection efforts. While recruiting the intended sample was unsuccessful, work to understand protective and resilience factors related to SDP among Indigenous women remains of vital importance. Future studies should prioritize building research partnerships with specific tribes and Native communities, with emphasis on bringing research skills and resources to address the needs and questions of that community. Additionally, collaborating with Tribal Epidemiology Centers could help future work prioritize needs of and improve health for Native communities.
6.3 References


