Assessing Opioid Use Disorder and Access to Drug Treatment Among Pregnant and Postpartum People in the U.S.: A Data-Driven Approach to Inform Equitable Public Health Responses

A thesis submitted by

Chandni Joshi, MPH

in partial fulfillment of the requirements for the degree of

Doctor of Public Health

Tufts University

School of Medicine

Official graduation month and year: August 2022

Advisors: Thomas J. Stopka PhD, MHS (Chair);

Margie Skeer ScD, MPH, MSW; Kenneth Chui PhD, MS/MPH

Abstract

Problem Statement

Harmful use of opioids during the pregnancy and postpartum period in the U.S. has reached epidemic proportions, and Massachusetts has been among the top ten states with the highest opioid use disorder (OUD) rates among pregnant and postpartum (P&P) people in the nation, with 1.5% of people delivering a live birth with evidence of OUD during pregnancy in 2018. However, less than half of all P&P people with OUD receive medications for OUD (MOUD), such as buprenorphine or methadone. Research has demonstrated that access to medications differs by geolocation and socioeconomic characteristics; however, a comprehensive understanding at the micro-level is lacking. Furthermore, there is a high unmet need for drug treatment services that are tailored to the needs of P&P people. The overarching aim of this dissertation is to identify and characterize locations of high OUD burden among P&P people and their access to holistic services, including MOUD.

Methods

I conducted a scoping review of the literature spanning 30 years to identify women-centered drug treatment models in the U.S. I then constructed statistical and spatial models, including bivariate and multivariable logistic regressions, 5-step hotspot cluster analyses, and two-step floating catchment area analyses to determine clusters of P&P people with an OUD history in Massachusetts and spatial accessibility to MOUD services across the state, and to identify social determinants of health associated with OUD prevalence and MOUD access.

Results

Based on the scoping review, the most pertinent needs of P&P people with OUD were non-stigmatized and non-judgmental care, the ability to choose the MOUD that works best for them, and access to social and clinical services in addition to MOUD. No studies reported on the treatment models for sexual and gender minority populations. Based on the multivariable logistic regression analyses, areas with the most vulnerable socioeconomic status in Massachusetts had increased odds of having high counts and rates of P&P people with an OUD history. Hotspot analyses revealed that the socioeconomically vulnerable areas were primarily located in Western and Central Massachusetts. However, these locations also had low access to MOUDs, depicted by the two-step floating catchment area analyses. Foreign-born people who gave birth in Massachusetts had less access to treatment for OUD compared to U.S.-born people.

Conclusion

Treatment services for OUD should be comprehensive and women-centered, taking into consideration the social determinants of health to provide equitable services. Efforts should be concentrated on increasing access to MOUDs overall, and improving access to both types of MOUDs, so P&P people can choose the MOUD that works best for them. Future studies should focus on the most vulnerable populations including foreign-born individuals; those experiencing homelessness, trauma, and violence; and non-binary pregnant persons; which might affect OUD and related treatment access.

Dedication

I would like to devote this work to my highly dedicated and flexible dissertation committee members, Professors Thomas J. Stopka, Margie Skeer, and Kenneth Chui, for their staunch support and trust in me through all these years. Your motivation, guidance, encouragement, and insights in this field have made this an incredible learning experience for me. Special thanks to Professor Stopka for his amazing mentorship and for the regular biweekly meetings on my progress that helped me keep on track, which I now realize is one of the hardest things to do during this five-year long doctoral journey. To Professor Janet Forrester, who served as my mentor and friend throughout my time at Tufts. To Professor Signe Flieger for organizing weekly Doctor of Public Health (DrPH) writing sessions. To my DrPH colleagues, Jean Lim, Ebuwa Igho-Osagie, Cheng Lin, Rina Asemamaw, Stella Stergiopoulos, and Pietra Check, who have been great friends, advisors, and comrades. To Ans Irfan and Anna Schlissel, for being my companions throughout this journey and supporting and motivating me in times of need.

I would like to dedicate this work to everyone who made my work-life balance possible. To the daycare staff at Open Door Preschool and Child Care Center at Laconia, NH, who took extra special care of my toddler so he could enjoy and learn new things while I worked. To my three siblings Roshani, Rajani, and Nripendra, who are my lifelong friends, and who are always there to listen to me, and support me in any and every way possible. To my mother, Urmila, who wanted me and my siblings to go to school because she didn't get that opportunity as a female child. To my late father, Ratna, who worked tirelessly so the children could get an education. And last but not the least, to my husband Shanta, and my toddler Josh, who are my life.

Acknowledgement

I would like to thank all the professors and staff of the Public Health and Professional Degree program who imparted so much knowledge and passion for this field, and who transformed my perspectives on so many public health issues of our time. Special thanks to Associate Professor Mei Chung for providing her expertise in the scoping review methods section. I am highly grateful to Ms. Amy Lapidow, Tufts Hirsh Health Sciences Library, for her expertise in systematic review literature search. I am very grateful to Assistant Professor Shikhar Shrestha, for providing his keen insights regarding spatial methodological considerations. I would also like to thank Ms. Carolyn Talmadge for support with spatial data acquisition and methodological support. I am thankful to the Tufts Initiative on Substance Use and Addiction for funding this study. Many thanks to Taylor Athanasiou and Ryan Bringhurst for helping and guiding me in managing the funding.

I am very grateful to the Massachusetts Department of Public Health and all its staff for providing data access, and especially to Ms. Elizabeth Erdman, Marianna Stewart, Dana Bernson, Malena Hood, and Amy Bettano, for their expertise with the Public Health Data Warehouse and for their guidance on data analyses. Thanks to Dr. Gagan Neupane and Ms. Serra Muftu for assisting with the scoping review. Thanks to Andy Hui for data analysis support. I am thankful to Ms. Reecha Koirala for assisting with the scoping review, data entry, and for formatting this thesis.

Table of Contents

List of Tables

Chapter 2

Chapter 3

Chapter 4

List of Figures

List of Copyrighted Materials

Chapter 2 was published in the Journal Drug and Alcohol Dependence, 226, Chandni Joshi, Margie R. Skeer, Kenneth Chui, Gagan Neupane, Reecha Koirala, Thomas J. Stopka, Women-centered drug treatment models for pregnant women with opioid use disorder: A scoping review, 1-10, Copyright Elsevier (2021) (Joshi et al., 2021).

Permission to reprint the material in this thesis was granted at no charge via email on 9/21/2021.

List of Abbreviations

ACS	American Community Survey
APCD	All Payer Claims Database
BSAS	Bureau of Substance Addiction Services
BUP	Buprenorphine
CA	California
CDC	Centers for Disease Control and Prevention
CI	Confidence Interval
CPS	Child Protective Services
CT	Connecticut
DATA	Drug Addiction Treatment Act
DC	District of Columbia
DMH	Department of Mental Health
DSM-5	Diagnostic and Statistical Manual of Mental Disorders Fifth Edition
E2SFCA	Enhanced 2-Step Floating Catchment Area
EC	Enhanced Care
ESRI	Environmental Systems Research Institute
FDA	Food and Drug Administration
FDR	False Discovery Rate
FFS	Fee-For-Service
GIS	Geographic Information System
HIPAA	Health Insurance Portability and Accountability Act
ICD	International Classification of Diseases
ICE	Index of Concentration at the Extremes
IPC	Interprofessional Collaboration
IQR	Inter Quartile Range
IRB	Institutional Review Board
IRR	Incident Risk Ratio
KDE	Kernel Density Estimation
KY	Kentucky
MA	Massachusetts
MC	Managed Care
MD	Maryland
MATRIS	Massachusetts Ambulance Trip Record Information System
MDPH	Massachusetts Department of Public Health
MOM	Maternal Opioid Misuse
MOUD	Medication for Opioid Use Disorder
MTD	Methadone
NH	New Hampshire
NIH	National Institutes of Health
NM	New Mexico
NOWS	Neonatal Opioid Withdrawal Syndrome
NS	Not Significant
NY	New York
Ob/Gyn	Obstetric/Gynecologic
OBOT	Office-based Opioid Treatment
OH	Ohio
OR	Odds Ratio

OTP	Opioid Treatment Program
OUD	Opioid Use Disorder
PA	Pennsylvania
PHD	Public Health Data
PI	Principle Investigator
PMP	Prescription Monitoring Program
PN	Patient Navigation
P&P	Pregnant and Postpartum
PRAMS	Pregnancy Risk Assessment Monitoring System
RCT	Randomized Controlled Trials
RUCA	Rural-Urban Commuting Area
SAMHSA	Substance Abuse and Mental Health Services Administration
SC	South Carolina
SD	Standard Deviation
STI	Sexually Transmitted Infection
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
SUD	Substance Use Disorder
SVI	Social Vulnerability Index
TANF	Temporary Assistance for Needy Families
TEDS	Treatment Episode Data Set Admissions
UC	Usual Care
USPS	United States Postal Service
UT	Utah
VT	Vermont
WIC	Special Supplemental Nutrition Program for Women, Infants, and Children
WV	West Virginia
ZCTA	ZIP Code Tabulation Area
ZIP	Zone Improvement Plan

Chapter 1: Introduction

1.1 BACKGROUND & SIGNIFICANCE

1.1.1 Ecological Framework for Pregnant and Postpartum People's Harmful Opioid Use

Opioid use disorder (OUD) during pregnancy and the postpartum period in the U.S. has reached epidemic proportions (Haight, Ko, Tong, Bohm, & Callaghan, 2018) but only one-half of all pregnant and postpartum (P&P) people with OUD receive medications for OUD (MOUD), such as buprenorphine or methadone (Krans, Kim, James, Kelley, & Jarlenski, 2019). *OUD is defined as tolerance, craving, inability to limit or cut back on use, and continued use amid negative social and economic effects,* according to the Diagnostic and Statistical Manual of Mental Disorders Fifth Edition (DSM-5) (Criteria from American Psychiatric Association, 2013) (refer to appendix 1.1 for more details). It is important to stress that OUD is a chronic and treatable disease (National Institute on Drug Abuse, 2014b), and that the development of OUD is strongly influenced by environmental and contextual circumstances and a genetic predisposition (Koob & Volkow, 2016; Sloboda, Glantz, & Tarter, 2012).

OUD among P&P people and their use of MOUD occurs within the broader context of their lives, which includes their socioeconomic situation, relationships with their families and extended family, and social support structures, as well as the influence of gender and culture (Substance Abuse and Mental Health Services Administration, 2009). The importance and effect of multi-systems, as well as their bidirectional influence on P&P people's lives, can be elaborated by Bronfenbrenner's socio-ecological model (Bronfenbrenner, 1989), which suggests that the multiple systems and

relationships surrounding a person influence the person with OUD and the person, along with the effects of their opioid use, influences their relationships and the systems that surround and interact with them (Substance Abuse and Mental Health Services Administration, 2009).

In Figure 1.1, a P&P person is shown as the core of a circle within other concentric circles. Each ring represents a separate system. The closest neighboring ring (the microsystem) represents their closest relationships. For example, the relationship between a P&P person with OUD and family can reduce their access to MOUD treatment due to their pregnancy status or caregiving responsibilities (see Chapter 2). The next ring (the mesosystem) represents the interdependence between their closest relationships and the systems; the subsequent ring (the exosystem) represents bigger mechanisms that influence the person but in which the person does not play an active role, such as county funding for substance use treatment or state and federal legislation governing sentencing and child protective services. The macrosystem is the largest system that encompasses cultural values and beliefs, political ideologies, gender socialization and the like (Bronfenbrenner, 1989; Substance Abuse and Mental Health Services Administration, 2009). For example, a P&P person's failure to fulfill ascribed roles (as mothers or caregivers) due to their OUD can result in stigma that may prevent treatment and recovery efforts, and contribute to low self-esteem and self-efficacy for recovery (Substance Abuse and Mental Health Services Administration, 2009) (see Chapter 2). This dissertation focuses on improving access to high quality OUD treatment programs that cater to the clinical and social needs of P&P people.

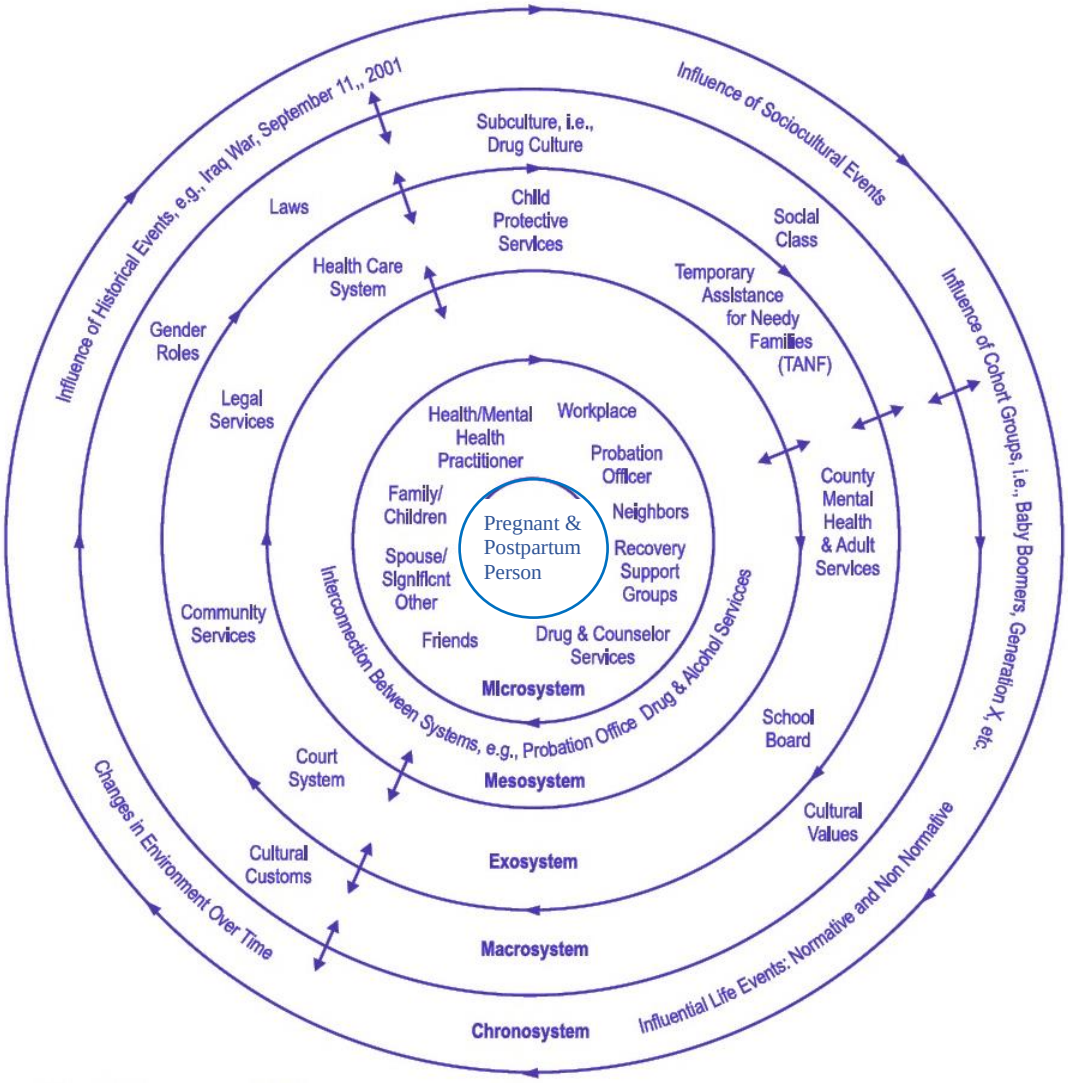

Figure 1.1 Socioecological framework for use of opioids among pregnant and postpartum people, adapted from Bronfenbrenner (1989) (Bronfenbrenner, 1989; Substance Abuse and Mental Health Services Administration, 2009)

1.1.2 Federal and State Policy on Harmful Maternal Opioid Use and MOUD

OUD is a chronic and treatable disease, which has reached epidemic proportions in the U.S. Several federal policies support the prevention and treatment of OUD among P&P people. These policies comprise: the Mental Health Parity and Addiction Equity Act of 2008, the Affordable Care Act of 2010, and the Comprehensive Addiction and

Recovery Act of 2016 (National Institute on Drug Abuse, 2014a). Federal legislation also aims to prevent pregnant people from being excluded from accessing healthcare because of their substance use. Pieces of federal legislation mandate that pregnant people are prioritized for available opioid treatment programs (OTPs) (Guttmacher, 2019) as research shows that pregnant people are less likely than nonpregnant people to receive an appointment for treatment of OUD (Cerdá & Krawczyk, 2020).

The U.S. Congress passed a number of pieces of legislation to improve access to treatment for OUD, by incorporating OUD treatment within general medical settings (Drug Addiction Treatment Act of 2000, 2000), and by increasing the number and type of clinicians who can prescribe MOUD (American Society of Addiction Medicine, 2020; Drug Addiction Treatment Act of 2000, 2000; Substance Abuse and Mental Health Services Administration, 2021a). Additionally, the COVID-19 pandemic has resulted in relaxed federal and state MOUD guidelines, including buprenorphine initiation via telemedicine, OTPs allowing take-home doses of methadone, prohibition of Medicaid prior authorization requirements for MOUD, among others, which are expected to increase MOUD access and decrease barriers to continuity of care (Au-Yeung, Blewett, & Winkelman, 2021; National Institute on Drug Abuse, 2021).

Massachusetts (MA) has several pieces of legislation that reduce P&P people's access to treatment and care. Healthcare professionals in MA are required to report suspected prenatal drug use to child protective services (CPS) agency, which can be used as evidence in child-welfare proceedings (Center for Behavioral Health Statistics and Quality, 2018; Guttmacher, 2019). There are no OTPs in MA specifically for P&P people and P&P people with OUD do not have preferential access to state-funded treatment programs (Guttmacher, 2019). Further, P&P people are not protected from

discrimination against getting into publicly funded treatment programs (Guttmacher, 2019).

The Baker-Polito gubernatorial administration in MA has made combating the opioid crisis a top priority (Massachusetts Department of Public Health, 2017). The MA legislature formed a working group in February 2015 to devise strategies to lower the rate of opioid-related deaths, and one of the strategies was mandated reporting of opioid treatment and overdose data in the state starting 2015, resulting in the creation of a statewide linked database of more than two dozen administrative data sources, providing a virtual census of the state population (An Act Requiring Certain Reports For Opiate Overdoses, 2015). A strength of this dissertation is the utilization of this first of its kind dataset and related data warehouse (Massachusetts Department of Public Health, 2019; National Academy for State Health Policy, 2016).

1.1.3 Epidemic of OUD Among P&P People and its Impacts

Harmful perinatal opioid use and frequently related neonatal opioid withdrawal syndromes (NOWS) are major public health concerns in the U.S. (Hirai, Ko, Owens, Stocks, & Patrick, 2021). NOWS is a generalized disorder characterized by a cluster of signs and symptoms of the central nervous system, including seizures, gastrointestinal dysfunction, respiratory distress, vomiting, and poor feeding and sucking (Substance Abuse and Mental Health Services Administration, 2009). P&P people with OUD have more than doubled in number in the past decade (Hirai et al., 2021).

MA has one of the highest OUD rates among P&P people in the nation (Haight et al., 2018). In MA in 2018, 1.5% of people delivered a live birth with evidence of OUD

during pregnancy, and 11.7 infants per 1,000 live births were diagnosed with NOWS (Massachusetts Department of Public Health, 2021a).

The COVID-19 pandemic has exacerbated the OUD epidemic, with several studies among the general population reporting increases in the number of positive urine drug screens for opioids like fentanyl and heroin (Niles, Gudin, Radcliff, & Kaufman, 2021; Wainwright et al., 2020), and substantial rises in emergency visits for drug overdose, including nonfatal overdose (Ochalek, Cumpston, Wills, Gal, & Moeller, 2020; Shreffler, Shoff, Thomas, & Huecker, 2021). A limited number of studies report on the prevalence of OUD among P&P people (Haight et al., 2018; Hirai et al., 2021). This dissertation provides the latest estimates of OUD prevalence among P&P people in MA over a period of nine years from 2011 to 2019, using population representative data.

Opioid use during the perinatal period increases risks for poor maternal and child health outcomes. Opioid exposure during pregnancy is associated with maternal death (Admon et al., 2019; Metz et al., 2016; Smid et al., 2019), still birth, fetal growth restriction, preterm birth, and certain birth defects including oral clefts, congenital heart defects, clubfoot, (Lind et al., 2017; Yazdy, Desai, & Brogly, 2015), autism (Rubenstein et al., 2019), and educational disabilities (Fill et al., 2018). Furthermore, fetuses exposed to opioids have lower birth weights compared to unexposed fetuses, and usually undergo NOWS at birth (The American College of Obstetricians and Gynecologists, 2017). Infants diagnosed with NOWS have longer and more complicated hospital stays than non-affected infants (Winkelman, Villapiano, Kozhimannil, Davis, & Patrick, 2018).

P&P people who have not been treated for OUD are more likely to face barriers accessing prenatal care; to engage in high-risk activities, such as trading sex for money or drugs; and to be involved with the criminal justice system (Winkelman, Chang, & Binswanger, 2018). Such behaviors expose them to sexually transmitted infections

including HIV, which can be passed to the fetus; violence; and legal ramifications, including loss of child custody, criminal investigation, and incarceration (Radel, Baldwin, Crouse, Ghertner, & Waters, 2018; The American College of Obstetricians and Gynecologists, 2017).

Correspondingly, the costs associated with OUD are significant and are rising, burdening individuals, as well as local, state, and federal governments. At the individual level, hospital stay costs for a newborn with NOWS are nearly nine times higher than a newborn without NOWS in the U.S. (with a mean cost of $9,500 versus $1,100 respectively in 2016) (Winkelman, Villapiano, et al., 2018). At the systems level, Medicaid-covered hospital costs for NOWS-related births rose by more than seven times within a decade, from $65 million to $462 million between 2004 and 2014 (Winkelman, Villapiano, et al., 2018). Similarly, during the same time period, in Medicaid-covered births, the proportion of neonatal hospital expenses attributed to NOWS increased more than three times, from 1.6 percent to 6.7 percent (Winkelman, Villapiano, et al., 2018). Additionally, there are significantly associated child and family assistance costs. An estimated 17.7% of federal government spending in 2018 on programs like child welfare, food and nutritional assistance, and housing and income assistance were related to opioid use and addiction (Society of Actuaries, 2019). Improving access to OUD treatment for P&P people could reduce costs associated with healthcare and social services.

1.1.4 Factors Associated With OUD Among P&P People

Studies depict differences in the prevalence of OUD among P&P people, based on race and ethnicity, nativity, socioeconomic status, demographic characteristics, and geographic location. Compared to mothers without OUD, mothers with OUD were

significantly more likely to be younger in age (<30 years), non-Hispanic White, born in the U.S., single, unemployed, less educated, and on public health insurance (i.e., Medicaid), according to a population-based survey in MA (Massachusetts Department of Public Health, 2017). Moreover, the largest percentages of babies with NOWS were born in non-urban counties that had high unemployment rates and a lack of mental health services in eight U.S. states (Patrick, Faherty, et al., 2019).

Previous studies mainly report on patient-level factors associated with OUD among P&P people (Massachusetts Department of Public Health, 2017; Patrick, Davis, Lehmann, & Cooper, 2015; Patrick, Faherty, et al., 2019). This dissertation seeks to go beyond patient-level factors and identify neighborhood-level social determinants of health that are associated with OUD among P&P people.

1.1.5 Treatment for OUD in P&P People

The evidence-based treatment recommended for OUD during pregnancy and the postpartum period is opioid pharmacotherapy with buprenorphine and methadone (Higgins, Goodman, & Meyer, 2019; National Institute on Drug Abuse, 2017; Substance Abuse and Mental Health Services Administration, 2018). Currently, naltrexone is not recommended in pregnancy because of concerns for fetal well-being from a period of maternal opioid abstinence (because naltrexone initiation requires 7- to-10-day period of opioid abstinence) (Caritis & Venkataramanan, 2020), the potential for relapse, and the unknown fetal effects (due to limited data on naltrexone during pregnancy) (Higgins et al., 2019; Rodriguez & Klie, 2019). Even though not recommended, medically-assisted detoxification with MOUDs and other medications such as clonidine and lofexidine is commonly practiced due to lack of access to MOUDs and preference of some people to not use medications during pregnancy (Boyars & Guille, 2018). Medically-assisted

detoxification with methadone is linked to reduced risk and severity of NOWS, and shorter hospital stay (Bell et al., 2016; Stewart et al., 2013; Welle-Strand et al., 2015).

Effective MOUD can help individuals with OUD avoid opioid withdrawal symptoms and relapse, and reduce cravings (National Institute on Drug Abuse, September 2009; The American College of Obstetricians and Gynecologists, 2017). MOUD in pregnancy helps regulate maternal opioid levels thus protecting the fetus from frequent withdrawal episodes, and minimizes the risk of infectious diseases like HIV and the hepatitis C virus by eliminating and reducing needle use (Krans et al., 2019; Substance Abuse and Mental Health Services Administration, 2009). At the same time, prenatal exposure to methadone and buprenorphine is linked to NOWS, which is treatable and requires collaboration with pediatric care teams to provide appropriate clinical care of affected infants (The American College of Obstetricians and Gynecologists, 2017). Pregnant people treated for OUD with methadone or buprenorphine have more favorable maternal-fetal and maternal-infant health outcomes. For example, for each additional week of MOUD among pregnant people, the odds of overdose decreased by 2% (AOR=0.98; 95% CI: 0.97, 0.99), preterm birth decreased by 1% (AOR= 0.99; 95% CI: 0.99 to 1.00), and postpartum MOUD continuation increased by 95% (AOR= 1.95; 95% CI: 1.87 to 2.04) (Krans et al., 2021).

1.1.6 Factors Associated With Access to MOUD Among P&P People

In the U.S., only 33 to 50 percent of all P&P people with OUD receive MOUD (Godwin, Green, Jones, & Robbins, 2020; Krans et al., 2019). Among people with some college education in MA, Black people were 42 percent less likely than White people to get MOUD in the year before childbirth (AOR=0.58; 95% CI: 0.40 to 0.84) (Schiff, 2019). In studies of single states as well as the entire U.S., MOUD was more likely to be

provided to pregnant people with OUD who were older (Lo-Ciganic et al., 2019; Short, Hand, MacAfee, Abatemarco, & Terplan, 2018), White (Lo-Ciganic et al., 2019; Short et al., 2018), unemployed (Short et al., 2018), and did not have a co-occurring psychiatric illness (e.g., depression, post-traumatic stress disorder) (Rose-Jacobs, Trevino-Talbot, Vibbert, Lloyd-Travaglini, & Cabral, 2019; Short et al., 2018). Among general migrant populations, cultural and language barriers resulted in underutilization of substance use treatment services in states like New York and California (Pagano, 2014; Yu, Clark, Chandra, Dias, & Lai, 2009). However, there is a lack of studies on spatially oriented access to MOUD as well as P&P people with OUD who were not born in the U.S. and how the associated differences impact their OUD and MOUD access. My dissertation addresses this research gap.

Provider-level barriers and facilitators for MOUD utilization have been reported by a recent literature review of the general population that *excluded P&P people* (Mackey, Veazie, Anderson, Bourne, & Peterson, 2019). The provider-level barriers included stigma (e.g., reservations about being an OUD provider and bringing more OUD patients to one's clinical practice, the assumption that OUD patients are "difficult", and the perception that MOUD is substituting one drug for another); logistical barriers (e.g., lack of time, insufficient insurance compensation, or the need for prior authorizations, lack of substance use disorder [SUD] specialists, and questions about drug diversion); perceived lack of patient demand for treatment; and knowledge gaps regarding OUD and MOUD, lack of training and resultant low confidence in prescribing MOUD, and not knowing how to get a waiver to prescribe MOUD (Mackey et al., 2019). The provider-level facilitators to MOUD treatment provision were mentoring, access to education and training, information on referral to specialty care and presence of peer and institutional support (Mackey et al., 2019).

There have been limited studies on the system-level barriers to MOUD access among P&P people, and the few existing studies have found barriers such as: rural county residence (Lo-Ciganic et al., 2019), lack of food and housing access (Rose-Jacobs et al., 2019), treatment programs that were residential (Short et al., 2018), and court/criminal justice referral (Short et al., 2018). Pregnant people living in the Southern region of the U.S. were 60% less likely to receive MOUD as compared to those living in the Northeast (AOR=0.4; 95%CI: 0.4 to 0.4) (Short et al., 2018). The authors linked these disparities to possible differences in child abuse legislation among states, poorer provision of SUD treatment, fewer states in the South offering methadone prescription services under Medicaid formularies, and the South's general rurality affecting MOUD accessibility (as OTPs tend to be located in urban areas) (Short et al., 2018). Furthermore, states that had Medicaid coverage for methadone and did not have prenatal child abuse laws had 63% of pregnant people receive MOUD; conversely, only 19% pregnant people received MOUD in states that did not have Medicaid coverage for methadone and had prenatal child abuse laws (Angelotta, Weiss, Angelotta, & Friedman, 2016). The authors ascribed these differences to the non-coverage of methadone maintenance by Medicaid in the majority of states that had prenatal child abuse laws (Angelotta et al., 2016).

There is a need for studies that go beyond individual risk factors and look at the provider and system level factors. This dissertation examines system-level facilitators and barriers to treatment and care services access among P&P people with OUD in the U.S., and neighborhood-level social determinants of health associated with maternal OUD and access to MOUD. Neighborhood conditions reflect a wide range of the social context of one’s environment related to perinatal substance use and availability of treatment, including the level of resources in the community, the amount of poverty,

joblessness, common moral stances and perceptions, and normality of substance use in a given community (Finch, Vega, & Kolody, 2001). Hence neighborhood-level factors are essential to understanding of the prevalence of OUD and access to treatment services.

1.1.7 The Concept of Access and Spatial/Geographic Access

Access to services is a multifaceted concept, which reflects the degree of "fit" between the individuals and the service delivery system (Penchansky & Thomas, 1981). According to Gulliford *et al*., access comprises five components: 1. Availability of an adequate amount of services (including staff, facilities, and programs) proportional to the population's needs and the location of services in proximity to those that need them; 2. Affordability of services (cost, insurance acceptance and coverage); 3. Accommodation i.e., the provision of services in such a way that they can be accessed without difficulty by those in need (e.g., appropriate hours of service, accessible buildings, provision of transport); 4. Appropriateness of services to meet the social, economic, educational, cultural and linguistic needs of patients; and 5. Acceptability in terms of meeting patient attitudes and demands (Gulliford et al., 2002).

Many factors affect access to health care in a given region, including the number of health facilities in that location (supply), the population size in that area (demand), the health status of the community, the socioeconomic and financial resources available to the population, people's understanding of health and the healthcare system, and geographical hindrances between population and health services (Aday & Andersen, 1974). This dissertation focuses on geographic access to MOUDs for P&P people, taking the above factors into consideration.

Geographic/spatial accessibility focuses on the geographic location of resources and their possible impact on an individual's capacity or willingness to use them

(Guagliardo, 2004). Spatial access is based on the principle of distance decay, which states that as the distance from a service rises, access or consumption declines. Distance, which can affect travel times to outpatient care settings, is increasingly found to have a significant impact on SUD service utilization and treatment retention (Friedmann, D'Aunno, Jin, & Alexander, 2000). For example, Beardsley *et al.* found that patients who traveled less than one mile had higher chances of completing SUD treatment programs compared to those who traveled more than one mile; and that those who traveled more than 4 miles had shorter lengths of stay in treatment in Baltimore, Maryland (Beardsley, Wish, Fitzelle, O'Grady, & Arria, 2003). Also, Amiri *et al.* found that adherence to methadone treatment decreased with increasing distance from home to treatment centers (Amiri et al., 2018). Ongoing use (i.e., treatment retention) is particularly significant for methadone-maintained patients due to the importance of continued medication that is often needed to achieve and retain treatment gains (Rosenblum et al., 2011).

Patients on methadone living in rural or other places with inadequate public transit can find distance to be a particularly important factor (Rosenblum et al., 2011). A population-based study of medication treatment for OUD among Medicaid enrollees from 14 states showed that residents of urban counties had significantly higher chances of receiving MOUD than rural county residents (Stein et al., 2018). Buprenorphine greatly improved MOUD access in rural counties, according to the same study; however, residents of counties with low poverty rates and smaller percentages of Black and Hispanic people received MOUD at a far higher rate than residents of counties without those characteristics (Stein et al., 2018). These studies indicate that racial and ethnic minorities and those below poverty lines have less access to MOUD.

Limited studies report on spatial access to MOUD in the U.S. Previous studies report on access at the macro level, e.g., at state (C. Jones, Campopiano, Baldwin, & McCance-Katz, 2015; Knudsen, 2015) or county levels (Abraham, Andrews, Yingling, & Shannon, 2018; Haffajee, Lin, Bohnert, & Goldstick, 2019; Rosenblatt, Andrilla, Catlin, & Larson, 2015; Stein et al., 2015). This dissertation assesses accessibility to MOUD among P&P people at a more *granular level of geography*, the ZIP Code Tabulation Area (ZCTA) level, and identifies neighborhood-level (i.e., ZCTA) factors that affect such access.

1.1.8 Need for Women-Centered Programming for P&P People With OUD

P&P people with OUD have additional treatment needs beyond MOUD. These needs arise from P&P people being disproportionally affected by intimate partner violence, sexual abuse, transactional sex, malnutrition, and co-occurring psychiatric disorders that can inversely impact treatment engagement and retention (Krans et al., 2018). To address the holistic needs of P&P people with OUD, the Substance Abuse and Mental Health Services Administration (SAMHSA) recommends women-centered programming, which includes components like trauma-informed care, education on parenting (e.g., infant feeding, safe sleep, and local child welfare laws) and family planning (e.g., offering long-acting reversible contraceptives), assistance with housing and other relevant resources (e.g., linking with the Women, Infant and Child [WIC] program, childcare, transportation), screening and treatment of infectious diseases and psychiatric disorders, among others (Substance Abuse and Mental Health Services Administration, 2018). However, a national census of public and private substance treatment facilities in the U.S. depicted that only 40% of the treatment facilities offered women-centered programming while 81–95% of people had an unmet need for such

services (Terplan et al., 2015). Even among programs that offer women-centered programming, significant variation in the type of services offered exists (Terplan et al., 2015). There is a need to evaluate such service variations and the benefits of comprehensive women-centered services (Krans et al., 2018; World Health Organization, 2014). This dissertation fills a gap in the literature identifying comprehensive women-centered drug treatment models of access, coordination, and quality for P&P people with OUD in the U.S. By highlighting effective and well-received best practice models, this dissertation intends to inform the development of improved programs for P&P people with OUD.

In conclusion, this dissertation explores the spatial and non-spatial factors associated with the prevalence of OUD and access to MOUD among P&P people in MA, through a socioecological perspective, and identifies the characteristics of comprehensive women-centered models of care for this population.

1.2 AIMS AND HYPOTHESES

This dissertation is guided by the following specific aims and hypotheses:

Aim 1

Aim 1 systematically maps the research done on the models of drug treatment and care for P&P people with OUD in the U.S. by conducting a scoping review of the literature published between January 1990 and May 2020 in the U.S., with the following specific objectives:

1a) to identify models of drug treatment and care that have been used for P&P people with OUD in the U.S., and

1b) to examine the patient, provider, structural and policy level barriers and facilitators to access, coordination, and quality of such models of treatment and care.

Aim 2

Aim 2 identifies locations of high maternal OUD burden and characterized these locations of higher risk in terms of selected social determinants of health. The social determinants of health used in this dissertation include a range of sociodemographic variables from the American Community Survey (ACS) as well as contemporary composite scores depicting socioeconomic vulnerability and extreme concentration of privilege. The specific objectives are:

2a) to identify clusters of OUD among P&P people during 2011 to 2019 in MA using GIS and spatial epidemiology, and

2b) to find social determinants of health associated with the counts and rates of OUD among this population at the neighborhood level (specifically in MA ZCTA).

Hypothesis for Aim 2

ZCTAs that are more disadvantaged in terms of socioeconomic status and rurality, will have higher OUD prevalence among people who gave birth during the study period.

Aim 3

Aim 3 identifies locations with low geographic access to MOUD and characterizes these locations of higher risk in terms of selected social determinants of health. The specific objectives are:

3a) to determine spatial accessibility to MOUD among P&P people during 2016 to 2020 in MA, and

3b) to find ZCTA sociodemographic characteristics associated with geographic accessibility to MOUD among this population in MA.

Hypothesis for Aim 3

ZCTAs that are more disadvantaged in terms of socioeconomic status, rurality, and high foreign-born population, will have lower MOUD access among P&P people in MA.

1.3 STUDY POPULATION

In this dissertation, I refer to the study population as P&P people. A P&P person is someone who is currently pregnant or gave birth within the last year (Centers for Disease Control and Prevention, 2022). This definition includes binary and non-binary people to make the results more inclusive. The populations differ slightly across chapters 2, 3, and 4 due to data limitations. In Chapter 2, the study population is pregnant people. In Chapter 3, the study population is mothers identified from birth records who gave birth between 2011 and 2019. In Chapter 4, the study population is women who gave birth in the past 12 months between 2016 and 2020, based on the time at which they completed an ACS survey.

Appendix 1.1: Definition of OUD

DSM-V Criteria for Diagnosis of an OUD (Criteria from American Psychiatric Association, 2013)
OUD is defined as a problematic pattern of opioid use leading to clinically significant impairment or distress, as manifested by at least two of the following, occurring within a 12-month period:

1. Opioids are often taken in larger amounts or over a longer period than was intended.
2. There is a persistent desire or unsuccessful efforts to cut down or control opioid use.
3. A great deal of time is spent in activities necessary to obtain the opioid, use the opioid, or recover from its effects.
4. Craving, or a strong desire or urge to use opioids.
5. Recurrent opioid use resulting in a failure to fulfill major role obligations at work, school, or home.
6. Continued opioid use, despite having persistent or recurrent social or interpersonal problems caused or exacerbated by the effects of opioids.
7. Important social, occupational, or recreational activities are given up or reduced because of opioid use.
8. Recurrent opioid use in situations in which it is physically hazardous.
9. Continued opioid use, despite knowledge of having a persistent or recurrent physical or psychological problem that is likely to have been caused or exacerbated by the substance.
10. Tolerance,* as defined by either of the following:
    A. A need for markedly increased amounts of opioids to achieve intoxication or desired effect.
    B. A markedly diminished effect with continued use of the same amount of an opioid.
11. Withdrawal,* as manifested by either of the following:
    A. The characteristic opioid withdrawal syndrome.
    B. Opioids (or a closely related substance) are taken to relieve or avoid withdrawal symptoms.

*Note: This criterion is not considered to be met for those individuals taking opioids solely under appropriate medical supervision.

Severity:
Mild: Presence of 2–3 symptoms.
Moderate: Presence of 4–5 symptoms.
Severe: Presence of 6 or more symptoms.

Chapter 2: Women-Centered Drug Treatment Models for Pregnant Women With Opioid Use Disorder: A Scoping Review[1]

[1] Joshi C, Skeer MR, Chui K, Neupane G, Koirala R, & Stopka TJ. Women-centered drug treatment models for pregnant women with opioid use disorder: A scoping review. *Drug Alcohol Depend.* 2021 Sep 1;226:108855. DOI: 10.1016/j.drugalcdep.2021.108855. PMID: 34198134.

Reprinted with permission of publisher.

2.0 ABSTRACT

Background: While there is a high unmet need for drug treatment services tailored to the needs of pregnant women, fewer than half of the opioid use disorder (OUD) treatment programs in the U.S. offer such services. We conducted a scoping review of the literature to identify women-centered drug treatment models that address access, coordination, and quality of care, and their facilitators and barriers.

Methods: We searched PubMed, EMBASE, PsycInfo, Sociology Database, Web of Science, CINAHL, EBSCO Open Dissertations, Health Services Research Projects in Progress, and relevant agency websites from 1990 to 2020. We included studies that evaluated multicomponent models of care that provided medication for OUD (MOUD) to pregnant women in the U.S.

Results: Of the 1,578 unduplicated articles screened, 26 articles met the inclusion criteria, which reported on 19 different studies and included 3,193 women. We identified seven different models of care and found that: (1) access was improved by co-locating various services for drug treatment and care, (2) coordination was enhanced by inter-professional collaboration, (3) quality was improved by treating pregnant patients in

groups, and (4) stigmatization and criminalization of substance use during pregnancy was a significant barrier to care.

Conclusions: There is an urgent need to bolster patient-provider relationships that are built on trust, are free of stigma, and that empower patients to make their own decisions. Improved policies and regulations to reduce stigma around the use of opioids and MOUD are needed, so that pregnant women with OUD can access high quality care.

Keywords

Pregnant, perinatal, opioid use disorder, scoping review, treatment

2.1 INTRODUCTION

Use of opioids during pregnancy in the U.S. has reached epidemic proportions, with rates more than quadrupling between 1999 and 2014, from 1.5 to 6.5 opioid use disorder (OUD) diagnoses per 1,000 hospital deliveries annually (Haight et al., 2018). Medication for OUD (MOUD), including methadone and buprenorphine, is the recommended treatment for pregnant women with OUD (Higgins et al., 2019; Substance Abuse and Mental Health Services Administration, 2018). Previous studies on pregnant women found that MOUD improved maternal and neonatal health outcomes (Klaman et al., 2017; Krans et al., 2019; Substance Abuse and Mental Health Services Administration, 2009), and saved state and federal dollars spent on healthcare, criminal justice, and child and family assistance (Research Data Assistance Center, 2016; Rhyan, 2017; Winkelman, Villapiano, et al., 2018). However, less than half of pregnant women with OUD have received MOUD during their pregnancy or peri-partum period (Godwin et al., 2020; Krans et al., 2019).

Women with OUD have additional treatment needs beyond MOUD. These needs arise from women being disproportionally affected by intimate partner violence, sexual abuse, transactional sex, unintended pregnancy, malnutrition, and co-occurring psychiatric disorders that can inversely impact treatment engagement and retention (Krans et al., 2018). To address the holistic needs of pregnant women with OUD, the Substance Abuse and Mental Health Services Administration (SAMHSA) recommends women-centered programming, which includes components like trauma-informed care, education on parenting (e.g., infant feeding, safe sleep and local child welfare laws) and family planning (e.g., offering long-acting reversible contraceptives), assistance with housing and other relevant resources (e.g., linking with the Women, Infant and Child [WIC] program, childcare, transportation), screening and treatment of infectious diseases

and psychiatric disorders, among others (Substance Abuse and Mental Health Services Administration, 2018). However, a national census of public and private substance treatment facilities in the U.S. depicted that only 40% of the treatment facilities offered women-centered programming while 81–95% of women had an unmet need for such services (Terplan, Longinaker, & Appel, 2015). Even among programs that offer women-centered programming, significant variation in the type of services offered exists (Terplan et al., 2015). There is a need to evaluate such service variations and the benefits of comprehensive women-centered services (Krans et al., 2018; World Health Organization, 2014).

The goal of our study was to fill a gap in the literature identifying comprehensive women-centered drug treatment models of access, coordination, and quality for pregnant women with OUD in the U.S. By highlighting effective and well-received best practice models, we intend to inform the development of improved programs for pregnant women with OUD.

2.2 MATERIALS AND METHODS

We conducted a scoping review of the literature to identify key characteristics of a best practice model of drug treatment and care for pregnant women with OUD. Scoping reviews are similar to systematic reviews but address more complex and exploratory research questions, which include mapping key concepts, types of evidence and gaps in research (Arksey & O'Malley, 2005; Colquhoun et al., 2014). We followed the scoping review methodology framework by Arksey and O'Malley (Arksey & O'Malley, 2005), and the PRISMA extension for scoping review reporting requirements by Tricco *et al.* (Tricco et al., 2018). For the conceptual model, we used Bronfenbrenner's socio-ecological model (Bronfenbrenner, 1989) to understand the concepts of barriers and

facilitators to drug treatment for women with OUD. We used Gulliford *et al.*'s five dimensions of access to care, which encompasses availability, affordability, appropriateness, acceptability, and accommodation of patients' various needs (Gulliford et al., 2002); Powell *et al.*'s concept of coordination of care that involves formal and informal communication among clinical and non-clinical staff, and patients (Powell et al., 2008); and Campbell *et al.*'s definition of quality of care that includes technical quality and quality of interpersonal care (Campbell, Roland, & Buetow, 2000).

2.2.1 Study Selection Criteria

Studies that were eligible for inclusion included original research studies and systematic reviews that were published between January 1990 and May 2020. We specified 1990 as the starting year since the first wave of the current opioid crisis began in mid-1990s (DeWeerdt, 2019). We searched for studies in peer reviewed journals and the gray literature without any restrictions on study design. Eligible studies addressed models of care (see Table 2.1 for definition) for pregnant women, with MOUD as an essential component. Eligible studies included those that focused on treatment with methadone, buprenorphine (including extended-release buprenorphine) and/or naltrexone initiation and maintenance (Hand, Short, & Abatemarco, 2017). Exclusion criteria were: 1) animal studies and duplicates, 2) studies before 1990, 3) studies that did not focus on pregnant women with OUD and MOUD administration, and 4) studies that were conducted outside the U.S. (to find models that are more easily applicable to the U.S., considering local and federal policies that are often unique to the U.S.). Once the full texts were obtained, we applied four additional exclusion criteria: 1) articles that were opinion or discussion pieces, 2) articles based on single case reports, 3) studies that did not include at least one of the three model components (i.e., access, coordination, and

quality of care [refer to Table 2.1 for definition]), and 4) studies that did not evaluate at least one of these components. We did not pre-define the types of outcomes.

Table 2. 1 Definitions for scoping review of women-centered drug treatment models for pregnant women with opioid use disorder, 1990-2020.

Terms	**Definitions**
Model of care	It details how a diverse array of health services is structured and distributed. This definition includes principles (e.g., accessibility, equity, coordination), care delivery systems (e.g., multidisciplinary, on-line, etc.) and the types of services provided (e.g., mental healthcare, obstetric care) (Joshi et al., 2013). These principles, care delivery systems, and service types are underpinned by organizational and infrastructural elements, which include: •. Health service funding availability and costs to clients or systems in governmental, non-governmental, and private organizations. • Provider workforce: obstetricians, primary care physicians, addiction medicine specialists, psychiatrists, nurses, social workers, care navigators. • Organization: team, network, integrated service.
Access to service	Access is comprised of the following five components (Gulliford et al., 2002): 1. Availability of an adequate amount of services (including staff, facilities and programs) proportional to the population's needs and the location of services in proximity to those that need them. 2. Affordability of services (cost, insurance acceptance and coverage). 3. Accommodation — the provision of services in such a way that they can be accessed without difficulty by those in need (e.g., appropriate hours of service, accessible buildings, provision of transport). 4. Appropriateness of services to meet the socioeconomic, educational, cultural, and linguistic needs of patients. 5. Acceptability in terms of meeting patient attitudes and demands.
Coordination of care	It includes coordination and communication among various providers, patients, their families, and services to improve the quality of care and achieve common goals for patients (Joshi et al., 2013). This can include: • Communication with patients and their families. • Informal communication between staff or services. • Team meetings, case conferences, inter-agency meetings. • Assessments and records shared among staff and/or agencies. • Coordination with non-health services including social workers and social services. • Referrals and inter-service agreements.
Quality of care	Technical quality of care (i.e., clinical care that is consistent with evidence-based guidelines) and quality of interpersonal care (i.e., patient satisfaction) (Campbell et al., 2000).

2.2.2 Data Sources and Searches

We identified published literature from PubMed, EMBASE, CINAHL, PsycInfo, Sociology Database and Web of Science. This was followed by snowballing of the reference lists and citation search of included articles. For unpublished literature, we searched EBSCO Open Dissertations, Health Services Research Projects in Progress, NIH RePORTER and SAMHSA's website.

We combined three domains of keywords 'pregnant women', 'opioid use disorder' and 'treatment' (Appendix Table 2.3). The search strategy was based on previous publications and finalized through consultation with a medical librarian.

2.2.3 Study Selection

Two authors independently screened the titles, abstracts, and full texts. Any discrepancies were reconciled through discussion. We used EPPI-Reviewer 4 software (Digital Solution Foundry and EPPI-Centre, 2020) for screening titles and abstracts and assessing full texts.

2.2.4 Data Extraction

Two authors collaboratively extracted and compiled data in a Microsoft Excel spreadsheet, including information on author and year, study design, location and setting, sample size, patient and provider characteristics, interventions including MOUD and care components, study outcomes, limitations, and recommendations.

2.2.5 Data Synthesis and Analysis

We analyzed the data using numerical data synthesis, qualitative thematic analysis and systematic narrative synthesis (Arksey & O'Malley, 2005). To report participants' demographic and socioeconomic characteristics, we calculated a weighted mean for normally distributed data and a weighted median for data that were not

normally distributed. We examined whether data were normally distributed based on the mean and the corresponding standard deviation values (Habibzadeh, 2017). We calculated retention rates based on participant demographic data at baseline and follow up or presented the retention rates reported by studies that had a clear dropout definition. We reported outcomes that were statistically significant at $p<0.05$.

For the qualitative analysis, first, we coded the data in NVivo 12+ (NVIVO, 2020), which was guided by our analytical frameworks. We then conducted a thematic analysis inductively to identify and analyze themes and explanations (Braun & Clarke, 2006), which were subsequently grouped according to the different types of treatment models, the three model components (i.e., access, coordination, quality), and corresponding barriers and facilitators from each article. We continually revised the themes as the articles were compared for similarities and differences (Palombi, St Hill, Lipsky, Swanoski, & Lutfiyya, 2018; Pope, Ziebland, & Mays, 2000).

For the quantitative analysis, we conducted a narrative synthesis, as high levels of methodological and clinical heterogeneity contraindicated meta-analysis (Centre for Reviews and Dissemination, 2009). We synthesized quantitative data from multiple studies to find the overall effects and textually described the study effects, noting the variations in study characteristics and implementation, to summarize and explain the findings of the synthesis (Centre for Reviews and Dissemination, 2009).

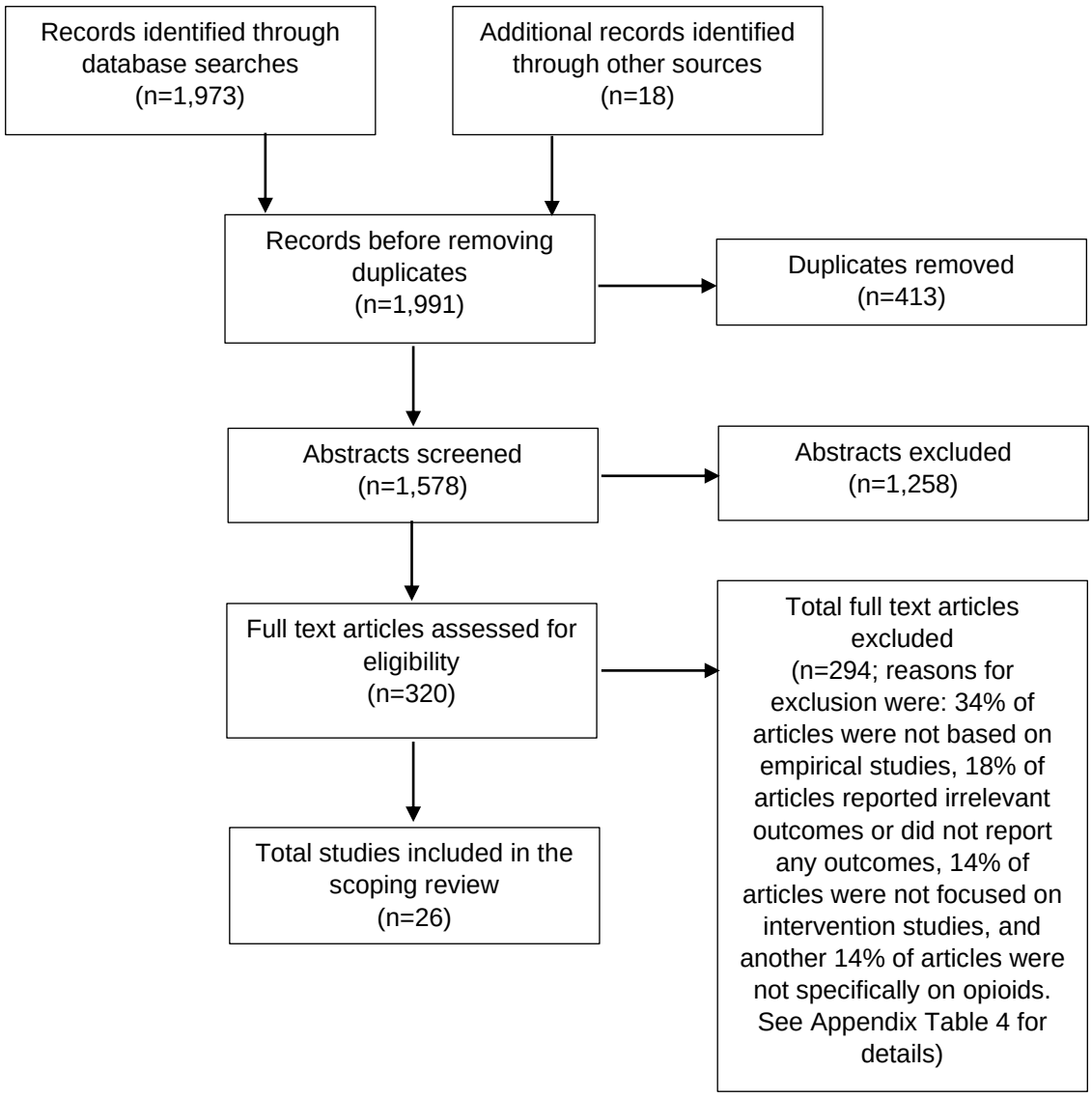

Figure 2. 1 PRISMA flow diagram for selection of papers for scoping review of women-centered drug treatment models for pregnant women with opioid use disorder, 1990–2020.

2.3 RESULTS

From 1,578 unique articles, we ultimately included a total of 26 articles reporting on 19 different studies from 16 U.S. states. These 26 articles included 3,193 women, with individual study sample sizes ranging between 4 to 1,098 (Figure 2.1).

2.3.1 Study Design and Location

We categorized the articles by study design, including randomized controlled trials (n=7), cohort studies (n=4), quasi-experimental studies (n=10), and qualitative studies (n=5). We categorized the location of studies into Northeast, Midwest, South and West census regions (US Census Bureau). The highest number of studies were conducted in the Northeast (42.3%), half of the studies were from urban areas (50.0%), and nearly one-third of the studies (30.8%) were conducted in university hospitals.

2.3.2 Participant Characteristics

Participants had a mean age of 28.0 years. More than half of participants (59.6%) had a high school education or higher, and 61.9% of participants were unemployed at the time of the study. Nearly a fifth of the participants (19.8%) were currently married or cohabiting. Overall, a very small proportion of participants (9.0%) were non-White, but a subset of these studies (n=7) had a majority of Black participants (Jansson, Svikis, Velez, Fitzgerald, & Jones, 2007; H. Jones, Haug, Silverman, Stitzer, & Svikis, 2001; H. Jones, Haug, Stitzer, & Svikis, 2000; Laken, McComish, & Ager, 1997; Silverman, Svikis, Robles, Stitzer, & Bigelow, 2001; Svikis, Lee, Haug, & Stitzer, 1997; Tuten, Svikis, Keyser-Marcus, O'Grady, & Jones, 2012). Around half of the participants (47.4%) reported having mental illness, 33.5% had an infectious disease, and 14.5% reported having current or past legal involvement.

Only one article reported on the history of trauma or violence among participants: Lander et al. (2015) reported that 17% of women experienced intimate partner violence. No articles mentioned the proportion of clients who experienced homelessness or who had limited English proficiency. Three articles mentioned limiting their study to patients speaking English.

2.3.3 Types of Treatment Models

Through our thematic analyses, we developed seven different treatment models of care for pregnant women with OUD (Table 2.2) based on previous healthcare models (Hogg, Rowan, Russell, Geneau, & Muldoon, 2008; Korthuis et al., 2017; Substance Abuse and Mental Health Services Administration, 2013). We categorized five models as practice-based: office-based opioid treatment, integrated prenatal care and MOUD, coordinated care (at the practice level), one-stop-shop (that provided a combination of services which addressed all potential needs for pregnant women with OUD under one roof), and patient navigation. We categorized two models as system-based: providing resources and technical provisions and coordinated care (called a 'maternal medical home' which is a system-based coordinated model that included a statewide quality improvement initiative including coordinated behavioral healthcare, obstetric/gynecologic care, MOUD, and social supports). Two of the system-based models also had practice-based components: 1) Jansson *et al.* reported a one-stop-shop model that compared the impact of system-level changes in provider payment and care delivery on pregnant women with OUD (i.e., resources and technical provisions) (Jansson et al., 2007), 2) Meyer *et al.* reported a model of coordinated care (i.e., practice-based) and the impacts of state-level increased access to MOUD on its pregnant clients (i.e., system-based resources and technical provisions) (Meyer et al., 2012). A total of 22 articles were

based at medical facilities (hospital, obstetric/gynecologic clinic, or primary care clinic) while four articles were based at opioid treatment programs (OTPs).

2.3.4 Study Outcomes

A wide variety of maternal and child health outcomes were reported by individual articles, the most prominent being: maternal attendance and retention at substance treatment, and frequency of drug screening and prenatal visit; and infants' gestational week, birth weight, length of stay at hospital, admission at neonatal intensive care unit and incidence of Neonatal Opioid Withdrawal Syndrome (NOWS). NOWS incidence was reported by more than a quarter of the articles (26.9%), with the incidence ranging between 13.0% to 58.3%. Patient satisfaction with various components of the model was reported by nearly a quarter of the articles (23.1%) (Table 2.3). However, several outcomes were not homogenously defined in these articles. For example, patient retention in drug treatment (the most-reported outcome at 53.8%) was reported using various time periods: different articles defined retention as when their study ended, until delivery of the child, or into the postpartum period. Accordingly, the articles reported a wide range of patient retention rates, from 24.0% to 100%. Positive urine drug testing (the second most-reported outcome at 46.2%) was also measured heterogeneously: different articles measured drug screening during various prenatal, delivery and postpartum periods, for opioids, cocaine and/or other drugs.

Table 2. 2 Women-centered drug treatment models for pregnant women with opioid use disorder: Scoping review, 1990-2020 (n=26).

Models	Summary	Included articles
Practice-based models		
Office-based opioid treatment	Buprenorphine prescribed by primary care providers who complete waiver training.	Cochran *et al.* (Cochran et al., 2018), Kahn *et al.* (Kahn et al., 2017), Krans *et al.* (Krans et al., 2018), Lopian *et al.* (Lopian, Chebolu, Kulak, Kahn, & Blondell, 2019)
Integrated prenatal care and MOUD	Model provided obstetric/gynecologic care and MOUD in the same setting.	*Chang *et al.* (Chang, Carroll, Behr, & Kosten, 1992), Goodman *et al.* (Goodman, 2015), Guille *et al.* (Guille et al., 2020), Mittal *et al.* (Mittal & Suzuki, 2017), Ostrach *et al.* (Ostrach & Leiner, 2019), Sutter *et al.* (Sutter et al., 2019)
Coordinated care (at the practice level)	Model provided two or more coordinated obstetric/gynecologic care, MOUD, mental/behavioral healthcare, and social support.	*Carroll *et al.* (Carroll, Chang, Behr, Clinton, & Kosten, 1995), Fallin-Bennett *et al.* (Fallin-Bennett, Elswick, & Ashford, 2020), Hodgins *et al.* (Hodgins, Lang, Malseptic, Melby, & Connolly, 2019), Laken *et al.* (Laken et al., 1997), Lander *et al.* (2015) (Lander, Gurka, Marshalek, Riffon, & Sullivan, 2015), *Lander *et al.* (2016) (Lander, Marshalek, & Sullivan, 2016), Meyer *et al.* (Meyer et al., 2012), Paterno *et al.* (Paterno, Jablonski, Klepacki, & Friedmann, 2019), *Wilder *et al.*, (Wilder, Lewis, & Winhusen, 2015)
One-stop-shop	Model provided multidisciplinary care including obstetric/gynecologic care, mental/behavioral healthcare, MOUD, family planning, pediatric care and social services (transportation, nutrition and childcare).	Jansson *et al.* (Jansson et al., 2007), Jones *et al.* (2000) (H. Jones et al., 2000), Jones *et al.* (2001) (H. Jones et al., 2001), Silverman *et al.* (Silverman et al., 2001), Svikis *et al.* (Svikis et al., 1997), Tuten *et al.* (Tuten et al., 2012)
Patient navigation	A clinical patient navigator provided case management, clinical support, motivational interviewing, and addiction-relapse prevention programming.	Cochran *et al.* (Cochran et al., 2018)
System-based models/changes		

Models	Summary	Included articles
Resources and technical provisions	Changes in healthcare delivery system, e.g., provider availability and remuneration.	Jansson *et al.* (Jansson et al., 2007); Meyer *et al.* (Meyer et al., 2012)
Coordinated care	A statewide quality improvement initiation including coordinated behavioral healthcare, obstetric/gynecologic care, MOUD and social supports.	Crane *et al.* (Crane et al., 2019)

*****These models are based on opioid treatment programs, while the others are medical models.

Table 2. 3 Study characteristics, models, and their outcomes 1990-2020 (n=26).

	Study characteristics				Practice-based models				System-based models/changes			Outcomes		
	Author (year)	State/ region	Sam-ple size	MOUD provided	Office-based opioid treatment	Co-located care	Coordi-nated care	One-stop-shop	Patient navigation	Provider payment & delivery system	State-level improved MOUD access	Maternal medical home	Patient retention	Patient satis-faction	NOWS incidence
Randomized Controlled Trials	Jones (2001)	MD	85	MTD				✓					94.1% overall at 7-days follow up, EC 93.6%, UC 94.7%		
	Jones (2000)	MD	93	MTD				✓							
	Lander (2015)	WV	45	BUP			✓						51.1% overall 4 weeks postpartum, EC 51.9%, UC 50.0%	↑	22.7% overall, EC 23.1%, UC 22.2%
	Carroll (1995)	CT	14	MTD			✓								
	Silverman (2001)	MD	40	MTD				✓					47.5% overall at the end of 24 weeks study period, EC 55.0%, UC 40.0%		
	Svikis (1997)	MD	142	MTD				✓					55.6% overall at 30 days follow up		
	Tuten (2012)	MD	143	MTD				✓					77.4% overall until delivery, incentivized 74.4%, non-incentivized 83.7%		
Qualitative Studies	Sutter (2019)	NM	-	MTD, BUP		✓								↑	
	Fallin-Bennett (2020)	KY	9	BUP			✓							↑	
	Hodgins (2019)	MA	4	MTD			✓								
	Kahn (2017)	NY	14	BUP	✓									↑	
	Ostrach (2019)	Central Appalachia	27	BUP		✓									

	Study characteristics				Practice-based models					System-based models/changes			Outcomes		
	Author (year)	State/ region	Sam-ple size	MOUD provided	Office-based opioid treatment	Co-located care	Coordi-nated care	One-stop-shop	Patient navigation	Provider payment & delivery system	State-level improved MOUD access	Maternal medical home	Patient retention	Patient satis-faction	NOWS incidence
Cohort Studies	Crane (2019)	OH	1098	MTD, BUP								✓	EC 63.1%, UC 44.2% six months postpartum		43.1% overall, EC 50.0%, UC 41.1%
	Krans (2018)	PA	335	BUP	✓										
	Lopian (2019)	NY	108	BUP	✓								73.2% at 12 months		
	Wilder (2015)	OH	229	MTD			✓						89.0% before delivery, 38.1% six months postpartum		
Quasi-experimental Studies	Chang (1992)	CT	12	MTD		✓							100% at delivery		
	Cochran (2018)	PA	21	BUP					✓				100% postpartum		
	Guille (2020)	SC	98	BUP		✓							88.8% overall, EC 85.4%, UC 91.7% 6-8 weeks postpartum		53.6% overall, EC 45.4%, UC 63.2%
	Goodman (2015)	NH, VT	40	BUP		✓								↑	
	Jansson (2007)	MD	240	MTD				✓		✓			FFS 37.1%, 24.1% MC		22.1% overall, 29.5% in FFS, 13.0% in MC
	Laken (1997)	MI	168	MTD			✓								
	Lander (2016)	WV	27	BUP			✓						51.9% overall four weeks postpartum	↑	23.1% overall
	Meyer (2012)	VT	149	MTD, BUP			✓				✓				58.3% overall
	Mittal (2017)	MA	14	MTD, BUP		✓							93.8% till early postpartum		
	Paterno (2019)	MA	38	MTD, BUP			✓								44.7% overall, 31.6% pre-test, 57.9% post-test

Note: **BUP**: Buprenorphine; **CT**: Connecticut; **EC**: Enhanced Care; **FFS**: Fee-for-service; **MA**: Massachusetts; **MC**: Managed Care; **MD**: Maryland; **MI**: Michigan; **MTD**- Methadone; **NH**: New Hampshire; **NY**: New York; **NOWS**: Neonatal Opioid Withdrawal Syndrome; **OH**: Ohio; **PA**: Pennsylvania; **SC**: South Carolina; **UC**: Usual Care; **VT**: Vermont; **WV**: West Virginia; ↑: Increase

2.3.5 Model Components and Their Facilitators and Barriers

We assessed salient strategies to enhance access, coordination, and quality of care, and their corresponding barriers and facilitators, using thematic analyses. Since these concepts are interrelated, some of the findings in each of these domains are similar or overlapping. More than half of the articles (57.7%) provided buprenorphine alone or as an alternative with methadone, and 42.3% of the articles provided only methadone to their clients (Table 2.3).

2.3.5.1 Key strategies to enhance access to care

The studies included in our review addressed various dimensions of access, as defined by Gulliford *et al.*: *availability* (of an adequate amount of service that is suitably located), *accommodation* (of patients' various needs so that they can use the service without difficulty), *affordability* (in terms of patients' ability to pay) and *acceptability* (in terms of patients' attitudes and demands) (Gulliford et al., 2002).

To make drug treatment and care more *available* to patients, the key strategies reported were: co-locating OTP with various care components like obstetric/gynecologic care, mental healthcare and pediatric care (42.3%); offering free or facilitated transportation to and from the program (30.8%); and providing office-based opioid treatment (15.4%). Other strategies reported by very few articles were sending mobile methadone clinics to rural areas (3.8%), and increasing the number of buprenorphine providers (3.8%).

Accommodation of various needs of patients was addressed by salient strategies like provision of mental health services (50.0%); delivering patient education on pregnancy, substance use, and parenting (50.0%); offering childcare (30.8%) and nutritional support (23.1%); facilitating housing (11.5%); and screening for sexually transmitted infections (STIs) (11.5%). Strategies reported by very few articles to improve

accommodation included provision of vocational services (7.7%), support for violence and trauma (7.7%), facilitating access to WIC services (3.8%), and providing infant supplies (3.8%).

Key strategies reported to improve *acceptability* of care were contingency management ([26.9%], a type of behavioral therapy, which involves rewards to reinforce positive behavioral change (Petry, 2011) ; building a trusting relationship between patients and providers (19.2%); and use of a non-judgmental approach by providers (19.2%).

Trust was developed between patients and providers through providers implementing: 1) patient-centered care that empowered women to make healthcare decisions, 2) shared decision-making resources to mothers, and 3) longer group consultations that facilitated opportunities to discuss topics not possible otherwise. Providers were better able to use a non-judgmental approach when interventions worked to decrease internalized stigma tied to maternal OUD. Such successful interventions included: educating clinicians on maternal substance use (Lander et al., 2016), discussing patients' experiences with systemic stigma in the healthcare system with clinicians (Lander et al., 2016), informing providers and patients about child protective services (CPS) procedures (Crane et al., 2019), and providing longer group consultations that inspired trust and a sense of community (Sutter et al., 2019). Patients perceived medical facilities to be less stigmatizing than OTP sites, with regard to OUD and MOUD treatment. Very few articles reported strategies to improve *affordability* of care, which included: treatment being covered by Medicaid (7.7%), provision of private funding (3.8%), reduced program fees for pregnant women (3.8%), and paid maternity leave (3.8%).

Reported facilitators of access to care were co-location of treatment and care services (15.4%), office-based opioid treatment (7.7%), contingency management (15.4%), non-judgmental providers (15.4%), childcare provision (11.5%), group modality of care (e.g., providing health education to pregnant women in groups [23.1%]), residential care for patients experiencing homelessness (3.8%), use of a patient navigator (3.8%), and increase in MOUD treatment slots (3.8%). Group care increased trust between providers and patients through social connectedness, motivated abstinence, and increased staff satisfaction, allowing for longer appointment times.

Barriers to accessing treatment and care that were reported included: lack of transportation and long travel time (19.2%), lack of childcare (7.7%), judgmental clinicians (7.7%), insufficient access to MOUD (7.7%), health insurance (including Medicaid) not covering treatment during postpartum period (15.4%), programs not accepting public insurance (3.8%), insufficient funding (3.8%), structural and institutional stigmatization (3.8%), and criminalization of substance use during pregnancy (3.8%).

A qualitative study highlighted stigma and criminalization as the main reasons for patients' reluctance to accept MOUD treatment offered to them, which included: family and friends' disapproval of MOUD treatment (that MOUD is just replacing one drug with another), and fear of involvement of law enforcement and social services (Ostrach & Leiner, 2019).

2.3.5.2 Key strategies to enhance coordination of care

Coordination of care involves formal and informal communication and coordination with clinicians and non-clinicians, and their patients to achieve common goals for patients (Powell et al., 2008). The most salient strategy reported to enhance coordination of care was inter-professional collaboration ([76.9%], defined as collaboration among multiple health workers from different professional backgrounds to

provide comprehensive clinical and non-clinical services (World Health Organization, 2010). In this review, interdisciplinary staff included physicians, nurses, CPS, community health workers, and social workers. Their roles provided obstetric and gynecologic care, psychiatric care, behavioral healthcare, counseling, MOUD, and social needs such as nutritional support, transportation, and childcare.

Other key strategies reported to enhance coordination of care were referral to health and social services (30.8%), communication between patients and clinical/non-clinical staff to assess patients' medical and social needs and priorities (26.9%), close coordination between OTPs and obstetric/gynecologic care (19.2%), and case management (15.4%).

Care coordination facilitators reported were: co-location of various treatment and care services (15.4%); inter-professional collaboration (7.7%); access to electronic medical records shared by various providers (3.8%); and establishing a formal drug screening, intervention and referral process (3.8%). Interdisciplinary teams were highlighted as effective at reducing providers' stigma towards pregnant women who use substances.

The barriers in the care coordination realm were: limited communication with providers outside of the system resulting in difficulty coordinating care among multiple providers (3.8%), and fragmentation of comprehensive services as a result of system change in provider payment and care delivery (3.8%).

2.3.5.3 Key strategies to enhance quality of care

Quality of care involves the technical quality of care (i.e., clinical care that is consistent with evidence-based guidelines) as well as the quality of interpersonal care, based on patient satisfaction (Campbell et al., 2000). Salient strategies utilized to

improve quality of care included: using a group modality of care (65.4%), providing continuity of care from prenatal to postpartum periods (30.4%), patient-provider joint decision-making (15.4%), staff development and training on improving clinical care and reducing stigma (11.5%), and tailoring services to the specific needs of pregnant women with OUD (11.5%). Strategies reported by a few studies were: making guidelines for clinical care easily accessible to providers (7.7%), establishing formal policies and protocols for treatment and care (3.8%), and conducting multidisciplinary quality improvement meetings (3.8%).

Facilitators reported for quality of care were: co-locating treatment and care services (15.4%), group modality of care (11.5%), contingency management (15.4%), trusting patient-provider relationships (11.5%), an interdisciplinary team that is well-informed on substance use during pregnancy (11.5%), non-judgmental care (23.1%), and close communication among interdisciplinary staff (3.8%). Non-judgmental care and job satisfaction resulted from training the care team (including both clinicians and non-clinicians). Barriers reported were: low referral rates (3.8%), late referral of patients to appropriate treatment and care (3.8%), short appointment time (3.8%), lack of knowledge on referral programs (3.8%), and provider bias (3.8%).

We found that patient satisfaction resulted from non-judgmental care, a trusting patient-provider relationship, service tailored to the specific needs of pregnant women with OUD, a group care modality, and co-location of treatment and care. Group care provided social support to women. Patients were more comfortable sharing their information with non-clinicians than clinicians. The pregnancy-only group reported that such care addressed their specific needs. Providing care in a non-OTP site reduced stigma. Co-locating treatment and care facilitated continuity and coordination of care.

2.4 DISCUSSION

We conducted a novel scoping review to identify drug treatment model components and outcomes, with a focus on key elements of access, coordination, and quality of care for pregnant women with OUD in the U.S. Our review assessed nearly 2,000 studies from 1990 to 2020, and only 26 studies were ultimately included in our final review and analyses. This speaks to the paucity of research focused on comprehensive women-centered MOUD treatment models for pregnant women in the U.S. Our overall findings indicate that the model elements most frequently associated with improved access, coordination, and quality of care were co-locating treatment services, inter-professional collaboration, and group care modality respectively. Non-judgmental care from providers facilitated all three of these model elements.

In this review, we found that many of the programs that co-located drug treatment and care were in university hospitals, which tend to have more resources available than other sites. Hence, such models may need adaptation before they can be replicated in other settings. Additionally, the varying regulatory environments in different states of the country will impact whether a model feasible in one state will be replicable in another state. For example, Medicaid expansion has been adopted by 39 states and Washington DC (Kaiser Family Foundation, 2020), and MOUD treatment past the 60 days postpartum period is covered by Medicaid only in these locations (Kaiser Family Foundation, 2019). This is an important consideration as, based on our review, one of the key strategies to enhance quality of care was continuity of care from prenatal to postpartum periods.

A salient strategy to improve coordination of care was inter-professional collaboration, which allows providers to achieve together more than they can individually (Green & Johnson, 2015). Such collaboration is highly appropriate for chronic and

complex conditions like OUD during pregnancy that requires services from multiple specialty providers. Throughout our review, we found that pregnant women with OUD have a wide range of needs, including clinical services like obstetric, gynecologic, pediatric, psychiatric, MOUD, and lactation; and social support including childcare, transportation, housing, nutrition. However, unmet need for such social support, insufficient access to MOUD, as well as financial and insurance issues were major barriers to access treatment.

Another significant barrier to treatment was stigmatization and criminalization of substance use during pregnancy. For example, Massachusetts requires mandated reporters to report pregnant women who receive MOUD to the Department of Children and Families (Massachusetts Office of the Child Advocate, 2020). Such policies can deter pregnant patients with OUD from seeking timely prenatal care and can hinder disclosure of drug use to providers due to concerns related to mandatory reporting. Decreasing stigma and criminalization will help women feel more comfortable accessing care, which will ensure a safer pregnancy for the mother and child (Fonti, Davis, & Ferguson, 2016). In this review, we found that providing training and education to the care team (including clinicians and non-clinicians) improved their attitudes towards patients with OUD and their job satisfaction. This is in line with the results of a scoping review by Park *et al.* which recommends strategies to achieve stigma reduction in two major ways: the first is to normalize MOUD so that it is no longer considered 'substituting one addiction with another' and the second is to emphasize OUD as a chronic disease, a mainstream medical issue just like diabetes, that needs long-term care and support which can be managed at the primary care level (Park et al., 2020).

In addition to the evaluated models identified in this review, a hub and spoke model called CHARM initiated in Vermont in 2013, seems promising. This model creates

a HUB within the regional OTPs for the highest acuity patients in need of extensive daily services and a SPOKE for the office-based treatment of the stable patient (Substance Abuse and Mental Health Services Administration, 2016). Additionally, the Maternal Opioid Misuse (MOM) model by the Center for Medicare and Medicaid Innovation is being piloted in ten states to address fragmentation in the care of pregnant and postpartum Medicaid beneficiaries with OUD through state-driven transformation of the delivery system, with an aim to increase such women's access to a well-coordinated, high-quality care (Centers for Medicare and Medicaid Services, 2020). The hub and spoke and MOM models were not included in this review as we did not find any studies that evaluated them, which was an eligibility criterion for our review.

Implementing a comprehensive women-centered model benefits the mother and their child in terms of increased preventative care by mothers (e.g., postpartum visits, use of long-acting reversible contraception) and enhanced neonatal health (e.g., lower rates for and duration of NOWS, shorter neonatal intensive care unit and hospital lengths of stay, and increased initiation and continuation of breastfeeding at discharge) (Paterno et al., 2019; Singh et al., 2020). The utilization of MOUD reduces all-cause and overdose mortality (Sordo et al., 2017), and improving access to and retention of patients in quality care should be the cornerstone of public health response to the opioid epidemic.

Our scoping review has important limitations. First, there were high levels of heterogeneity in how the outcomes were defined in each article. This made meta-analysis impossible. Second, many of the studies included focused on small samples with homogenous participants, limiting external validity. To cumulate statistical support for such programs, data could be pooled from several programs through multisite studies, as the number of pregnant women participating in most MOUD programs at any

time is likely to be small. The number of relevant published studies was limited and a large proportion of them were of weak study design and low generalizability. In addition, no studies reported on cost and cost-effectiveness. Also, we did not differentiate models based on whether they were OTPs or a medical facility. Future research should focus on models that work for gender non-conforming people and assess whether women-centered programs work for this population. In our study, we did not find any treatment models for sexual and gender minority populations, such as non-binary or trans people who can be pregnant and have OUD, even though we conducted a comprehensive search of the literature that included search terms not limited to pregnant women.

2.5 CONCLUSIONS

We conducted a comprehensive scoping review of drug treatment and care programs for pregnant women with OUD in the U.S. over the past thirty years. We found that co-locating various services for treatment and care improved access, inter-professional collaboration enhanced coordination and caring for pregnant women in groups improved quality of care. The contemporary needs include: 1) enhanced inter-professional collaboration to meet the social needs of patients by including childcare, transportation, housing, and nutrition services; 2) bolstered patient-provider relationships that are built on trust, are free of stigma, and that empower patients to make their own decisions; and 3) improved policies and regulations to reduce stigma around opioid use and MOUD, so that pregnant women with OUD can access high quality care. Our approach can be replicated for use in studies focused on similar topics elsewhere. Future studies are needed to assess treatment access for the most vulnerable populations including those experiencing homelessness, those speaking a language other than English, victims of trauma and violence, and non-binary pregnant persons.

ROLE OF FUNDING SOURCE

This work was supported by the Tufts Initiative on Substance Use and Addiction (PI: Stopka). The funder has no role in the study's design, conduct or reporting.

CONTRIBUTORS

Conception and design: C. Joshi, T.J. Stopka, M. Skeer, K. Chui.

Analysis and interpretation of the data: C. Joshi, T.J. Stopka, M. Skeer, K. Chui, G. Neupane, R. Koirala.

Drafting of the article: C. Joshi.

Critical revision of the article for important intellectual content: C. Joshi, T.J. Stopka, M. Skeer, K. Chui, G. Neupane, R. Koirala.

Final approval of the article: C. Joshi, T.J. Stopka, M. Skeer, K. Chui, G. Neupane, R. Koirala.

Obtaining of funding: T.J. Stopka, C. Joshi, M. Skeer, K. Chui.

Administrative, technical, or logistic support: C. Joshi, R. Koirala.

Collection and assembly of data: C. Joshi, R. Koirala, G. Neupane.

DECLARATION OF COMPETING INTEREST

The authors report no declarations of interest.

ACKNOWLEDGEMENT

We are very grateful to Dr. Mei Chung, with the Tufts University School of Medicine, for providing her keen insights regarding methodological considerations. We would also like to thank Ms. Amy Lapidow, with the Tufts Hirsh Health Sciences Library, for support with the systematic literature search. We are also thankful to Ms. Serra

Muftu, a student researcher at Tufts University, for her content area expertise. We are thankful to the Tufts Initiative on Substance Use and Addiction for funding this study.

Appendix Table 2. 1 Detailed model characteristics and their outcomes: Scoping review on women-centered drug treatment models for pregnant women, 1990-2020

Author, year	Study design, setting	Model components	Outcomes/Findings	Strengths/Limitations
Goodman *et al.*, 2015	Quasi-experimental study post-test; University hospital in rural NH and VT	**Access:** Co-located prenatal clinic and OTP, financed through existing Medicaid, social worker helped patient access insurance and social services, private funding for nutrition and education programs. **Coordination:** IPC providing MOUD, ob/gyn, mental and behavioral healthcare and social needs, medical referral pathways, frontline staff coordinate care and manage referral. **Quality:** Continuity of care from prenatal to postpartum period, multidisciplinary quality improvement meetings, clinician training on screening for OUD, intervention and SUD during pregnancy. **Other services:** Universal screening for OUD, prenatal education and contraception provision, information regarding local child welfare laws, individual and family counseling, addiction recovery group for pregnant and postpartum women, treatment for psychiatric illness.	Increased proportion of recommended prenatal visits attended. **Facilitators**: Co-located clinic improved access to prenatal care, continuity of care throughout pregnancy and postpartum, and facilitated smooth coordination with other services. Structured screening and intervention for drug use in prenatal clinic facilitated referral to treatment. Shared education program enhanced communication among multidisciplinary staff, which in turn improved provider satisfaction and attitude towards women with OUD and patient satisfaction with quality of care. Multidisciplinary quality improvement meetings improved continuity of care for women. Patients reported satisfaction regarding colocation of prenatal care and addiction treatment. **Barriers**: Limited public transport, rescheduling transport reimbursed by Medicaid, continuity of private funding as many services are not directly reimbursable.	Limitations: Small sample size, homogenous patient population
Lander *et al.*, 2015	Randomized controlled trial comparing mixed gender group vs pregnancy-only group, other services similar; University hospital in urban WV	**Access:** Group therapy (Pregnancy only vs mixed gender). **Coordination**: IPC providing ob/gyn, MOUD psychiatric and pediatric care (both groups). **Quality**: Patient education on breastfeeding, contraceptives, NOWS (both groups).	Patients reported similar satisfaction with the two group experiences. Pregnancy-only group rated group topic relevance significantly better than those in the mixed-gender group. Treatment retention and relapse rates not significantly different between the two groups. The relapse rate was 42.2% four weeks postpartum, and 47.8% reported decline in quality of life. **Facilitators**: Medicaid covered Buprenorphine, but not methadone, women were allowed to bring their children in group therapy, group provided social	Strengths: Strong study design (i.e., RCT) Limitations: Small sample size, high loss to follow up

Author, year	Study design, setting	Model components	Outcomes/Findings	Strengths/Limitations
			support to women, women felt accepted by the therapist and other group members and found health education topics highly relevant in pregnancy-only groups. **Barrier**: Medicaid not covering treatment postpartum.	
Crane *et al.*, 2019	Cohort study comparing MOMS patients with pregnant Medicaid beneficiaries with OUD; Four clinical organizations: community behavioral health, residential behavioral health, hospital-based ob/gyn practice, and co-located ob/gyn and behavioral health in OH	**Access:** Facilitated access to OTP and housing and transport. Co-located behavioral health and obstetric care (MOMS). **Coordination**: IPC providing MOUD, ob/gyn and behavioral healthcare; referral pathways to community providers (MOMS). **Quality**: Simplified prior authorization for buprenorphine, provider training on treatment algorithms and on collaborating with CPS, continuity of care from prenatal to postpartum period, shared patient-provider decision-making (MOMS). **Other services:** STI screening (MOMS).	MOMS participants increased use of prenatal care and behavioral health, increased use and retention in OTP, decreased out-of-home placements of infants, had higher odds of NOWS incidence and neonatal sepsis. **Facilitators**: Co-located ob/gyn and behavioral health practice increased access to and coordination of care, residential care improved access for homeless patients, non-OTP sites had higher retention rates due to absence of OUD-related stigma, communication and coordination among CPS, ob/gyn providers and behavioral healthcare providers decreased patients' fear of loss of child custody and decreased CPS providers' stigma regarding maternal OUD.	Strengths: Large sample size Limitations: Homogenous patient population, low generalizability
Hodgins *et al.*, 2019	Qualitative study; Hospital providing ob/gyn care in MA	**Access**: Facilitated transportation, housing assistance, connecting with WIC. **Coordination**: Care plan, referral to medical and social services, ob/gyn outreach to get patients referred, IPC among nurse and social worker and community health worker. **Quality**: Continuity of care from prenatal to postpartum period, relationship building between	**Facilitators:** Specialized, time-intensive care coordination among a team with diverse professional skills and an understanding of addiction and pregnancy, addressed women's unique needs and provided non-judgmental care. Forming trusting patient-provider relationship facilitated the holistic understanding of patients' needs, patient engagement, and connected patients with resources.	Limitations: Weak study design (i.e., qualitative case study with a very small sample size, N=4, and a homogenous study population), no information on patient

Author, year	Study design, setting	Model components	Outcomes/Findings	Strengths/Limitations
		patient and provider. **Other services:** Patient education and emotional support.	Providers in close proximity were more familiar with the program and inclined to refer patients. Non-clinicians were deemed more trustworthy and cost-effective. **Barriers**: Low and late referral of patients to program, resulting in limited time to provide quality services to patients. Providers reported job satisfaction but also struggled with bias or conflict with personal values and the necessity to work outside traditional hours. Brief office visits limited clinicians' ability to identify and address the needs of this population. Lack of broader care integration and inefficient knowledge dissemination about such program models.	characteristics, low generalizability
Lander *et al.*, 2016	Quasi-experimental study post-test; University hospital in urban WV	**Access:** Pregnancy only group. **Coordination**: IPC providing MOUD, ob/gyn, psychiatric, pediatric care, case management and lactation services. **Quality**: Clinician training on substance use disorder during pregnancy; patient education on coordination of prenatal care, experiences of stigma in the health care system, birth control, breastfeeding, and labor and delivery issues.	Relapse rate 37.1% four weeks postpartum. **Facilitators**: Group modality increased access, addressed specialized clinical needs and promoted interpersonal connection. Patients reported being highly satisfied with therapist–participant relationship and the relevance of topics in patient education. Non-judgmental care from providers and an interdisciplinary team reduced stigma towards substance use among pregnant women. **Barriers**: Transport and childcare.	Limitations: Small sample size, high loss to follow up, low generalizability
Guille *et al.*, 2020	Quasi-experimental study comparing telemedicine vs in person care, other services similar; Ob/gyn clinic in SC	**Access**: Co-located MOUD and ob/gyn services either in-person or via telemedicine. **Coordination**: IPC providing MOUD, ob/gyn, substance use and psychiatric treatment (both groups). **Quality**: Psychiatrist with prenatal and addiction training, shared decision-making between provider and patients (both groups).	Similar outcomes for telemedicine and in-person care regarding treatment retention, NOWS, positive maternal urine drug screen and infants' length of hospital stay. Positive urine drug screening at delivery was 20.0% and at postpartum was 16.5% overall.	Limitations: small sample size, short follow-up period, low generalizability

Author, year	Study design, setting	Model components	Outcomes/Findings	Strengths/Limitations
Mittal *et al.*, 2017	Quasi-experimental study post-test; University hospital in urban MA	**Access**: Co-located ob/gyn, psychiatric care and MOUD. **Coordination**: Referred to the program by prenatal care providers, IPC providing MOUD, ob/gyn, and psychiatric care and social service. **Quality**: Patient-provider joint decision making.	Patient retention in the program until delivery was 93.8% and postpartum was 87.5%. NOWS incidence was 80.0%. **Facilitators**: Co-location of services and access to electronic medical record improved coordination and referral. Development of pain management protocol and policy improved communication between obstetrics and anesthesia colleagues who also managed pain postpartum. **Barrier**: Limited communication with providers outside their system.	Limitations: Very small sample size, low generalizability.
Cochran *et al.*, 2018	Quasi-experimental study pre- and post-test; University hospital in urban PA	**Access**: Financial assistance for travel, OBOT (both groups), patient navigator (nurse) accompanied women to their appointments (post-test). **Coordination**: Case management (post-test), referral to medical care and psychosocial services (both groups). **Quality**: Continuity of care from prenatal to postpartum period (post-test). **Other services:** STI education, motivational interviewing (post-test).	PN intervention showed a significant improvement in illicit opioid use abstinence (B=0.15, 95% CI=0.1–0.2), and significant decreases in drug use (AOR=5.25, 95% CI=2.1–13.0), and depression (AOR=7.70, 95% CI=2.4–25.1) but no significant increase in OTP attendance. Most study participants also had adequate or greater prenatal care utilization. Patient retention was 100% postpartum.	Limitations: Very small sample size, homogenous patient population
Sutter *et al.*, 2019	Qualitative study; University hospital in urban NM	**Access**: Group prenatal care; co-located MOUD, ob/gyn care, psychiatry, and therapy; provision of infant supplies. **Coordination**: Case management; referral to community resources; IPC among buprenorphine waivered physicians, volunteer yoga instructors, substance abuse counselor and community support workers. **Quality**: Patient-provider shared decision making, continuity of care from prenatal to postpartum period. **Other services:** Group prenatal care; patient education on OUD, breastfeeding, NOWS, contraception and intimate partner violence.	Group care increased trust between providers and patients and social connectedness, and motivated abstinence, increased staff satisfaction, allowed for longer appointment times which in turn allowed for in-depth discussion on maternal and newborn health. Confidentiality was not reported as a concern for group care.	Strengths: Large sample size Limitations: No information on patient characteristics

Author, year	Study design, setting	Model components	Outcomes/Findings	Strengths/Limitations
Krans *et al.*, 2018	Cohort study comparing group receiving BUP with group receiving BUP and women-centered services (BUP+); University hospital in PA	**Access**: OBOT (both groups), social workers help patient access housing, transportation, infant supplies (BUP+). Provision of childcare (BUP+). **Coordination**: IPC among buprenorphine waivered ob/gyn, nurse with addiction medicine training and social worker (BUP+). **Quality**: Continuity of care from prenatal to postpartum period (BUP+). **Other services**: Pregnancy specific MOUD dosing, breastfeeding education and support, family planning counseling, behavioral health counseling, STI screening, parenting skills training and trauma-informed care (BUP+).	Compared to BUP patients, BUP+ patients were more likely to attend their postpartum visit (67.9% vs. 52.6%; p=.05), receive long-acting reversible contraception (13.0%, vs 23.9%, p=.03), had higher BUP dose at the time of delivery (16.0 vs 14.1, p=0.02). **Facilitator**: Intervention tailored to the specific needs of women with OUD. Women-centered services may reduce stigma associated with the OUD and decrease barriers to treatment initiation among pregnant women.	Limitations: Low generalizability in terms of program and patient characteristics
Laken *et al.*, 1997	Quasi-experimental study post-test; OTP in urban Detroit, MI	**Access**: Free transportation, patient advocacy. **Coordination**: Case management, IPC providing MOUD, mental health, obstetric care, social service. **Other services:** Individual and group counseling, education classes on pregnancy and substance use, and vocational services.	Case management encouraged patient retention until delivery in OTP.	Strengths: Large sample of low-income minority population
Ostrach *et al.*, 2019	Qualitative study; Outpatient clinic in rural, Central Appalachian region	**Access**: Co-located prenatal clinic and OTP, Medicaid covered treatment for 90% patients. **Coordination**: Wrap-around referral to community-based programs.	**Facilitators**: Supportive, non-judgmental care from service providers. **Barriers**: Poor quality of care from judgmental clinicians, family and friends' disapproval of MOUD use, involvement of law enforcement and social services, lack of access to MOUD, ambivalence about MOUD use because of structural and institutional stigmatization and criminalization. Medicaid did not cover treatment in postpartum period. Long travel time.	Limitations: Small sample size, weak study design (i.e., qualitative study with 27 participants, and a homogenous patient population, and short follow-up period).

Author, year	Study design, setting	Model components	Outcomes/Findings	Strengths/Limitations
Paterno *et al.*, 2019	Quasi-experimental study pre- and post-test; Community hospital in rural MA	**Access**: Nurse-led, community-based screening, referral, and advocacy program. **Coordination**: Systematic referral to mental health services, recovery peer support, support for families with young children, residential treatment or detoxification, basic living needs, and support for women who experienced intimate partner violence. IPC among ob/gyn, nurses, pediatricians and social workers. **Other services**: Screening for OUD, patient education on NOWS, breastfeeding, OUD and local child welfare laws.	Infants' birth weight increased (3.0kg vs 3.4 kg, p=0.035) and more women received prenatal referrals to recovery peer support (0% vs 68.4%, p<0.001) and family support services (5.3% vs 52.6%, p=0.003) post-test.	Limitations: Very small sample size, homogenous patient population.
Wilder *et al.*, 2015	Cohort study comparing pregnant vs postpartum women; OTP in OH	**Access**: Conditional eligibility for reduced program fees for pregnant women, but not postpartum women. The clinic is not-for-profit but does not accept Medicaid or other public assistance (both groups). **Coordination**: Women referred to this clinic from hospitals, coordination of care with prenatal care providers (both groups). **Other services**: Individual counseling and group therapy (both groups).	MOUD discontinuation rates much higher among postpartum, compared to prenatal women (62% vs 11.0%). **Facilitator**: Longer duration of prenatal methadone treatment may protect against early drop-out in the postpartum period.	Limitations: Homogenous patient population
Carroll *et al.*, 1995	Randomized controlled trial; University hospital in urban CT	**Access**: Childcare and contingency management (intervention group). **Coordination**: IPC providing MOUD, ob/gyn care and counseling (intervention group). **Other services**: Group counseling (both groups), relapse prevention groups and weekly prenatal care (intervention group).	Increased attendance at prenatal care visits in intervention group compared to control group (14.7 vs 5.1, p<0.01). The positive contingency rewards offered for abstinence did not appear to be strong incentives. The weekly relapse-prevention groups were highly valued, well attended, and provided important sources of support for the women. The therapeutic childcare made it possible for the women with preschool-age children to participate in the program.	Strengths: Strong study design (i.e., RCT), heterogenous patient population Limitations: Very small sample size

Author, year	Study design, setting	Model components	Outcomes/Findings	Strengths/Limitations
Meyer *et al.*, 2012	Quasi-experimental study pre- and post-test; OTP in rural VT	**Access**: Increased availability of treatment slots due to FDA approval of buprenorphine and physician waivered to provide buprenorphine. Mobile units to increase methadone access in remote areas. **Coordination**: Improved coordination of ancillary services for pregnant women, case management, referral to community treatment providers, IPC providing MOUD, obstetric and pediatric care, social and child protective services. Guidelines outlining the necessary elements of care from each specialty of the multidisciplinary team was published on a state website for easy access by any provider. **Other services**: Parenting classes, STI screening.	With increased number of treatment slots, the number of pregnant women receiving MOUD increased and the gestational age at the start of MTD therapy decreased from 22 weeks to 4 weeks between 2000 and 2006 ($p < 0.001$). Post-test, weight z-score of infants increased ($p < 0.05$), infants discharged to the care of the mother increased (69.0% vs 91.3%, $p<0.001$) and infants remaining in maternal care at 1 year improved (62.5% vs 84.8%, $p<0.05$). NOWS incidence was 58.3%. **Facilitators**: Patient-provider relationship building, use of existing community health services to coordinate care reduced cost of program.	Limitations: Limited information on patient characteristics
Jansson *et al.*, 2007	Quasi experimental study comparing FFS and MC; Hospital in urban MD	**Access**: One-stop-shop providing onsite methadone, obstetric, pediatric and psychiatric care (both groups). Provision of free transportation, nutritional support, childcare services and parenting education (FFS). **Coordination**: IPC providing MOUD, ob/gyn, physical, mental health and pediatric care. Compared to FFS, MC provided more fragmented services as different managed care companies authorized varying components of the women's and children's care. **Other services**: Group counseling, individual psychotherapy (both group).	Compared to FFS, MC had higher proportions of patients on MTD at delivery (64% vs 99%, $p=0.001$); lower patient retention until delivery (37% vs 24%, $p=0.001$) and lower patient retention postpartum (83 days vs 25 days, $p<0.00$), fewer NOWS treated (39 vs 14, $p=0.005$), lower 2-, 4- and 6-month immunization rates ($p<0.001$) and higher intervention by CPS (13.6% vs 25.0%, $p<0.05$). **Barriers**: Health insurance did not pay for treatment after 8 weeks postpartum. Patients were much less stable in treatment and reported reduced psychological well-being in the immediate postpartum period.	Strengths: High proportion of low-income minority population in the sample

Author, year	Study design, setting	Model components	Outcomes/Findings	Strengths/Limitations
Jones *et al.*, 2001	Randomized controlled trial comparing groups provided with and without financial incentives; Hospital in urban MD	**Access**: One-stop-shop providing onsite methadone, obstetric, pediatric and psychiatric care; provision of free transportation, nutritional support and childcare services (both groups); and contingency management (intervention). **Coordination**: IPC providing MOUD, ob/gyn, mental health and pediatric care (both groups). **Other services**: Group counseling and individual psychotherapy (both groups).	Escalating voucher incentives (dependent on attendance at treatment and provision of drug-negative urine, between $5 and $70 per day) enhanced treatment attendance and drug abstinence. Patient retention was 94% within 14 days of treatment.	Strengths: Strong study design (i.e., RCT), heterogenous patient population
Jones *et al.*, 2000	Randomized controlled trial comparing groups provided with and without financial incentives; Hospital in urban MD	**Access**: One-stop-shop providing onsite methadone, obstetric, pediatric and psychiatric care; provision of free transportation, nutritional support, childcare services (both groups); and contingency management (intervention). **Coordination**: IPC providing MOUD, ob/gyn, mental health and pediatric care (both groups). **Other services**: Group counseling and individual psychotherapy (both groups).	Voucher incentives ($5/day) enhanced treatment attendance by methadone-treated subjects. Group receiving incentive attended 10 more treatment hours per week ($t=2.11$, $p<0.05$) and 1.5 more treatment days per week ($t=1.82$, $p<0.05$) compared to group not receiving incentives. Such incentives did not significantly improve attendance in abstinence-treated patients or impact drug abstinence in methadone-treated patients.	Strengths: Strong study design (i.e., RCT), large proportion of low-income minority patient population
Tuten *et al.*, 2012	Randomized controlled trial comparing groups provided with and without financial incentives; Hospital in urban MD	**Access**: One-stop-shop providing onsite methadone, obstetric, pediatric and psychiatric care; provision of free transportation, nutritional support, childcare services (both groups); and contingency management (intervention). **Coordination**: IPC providing MOUD, ob/gyn, mental health and pediatric care (both groups). **Other services**: Group counseling and individual psychotherapy (both groups).	Drug abstinence and treatment retention did not differ between patients who received fixed voucher amount and patients who received escalating voucher amount (dependent on providing drug negative urine samples).	Strengths: Strong study design (i.e., RCT), heterogenous patient population
Silverman *et al.*, 2001	Randomized controlled trial comparing groups provided with and without	**Access**: Contingency management in an employment setting, where employment and salary were based on drug abstinence. Women received 8 weeks of paid maternity leave (intervention). One-stop-shop providing onsite methadone, obstetric,	Women who received the employment intervention were two times more likely to be drug abstinent compared to those who did not get the intervention (33% vs. 59% respectively, $p<0.05$). Patient retention was 47% at 6 months.	Strengths: Strong study design (i.e., RCT), high proportions of minority patient population

Author, year	Study design, setting	Model components	Outcomes/Findings	Strengths/Limitations
	contingency management in the form of employment; Hospital in urban MD	pediatric and psychiatric care; provision of free transportation, nutritional support and childcare services (both groups). **Coordination**: IPC providing MOUD, ob/gyn, mental health and pediatric care (both groups). **Other services**: Group counseling and individual psychotherapy.		Limitations: Small sample size
Svikis *et al.*, 1997	Randomized controlled trial comparing groups provided with and without financial incentives; Hospital in urban MD	**Access**: One-stop-shop providing onsite methadone, obstetric, pediatric and psychiatric care; provision of free transportation, nutritional support and childcare services (both groups); and contingency management (intervention). **Coordination**: IPC providing MOUD, ob/gyn, mental health and pediatric care (both groups). **Other services**: Group counseling and individual psychotherapy (both groups).	Treatment retention was higher in incentivized group. Financial incentives did not affect attendance in methadone patients. However, non-methadone patients receiving higher incentives amount ($5/$10) attended more days compared to those receiving lower incentive amount ($0/$1) (3.3 days vs 2.3 days out of 7 days, $p<0.05$). Patient retention at 30 days was 55.6% overall, with higher retention rates for MTD than non MTD (86.4% vs 28.9%).	Strengths: Strong study design (i.e., quasi-experimental study), high proportions of minority patient population
Chang *et al.*, 1992	Quasi-experimental study with a control group; CT	**Access**: Co-located OTP and ob/gyn care, childcare, onsite weekly prenatal care, contingency management (intervention). **Other services**: Relapse prevention groups (intervention) and group counseling (both groups).	Increased attendance at prenatal care, urine toxicology positive screens for illicit substances and heavier infants in intervention group compared to control group (p value not reported). **Facilitators**: Services tailored to special needs of pregnant women with OUD, co-located care, childcare, group therapy.	Strengths: High proportions of minority patient population Limitations: Small sample size
Kahn *et al.*, 2017	Qualitative study; Primary care outpatient clinic in suburban NY	**Access**: OBOT, women could bring their children with them. **Other services:** Pregnancy and parenting educational support groups.	**Facilitators**: Patients reported the educational contents as useful, delivery of the educational information as supportive and nonjudgmental, and appreciated the social support provided by the groups. Social workers collaborated with physicians to implement a patient-centered, practice-based intervention to improve the parenting knowledge and skills of women in treatment for OUD. **Barriers**: transportation, office coordination, HIPAA	Strengths: Heterogenous patient population Limitations: Weak study design (i.e., qualitative study with 14 participants), very small sample size

Author, year	Study design, setting	Model components	Outcomes/Findings	Strengths/Limitations
			considerations, childcare, and competition with other components of treatment.	
Lopian *et al.*, 2019	Cohort study comparing patients attending and not attending women's group; Primary care outpatient clinic in suburban NY	**Access**: OBOT (both groups). **Other services**: Women's group for health education and risk reduction (intervention).	Attendance at women's group had worse outcome in terms of positive marijuana toxicology results at 12 months (28% vs 4.7%, p=0.01) and positive toxicology results at 12 months for use of any drug (46.2% vs 19.8% p=0.01). **Facilitators**: OBOT facilitates patient retention, having private insurance provided coverage for more providers compared to Medicaid. **Barriers**: Transportation, having Medicaid.	Strength: Heterogenous patient population
Fallin-Bennett *et al.*, 2020	Qualitative study; Private OTP in KY	**Quality**: Peer support.	Peer support specialists were reported to be trustworthy and to have a strong, positive impact on patients' recovery, but to have a need to clarify boundary between them and the patients. An authentic, supportive and strict peer supporter who holds patients accountable for their recovery was desirable. **Facilitator**: Patient-provider rapport building.	Limitations: Weak study design (i.e., qualitative study with 9 participants and a , homogenous patient population)

CT: Connecticut; **CPS**: Child Protective Services; **FDA**: Food and Drug Administration; **FFS**: Fee for service; **IPC**: Interprofessional Collaboration; **MA**: Massachusetts; **MC**: Managed Care; **MD**: Maryland; **MI**: Michigan; **MOUD**: Medication for Opioid Use Disorder; **NH**: New Hampshire; **NOWS**: Neonatal Opioid Withdrawal Syndrome; **NY**: New York; **OBOT**: Office-based Opioid Treatment; **Ob/gyn**: obstetric/gynecologic; **OH**: Ohio; **OTP**: Opioid Treatment Program; **OUD**: Opioid Use Disorder; **PA**: Pennsylvania; **SC**: South Carolina; **STI**: Sexually Transmitted Infections; **VT**: Vermont; **WIC**: Women, Infant and Children's Program; **WV**: West Virginia

Appendix Table 2. 2 Published literature search outputs: Scoping review on women-centered drug treatment models for pregnant women, 1990-2020

Database	# Articles	Duplicates within each database	# Unique articles within each database
PubMed	738	104	634
CINAHL	120	27	93
EMBASE	444	165	279
PsycInfo	384	43	341
Sociology Database	165	4	161
Web of Science	122	70	52
Hand search	18	0	18
Total	1,991	413	1,578

Appendix Table 2. 3 Published literature search strategy: Scoping review on women-centered drug treatment models for pregnant women, 1990-2020

Database	Date searched	Search terms and combinations
PubMed	5/27/2020	**1. Pregnant women:** pregnan* OR Pregnancy[MeSH Terms] OR Prenatal Care[MeSH Terms] OR "Pregnant Women"[MeSH Terms] OR "Perinatal Care"[MeSH Terms] **2. Opioid use disorder:** (opioid-related disorders[MeSH Terms]) OR "opioid use disorder" OR "opioid addiction" OR "opioid use" OR "opioid misuse" OR "opioid-related disorders" OR "opioid dependence" OR "opiate abuse" OR "opiate use" OR "opiate misuse" OR "opiate addiction" OR "opioid abuse" OR "opiate dependence" OR narcotic-related disorders[MeSH Terms] OR "Narcotic-Related Disorders" **3. Treatment:** "Opiate Substitution Treatment"[Mesh] OR "Opioid Substitution Treatment*" OR "Opioid-Related Disorders/drug therapy"[Mesh] OR "Opioid-Related Disorders/rehabilitation"[Mesh] OR "Medication Assisted Treatment of Opioid" OR "Medication for opioid use disorder" OR "Medication for Addiction Treatment*" **Final search combination: 1 AND 2 AND 3**
EMBASE	5/7/2020	**1. Pregnant women:** 'pregnant woman' OR 'perinatal care' OR pregnan* OR 'prenatal care'/exp OR 'prenatal care' OR 'pregnancy'/exp OR pregnancy **2. Opioid use disorder:** 'narcotic dependence'/exp OR 'opioid use disorder'/exp **3. Treatment:** 'narcotic antagonist'/exp OR 'opiate substitution treatment'/exp OR 'methadone treatment'/exp **Final search combination: 1 AND 2 AND 3**
Sociology database	5/14/2020	**1. Pregnant women:** MAINSUBJECT.EXACT("Prenatal care") OR MAINSUBJECT.EXACT("Perinatal care") OR MAINSUBJECT.EXACT("Pregnancy") OR "pregnant wom?n" OR pregnan*) OR "antepartum" **2. Opioid use disorder:** (MAINSUBJECT.EXACT("Drug addiction") OR (MAINSUBJECT.EXACT("Narcotics") OR MAINSUBJECT.EXACT("Heroin") OR MAINSUBJECT.EXACT("Fentanyl") OR MAINSUBJECT.EXACT("Methadone") OR MAINSUBJECT.EXACT("Morphine"))) OR "opium*" OR ("opioid*" OR "narcotic* use*" OR "opioid addict*" OR "opioid related disorder*" OR "opioid use*" OR "opioid dependen*" OR "opiate use*" OR "opiate addict*" OR "opiate depend*" OR "narcotic related disorder*") OR ("narcotic* dependen*" OR "narcotic* misuse*" OR "narcotic* addict*" OR "opioid misuse*" OR "opiate misuse*") **3. Treatment:** MAINSUBJECT.EXACT("Rehabilitation") OR MAINSUBJECT.EXACT("Substance abuse treatment") OR MAINSUBJECT.EXACT("Medical treatment") OR MAINSUBJECT.EXACT("Drug therapy") OR "drug rehabilit*" **Final search combination: 1 AND 2 AND 3**

Database	Date searched	Search terms and combinations
Web of Science	5/9/2020	**1. Pregnant women:** TS=(pregnan* OR "prenatal care" OR "perinatal care" OR "pregnant wom?n") Indexes=SCI-EXPANDED, SSCI, A&HCI, ESCI, CCR-EXPANDED, IC Timespan=All years **2. Opioid use disorder:** TS=("opioid related disorder*" OR "opioid addict*" OR "opioid *use*" OR "opioid dependen*" OR "opiate dependen*" OR "opiate *use*" OR "opiate addict*" OR "narcotic related disorder*" OR "narcotic* *use*" OR "narcotic* dependen*" OR "narcotic* addict*") Indexes=SCI-EXPANDED, SSCI, A&HCI, ESCI, CCR-EXPANDED, IC Timespan=All years **3. Treatment:** TS=("substance use disorder treatment" OR "opiate* substitution treat*" OR "opioid* substitution treat*" OR "narcotic* antagonist*" OR "opioid* antagonist*" OR "opiate* antagonist*" OR "methadone treat*" OR "buprenorphine treat*" OR "naltrexone treat*") Indexes=SCI-EXPANDED, SSCI, A&HCI, ESCI, CCR-EXPANDED, IC Timespan=All years **Final search combination: 1 AND 2 AND 3**
PsycInfo	5/14/2020	**1. Pregnant women:** MAINSUBJECT.EXACT("Pregnancy") OR MAINSUBJECT.EXACT("Prenatal Care") OR MAINSUBJECT.EXACT("Antepartum Period") OR MAINSUBJECT.EXACT("Perinatal Period") **2. Opioid use disorder:** (MAINSUBJECT.EXACT("Heroin") MAINSUBJECT.EXACT("Buprenorphine") OR MAINSUBJECT.EXACT("Morphine") OR MAINSUBJECT.EXACT("Oxycodone") OR MAINSUBJECT.EXACT("Papaverine") OR MAINSUBJECT.EXACT("Fentanyl") OR MAINSUBJECT.EXACT("Codeine") OR MAINSUBJECT.EXACT("Opiates") OR MAINSUBJECT.EXACT("Prescription Drug Misuse") OR MAINSUBJECT.EXACT("Opioid Use Disorder") OR MAINSUBJECT.EXACT("Substance Related and Addictive Disorders") OR MAINSUBJECT.EXACT("Morphine Dependence") OR MAINSUBJECT.EXACT("Heroin Addiction") OR MAINSUBJECT.EXACT("Substance Use Disorder")) OR (MAINSUBJECT.EXACT("Drug Abuse") OR MAINSUBJECT.EXACT("Drug Addiction")) OR MAINSUBJECT.EXACT("Drug Dependency") **3. Treatment:** MAINSUBJECT.EXACT.EXPLODE("Addiction Treatment") OR MAINSUBJECT.EXACT.EXPLODE("Medication-Assisted Treatment") OR MAINSUBJECT.EXACT.EXPLODE("Methadone Maintenance") OR MAINSUBJECT.EXACT.EXPLODE("Narcotic Antagonists") **Final search combination: 1 AND 2 AND 3**

Database	Date searched	Search terms and combinations
CIHAHL	5/14/2020	**1. Pregnant women:** (MH "Pregnancy Care (Saba CCC)/TH/UT") OR ((MH "Pregnancy/PF") OR (MH "Perinatal Care/PF") OR (MH "Expectant Mothers/PF") OR "antepartum" OR (MH "Prenatal Care/PF") OR (MH "Substance Abuse, Perinatal/DT") **2. Opioid use disorder or Treatment :** (MH "Opium+") OR (MH "Analgesics, Opioid+") OR (MH "Narcotics+") OR "opioid related disorder*" OR "opioid addict*" OR "opioid *use*" OR "opioid dependen*" OR "opiate *use*" OR "opiate addict*" OR "opiate depend*" OR "narcotic related disorder*" OR "narcotic* *use*" OR "narcotic* dependen*" OR "narcotic* addict*" OR (MH "Substance Dependence/DT/PF/RH/TH") OR (MH "Substance Use Rehabilitation Programs/PF/UT") OR (MH "Substance Use Disorders/DT/RH/TH") OR (MH "Substance Dependence/DT/RH/TH") OR (MH "Methadone/TU") OR (MH "Buprenorphine/TU")) OR (MH "Rehabilitation Centers/UT") OR (MH "Substance Use Treatment (Iowa NIC)/UT") **Final search combination: 1 AND 2**

Appendix Table 2. 4 List of excluded articles with reasons: Scoping review on women-centered drug treatment models for pregnant women, 1990-2020

Author (year)	Title	Reason for exclusion
Addiction and pregnancy (1998)	Addiction and pregnancy: Empowering recovery through peer counseling.	E7
Alexander (2017)	A Call for Compassionate Care.	E7
Alto (2011)	Management of women treated with buprenorphine during pregnancy.	E7
Andrews (1995)	Searching for solutions to alcohol and other drug abuse during pregnancy: Ethics, values, and constitutional principles.	E7
Bachhuber (2017)	Medicaid Coverage of Methadone Maintenance and the Use of Opioid Agonist Therapy Among Pregnant Women in Specialty Treatment.	E5
Bagley (2018)	Frequency and associated risk factors of non-fatal overdose reported by pregnant women with opioid use disorder.	E6
Bandstra (2010)	Prenatal drug exposure: infant and toddler outcomes.	E4
Bandstra (2012)	Maternal Opioid Treatment: Human Experimental Research (MOTHER) Study: maternal, fetal and neonatal outcomes from secondary analyses.	E7
Bell (2012)	Buprenorphine in the treatment of heroin addiction.	E8
Benningfield (2012)	Opioid dependence during pregnancy: relationships of anxiety and depression symptoms to treatment outcomes	E6
Bogenschutz (2003)	Pharmacologic treatments for women with addictions.	E5
Brands (2002)	Changing patient characteristics with increased methadone maintenance availability.	E8
Brar (2020)	Antenatal interventions based upon fetal surveillance of the daily opioid-exposed fetus: a descriptive analysis.	E6
Brindis (1997)	California's approach to perinatal substance abuse: Toward a model of comprehensive care.	E2
Brogly (2018)	Prenatal treatment and outcomes of women with opioid use disorder.	E6
Caritis (2020)	Naltrexone use in pregnancy: a time for change.	E4
Carter (2019)	Opioid use disorder during pregnancy: An overview.	E7
Chang (1992)	Improving treatment outcome in pregnant opiate-dependent women.	E1
Chavkin (1998)	Policies towards pregnancy and addiction. Sticks without carrots.	E7
Christensen (2008)	Management of chemical dependence in pregnancy.	E7
Clark (2013)	Double trouble-pregnancy and antagonist treatment in opioid dependence; two contentious issues needing further consideration and research.	E7

Author (year)	Title	Reason for exclusion
Cleary (2011)	Methadone and perinatal outcomes: a retrospective cohort study.	E8
Clemans-Cope (2019)	Pregnant women with opioid use disorder and their infants in three state Medicaid programs in 2013-2016.	E5
Cochran (2018)	Optimizing Pregnancy Treatment Interventions for Moms (OPTI-Mom): A Pilot Study.	E1
Cochran, (2019)	A pilot multisite study of patient navigation for pregnant women with opioid use disorder.	E5
Coleman-Cowger (2012)	Mental health treatment need among pregnant and postpartum women/girls entering substance abuse treatment.	E2, E5
Comerford (1998)	Pregnancy among women with a history of injection drug use.	E5
Conners (2004)	Children of Mothers with Serious Substance Abuse Problems: An Accumulation of Risks.	E2, E3
Conners (2006)	Substance abuse treatment for mothers: Treatment outcomes and the impact of length of stay.	E2
Conte (1995)	Developmental, clinical and psychosocial aspects of opiate addiction in pregnancy and the newborn.	E7
Cook (2017)	Screening and Management of Substance Use in Pregnancy: A Review.	E5
Corse (1995)	Enhancing provider effectiveness in treating pregnant women with addictions.	E2, E5
Courty (2012)	[Perinatality in the context of addictions].	E8
Coy (1997)	Southcentral Foundation—Dena A. Coy: A model program for the treatment of pregnant substance-abusing women.	E2
Critchfield (2018)	The opioid crisis: Prenatal and postnatal care.	E7
Dakkak (2019)	Substance use disorders: Considerations in maternity and neonatal care.	E7
Daley (1997)	Characteristics and treatment needs of sexually abused pregnant women in drug rehabilitation: The Massachusetts MOTHERS Project.	E4
Daley (1998)	Substance abuse treatment for pregnant women: A window of opportunity?	E2
Daley (2011)	The impact of substance abuse treatment modality on birth weight and health care expenditures.	E2
Davidson (1993)	Methadone therapy.	E7
Davie-Gray (2013)	Psychosocial characteristics and poly-drug use of pregnant women enrolled in methadone maintenance treatment.	E8
Day (2003)	Drug misuse in pregnancy: The impact of a specialist treatment service.	E8
Debelak (2013)	Buprenorphine + naloxone in the treatment of opioid dependence during pregnancy—Initial patient care and outcome data.	E4
DePetrillo (1995)	Methadone dosing and pregnancy: impact on program compliance.	E4
Derauf (2003)	THE PREVALENCE OF METHAMPHETAMINE AND OTHER DRUG USE DURING PREGNANCY IN HAWAII.	E5
Dryden (2012)	Strength in numbers: a step closer to standardising perinatal care for drug-misusing women and their infants.	E7

Author (year)	Title	Reason for exclusion
Ecker (2019)	Substance use disorders in pregnancy: clinical, ethical, and research imperatives of the opioid epidemic: a report of a joint workshop of the Society for Maternal-Fetal Medicine, American College of Obstetricians and Gynecologists, and American Society of Addiction Medicine.	E7
Edmondson (1994)	Drug use and pregnancy.	E2
Einbinder, (2010)	A qualitative study of exodus graduates: family-focused residential substance abuse treatment as an option for mothers to retain or regain custody and sobriety in Los Angeles, California.	E2, E3
Eisen (2000)	Evaluation of substance use outcomes in demonstration projects for pregnant and postpartum women and their infants: Findings from a quasi-experiment.	E2
Ellis (2019)	Correlates of Treatment Retention and Opioid Misuse Among Postpartum Women in Methadone Treatment.	E6
Enos (2011)	Vt. program targets mothers-to-be to address opiate treatment gap.	E7
Erickson (2012)	Therapist effects in a NIDA CTN intervention trial with pregnant substance abusing women: Findings from a RCT with MET and TAU conditions.	E2
Falletta (2018)	Perceptions of child protective services among pregnant or recently pregnant, opioid-using women in substance abuse treatment.	E5
Finnegan (2009)	New approaches in the treatment of opioid dependency during the pregnancy.	E7
Finnegan (2010)	Methadone treatment for pregnant heroin addicted women.	E7
Fitzsimons (2007)	Mood disorders affect drug treatment success of drug-dependent pregnant women.	E6
Fullerton (2014)	Medication-assisted treatment with methadone: Assessing the evidence.	E6
Gerada (1996)	The drug-addicted mother: Pregnancy and lactation.	E5
Gerada (1996)	The drug-addicted mother: Pregnancy and lactation.	E5
Gonzalez (2019)	Infectious complications in IV abusers: A detailed review of hospitalized IV abusers.	E2
Gonzalez (2019)	Infectious complications in IV abusers: A detailed review of hospitalized IV abusers.	E2, E3
Gopalan (2019)	Benzodiazepine withdrawal in pregnant women with opioid use disorders: An observational study of current clinical practices at a tertiary obstetrical hospital.	E4, E6
Gopman (2014)	Prenatal and postpartum care of women with substance use disorders.	E7
Greenfield (2019)	Opioid use disorder in women: Evidence from the national institute on drug abuse clinical trials network (CTN) and the implications for treatment.	E7
Grella (1997)	Predictors of treatment retention in enhanced and standard methadone maintenance treatment for HIV risk reduction.	E3
Grella (2004)	Substance Abuse Treatment for Women: Changes in the Settings Where Women Received Treatment and Types of Services Provided, 1987-1998.	E2, E5

Author (year)	Title	Reason for exclusion
Gressler (2018)	Treatment modalities for pregnant women with opioid use disorder.	E7
Gressler (2019)	Association of Criminal Statutes for Opioid Use Disorder With Prevalence and Treatment Among Pregnant Women With Commercial Insurance in the United States.	E5
Grossman (1992)	Pregnancy and women's issues.	E2
Grossman (2017)	Neonatal Abstinence Syndrome Management: A Review of Recent Evidence.	E4
Gupta (2013)	Marked variability in peri-partum anesthetic management of patients on buprenorphine maintenance therapy (BMT): can there be an underlying acute opioid induced hyperalgesia precipitated by neuraxial opioids in BMT patients?	E5, E8
Gurganus (2015)	Implementing the Regional Epidemiological Outcomes Workgroup (REOW) in the State of Oklahoma for Substance Abuse Prevention: An ODMHSAS Project.	E2, E3
Gustavsson (1997)	Criminalizing women's behavior.	E2, E7
Haasen (2006)	Innovations in agonist maintenance treatment of opioid-dependent patients.	E7
Hand (2017)	Treatments for opioid use disorder among pregnant and reproductive-aged women.	E7
Hanson (2015)	Family-Based Recovery: An Innovative In-Home Substance Abuse Treatment Model for Families with Young Children.	E2, E3
Harris (1992)	Sociologic aspects of pregnancy.	E2
Haug (2001)	Smoking during pregnancy and intention to quit: a profile of methadone-maintained women.	E4
Haug (2004)	Motivational enhancement therapy for nicotine dependence in methadone-maintained pregnant women.	E4
Haugaard (1998)	Mandated interventions with drug-dependent, pregnant women.	E5
Haycraft (2018)	Pregnancy and the Opioid Epidemic.	E7
Heather (2020)	U.S. Survey of factors associated with adherence to standard of care in treating pregnant women with opioid use disorder.	E5
Heil (2008)	Comparison of characteristics of opioid-using pregnant women in rural and urban settings.	E6
Heil (2011)	Unintended pregnancy in opioid-abusing women.	E5
Higgins (2002)	Voucher-based incentives: A substance abuse treatment innovation.	E5
Hinst (2000)	Substitution therapy by methadone in pregnancy.	E8
Hoegerman (1991)	Narcotic use in pregnancy.	E5
Holbrook (2012)	Infections and obstetric outcomes in opioid-dependent pregnant women maintained on methadone or buprenorphine.	E4
Holbrook (2015)	Methadone versus buprenorphine for the treatment of opioid abuse in pregnancy: science and stigma.	E7
Holbrook (2015)	Methadone versus buprenorphine for the treatment of opioid abuse in pregnancy: Science and stigma.	E7
Holbrook (2015)	Medication-assisted treatment for pregnant women: A systematic review of the evidence and implications for social work practice.	E6
Hollander (2019)	Medical specialty of buprenorphine prescribers for pregnant women with opioid use disorder.	E7

Author (year)	Title	Reason for exclusion
Holloman (2019)	Pregnancy outcomes of women supervised under professional methadone programs.	E6
Hser (2011)	Long-term outcomes among drug-dependent mothers treated in women-only versus mixed-gender programs.	E2
Huhn (2018)	Serious about the Opioid Epidemic? Expand Medicaid.	E7
Hulse (2002)	A possible role for implantable naltrexone in the management of the high-risk pregnant heroin user.	E7
Hulse (2003)	Naltrexone implant and blood naltrexone levels over pregnancy.	E7
Hulse (2004)	Methadone maintenance vs. implantable naltrexone treatment in the pregnant heroin user.	E8
Hutchinson (2012)	The efficacy of escalating and fixed contingency management reinforcement on illicit drug use in opioid-dependent pregnant women.	E4
Goodman (2019)	Feasibility and Acceptability of a Checklist and Learning Collaborative to Promote Quality and Safety in the Perinatal Care of Women with Opioid Use Disorders.	E6
Hytinantti (2008)	Neonatal outcome of 58 infants exposed to maternal buprenorphine in utero.	E8
Ingersoll (2004)	Psychopathology and treatment outcome of drug dependent women in a perinatal program.	E2
Irner (2012)	Substance use during pregnancy and postnatal outcomes.	E8
Jackson (2012)	Barriers to receiving substance abuse treatment among rural pregnant women in Kentucky.	E5
Jancaitis (2020)	Factors associated with treatment retention in pregnant women with opioid use disorders prescribed methadone or electing non-pharmacological treatment	E6
Jansson (1996)	Pregnancy and addiction: A comprehensive care model.	E2
Jansson (2005)	Intensity of Case Management Services: Does More Equal Better for Drug-Dependent Women and Their Children?	E3
Jansson (2007)	Maternal vagal tone change in response to methadone is associated with neonatal abstinence syndrome severity in exposed neonates.	E4
Jansson (2017)	Maternal buprenorphine treatment and infant outcome.	E4
Jean (2020)	Obstetrician–gynecologists' practice patterns related to opioid use during pregnancy and postpartum—United States, 2017.	E5
Jennifer (2018)	Federal and State Policy Efforts to Address Maternal Opioid Misuse: Gaps and Challenges.	E4
Jessup (2003)	Extrinsic barriers to substance abuse treatment among pregnant drug dependent women.	E2
Johnson (2018)	Opioid Use Disorders and Pregnancy.	E7
Jones (2002)	Patient compliance and maternal/infant outcomes in pregnant drug-using women.	E2
Jones (2005)	Buprenorphine versus methadone in the treatment of pregnant opioid-dependent patients: effects on the neonatal abstinence syndrome.	E4
Jones (2005)	Randomized controlled study transitioning opioid-dependent pregnant women from short-acting morphine to buprenorphine or methadone.	E4

Author (year)	Title	Reason for exclusion
Jones (2008)	Treatment of opioid-dependent pregnant women: clinical and research issues.	E5
Jones (2008)	Scientific Evidence and Practical Experience with Methadone-Assisted Withdrawal of Heroin-Dependent Pregnant Patients.	E4
Jones (2010)	Neonatal abstinence syndrome after methadone or buprenorphine exposure.	E4
Jones (2011)	Methadone and the causes of maternal and perinatal complications: A response to Pinto et al. "substance abuse during pregnancy: Effect on pregnancy outcomes".	E7
Jones (2012)	Maternal Opioid Treatment: Human Experimental Research (MOTHER)--approach, issues and lessons learned.	E7
Jones (2012)	Methadone and buprenorphine for the management of opioid dependence in pregnancy.	E7
Jones (2012)	Acceptance of naltrexone by pregnant women enrolled in comprehensive drug addiction treatment: an initial survey.	E4
Jones (2012)	Acceptance of naltrexone by pregnant women enrolled in comprehensive drug addiction treatment: an initial survey.	E1
Jones (2013)	Cigarette smoking in opioid-dependent pregnant women: neonatal and maternal outcomes.	E4
Jones (2013)	The relationship between maternal methadone dose at delivery and neonatal outcome: Methodological and design considerations.	E4
Jones (2013c)	Treating opioid use disorders during pregnancy: historical, current, and future directions.	E7
Jones (2013d)	Naltrexone in the treatment of opioid-dependent pregnant women: common ground.	E7
Jones (2014)	Clinical care for opioid-using pregnant and postpartum women: the role of obstetric providers.	E7
Jones (2014)	Clinical care for opioid-using pregnant and postpartum women: the role of obstetric providers.	E7
Jones (2016)	Neonatal abstinence syndrome: Presentation and treatment considerations.	E7
Jones (2019)	Analgesia, Opioids, and Other Drug Use During Pregnancy and Neonatal Abstinence Syndrome.	E7
Jumah (2016)	Observational study of the safety of buprenorphine+naloxone in pregnancy in a rural and remote population.	E8
Kalin (2019)	New findings relevant to substance use disorders.	E7
Kaltenbach (1998)	Opioid dependence during pregnancy. Effects and management.	E7
Kandall (1999)	The methadone-maintained pregnancy.	E7
Killion (2017)	Opioid Use in Pregnancy.	E7
Kissin (2001)	Characterizing pregnant drug-dependent women in treatment and their children.	E4
Klaman (2017)	Treating Women Who Are Pregnant and Parenting for Opioid Use Disorder and the Concurrent Care of Their Infants and Children: Literature Review to Support National Guidance.	E4
Kleber (2007)	Treatment of patients with substance use disorders, second edition. American Psychiatric Association.	E3
Klein (2016)	Pharmacotherapy for Substance Use Disorders.	E7
Korthuis (2017)	Primary care-based models for the treatment of opioid use disorder: A scoping review.	E3
Kraft (2017)	Buprenorphine for the Neonatal Abstinence Syndrome.	E7

Author (year)	Title	Reason for exclusion
Krans (2015)	Caring for Opioid-dependent Pregnant Women: Prenatal and Postpartum Care Considerations.	E7
Krans (2018)	The Pregnancy Recovery Center: A women-centered treatment program for pregnant and postpartum women with opioid use disorder.	E1
Krans (2019)	Medication-Assisted Treatment Use Among Pregnant Women With Opioid Use Disorder.	E5
Kreek (2010)	Pharmacotherapy in the treatment of addiction: Methadone.	E7
Kremer (2015)	Clinical, Ethical, and Legal Considerations in Pregnant Women With Opioid Abuse.	E7
Kuehn (2005)	Office-based treatment for opioid addiction achieving goals.	E7
Kyei-Aboagye (1998)	The effect of postdetoxification drug-free residential living on birth outcome in the pregnant drug abuser.	E4
Laken (1996)	Effects of case management on retention in prenatal substance abuse treatment.	E2
Land (2017)	Current systems of care for pregnant and parenting opiate-addicted women in Broome County of New York State.	E6
Lander (2013)	Rural healthcare disparities: challenges and solutions for the pregnant opioid-dependent population.	E4
Leinaar (2019)	Healthcare Access, Pregnancy Intention, and Contraceptive Practices Among Reproductive-Aged Women Receiving Opioid Agonist Therapy in Northeast Tennessee.	E4
Liu (2009)	Screening for hepatitis C virus infection in methadone-maintained mothers and their infants.	E8
Lo-Ciganic (2019)	Adherence trajectories of buprenorphine therapy among pregnant women in a large state Medicaid program in the United States.	E5
Mackay (2018)	Novel case of maternal and neonatal kratom dependence and withdrawal.	E7
MacQueen (2016)	Neonatal Abstinence Syndrome.	E7
Mactier (2011)	The management of heroin misuse in pregnancy: Time for a rethink?	E5
Mactier (2012)	Neonatal abstinence syndrome can be a problem.	E7
Mahan (1996)	Crack cocaine, crime, and women: Legal, social, and treatment issues.	E5
Malow (1994)	A description of the Maternal Addiction Program of the University of Miami/Jackson Memorial Medical Center.	E4
Marcellus (2015)	Reenvisioning success for programs supporting pregnant women with problematic substance use.	E8
Mark (2015)	Medicaid Coverage of Medications to Treat Alcohol and Opioid Dependence.	E3, E5
Martin (2009)	Psychopharmacologic management of opioid-dependent women during pregnancy.	E4
Martin (2015)	Opioid use disorder during pregnancy in Tennessee: expediency vs. science.	E7
Martin (2019)	Pain, Opioids, and Pregnancy: Historical Context and Medical Management.	E7
Martins (2019)	Opioid use in pregnant women and neonatal abstinence syndrome - A review of the literature.	E4
Mayhew (2010)	Legal Aspects of Prescribing Opioids.	E7

Author (year)	Title	Reason for exclusion
McCarthy (2012)	Intrauterine abstinence syndrome (IAS) during buprenorphine inductions and methadone tapers: Can we assure the safety of the fetus?	E4
McCarthy (2017)	Opioid dependence and pregnancy: minimizing stress on the fetal brain.	E5
McComish (2003)	Family-focused substance abuse treatment: A program evaluation.	E2
McCullough (2013)	An ethical framework for conducting research on pregnant, opioid-dependent women.	E7
McLemore (2013)	Novel pharmacotherapeutic strategies for treatment of opioid-induced neonatal abstinence syndrome.	E7
McQueen (2016)	Neonatal Abstinence Syndrome.	E7
Meinhofer (2020)	Substance use disorder treatment services for pregnant and postpartum women in residential and outpatient settings.	E5
Messaadi (2014)	The continued care of pregnant women receiving opiate substitution treatment by midwives.	E8
Mey (2019)	Yes to Recreational Drugs and Complementary Medicines But No to Life-Saving Medications: Beliefs Underpinning Treatment Decisions Among PLHIV.	E8
Meyer (2015)	Caring for pregnant opioid abusers in Vermont: A potential model for non-urban areas.	E7
Meyer (2019)	Research on women with substance use disorders: Reviewing progress and developing a research and implementation roadmap.	E2, E7
MIDIRS Update (2015)	MIDIRS Update.	E2
Miles (2007)	Methadone-exposed newborn infants: outcome after alterations to a service for mothers and infants.	E8
Miller (2011)	Opioid use disorder during pregnancy.	E4
Miller (2016)	Opiate treatment in the criminal justice system: a review of crimesolutions.gov evidence rated programs.	E4
Miller (2019)	Maternal and neonatal characteristics of a Canadian urban cohort receiving treatment for opioid use disorder during pregnancy.	E8
Minozzi (2013)	Maintenance agonist treatments for opiate-dependent pregnant women.	E6
Mitchell (2006)	Patient and physician characteristics in relation to clinical decision making in methadone maintenance treatment.	E8
Mitchell (2014)	Treatment Outcomes of African American Buprenorphine Patients by Parole and Probation Status.	E3
Mittal (2014)	Buprenorphine for the treatment of opioid dependence in pregnancy.	E7
Morrison (1993)	Liaison services for pregnant drug users.	E7, E8
Mosley (1996)	PROTOTYPES: An urban model program of treatment and recovery services for dually diagnosed perinatal program participants.	E2
Mozurkewich (2014)	Buprenorphine and methadone for opioid addiction during pregnancy.	E7
Mucke (2017)	Neonatal Abstinence Syndrome: Twelve Years of Experience at a Regional Referral Center.	E8

Author (year)	Title	Reason for exclusion
Nardi (1997)	Risk factors, attendance, and abstinence patterns of low-income women in perinatal addiction treatment: Lessons from a 5-year program.	E2, E4
Newman (2006)	Response to "transferring methadone-stabilized pregnant patients to buprenorphine".	E7
Newman (2011)	Efficacy versus effectiveness of buprenorphine and methadone maintenance in pregnancy.	E7
Newman (2015)	Rooming-in care for infants of opioid-dependent mothers: Implementation and evaluation at a tertiary care hospital.	E7
Newman (2015)	Rooming-in care for infants of opioid-dependent mothers: Implementation and evaluation at a tertiary care hospital.	E8
Nguyen (2018)	Treating women with opioid use disorder during pregnancy in Appalachia: Initial neonatal outcomes following buprenorphine + naloxone exposure.	E4
Niccols (2010)	Maternal mental health and integrated programs for mothers with substance abuse issues.	E2, E4
Nielsen (2019)	Maternal and infant characteristics associated with maternal opioid overdose in the year following delivery.	E5
Nocon (2006)	Buprenorphine in pregnancy: the advantages.	E4
O'Connor (2011)	Observational Study of Buprenorphine Treatment of Opioid-Dependent Pregnant Women in a Family Medicine Residency: Reports on Maternal and Infant Outcomes	E4
O'Donnell (2017)	Opioid Use Disorder and Pregnancy.	E7
Ondersma (2010)	External pressure, motivation, and treatment outcome among pregnant substance-using women.	E2
Pachter (1998)	Pregnancy while drug dependent: "Not just me".	E2
Page (2017)	Hepatitis C Cascade of Care Among Pregnant Women on Opioid Agonist Pharmacotherapy Attending a Comprehensive Prenatal Program.	E4
Pan (2017)	Peripartum Anesthetic Management of the Opioid-tolerant or Buprenorphine/ Suboxone-dependent Patient.	E7
Park (2012)	Evaluation and management of opioid dependence in pregnancy.	E7
Patrick (2012)	Neonatal abstinence syndrome and associated health care expenditures: United States, 2000-2009.	E5
Patrick (2019)	Barriers to accessing treatment for pregnant women with opioid use disorder in Appalachian states.	E5
Peeler (2019)	Best practices for pregnant incarcerated women with opioid use disorder.	E7
Perry (2003)	Assessing maternal perceptions of harmful effects of drug use during pregnancy.	E4, E6
Potera (2018)	Opioid Use by Pregnant Women Jumps Fourfold.	E5
Potter (2003)	Obstetrics and gynecology resident education in tobacco, alcohol, and drug use disorders.	E7
Pritham (2012)	Opioid Dependency in Pregnancy and Length of Stay for Neonatal Abstinence Syndrome.	E1
Pritham (2012)	Opioid dependency in pregnancy and length of stay for neonatal abstinence syndrome.	E4
Pryor (2017)	The opioid epidemic and neonatal abstinence syndrome in the USA: a review of the continuum of care.	E7

Author (year)	Title	Reason for exclusion
Quigley (2012)	Substance Use Characteristics and Treatment Perceptions among Opioid Dependent Pregnant Women Initiating Methadone Treatment.	E4
Raskin (1993)	Psychiatric aspects of substance use disorders in childbearing populations.	E7
Redko (2007)	PATHWAYS OF SUBSTANCE USERS LINKING (OR NOT) WITH TREATMENT.	E3
Reising (2019)	CARE AND TREATMENT RECOMMENDATIONS FOR Pregnant Women WITH OPIOID USE DISORDER.	E4
Rizk (2019)	Maternity Care for Pregnant Women with Opioid Use Disorder: A Review.	E7
Rizk (2019)	Maternity Care for Pregnant Women with Opioid Use Disorder: A Review.	E7
Rizzo (2014)	Parenting concerns of pregnant women in buprenorphine treatment.	E6
Robinson (2002)	Buprenorphine: an analgesic with an expanding role in the treatment of opioid addiction.	E7
Rodriguez (2019)	Pharmacological treatment of opioid use disorder in pregnancy.	E7
Rogers (2009)	Narrating childhood: Making meaning amid poverty and social isolation.	E3
Romisher (2018)	Neonatal Abstinence Syndrome Exploring Nurses' Attitudes, Knowledge, and Practice.	E5
Roper (2017)	Opioid Use Disorder in Pregnancy.	E7
Rosado (2005)	Cash Value of Voucher Reinforcers in Pregnant Drug-Dependent Women.	E4
Rose-Jacobs (2019)	Pregnant women in treatment for opioid use disorder: Material hardships and psychosocial factors.	E4
Rosenthal (2019)	Obstetric management of women with opioid use disorder.	E7
Ruan (2017)	Opioid dependence and pregnancy: minimizing stress on the fetal brain.	E7
Ruley (2019)	Prenatal Opioid Maintenance in the United States and Its Effect on Neonatal Abstinence Syndrome: The Case of West Virginia's Opioid Epidemic.	E4
Ryan, (2017)	Maternal-fetal monitoring of opioid-exposed pregnancies: analysis of a pilot community-based protocol and review of the literature.	E8
Ryland (1996)	A rural collaborative model of treatment and recovery services for pregnant and parenting women with dual disorders.	E4
Saia (2016)	Caring for Pregnant Women with Opioid Use Disorder in the USA: Expanding and Improving Treatment.	E7
Saia (2017)	Prenatal treatment for opioid dependency: observations from a large inner-city clinic.	E4
Salisbury-Afshar (2015)	Buprenorphine maintenance vs. methadone maintenance or placebo for opioid use disorder.	E7
Salmon (2000)	Women's perception of provider, social, and program support in an outpatient drug treatment program.	E2
SAMHSA (2016)	Children and Recovering Mothers (CHARM) Collaborative in Burlington, Vermont: A Case Study in "Practice and Policy Considerations for Child Welfare, Collaborating Medical, and Service Providers".	E7

Author (year)	Title	Reason for exclusion
SAMHSA (2016)	A Collaborative Approach to the Treatment of Pregnant Women with Opioid Use Disorders.	E7
Sander (2005)	Prescription opioid dependence and treatment with methadone in pregnancy.	E6
Sanders (1998)	Assessment of client satisfaction in a peer counseling substance abuse treatment program for pregnant and postpartum women.	E2
Scully (1997)	Factors associated with treatment retention for drug-dependent pregnant and parenting women.	E4
Shainker (2012)	Opioid addiction in pregnancy.	E7
Shannon (2007)	Understanding motivations and intentions for long-term substance abuse treatment among pregnant, drug-dependent women.	E6
Shannon (2010)	Examining differences in substance use among rural and urban pregnant women.	E6
Sheehan (2013)	Management of the pregnant substance abusing woman.	E4
Sherman (1998)	How did the SISTERS program work and what was its impact?	E2
Siefert (2001)	Improving pregnancy outcome during imprisonment: A model residential care program.	E2
Singer (1992)	Generations of suffering: Experiences of a treatment program for substance abuse during pregnancy.	E2
Smith (2017)	Exploring the Link Between Substance Use and Mental Health Status: What Can We Learn from the Self- medication Theory?	E2, E3
Staudt (2018)	Best practices for enhancing substance abuse treatment retention by pregnant women.	E2
Stevens (1995)	A therapeutic community for substance-abusing pregnant women and women with children: Process and outcome.	E2
Stewart (2016)	Opioid Use Disorder in Pregnancy: Health Policy and Practice in the Midst of an Epidemic.	E4
Stine (2009)	Characteristics of opioid-using pregnant women who accept or refuse participation in a clinical trial: screening results from the MOTHER study.	E4
Stitzer (2013)	Dual dilemma—Should naltrexone be used in the treatment of opioid-dependent pregnant women?	E7
Stover (2015)	Opioids in pregnancy and neonatal abstinence syndrome.	E7
Straus (2018)	Massachusetts Child Psychiatry Access Program for Moms: Utilization and Quality Assessment.	E2
Sun (2004)	Principles for Practice with Substance-Abusing Pregnant Women: A Framework Based on the Five Social Work Intervention Roles.	E7
Svikis (1997)	Cost-effectiveness of treatment for drug-abusing pregnant women.	E2
Svikis (2007)	Behavioral strategies to improve treatment participation and retention by pregnant drug-dependent women.	E2
Syvertsen (2018)	Conceptualizing Neonatal Abstinence Syndrome as a Cascade of Care: A Qualitative Study With Healthcare Providers in Ohio.	E5
Terplan (2014)	The obstetric and neonatal impact of maternal opioid detoxification in pregnancy.	E7
Terplan (2015)	Psychosocial interventions for pregnant women in outpatient illicit drug treatment programs compared to other interventions.	E1
Terplan (2017)	Beyond the Treatment Box: Perspectives on the Federal Response to Opioid Use, Pregnancy, and Neonatal Abstinence Syndrome.	E7
Thompson (1998)	The frequency and impact of violent trauma among pregnant substance abusers.	E2

Author (year)	Title	Reason for exclusion
Tomedi (2012)	A pilot study of the nutritional status of opiate-using pregnant women on methadone maintenance therapy.	E4
Trinh (1998)	The role of social support in the lives of pregnant women in recovery.	E5
Tuten (2003)	Comparing homeless and domiciled pregnant substance dependent women on psychosocial characteristics and treatment outcomes.	E4
Tuten (2018)	The Impact of Early Substance Use Disorder Treatment Response on Treatment Outcomes Among Pregnant Women With Primary Opioid Use.	E4
Twomey (2010)	After family treatment drug court: Maternal, infant, and permanency outcomes.	E3
Uchtenhagen (2003)	Substitution management in opioid dependence.	E5
Vargo (2012)	"Neonatal abstinence syndrome: One community's efforts to reverse the trend".	E3, E4
Varty (2011)	Women's experiences of using heroin substitute medication in pregnancy.	E8
Vilkins (2017)	Comparison of Post-Cesarean Section Opioid Analgesic Requirements in Women With Opioid Use Disorder Treated With Methadone or Buprenorphine.	E4
Waal (2013)	Is sustained release natrexone an option for heroin-dependent pregnant women?	E7
Walhovd (2009)	Effects of prenatal opiate exposure on brain development - A call for attention.	E7
Walker (2018)	Provision of Buprenorphine to Pregnant Women by For-Profit Clinics in an Appalachian City.	E5
Wang (1999)	Methadone treatment during pregnancy.	E7
Weinstein (2000)	Mothers and methadone.	E7
Whalen (2017)	Buprenorphine for the Neonatal Abstinence Syndrome.	E7
Wilbourne (2001)	Clinical management of methadone dependence during pregnancy.	E7
Wilder (2015)	Medication assisted treatment discontinuation in pregnant and postpartum women with opioid use disorder.	E5
Winhusen (2008)	Motivational enhancement therapy to improve treatment utilization and outcome in pregnant substance users.	E2
Winklbaur (2008)	Opioid dependence and pregnancy.	E7
Winklbaur (2008b)	Treating pregnant women dependent on opioids is not the same as treating pregnancy and opioid dependence: a knowledge synthesis for better treatment for women and neonates.	E4
Wong (2011)	Substance Use in Pregnancy.	E7
Worley (2005)	Building a residential treatment program for dually diagnosed women with their children	E2
Young (2007)	Management of opioid dependence in pregnancy: A review of the evidence	E7
Young (2012)	Treatment of opioid dependence in the setting of pregnancy.	E7

Author (year)	Title	Reason for exclusion
Young-Wolff (2020)	Correlates of Pregnant Women's Participation in a Substance Use Assessment and Counseling Intervention Integrated into Prenatal Care	E2
Zane (2019)	Treatment for substance use disorders in pregnant women: Motivators and barriers	E4

E1: Duplicate article
E2: Study not specifically on opioids
E3: Pregnant women not the major focus of the study
E4: Outcomes not relevant/reported
E5: Not intervention study
E6: Intervention not relevant
E7: Discussion/single case study article
E8: Study conducted outside the U.S.

Chapter 3: Assessing Disparities in History of Opioid Use Disorder Among Pregnant and Postpartum People in Massachusetts: A Statistical and Spatial Epidemiological Study

3.0 ABSTRACT

Introduction: Massachusetts has one of the highest opioid use disorder (OUD) rates among pregnant and postpartum people in the nation. This study aims to identify and characterize locations of high OUD burden among this population in Massachusetts.

Methods: We identified pregnant and postpartum people with a history of OUD between 2011 and 2019, from a population-based retrospective cohort study using linked administrative and vital statistics databases in Massachusetts. We then conducted bivariate and multivariable logistic regressions to identify ZIP Code Tabulation Area (ZCTA) characteristics that were associated with the OUD rates and counts. Such ZCTA characteristics were based on sociodemographic data from the American Community Survey 2016-2020. We also conducted 5-step hotspot cluster analyses to identify hotspot and coldspot clusters of OUD counts and rates among this population.

Results: Among 624,521 people who delivered a live birth between 2011 and 2019 and used MassHealth during this period in Massachusetts, we identified 15,662 cases with an OUD history. The OUD count hotspots were concentrated in Eastern Massachusetts, while the OUD rate hotspots were in Western and Central Massachusetts. In multivariable models, more vulnerable ZCTAs in terms of socioeconomic, minority status, and language social vulnerability indices were more likely to have higher OUD counts. ZCTAs with higher proportions of White populations were more likely to have higher OUD rates. Compared to U.S.-born people, fewer proportions of foreign-born people received any OUD-related treatment services, such as receipt of medication for OUD, and enrollment in state-funded addiction treatment programs.

Such enrolment was defined based on evidence of opioid treatment receipt, receipt of pregnant and postpartum enhancement services in residential program, or having opioids as the primary, secondary or tertiary substance at enrolment.

Conclusions: Provision of treatment services for OUD should take into consideration the social determinants of health to provide equitable services. Future studies should explore nativity (U.S. vs foreign-born) as a crucial factor that might affect OUD and related treatment access.

KEYWORDS

Hotspot, Cluster, Geographic information systems, Opioid use disorder, Pregnancy

3.1 INTRODUCTION

Perinatal opioid use and neonatal opioid withdrawal syndrome (NOWS) are major public health concerns in the U.S. The number of pregnant and postpartum (P&P) people with opioid use disorder (OUD) has doubled in the past decade (Hirai et al., 2021). Massachusetts (MA) has one of the highest OUD rates in the nation (Neonatal Quality Improvement Collaborative of Massachusetts, 2017). In MA during 2018, 1.5% of people who delivered a live birth had evidence of OUD during pregnancy, and 11.7 infants per 1,000 live births were diagnosed with NOWS (Massachusetts Department of Public Health, 2021a). Maternal OUD is associated with severe maternal complications including mortality (Admon et al., 2019) and infants diagnosed with NOWS have longer and more complicated hospital stays than nonaffected infants (Winkelman, Villapiano, et al., 2018), necessitating the prevention and treatment of maternal OUD.

Levels of perinatal OUD in a community is affected by a wide range of social contexts within communities of residence, including the level of resources in the community, the amount of poverty, joblessness, common moral perceptions, and normality of substance use, and hence understanding such neighborhood level social determinants of health in relation to opioid use is essential (Finch et al., 2001). In a study of Latina mothers in Pennsylvania, higher levels of maternal smoking at the census-tract level was associated with increased individual odds of smoking (AOR = 1.28; 95% CI: 1.22, 1.34) (Chesnokova, French, Weibe, Camenga, & Yun, 2015). Moreover, the neighborhood where P&P people with OUD live might affect their health, their access to healthcare, their health outcomes, and those of their offspring. Compared to women without OUD, women with OUD at delivery were more likely to reside in small rural areas in a study in Maine (22.5% vs. 27.3%, $p<0.01$) (Gabrielson, Carwile, O'Connor, & Ahrens, 2020). Similarly, the highest number of babies with NOWS was born in rural

counties with high unemployment rates and a shortage of mental health providers in a study across eight U.S. states (Patrick, Faherty, et al., 2019). The incidence of NOWS increased with increasing proportions of state population with rural domicile (Pearson linear correlation coefficient, r = 0.61; 95% CI: 0.35, 0.77) and decreased with increasing proportions of state population that is Hispanic (Pearson linear correlation coefficient, r = − 0.38; 95% CI: − 0.62, − 0.07) in a nationwide state-level comparison study (Wolf et al., 2019).

Prior studies found differences in OUD and use of medications for OUD (MOUD) by race and ethnicity, nativity, demographic characteristics, socioeconomic status, and geographic location among P&P people. Black non-Hispanic people with some college education were 42% less likely to receive MOUD in the year before delivery, compared to White non-Hispanic people with some college education in MA (AOR=0.58; 95% CI: 0.40 to 0.84) (Schiff et al., 2020). Foreign-born immigrant P&P people were at equal risk of prenatal alcohol use compared with their U.S.-born counterparts, after adjusting for confounders that included socioeconomic status, social support, paternal health, and maternal stress and health history (average predicted probability = 53% among foreign-born vs. U.S. born pregnant women), in a study in 20 large U.S. cities (Perreira & Cortes, 2006). Furthermore, increased acculturation in the U.S. was associated with poorer health behaviors and higher risk of substance use disorder (SUD) during pregnancy (Harley & Eskenazi, 2006; Hernandez, von Sternberg, & Velasquez, 2020). These studies emphasize that foreign-born P&P people should be considered as at-risk populations. Also, there is a lack of studies among P&P people with OUD, and even fewer studies involving foreign-born populations.

The overall goal of our study was to examine neighborhood-level characteristics associated with OUD counts and rates among P&P people using a range of

sociodemographic variables from the American Community Survey (ACS) as well as contemporary composite scores on social vulnerability (Agency for Toxic Substances and Disease Registry, 2021) and on racial and income polarization (Krieger et al., 2016). The objectives of our study were: a) to identify clusters of OUD among P&P people in MA from 2011 to 2019 using GIS and spatial epidemiological analyses, and b) to find social determinants of health associated with the counts and rates of OUD within this population at the neighborhood level through multivariable logistic regression modeling.

3.2 METHODS

3.2.1 Study Design and Populations, Data Sources, and Unit of Analysis

We conducted a population-based retrospective cohort study using data from the Public Health Data (PHD) Warehouse, a collection of linked statewide MA datasets overseen by the MA Department of Public Health (MDPH). At the time of study initiation, the warehouse included data from calendar years 2011 to 2019 linked at the individual level across administrative MA databases. Among the more than two dozen databases linked in the PHD, we used data from the following administrative datasets: (1) All Payer Claims Database (APCD): medical and pharmacy claims submitted by commercial insurance carriers and public programs (Medicaid/MassHealth), and member eligibility data provided by MassHealth on enrolled clients, (2) Vital Records: birth certificate, (3) Bureau of Substance Addiction Services (BSAS) licensed SUD treatment data, (4) the Center for Health Information and Analysis Case Mix records: hospitalization, outpatient observation, and emergency department discharge, (5) the Prescription Monitoring Program (PMP), (6) MA Ambulance Trip Record Information System (MATRIS), and (7) Department of Mental Health (DMH) data. The data were accessed between November 2021 and May 2022. A detailed description of these datasets, data structure, and linkage

rates among datasets has been described previously (Commonwealth of Massachusetts, 2015; Massachusetts Department of Public Health, 2021c, 2021d).

We also used publicly available data from the ACS 2016-2020 (United States Census Bureau, 2021b) to characterize ZIP Code Tabulation Areas (ZCTA). ZCTA, the geographical unit of this analysis, is defined by the U.S. Census Bureau as “the generalized areal representations of United States Postal Service (USPS) ZIP Code service areas”. ZCTAs match social and neighborhood areas better than USPS ZIP Codes (United States Census Bureau, 2020). ZCTA code is the same as ZIP Code for an area in most instances. However, ZIP Codes assigned to businesses only or single delivery point address might not have a ZCTA code, and large water bodies and large unpopulated lands do not have a ZCTA code (United States Census Bureau, 2022b).

We conducted analyses at the individual level, as well as aggregated ZCTA level. We followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cohort studies (Equator Network, 2019) in this manuscript.

The study population included MA residents with a history of OUD who had MassHealth (Medicaid) at any point during the study period (i.e., 2011 to 2019) and who delivered a live birth with a documented gestational age of 20 weeks or more during the same period (Figure 3.1 shows how the study participants were selected). This study population is referred to as P&P people with OUD in this chapter. This includes binary and non-binary people to make the results more inclusive. A P&P person is someone who is currently pregnant or gave birth within the last year (Centers for Disease Control and Prevention, 2022). For this study, a P&P person was defined as having OUD in the PHD if they fulfilled of at least one of the following: (1) having two or more instances of nonfatal opioid overdoses in either Case Mix, BSAS, or MATRIS database; (2) having an indicator of opioid abuse or dependence in either APCD, Case Mix, BSAS, or DMH

database; or (3) having been prescribed MOUD such as methadone or buprenorphine in either the APCD or PMP database (Refer to Appendix 3.1 for details).

We limited our study population to those who used MassHealth during the study period, to ensure a study population with homogenous socioeconomic conditions that reduces the overall variability of the estimates (Martínez-Mesa, González-Chica, Duquia, Bonamigo, & Bastos, 2016). To identify any variations of our results due to insurance status, we also conducted sensitivity analyses on a similar population that included those who used MassHealth during the study period and those who did not. The study population was identified using birth certificates for infants born to MA residents. Birth certificate linkage rates with the main data set (i.e., the APCD) for our study period were 90.0%. We treated the birth of both singleton and multiples as a single delivery episode and included only the first delivery in the case of multiple deliveries by the same person during the study period to prevent clustering effects arising from the entry of a single person's data more than once in the analysis (Hedges & Citkowicz, 2015).

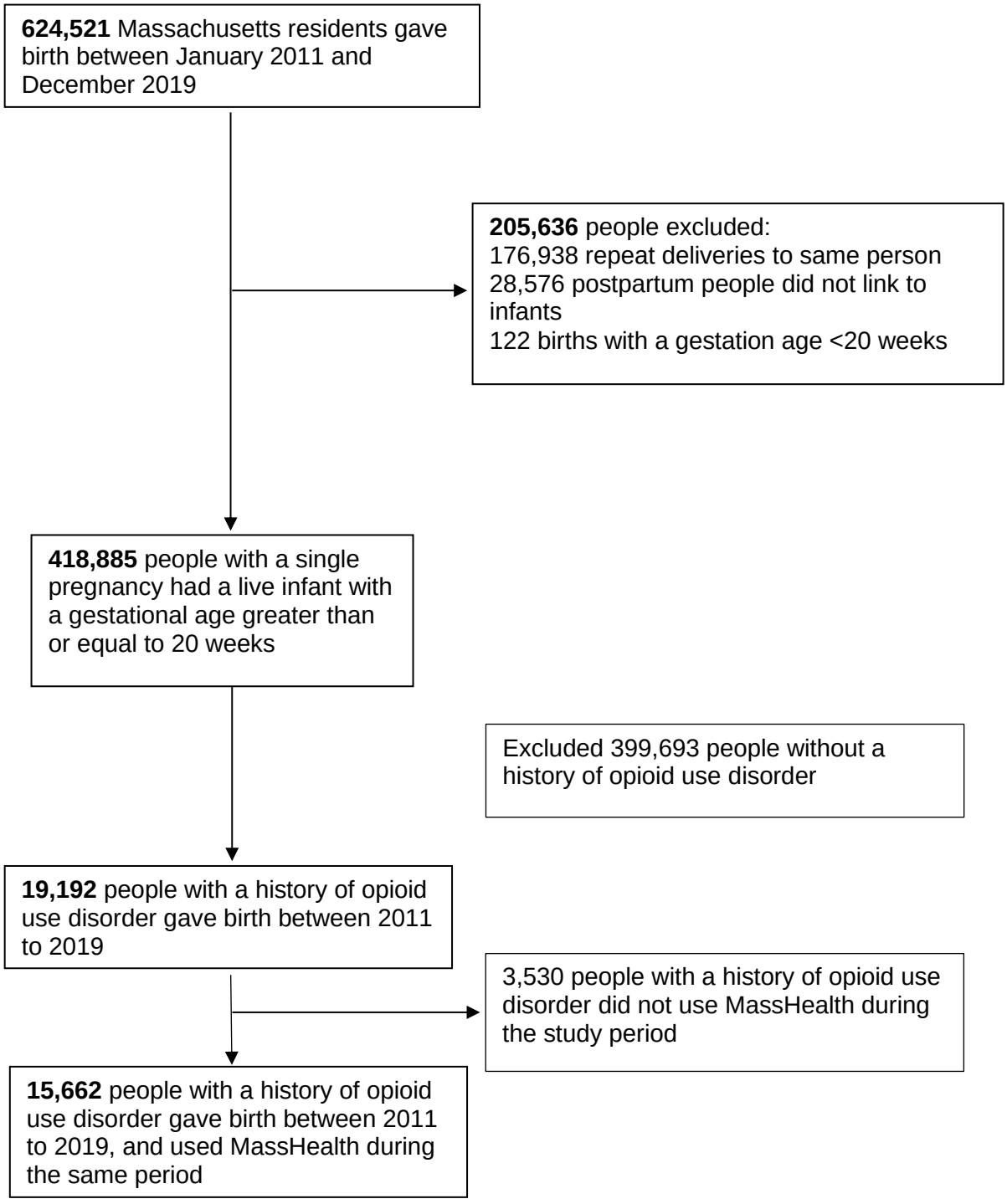

Figure 3. 1 Selection of the study participants

3.2.2 Measures

Variables That Characterize P&P People With a history of OUD

We first summarized the sociodemographic and clinical variables of people with an OUD history who gave birth during the study period. Variables including age at delivery, race/ethnicity, marital status, highest educational level, adequacy of prenatal care, and NOWS diagnosis among study participants were extracted from the birth certificate. Enrollment in MassHealth was derived from the APCD dataset. Enrollment in public addiction treatment programs for opioid use during the study period was defined as having any evidence of enrollment in a state-funded program including: (1) evidence of opioid treatment receipt, (2) receipt of P&P enhancement services i.e., comprehensive services that meet the patient's social needs in residential program, or (3) having opioids as the primary, secondary, or tertiary substance at enrolment. This variable was sourced from BSAS records, which includes acute treatment services, crisis stabilization, residential and intensive out-patient programs.

Receipt of MOUD during the study period was defined by either insurance claims for methadone or buprenorphine treatment in the APCD dataset or filled prescriptions for buprenorphine or buprenorphine/naloxone identified in the PMP database. We excluded Naltrexone as it is not currently recommended in pregnancy and is mainly prescribed for alcohol use disorder (Caritis & Venkataramanan, 2020). Including naltrexone would overestimate the receipt of MOUD among P&P people with OUD, by counting the cases where the medication was not prescribed for OUD. Nonfatal overdose during the person's lifetime was defined as having two or more instances of nonfatal opioid overdoses in either Case Mix, BSAS, or MATRIS database. Each ZCTA was classified as metropolitan if it fell within a Metropolitan Statistical Area and nonmetropolitan otherwise, as per the 2010 Rural-Urban Commuting Area Codes precalculated at 5-digit

ZIP Code (United States Department of Agriculture, 2020). Three variables: incarcerated in prison or jail, a history of homelessness during the person's lifetime, and foreign-born were from the database 'PHDSPINE.DEMO'. This database was created by the MDPH and contained preliminary variables designed to allow for code development. Incarcerated in prison or jail was defined as whether the person was incarcerated in MA's Department of Corrections or the Middlesex County House of Correction (Massachusetts Department of Public Health, 2022b). Data from the remaining houses of corrections in other MA counties were not available. Please refer to Table 3.1 for details on variables and their data sources.

Table 3. 1 Data sources and variables for the study

Data sources	Variables
	Individual-level
Public Health Data Warehouse	
1. All Payer Claims Database	Receipt of buprenorphine, receipt of methadone, opioid abuse or dependence, enrolment in MassHealth
2. Birth certificate	Age, education, race, marital status, prenatal care adequacy, neonatal opioid withdrawal syndrome, year, ZIP Code Tabulation Area (ZCTA)
3. Bureau of Substance Addiction Services	Enrolment in state-funded opioid program, any overdose, opioid abuse, or dependence
4. Case Mix	Any overdose, opioid abuse, or dependence
5. Prescription Monitoring Program	Receipt of buprenorphine
6. Massachusetts Ambulance Trip Record Information System	Any overdose
7. Department of Mental Health	Opioid abuse or dependence
8. PHDSPINE.DEMO (MDPH-created database for code development purposes)	Homelessness, incarceration, foreign-born, sex, Massachusetts residence
	Neighborhood-level
American Community Survey 2016-2020	Percentage households: with no vehicle, with bachelor's degree and higher education, in labor force, that received public assistance, that were single parent households Percentage White population, and foreign-born population in each ZCTA
Rural-Urban Commuting Area	Urbanicity of ZCTA (metropolitan vs. non-metropolitan residence)
Center for Disease Control and Prevention **(Krieger et al., 2016)**	Socioeconomic status Social Vulnerability Index (SVI), minority status and language SVI, housing type and transportation SVI, household composition and disability SVI Index of Concentration at the Extremes (ICE)

Note: Variables: any nonfatal overdose, receipt of buprenorphine, and opioid abuse or dependence were sourced from more than one dataset in the Public Health Data Warehouse.

Variables for Spatial Analyses at ZCTA Level

Counts of people with OUD who gave birth between 2011and 2019 in each MA ZCTA were extracted from the PHD Warehouse. Rates of OUD were calculated as counts of people who had OUD per 1,000 population who gave birth between 2011 and

2019. MDPH also calculates maternal OUD rates per 1,000 population (Massachusetts Department of Public Health, 2021a).

Outcome Measures and Covariates for Statistical Analyses at ZCTA Level

Outcome measures: We included two binary outcome variables: counts of maternal OUD history and rates of maternal OUD history. They were dichotomized into counts and rates below the state median and counts and rates greater than or equal to the state median.

Covariates: Thirteen covariates were considered for inclusion in our models based on the scientific literature (Lo-Ciganic et al., 2019; Schiff et al., 2020).

Statistical analyses: **In models 1 and 2**, we adjusted for five covariates: socioeconomic status social vulnerability index (SVI) (Agency for Toxic Substances and Disease Registry, 2021), minority status and language SVI, household composition and disability SVI, housing type and transportation SVI, and Index of Concentration at the Extremes (ICE) for racialized economic segregation (Krieger et al., 2017).

The SVIs at the ZCTA level for our analyses were calculated using precalculated SVIs at the census tract level available from the Center for Disease Control and Prevention (Agency for Toxic Substances and Disease Registry, 2021) using the method by Bilal et al., 2020 (Bilal, Barber, Tabb, & Diez-Roux, 2020). The SVIs were categorized into quartiles based on previous studies (Dasgupta et al., 2020; Dryden-Peterson et al., 2020), with higher quartiles representing increasing vulnerability. Each quartile increase in the *Socioeconomic status SVI* signifies that a higher proportion of the population in the ZCTA is living in poverty, is unemployed, has lower income or does not have a high school diploma. Each quartile increase in the *Minority Status and Language SVI* indicates a higher proportion of the population in the ZCTA belongs to a minority group or speaks English less than “very well.” Each quartile increase in the *Housing Type and*

Transportation SVI points to a higher proportion of the population in the ZCTA living in multiunit structures, mobile homes, or group quarters, or a higher proportion of the households as overcrowded or without a vehicle. Each quartile increase in the *Household Composition and Disability SVI* indicates a higher proportion of the population in the ZCTA is aged 65 years or older, 17 years or younger, more than 5-years old with a disability, or has a higher proportion of households with single parents.

ICE for racialized economic segregation compares White populations in the highest income quintile with non-White populations in the lowest income quintile, and was computed using the following formula:

$$ICE_i = (A_i - P_i) / T_i$$

where, A_i is equal to the number of affluent White non-Hispanic people in the i^{th} ZCTA (i.e., in the highest income quintile), P_i is equal to the number of poor persons of color in ZCTA i (i.e., in the bottom income quintile), and T_i is equal to the total population with known income level in ZCTA I (Krieger et al., 2016). The ICE was categorized into quartiles based on previous studies, with each quartile increase representing increased privilege (Chambers, Baer, McLemore, & Jelliffe-Pawlowski, 2019; Krieger et al., 2017).

In models 3 and 4, we adjusted for eight covariates at the ZCTA level: percent White, percent foreign-born, percent with bachelor's degree or higher education, percent in labor force, percent households that received public assistance, percent single parent households, percent households with no vehicle, and urbanicity. Urbanicity was binary (i.e., metropolitan vs. nonmetropolitan) while the rest of the seven covariates were continuous. Three more variables were considered for analysis but dropped due to multicollinearity based on Variance Inflation Factors of more than 6 (Vittinghoff, Glidden, Shiboski, & McCulloch, 2012). These were: percent population with limited English

proficiency, percent living in poverty, and percent Hispanic. Please refer to Figure 3.2 for details.

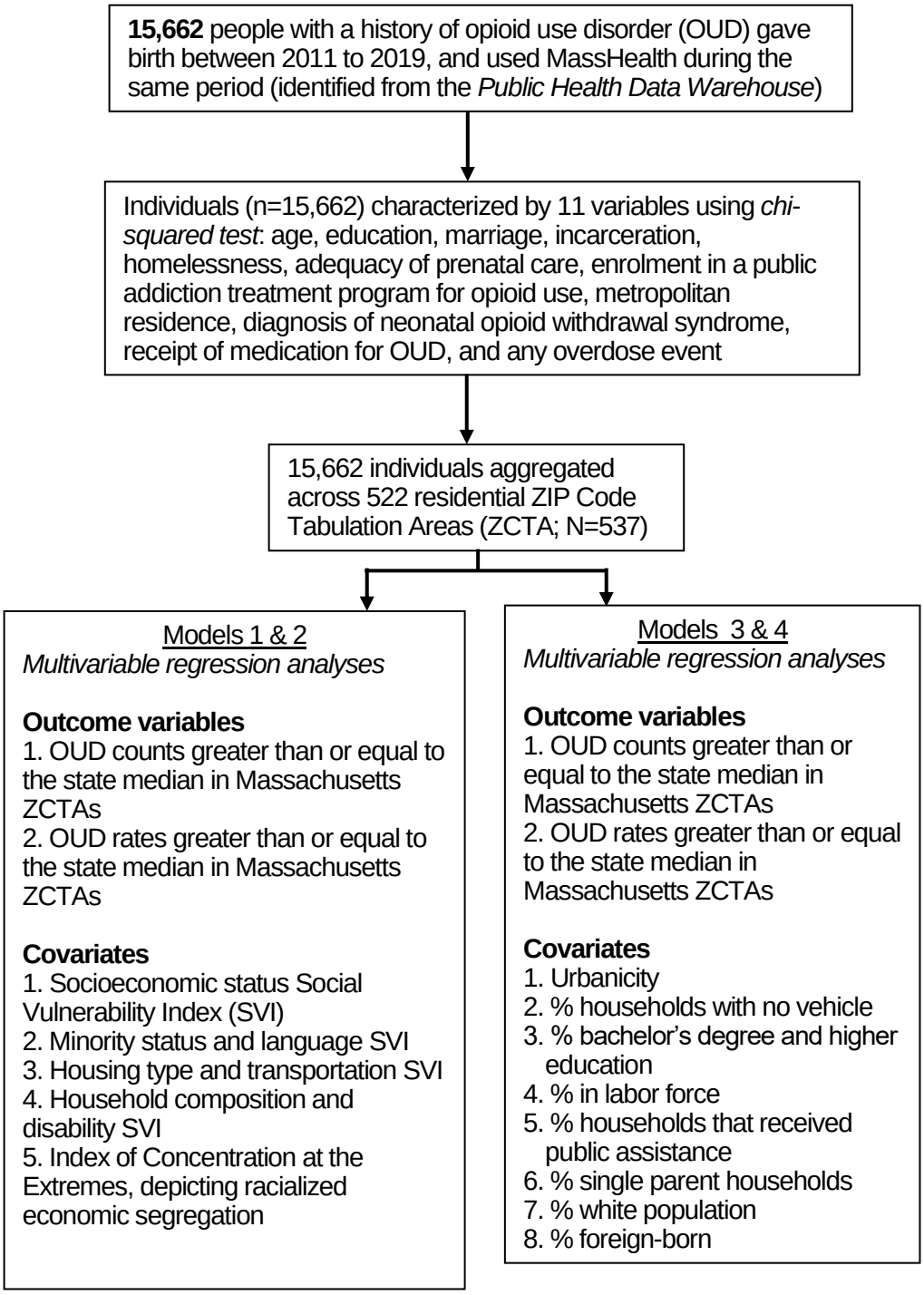

Figure 3. 2 Multivariable models to identify factors associated with OUD counts and rates in MA ZCTAs, 2011 to 2019.

3.3 ANALYSES

3.3.1 Characteristics of People with an OUD History Who Gave Birth Between 2011 and 2019

Using chi-squared tests, we compared the characteristics of people with an OUD history across six different racial/ethnic groups (White non-Hispanic, Black non-Hispanic, Asian/PI non-Hispanic, Hispanic, American Indian, and Unknown), and between people born in foreign countries versus those born in the U.S.

3.3.2 Statistical Analyses at ZCTA Level

The statistical analyses at ZCTA level were conducted based on a deidentified total count of maternal OUD in each ZCTA from the PHD Warehouse, and ZCTA sociodemographic data from the ACS. Firstly, we conducted bivariate logistic regression analyses to explore any association of ZCTA sociodemographic characteristics with maternal OUD counts and rates greater than or equal to the state median. Since many of the covariates had more than two categories, we used the type 3 analysis of effects which produces a p value for the composite null hypothesis that all levels of a categorical predictor have the same effect on the outcome as the reference category does (Harrell, 2001). All the variables that were significant at type 3 $p<0.05$ in bivariate analyses were considered for inclusion in the multivariable models. Associations tied to the final multivariable models were considered significant at a type 3 $p<0.05$. We conducted a complete case analysis (n=522 ZCTAs, N=537 ZCTAs). In this study, the missing data occurred in the outcome variable only, and in such instance, complete-case analysis and multiple imputation are equivalent, and complete-case analysis is preferred since it is

easier, more efficient, and more robust (von Hippel, 2007). All statistical analyses were conducted in SAS 9.4 and SAS Studio (SAS®, 2021).

3.3.3 Spatial Analyses at ZCTA Level

We conducted 5-step hotspot analyses to identify clusters of ZCTAs with high or low maternal OUD counts and rates among people on MassHealth who gave birth between 2011 to 2019, and for all people (i.e., both using and not using MassHealth) who gave birth between 2011 to 2019. We defined a hotspot as a location with a statistically significant cluster of ZCTAs with higher counts and rates of maternal OUD than the average count and rate for all ZCTAs across MA (Meyers, Hood, & Stopka, 2014). In the first step, we temporarily excluded large ZCTAs (i.e., >1.5 standard deviations above the mean square mile area) and island ZCTAs, that might bias distance calculations in subsequent steps. We then calculated the spatial connectivity of the ZCTAs in MA by calculating the mean and maximum distance between the geocentroid (i.e., the geographic center) of each ZCTA and the geocentroids of the two nearest neighboring ZCTAs to obtain distance parameters for the next step. Next, we conducted incremental spatial autocorrelation analyses at 30 different distances to determine the distance at which clustering was most intense (i.e., had the highest z-score) for each specified outcome. This distance was then used to calculate a spatial weights matrix that accounted for the spatial relationships of all ZCTAs, including the large and island ZCTAs excluded from previous steps, and maternal OUD counts and rates, improving the validity of the hotspot analysis. Lastly, we calculated the Getis-Ord Gi* statistic, which produces Z-scores, to identify clustering patterns across all MA ZCTAs. We applied False Discovery Rate (FDR) Correction parameters to account for multiple testing and spatial dependence. Ultimately, a ZCTA was identified as belonging

to a hotspot (or coldspot) cluster when it, and its neighboring ZCTAs, had a local mean maternal OUD count and rate that was higher (or lower) than the mean maternal OUD count and rate for all ZCTAs in MA. The details of the hotspot cluster analysis methods have been published elsewhere (Stopka, Krawczyk, Gradziel, & Geraghty, 2014). Additionally, we conducted Optimized Hotspot Analysis to portray the key covariates that were statistically significant in the multivariable logistic regression analyses. The analyses were conducted in ArcGIS Pro 2.9.2. The resulting maps were edited in MS Office 2010 Picture Editor for visual clarity.

3.3.4 Ethical Approval

The Tufts Health Sciences IRB reviewed and approved all study activities (IRB ID STUDY00000466).

3.4 RESULTS

3.4.1 Characteristics of People with a History of OUD

A total of **624,521** MA residents gave birth between January 2011 and December 2019. Of these, 0.33% (n=2,061) reported their gender as male at the time of delivering their child, 0.07% (n=437) did not specify their sex, while the rest reported themselves as female. We identified **19,192** deliveries to people with an indication of OUD history, after excluding: (1) multiple deliveries in the study period, births <20 weeks and those without a valid gestational age, (2) those that did not link to birth data (due to changes in reporting requirements starting 2016 pertaining to the Supreme Court decision on Gobeille v. Liberty Mutual, which no longer required self-insured companies to report to the APCD) (Hobbs & Medinus, 2020), and (3) those without a history of OUD (Figure 3.1). Of these people with OUD history, **15,662** people were on MassHealth during the study period, which constituted our study population.

Among our study population, higher proportions of non-Hispanic White people compared to all other racial/ethnic people received OUD-related treatment services (e.g., enrollment in an opioid treatment program, MOUD treatment), and lower proportions had not received any MOUD treatment at all. However, compared to the U.S.-born people, lower proportions of foreign-born people received OUD-related treatment services (Table 3.2).

Table 3. 2 Characteristics of people on MassHealth with a history of opioid use disorder who gave birth in Massachusetts, 2011 to 2019.

	No. (%) N=**15,662**							No. (%) N=**15,657**		
	White non-Hispanic (n=12,307)	Black non-Hispanic (n=906)	Asian/PI non-Hispanic (n=107)	Hispanic (n=1,852)	American Indian or Other (n=231)	Unknown (n=259)	P value	US-born (n=15,171)	Foreign-born (n=486)	P value from $\chi 2$ and Fisher's exact tests
Age *							<.01			<.01
<20 years	610 (4.96)	65 (7.17)	7 (6.54)	185 (9.99)	21 (9.09)	9 (3.47)		878 (5.79)	19 (3.91)	
20-24 years	3038 (24.69)	242 (26.71)	23 (21.5)	545 (29.43)	59 (25.54)	47 (18.15)		3872 (25.52)	81 (16.67)	
25-29 years	4243 (34.48)	261 (28.81)	31 (28.97)	547 (29.54)	64 (27.71)	87 (33.59)		5072 (33.43)	160 (32.92)	
30-34 years	3042 (24.72)	210 (23.18)	25 (23.36)	371 (20.03)	60 (25.97)	77 (29.73)		3645 (24.03)	139 (28.6)	
35-39 years	1150 (9.34)	93 (10.26)	15 (14.02)	167 (9.02)	19 (8.23)	32 (12.36)		1407 (9.27)	68 (13.99)	
≥40 years	224 (1.82)	35 (3.86)	6 (5.61)	37 (2)	8 (3.46)	7 (2.7)		297 (1.96)	19 (3.91)	
Education *							<.01			<.01
Associate degree and higher	1309 (10.64)	95 (10.49)	15 (14.02)	103 (5.56)	24 (0.15)	11 (4.25)		1485 (9.79)	72 (14.81)	
Less than associate degree	6813 (55.36)	537 (59.27)	55 (51.4)	1262 (68.14)	128 (0.82)	39 (15.06)		8584 (56.58)	250 (51.44)	
Married *	1805 (14.67)	106 (11.7)	20 (18.69)	238 (12.85)	36 (15.58)	42 (16.22)	<.05	2091 (13.78)	156 (32.1)	<.01
Incarcerated in prison/jail **	2224 (18.07)	177 (19.54)	12 (11.21)	261 (14.09)	30 (12.99)	69 (26.64)	<.01	2715 (17.9)	56 (11.52)	<.01
Adequacy of prenatal care *							<.01			>.10
Inadequate	4567 (37.11)	373 (41.17)	38 (35.51)	723 (39.04)	93 (40.26)	128 (49.42)		5738 (37.82)	181 (37.24)	
Adequate	3792 (30.81)	260 (28.7)	42 (39.25)	539 (29.1)	68 (29.44)	51 (19.69)		4616 (30.43)	135 (27.78)	
Intensive	3948 (32.08)	273 (30.13)	27 (25.23)	590 (31.86)	70 (30.3)	80 (30.89)		4817 (31.75)	170 (34.98)	
History of homelessness **	2715 (22.06)	185 (20.42)	13 (12.15)	333 (17.98)	40 (17.32)	75 (28.96)	<.01	3290 (21.69)	70 (14.4)	<.01
Enrolled in public addiction treatment program for opioid use **	8384 (91.92)	434 (77.92)	46 (76.67)	963 (85.22)	133 (84.18)	166 (89.73)	<.01	9918 (90.51)	205 (82.0)	<.01
Metropolitan residence * [#]	11756 (95.52)	893 (98.57)	104 (97.2)	1823 (98.43)	222 (96.1)	238 (91.89)	<.01	14553 (95.93)	479 (98.56)	<.01
NOWS diagnosis *	1064 (8.65)	36 (3.97)	4 (3.74)	100 (5.4)	14 (6.06)	12 (4.63)	<.01	1206 (7.95)	23 (4.73)	<.05

	No. (%) N=**15,662**							No. (%) N=**15,657**		
	White non-Hispanic (n=12,307)	Black non-Hispanic (n=906)	Asian/PI non-Hispanic (n=107)	Hispanic (n=1,852)	American Indian or Other (n=231)	Unknown (n=259)	P value	US-born (n=15,171)	Foreign-born (n=486)	P value from χ2 and Fisher's exact tests
Receipt of MOUD										
Methadone **	1707 (13.87)	39 (4.3)	14 (13.08)	166 (8.96)	21 (9.09)	16 (6.18)	<.01	1925 (12.69)	36 (7.41)	<.01
Buprenorphine **	7498 (60.92)	352 (38.85)	53 (49.53)	780 (42.12)	126 (54.55)	157 (60.62)	<.01	8790 (57.94)	171 (35.19)	<.01
Any MOUD **	8362 (67.95)	372 (41.06)	61 (57.01)	875 (47.25)	139 (60.17)	165 (63.71)	<.01	9775 (64.43)	194 (39.92)	<.01
No MOUD **	3945 (32.05)	534 (58.94)	46 (42.99)	977 (52.75)	92 (39.83)	94 (36.29)	<.01	5396 (35.57)	292 (60.08)	<.01
Any overdose events in lifetime	3239 (26.32)	168 (18.54)	21 (19.63)	351 (18.95)	56 (24.24)	74 (28.57)	<.01	3822 (25.19)	85 (17.49)	<.01

PI – Pacific Islander; **MOUD** – Medication for Opioid Use Disorder, **NOWS** – Neonatal Opioid Withdrawal Syndrome
*** At the time of the first delivery** between January 1, 2011, to December 31, 2019
**** At any time** from January 1, 2011, to December 31, 2019
# **Metropolitan residence** (vs non-metropolitan) is defined as per Rural-Urban Commuting Area codes available from https://www.ers.usda.gov/data-products/rural-urban-commuting-area-codes/
Note**:** There is no assumption of **temporality** among these variables.

3.4.2 ZCTA Sociodemographic Characteristics Associated with Counts and Rates of Maternal OUD History

In the multivariable logistic regression analyses, increasing vulnerability in the socioeconomic, and the minority status and language domains was associated with increased odds of the ZCTA having higher OUD **counts**, and the odds were greatest for the most vulnerable group. For example, compared to the first quartile of socioeconomic status SVI (the least vulnerable quartile), ZCTAs in the fourth quartile (the most vulnerable quartile) were nearly eight times more likely to have OUD **count** greater than or equal to the state median (AOR = 7.51, 95% CI: 3.14, 17.95), and the association was highly significant (p <0.01) (Table 3.3). Sensitivity analyses among all people with OUD who gave birth between 2011 and 2019 provided similar results (Table 3.5).

ZCTAs with higher socioeconomic vulnerability were more likely to have higher OUD **rates** (Table 3.3). On the other hand, ZCTAs with higher minority status and language vulnerability were less likely to have higher OUD **rates** (Table 3.3). This matches the findings that ZCTAs with higher proportions of White populations (i.e., the non-minority population) had higher odds of having elevated OUD **rates**, while ZCTAs with higher proportions of foreign-born populations (non-native English speakers) had lower odds of experiencing higher OUD **rates** (Table 3.4). For example, with each 1%-point increase in the foreign-born population in ZCTA, the odds of the ZCTA having OUD **rate** greater than or equal to the state median decreased by 7% (AOR = 0.93, 95% CI: 0.9, 0.98) (p <0.01) (Table 3.4).

Metropolitan ZCTAs were nearly 11 times more likely to have OUD **counts** that were greater than or equal to the state median (AOR = 10.93, 95% CI: 4.42, 27.04) (p <.01) (Table 3.4). ZCTAs with higher proportions of populations with a bachelor's degree and higher education were less likely to have higher OUD **counts**, while ZCTAs with higher

proportions of populations in the labor force and households that received public assistance were more likely to have higher OUD **counts** (Table 3.4). Results from sensitivity analyses assessing associations between OUD counts with metropolitan residences, proportions of ZCTA populations with a bachelor's degree and higher, proportions of ZCTA populations in the labor force, and households that received public assistance were similar (Table 3.6).

Table 3. 3 Factors associated with maternal opioid use disorder counts and rates in Massachusetts ZIP Code Tabulation Areas, 2011-2019 (N= 522).

	Models limited to people who used MassHealth during the study period			
	Maternal opioid use disorder counts		Maternal opioid use disorder rates	
	OR from bivariate models (95% CI)	Adjusted OR (95% CI)	OR from bivariate models (95% CI)	Adjusted OR (95% CI)
Socioeconomic status SVI				
0 to 24 percentiles (least vulnerable)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
25 to 49 percentiles	1.76 (1.07, 2.91) *	1.95 (1.10, 3.43) *	1.91 (1.16, 3.12) **	2.02 (1.15, 3.57) **
50 to 74 percentiles	2.52 (1.53, 4.17) **	2.77 (1.50, 5.11) **	2.01 (1.22, 3.29) **	2.58 (1.38, 4.84) **
75 to 99 percentiles (most vulnerable)	5.93 (3.47, 10.14) **	7.51 (3.14, 17.95) **	0.95 (0.58, 1.55)	5.75 (2.43, 13.59) **
Minority status and language SVI				
0 to 24 percentiles (least vulnerable)	1.00	1.00	1.00	1.00
25 to 49 percentiles	4.05 (2.37, 6.91) **	4.78 (2.69, 8.49) **	1.02 (0.60, 1.72)	1.02 (0.59, 1.75)
50 to 74 percentiles	5.05 (2.94, 8.64) **	5.73 (3.18, 10.32) **	0.51 (0.31, 0.85) **	0.51 (0.30, 0.87) **
75 to 99 percentiles (most vulnerable)	9.23 (5.26, 16.19) **	8.42 (4.32, 16.39) **	0.07 (0.03, 0.13) **	0.05 (0.02, 0.12) **
Housing type and transportation SVI				
0 to 24 percentiles (least vulnerable)	1.00	1.00	1.00	1.00
25 to 49 percentiles	2.21 (1.34, 3.64) **	1.49 (0.85, 2.62)	1.02 (0.62, 1.69)	1.15 (0.66, 2.03)
50 to 74 percentiles	3.30 (1.99, 5.47) **	1.36 (0.72, 2.56)	0.52 (0.32, 0.85) **	0.89 (0.48, 1.68)
75 to 99 percentiles (most vulnerable)	2.27 (1.38, 3.73) **	0.69 (0.35, 1.34)	0.30 (0.18, 0.51) **	0.53 (0.27, 1.01) ~
Household composition and disability SVI				
0 to 24 percentiles (least vulnerable)	1.00	1.00	1.00	-
25 to 49 percentiles	1.44 (0.88, 2.35)	1.64 (0.93, 2.89) ~	1.28 (0.78, 2.08)	-
50 to 74 percentiles	1.38 (0.84, 2.25)	1.02 (0.56, 1.85)	1.66 (1.02, 2.72) *	-
75 to 99 percentiles (most vulnerable)	2.07 (1.26, 3.40) **	1.01 (0.52, 1.93)	1.51 (0.93, 2.47) ~	-
ICE for racialized economic segregation				
75 to 99 percentiles (most privileged)	1.00	1.00	1.00	1.00
0 to 24 percentiles (least privileged)	4.02 (2.40, 6.73) **	1.00 (0.43, 2.30)	0.46 (0.28, 0.76) **	0.64 (0.28, 1.47)
25 to 49 percentiles	2.68 (1.62, 4.42) **	1.50 (0.80, 2.81)	1.04 (0.64, 1.70)	0.81 (0.43, 1.55)
50 to 74 percentiles	1.51 (0.92, 2.47)	1.21 (0.68, 2.12)	1.09 (0.67, 1.78)	1.06 (0.60, 1.89)

** **P value** <0.01; * P value <0.05; ~ 0.05 ≤ P value ≤ 0.10

P value from the Type 3 Analysis of Effects <0.05 in bivariate analyses were included in the multivariable analyses.
Ref: reference category, in subsequent rows, 1.00 is the reference category; **OR**: Odds Ratio; **SVI**: Social Vulnerability Index
Maternal opioid use disorder rate: Number of people with opioid use disorder per 1,000 people who gave birth between 2011 and 2019.
Socioeconomic status SVI: each quartile increase represents a higher proportion of population in the ZIP Code Tabulation Area (ZCTA) is living in poverty, is unemployed, has lower income, or does not have a high school diploma, *higher SVI scores indicate higher vulnerability in the subsequent SVIs as well.*
Minority status and language SVI: each quartile increase indicates a higher proportion of population in the ZCTA is minority or speaks English less than very well.
Housing type and transportation SVI: each quartile increase signifies a higher proportion of population in the ZCTA lives in multiunit structure, mobile homes, or group quarters, or a higher proportion of the households is overcrowded or does not have a vehicle.
Household composition and disability SVI: each quartile increase represents a higher proportion of population in the ZCTA is aged 65 years or older, or 17 years or younger, or more than 5 years old with a disability, or a higher proportion of households is single parent households.
ICE: Index of Concentration at the Extremes, compares White populations in the highest income quintile with non-White populations in the lowest income quintile, *higher positive scores indicate extreme concentration of privilege.*
Note: The **reference categories** for the four different SVIs and ICE were chosen to represent the *least disadvantaged* ZCTAs in terms of least vulnerability and most privileged**.**

Table 3. 4 Factors associated with maternal opioid use disorder counts and rates in Massachusetts ZIP Code Tabulation Areas, 2011-2019 (N= 522).

	Models limited to people who used MassHealth during the study period			
	Maternal opioid use disorder counts		Maternal opioid use disorder rates	
	OR from bivariate models (95% CI)	Adjusted OR (95% CI)	OR from bivariate models (95% CI)	Adjusted OR (95% CI)
Urbanicity				
Nonmetropolitan ZIP Code Tabulation Areas	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	-
Metropolitan ZIP Code Tabulation Areas	8.76 (3.87, 19.81) **	10.93 (4.42, 27.04) **	1.06 (0.6, 1.87)	-
Percent households with no vehicle	1.03 (1.01, 1.05) **	0.99 (0.96, 1.01)	0.93 (0.91, 0.95) **	0.99 (0.97, 1.02)
Percent bachelor's degree and higher education	0.94 (0.92, 0.96) **	0.93 (0.90, 0.96) **	0.99 (0.97, 1.01)	-
Percent in labor force	1.03 (1.01, 1.05) **	1.05 (1.02, 1.08) **	0.98 (0.96, 0.99) *	0.98 (0.95, 1.00) ~
Percent households that received public assistance	1.04 (1.02, 1.05) **	1.02 (1.01, 1.04) **	0.98 (0.97, 0.99) **	0.99 (0.98, 1.01)
Percent single parent households	1.04 (1.02, 1.05) **	0.99 (0.97, 1.01)	0.98 (0.97, 0.99) **	1.00 (0.98, 1.02)
Percent White population	0.95 (0.93, 0.96) **	0.98 (0.94, 1.01)	1.08 (1.06, 1.11) **	1.05 (1.01, 1.08) **
Percent foreign-born	1.05 (1.03, 1.07) **	1.02 (0.97, 1.07)	0.88 (0.86, 0.91) **	0.93 (0.90, 0.98) **

**** P value** <0.01; * P value <0.05; ~ 0.05 ≤ P value ≤ 0.10
P value from the Type 3 Analysis of Effects <0.05 in bivariate analyses were included in the multivariable analyses
Ref: reference category, in subsequent rows, 1.00 is the reference category
OR – Odds Ratio
Maternal opioid use disorder rate: Number of people with opioid use disorder per 1,000 people who gave birth between 2011 and 2019.

Table 3. 5 Factors associated with maternal opioid use disorder counts and rates among people with MassHealth in Massachusetts ZIP Code Tabulation Areas, 2011-2019 (N= 530).

	Models not limited by people's MassHealth use			
	Maternal opioid use disorder counts		Maternal opioid use disorder rates	
	OR from bivariate models (95% CI)	Adjusted OR (95% CI)	OR from bivariate models (95% CI)	Adjusted OR (95% CI)
Socioeconomic status SVI				
0 to 24 percentiles (least vulnerable)	1.00	1.00	1.00	1.00
25 to 49 percentiles	1.93 (1.17, 3.20) **	2.29 (1.30, 4.04) **	5.36 (3.01, 9.55) **	4.11 (2.15, 7.87) **
50 to 74 percentiles	2.66 (1.61, 4.40) **	3.36 (1.82, 6.20) **	12.60 (6.93, 22.91) **	11.37 (5.45, 23.73) **
75 to 99 percentiles (most vulnerable)	5.75 (3.39, 9.77) **	8.35 (3.57, 19.52) **	9.05 (5.04, 16.25) **	30.03 (10.02, 89.97) **
Minority status and language SVI				
0 to 24 percentiles (least vulnerable)	1.00	1.00	1.00	1.00
25 to 49 percentiles	3.04 (1.81, 5.12) **	3.57 (2.05, 6.24) **	0.83 (0.50, 1.37)	0.93 (0.49, 1.73)
50 to 74 percentiles	4.20 (2.48, 7.09) **	4.70 (2.65, 8.34) **	0.41 (0.25, 0.68) **	0.27 (0.14, 0.53) **
75 to 99 percentiles (most vulnerable)	7.23 (4.20, 12.44) **	7.81 (4.06, 15.00) **	0.19 (0.11, 0.33) **	0.04 (0.02, 0.11) **
Housing type and transportation SVI				
0 to 24 percentiles (least vulnerable)	1.00	1.00	1.00	1.00
25 to 49 percentiles	2.13 (1.30, 3.48) **	1.52 (0.88, 2.64)	1.93 (1.18, 3.14) **	1.77 (0.92, 3.42) ~
50 to 74 percentiles	3.30 (2.00, 5.47) **	1.38 (0.74, 2.57)	1.41 (0.87, 2.29)	0.95 (0.46, 1.99)
75 to 99 percentiles (most vulnerable)	1.91 (1.17, 3.13) **	0.58 (0.30, 1.11)	0.91 (0.56, 1.48)	0.52 (0.24, 1.10) ~
Household composition and disability SVI				
0 to 24 percentiles (least vulnerable)	1.00	1.00	1.00	1.00
25 to 49 percentiles	1.33 (0.82, 2.17)	1.43 (0.82, 2.49)	1.77 (1.07, 2.92) *	0.90 (0.47, 1.73)
50 to 74 percentiles	1.53 (0.94, 2.49) ~	1.20 (0.67, 2.13)	2.74 (1.66, 4.54) **	1.12 (0.58, 2.17)
75 to 99 percentiles (most vulnerable)	1.98 (1.21, 3.23) **	1.03 (0.54, 1.93)	4.98 (2.95, 8.38) **	1.79 (0.88, 3.62)
ICE for racialized economic segregation				
75 to 99 percentiles (most privileged)	1.00	1.00	1.00	1.00
0 to 24 percentiles (least privileged)	3.31 (2.00, 5.48) **	0.76 (0.34, 1.72)	3.46 (2.06, 5.80) **	2.42 (0.95, 6.15) ~
25 to 49 percentiles	2.35 (1.44, 3.85) **	1.18 (0.63, 2.19)	6.28 (3.68, 10.70) **	3.64 (1.74, 7.59) **
50 to 74 percentiles	1.34 (0.82, 2.19)	1.01 (0.58, 1.78)	2.71 (1.62, 4.54) **	2.02 (1.05, 3.85) *

** **P value** <0.01; * P value <0.05; ~ 0.05 ≤ P value ≤ 0.10
P value from the Type 3 Analysis of Effects <0.05 in bivariate analyses were included in the multivariable analyses.
Ref: reference category, in subsequent rows, 1.00 is the reference category; **OR**: Odds Ratio; **SVI**: Social Vulnerability Index
Maternal opioid use disorder rate: Number of people with opioid use disorder per 1,000 people who gave birth between 2011 and 2019.
Socioeconomic status SVI: each quartile increase represents a higher proportion of population in the ZIP Code Tabulation Area (ZCTA) is living in poverty, is unemployed, has lower income, or does not have a high school diploma, *higher SVI scores indicate higher vulnerability in the subsequent SVIs as well.*
Minority status and language SVI: each quartile increase indicates a higher proportion of population in the ZCTA is minority or speaks English less than very well.
Housing type and transportation SVI: each quartile increase signifies a higher proportion of population in the ZCTA lives in multiunit structure, mobile homes, or group quarters, or a higher proportion of the households is overcrowded or does not have a vehicle.
Household composition and disability SVI: each quartile increase represents a higher proportion of population in the ZCTA is aged 65 years or older, or 17 years or younger, or more than 5 years old with a disability, or a higher proportion of households is single parent households.
ICE: Index of Concentration at the Extremes, compares White populations in the highest income quintile with non-White populations in the lowest income quintile, *higher positive scores indicate extreme concentration of privilege.*
Note: The **reference categories** for the four different SVIs and ICE were chosen to represent the *least disadvantaged* ZCTAs in terms of least vulnerability and most privileged**.**

Table 3. 6 Factors associated with maternal opioid use disorder counts and rates among all people in Massachusetts ZIP Code Tabulation Areas, 2011-2019 (N= 530).

	Models not limited by people's MassHealth use			
	Maternal opioid use disorder counts		Maternal opioid use disorder rates	
	OR from bivariate models (95% CI)	Adjusted OR (95% CI)	OR from bivariate models (95% CI)	Adjusted OR (95% CI)
Urbanicity				
Nonmetropolitan ZIP Code Tabulation Areas	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	-
Metropolitan ZIP Code Tabulation Areas	8.58 (3.80, 19.35) **	10.00 (4.05, 24.65) **	0.58 (0.33, 1.03) ~	-
Percent households with no vehicle	1.02 (1.00, 1.03) **	0.98 (0.96, 1.01)	0.96 (0.94, 0.97) **	0.97 (0.93, 1.02)
Percent bachelor's degree and higher education	0.95 (0.93, 0.96) **	0.94 (0.91, 0.97) **	0.91 (0.89, 0.93) **	0.92 (0.89, 0.95) **
Percent in labor force	1.04 (1.02, 1.06) **	1.06 (1.03, 1.09) **	0.96 (0.94, 0.98) **	0.96 (0.94, 0.98) **
Percent households that received public assistance	1.03 (1.02, 1.05) **	1.03 (1.01, 1.04) **	1.02 (1.01, 1.03) **	1.03 (1.00, 1.05) **
Percent single parent households	1.03 (1.02, 1.05) **	0.99 (0.97, 1.01)	1.02 (1.00, 1.03) **	1.03 (1.00, 1.05) **
Percent White population	0.95 (0.94, 0.97) **	0.97 (0.93, 1.01)	1.05 (1.03, 1.06) **	1.05 (1.02, 1.09) **
Percent foreign-born	1.04 (1.02, 1.06) **	1.00 (0.96, 1.05)	0.90 (0.88, 0.92) **	0.94 (0.90, 0.98) **

**** P value** <0.01; ***** P value <0.05; ~ 0.05 ≤ P value ≤ 0.10
P value from the Type 3 Analysis of Effects <0.05 in bivariate analyses were included in the multivariable analyses
Ref: reference category, in subsequent rows, 1.00 is the reference category; **OR** – Odds ratio
Maternal opioid use disorder rate: Number of people with opioid use disorder per 1,000 people who gave birth between 2011 and 2019.

3.4.3 5-Step Hotspot Cluster Analyses of Counts and Rates of Maternal OUD History

The majority of the OUD **count** hotspots were detected in Eastern MA: Lynn and Saugus in Essex County; Melrose in Middlesex County; Holbrook in Norfolk County; and Norton, Somerset, Fall River, North and South Dartmouth, New Bedford, Fairhaven, and Acushnet in Bristol County (Figure 3.3 A, statistical significance at $p<0.05$). This is further supported by Figure 3.4 A which shows higher counts of people with a history of OUD in Eastern MA, compared to Central and Western MA. There were few OUD count hotspots in Western MA: Chicopee and West Springfield in Hampden County, and Pittsfield in Berkshire County (Figure 3.3 A, $p<0.05$).

Moreover, most of the maternal OUD count hotspots in Eastern and Western MA were also hotspots for socioeconomic status SVI, minority status and language SVI, and foreign-born populations (Figures 3.5 A, B, D, $p<0.05$). Somerset, Fall River, North and South Dartmouth, New Bedford, and Fairhaven in Bristol County (Eastern MA); and Chicopee and West Springfield in Hampden County (Western MA) were hotspots for *socioeconomic status SVI*. Lynn and Saugus in Essex County, Melrose in Middlesex County, and Holbrook in Norfolk County were hotspots for *minority status and language SVI* and *foreign-born population* (Figure 3.5 A, B, D, $p<0.05$).

OUD **rate** hotspots were found mainly in Western and Central MA: Rowe and Monroe in Franklin County; North Adam, Savoy, Windsor, and Otis in Berkshire County; Westfield and Russell in Hampden County; and Barre in Worcester County (Figure 3.3 B, $p<0.05$). There were few OUD rate hotspots in Eastern MA: Groton in Middlesex County and Medfield in Norfolk County (Figure 3.3 B, $p<0.05$). This is supported by Figure 3.4 B which shows higher OUD rates per 1,000 people in Western and Central MA, compared to Eastern MA. Moreover, most of these maternal OUD rate hotspots

were also hotspots for socioeconomic status SVI, minority status and language SVI, and foreign-born populations (Figure 3.5 A, B, D, $p<0.05$). Rowe and Monroe in Franklin County, and North Adam and Savoy in Berkshire County (both counties in Western MA) were hotspots for *socioeconomic status SVI*. Medfield in Norfolk County (Eastern MA) was a hotspot for both *minority status and language SVI*, and *foreign-born population SVI* (Figure 3.5 A, B, D, $p<0.05$).

Coldspots for OUD rates were found in Metro Boston area in Eastern MA (Figure 3.3 B, $p<0.05$). Similarly, Metro Boston area had lower maternal OUD rates per 1,000 people on MassHealth compared to other parts of MA, as seen in Figure 3.4 B.

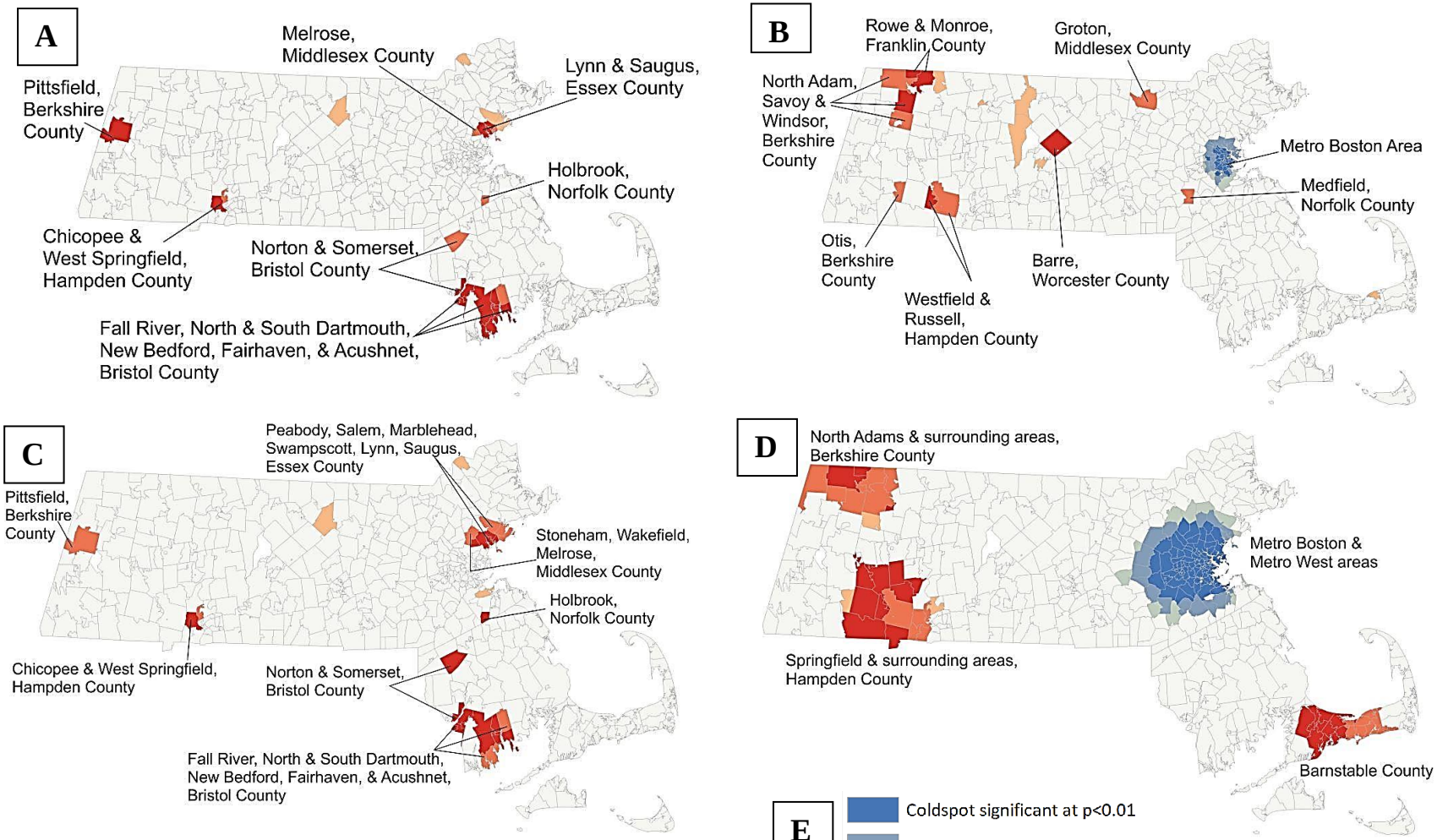

Figure 3.3 A-E: **Hotspots and coldspots for maternal OUD counts and rates** between 2011 and 2019.
A. OUD count among people on MassHealth; **B**. OUD rate among people on MassHealth; **C**. OUD count among all people; **D**. OUD rate among all people; **E**: Levels of statistical significance for hotspot and coldspot clusters.

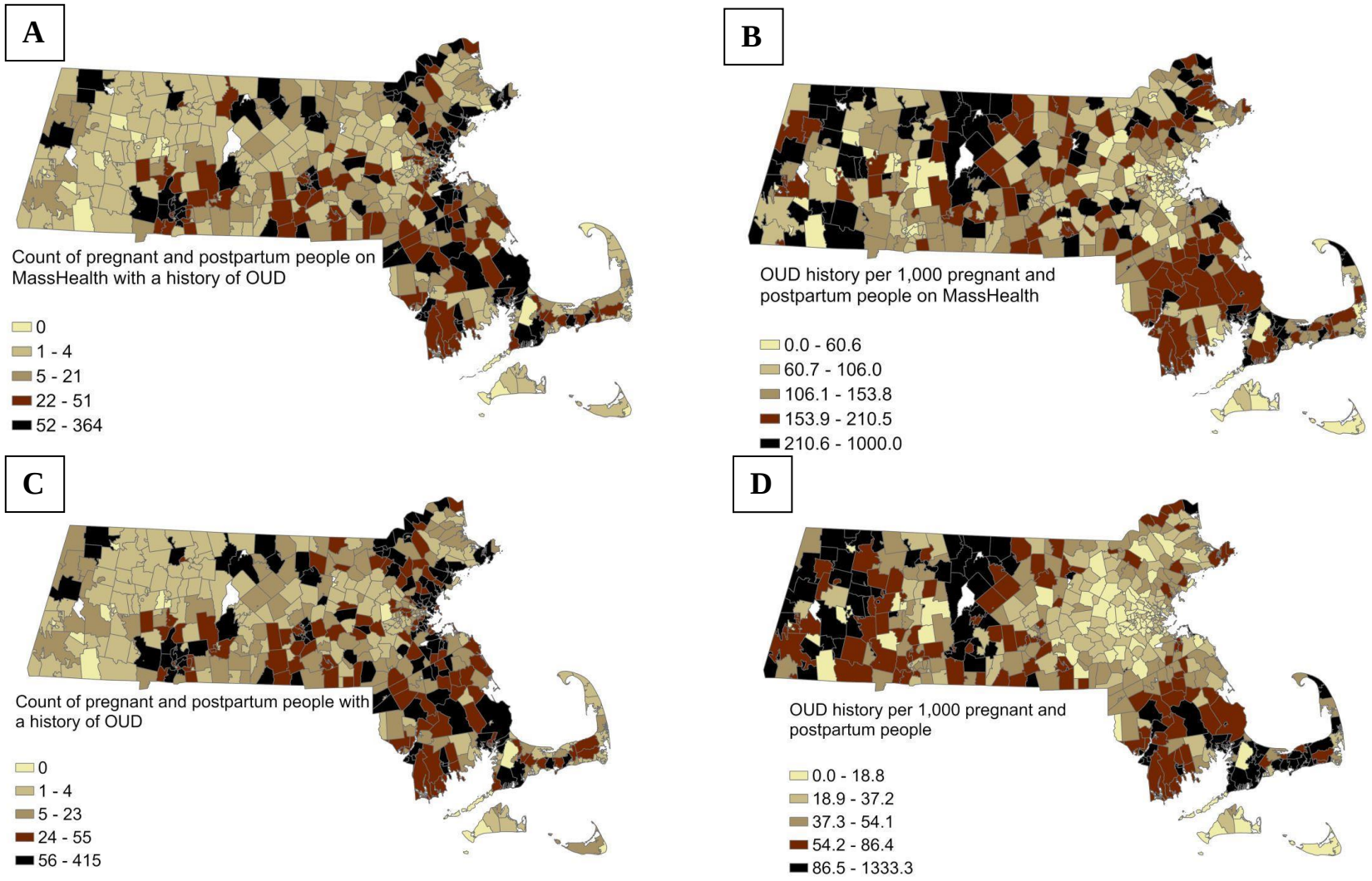

Figure 3.4 A-D: **Counts and rates of OUD** history among P&P people during 2011 to 2019 in Massachusetts ZCTAs.
A: Maternal OUD counts among people on MassHealth; **B**: Maternal OUD rates per 1,000 people on MassHealth
C: Maternal OUD counts among all people; **D**: Maternal OUD rates per 1,000 people

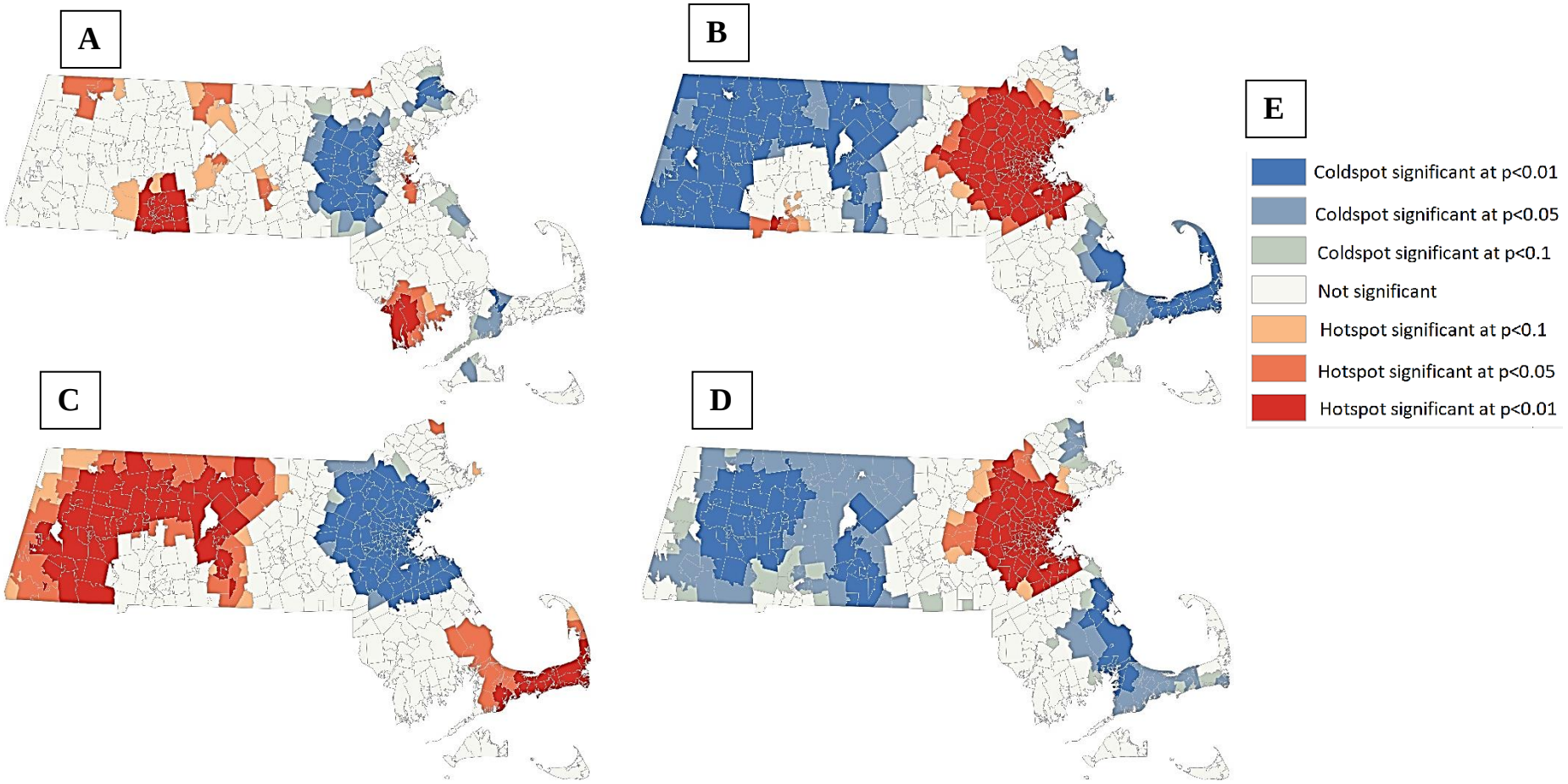

Figure 3.5 A-D: Optimized hotspot analyses showing:
A: **Socioeconomic status social vulnerability index (SVI**), *red* indicates clusters of ZIP Code Tabulation Areas (ZCTAs) with (statistically, in subsequent panels as well) significantly **higher** than the average vulnerability (i.e., more people living in poverty, unemployed, with lower income or without a high school diploma) and *blue* indicates clusters of ZCTAs with significantly lower than the average vulnerability (*blue* indicates lower vulnerability in the subsequent SVIs as well).
B: **Minority status and language SVI**, red depicts clusters of ZCTAs with significantly higher than the average vulnerability (i.e., *more people who are minority and speak English less than very well*).
C: **Proportion of population in each ZCTA who are White**, red signifies clusters of ZCTAs with significantly higher than the average number of White people, and blue indicates clusters of ZCTAs with significantly **lower** than the average number of White people.
D: **Proportion of population in each ZCTA who are foreign-born**, red highlights clusters of ZCTAs with significantly higher than the average number of foreign-born people, and blue indicates clusters of ZCTAs with significantly **lower** than the average number of foreign-born people.
Figure 3.4 E: **Levels of statistical significance** for hotspot and coldspot clusters.

3.5 DISCUSSION

We conducted a novel study of history of OUD among P&P people during 2011 to 2019 in MA utilizing spatial and statistical analyses. We used two population-representative data sources: the PHD Warehouse which is a virtual census of people who gave birth in MA, and the latest ACS 2016-2020. Among P&P people with a history of OUD who gave birth between 2011 and 2019, the OUD count hotspots were concentrated in Eastern MA, while the OUD rate hotspots were located in Central and Western MA. ZCTAs that were more socioeconomically vulnerable were more likely to have higher maternal OUD counts and rates. Also, foreign-born populations had lower access to OUD-related treatment compared to U.S.-born people. Our results identify the burden of disease and an understanding of the relative risk in terms of maternal OUD in MA.

Maternal OUD hotspots based on counts were detected in Eastern MA towns, which was expected because Eastern MA is more densely populated than Western and Central MA (United States Census Bureau, 2022a). Furthermore, most of the towns that were hotspots of maternal OUD counts had very high numbers of opioid-related overdose deaths in 2020 (Massachusetts Department of Public Health, 2022a). In contrast to the hotspots for maternal OUD counts, *maternal OUD hotspots based on rates* were found in Western and Central MA. The maternal OUD rates represent a relative understanding of risk that is normalized over the total pregnant populations in each geographic region. Compared to Eastern MA, Western and Central MA generally have lower population densities, large rural areas (United States Census Bureau, 2022a), and higher poverty rates (Massachusetts Department of Public Health, 2022c). These findings together highlight that Western and Central MA are more vulnerable in

terms of rurality and socioeconomic status and have higher OUD rates compared to Eastern MA.

ZCTAs that were socioeconomically vulnerable were more likely to have high maternal OUD counts and rates. This is highly concerning because socioeconomically marginalized people (as measured by income, employment, poverty, and education) have higher chances of fatal and non-fatal overdose, as depicted in a recent systematic review (van Draanen, Tsang, Mitra, Karamouzian, & Richardson, 2020). For example, the multivariable-adjusted rate for opioid-related healthcare utilization was 42% higher in the poorest vs. richest quartile in ZIP Codes of Southern Nevada (AOR: 1.42, 95% CI: 1.04−1.94) (Feng, Iser, & Yang, 2016). Also, in our study, hotspots for such socioeconomically vulnerable ZCTAs were mostly located in Western and Central MA. This means that the burden of maternal OUD is concentrated in these more vulnerable ZCTAs, which demands more OUD treatment locations. However, our previous study (i.e., Chapter 4) found that a large portion of Western MA had poor access to both MOUDs (methadone and buprenorphine) within 15-minute drive-time, while Central MA had poor access to buprenorphine providers within 15- and 30-minute drive-time (Joshi, Skeer, Chui, & Stopka, 2022). The greater distance needed to travel for treatment decreases P&P people's utilization of such treatment. Amiri *et. al.* found that patients who lived further than 10 miles from an OTP in Spokane county in Washington had 29% higher risk of missing doses of methadone compared to those residing within five miles (IRR = 1.29; 95% CI: 1.03 to 1.61, $p = 0.03$) (Amiri et al., 2018). These findings together highlight the disparity in OUD prevalence and access to OUD-related treatment and care among P&P people, such that many Western and Central MA ZCTAs that were socioeconomically vulnerable were more likely to have high maternal OUD counts and rates but were less likely to have good access to MOUD providers.

We found that foreign-born people who gave birth in MA had less access to treatment for OUD compared to U.S.-born people. This is of concern because foreign-born and U.S.-born women were at equal risk of alcohol use during pregnancy (average predicted probability = 53% among foreign-born vs. U.S. born pregnant women) (Perreira & Cortes, 2006) and their risk of substance use during pregnancy increased as immigrant women acculturated to the U.S. (Harley & Eskenazi, 2006; Hernandez et al., 2020). Future research should comprehensively examine the unmet health needs and predictors of access to treatment and care among foreign-born P&P people with OUD (Adigun, Barroso, Mixer, Myers, & Anderson, 2021) as the foreign-born population accounted for more than 44.9 million or 13.7% of the U.S. population in 2019 and is growing each year with approximately 1.2 million new migrants entering the U.S. annually (Batalova, Hanna, & Levesque, 2021).

3.6 STRENGTHS AND LIMITATIONS

One of the study's strengths is that it included analyses at the individual as well as the ZCTA level. As the data from each ZCTA applied to all residents in that ZCTA, it can help us in understanding the context in which an individual lives, but not whether that data applies to any specific individual in the dataset. Previous studies have noted that ZCTA level measurements tend to detect smaller effects compared to census block group and tract measures. Analyses of areas smaller than ZCTA, e.g., census tracts and census blocks, were not possible due to data privacy issues. Hence, we complemented these analyses at the ZCTA level with deidentified analyses at the individual level. Another strength is the use of the PHD Warehouse, which is a virtual census of MA, making our results generalizable to the MA population. However, MA ranks among one of the best states in terms of healthcare access in the nation, is the most educated state, with a large proportion of its population being White, and the Baker-Polito gubernatorial

administration in MA has made combating the opioid crisis a top priority. Because of these reasons, our findings might not be generalizable to populations outside of MA. We also attempted to make the results more inclusive by including non-binary pregnant people in our study.

The study has several other limitations. The count of maternal OUD could be *underestimated* due to several reasons. A) Data on 28,576 P&P people did not match with infants in the PHD Warehouse (i.e., 6.4% of total P&P people) due to the change in state reporting requirements starting in 2016, which no longer required self-insured companies to report to the APCD. This might result in an underestimation of OUD counts and rates and their resulting hotspots between the period 2016 to 2019 due to missing data. B) The highest proportion of maternal OUD is identified from the APCD, however this dataset was limited to 2014-2018 while our study period was from 2011-2019, which will result in an underestimation of OUD counts and rates and hotspots for the period between 2011 and 2013, and in 2019. C) The eligibility criteria for the study population included using MassHealth during the study period between 2011 and 2019. However, use of MassHealth was determined from the APCD data, which was limited to 2014-2018, further underestimating OUD counts and rates and hotspots during the period 2011-2013, as well as 2019. D) There was incomplete data entry for the ICD variable related to OUD diagnosis in the APCD Pharmacy database (estimated at 5%). This means that between 2014 and 2018, 95% of the data were missing, underestimating the OUD counts and rates and hotspots. Moreover, there were no data for the periods between 2011 to 2013 and 2019 for this database, further underestimating our results.

Another important study limitation is related to the temporality between OUD diagnosis and giving birth. A significant proportion of the P&P people might have OUD after the index pregnancy, and not necessarily during or before their pregnancy,

because this study is limited to people who had a delivery and who had OUD anytime between 2011 and 2019. This is even more likely since the mothers were limited to their first pregnancy, and 28.3% had repeat deliveries during the study period. Due to this limitation in temporality, we use the term ‘history of OUD’ throughout the dissertation.

Another limitation is that the study population of P&P who used MassHealth is limited to the APCD dataset. However, we also conducted sensitivity analyses on P&P people not limited to MassHealth, and this population identified OUD cases from many datasets, including APCD, CaseMix, BSAS, PMP, and MATRIS. The sensitivity analyses depicted comparable results.

The COVID-19 pandemic might impact the number of P&P people with OUD, by increasing the number of people using substances due to increased stress, and by hindering the data collection procedure, thus underestimating the number of OUD cases despite rising OUD among this population.

3.7 CONCLUSION

We found disparities in OUD prevalence and access to OUD-related treatment and care among P&P people during 2011 to 2019. Compared to White non-Hispanic population, other race/ethnicity had lower access to care. Similarly, the foreign-born population had lower access to care than the U.S.-born population. ZCTAs with higher vulnerability in the socioeconomic, language and minority domains were more likely to have high OUD counts. The hotspots of OUD counts were concentrated in Eastern MA, while the hotspots of OUD rates were concentrated in Western and Central MA.

Hence provision of treatment services for OUD should take into consideration the social determinants of health to provide equitable services. Future studies should

explore nativity (i.e., U.S. vs foreign born) as a crucial factor that might affect OUD and related treatment access.

DISCLAIMER

While the work in this chapter analyzed the data provided by the Massachusetts Department of Public Health (MDPH) PHD Warehouse, the methods, analyses, and results do not represent the perspectives of MDPH.

ROLE OF THE FUNDING SOURCE

The Tufts Initiative on Substance Use and Addiction provided funding support for this study (PI: Stopka). The funder had no role in study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

DECLARATIONS OF INTEREST

None.

ACKNOWLEDGEMENT

We are very grateful to the Massachusetts Department of Public Health and all its staff for providing data access, and especially to Elizabeth Erdman, Marianna Stewart, Dana Bernson, Malena Hood, and Amy Bettano for their expertise and technical supports regarding the PHD Warehouse.

Appendix 3.1 Definition of OUD from the Massachusetts Department of Public Heath

Last Updated: 03/17/22

DEFINITION: OUD – defined by opioid overdoses, opioid abuse or dependence indicators (APCD, Casemix, BSAS, DMH), or a medication for OUD (buprenorphine or methadone).

a. Opioid overdose (please note, overdose events should be counted in the same dataset to ensure you are not double-counting one event):
   i. Two or more overdose events documented in Casemix or APCD. Diagnosis codes to search:
      1. ICD9: E850.0- E850.2, 965.00-965.02, 965.09, 970.1
      2. ICD10: T40.0X1A, T40.0X2A, T40.0X3A, T40.0X4A, T40.0X1D, T40.0X2D, T40.0X3D, T40.0X4D, T40.1X1A, T40.1X2A, T40.1X3A, T40.1X4A, T40.1X1D, T40.1X2D, T40.1X3D, T40.1X4D, T40.2X1A, T40.2X2A, T40.2X3A, T40.2X4A, T40.2X1D, T40.2X2D, T40.2X3D, T40.2X4D, T40.3X1A, T40.3X2A, T40.3X3A, T40.3X4A, T40.3X1D, T40.3X2D, T40.3X3D, T40.3X4D, T40.4X1A, T40.4X2A, T40.4X3A, T40.4X4A, T40.4X1D, T40.4X2D, T40.4X3D, T40.4X4D, T40.601A, T40.601D, T40.602A, T40.602D, T40.603A, T40.603D, T40.604A, T40.604D, T40.691A, T40.692A, T40.693A, T40.694A, T40.691D, T40.692D, T40.693D, T40.694D
   ii. Two or more overdoses in BSAS - CLT_ENR_OVERDOSES_LIFE > 1 and CLT_ENR_OVERDOSES_LIFE ^= 999
   iii. Two or more acute overdose events in MATRIS, where OPIOID_ORISUBCAT_MATRIS =2

OR

b. Opioid abuse or dependence in APCD, Case Mix ICD, BSAS, or DMH:
   i. At least one visit in APCD or Casemix with one of the following ICD codes:
      1. ICD 9: 304.00–304.02, 304.70–304.72, 305.50–305.52
      2. ICD 10: F11.10, F11.120, F11.121, F11.122, F11.129, F11.13, F11.14, F11.150, F11.151, F11.159, F11.181, F11.182, F11.188, F11.19, F11.20, F11.220, F11.221, F11.222, F11.229, F11.23, F11.24, F11.250, F11.251, F11.259, F11.281, F11.282, F11.288, F11.29,
   ii. At least one episode in BSAS treatment data where CLT_ENR_PRIMARY_DRUG in (5,6,7,21,22,23,24) or CLT_ENR_SECONDARY_DRUG in (5,6,7,21,22,23,24) or CLT_ENR_TERTRIARY_DRUG in (5,6,7,21,22,23,24)
   iii. At least one episode in DMH data where DISCHARGE_DISP_DMH in (48) - meaning they were released to Opioid-related treatment

OR

c. An indication of MOUD treatment
   i. Buprenorphine
      1. At least one prescription in PHDPMP.PMP where BUPRENORPHINE_PMP=1
      2. At least one visit in PHDAPCD.Medical14_18 where one of the following variables MED_PROC_CODE, MED_ICD_PROC1-MED_ICD_PROC7 has any of the following HCPCS or CPT code values: J0592, G2068, G2069, G2070, G2071, G2072, G2079, J0570-J0575
   ii. Methadone
      1. At least one visit in PHDAPCD.Medical14_18 where one of the following variables MED_PROC_CODE, MED_ICD_PROC1-MED_ICD_PROC7 has any of the following HCPCS, CPT, or ICD 10 procedure code values: H0020, G2067, G2078, S0109, J1230, HZ91ZZZ, HZ81ZZZ

Chapter 4: Spatial and Nonspatial Factors for Accessing Medication for Opioid Use Disorder Among Pregnant and Postpartum People in Massachusetts: A Cross-Sectional Study[1]

[1] Joshi, C., Chui, K., Skeer, M. R., & Stopka, T. J. (2022). Accepted for publication on *Substance Use and Misuse on July 26, 2022*.

4.0 ABSTRACT

Introduction: In Massachusetts, less than two-third of pregnant and postpartum (P&P) people with opioid use disorder (OUD) receive medications for OUD (MOUD), such as buprenorphine and methadone. Research has demonstrated that broadly, access to medications differs by location and by socioeconomic and geographic characteristics of communities, but a comprehensive understanding at the micro-level is lacking. This study aims to identify and characterize access to MOUD treatment among P&P people in Massachusetts.

Methods: We used enhanced two-step floating catchment area analyses, which incorporated supply and demand measures, as well as local drive-time, to determine spatial accessibility to MOUD among P&P people during 2016 to 2020 in Massachusetts ZIP Code Tabulation Areas (ZCTAs). We used four publicly available data sources to calculate geographic accessibility to MOUDs. We then merged the resulting accessibility indices with data from the American Community Survey to statistically analyze ZCTA characteristics that were associated with geographic accessibility to MOUD among the study population.

Results: We calculated access to 258 opioid (providing methadone and/or buprenorphine) treatment programs and 2,585 buprenorphine-waivered prescribers

among 74,969 P&P people during the period 2016 to 2020 in 448 ZCTAs (N=537 ZCTAs). ZCTAs with lower accessibility to both types of MOUDs were concentrated in Western Massachusetts. Central Massachusetts had poor accessibility to buprenorphine providers. Accessibility was greater in ZCTAs that were non-metropolian, that had higher social vulnerability, and that had less extreme concentration of privilege.

Conclusions: The greater accessibility of MOUD providers in more vulnerable ZCTAs can be interpreted as an equitable distribution across Massachusetts ZCTAs, which might be partially explained by the 'not in my backyard' phenomenon. There is a need to improve MOUD access overall, and to enhance access to both types of medications, so P&P people can choose the one that works best for them.

KEYWORDS

Geographic access, Two step floating catchment area analysis, Medication assisted treatment, Opioid Treatment Program, Pregnancy

4.1 INTRODUCTION

Opioid use disorder (OUD) during pregnancy in the U.S. has reached epidemic proportions, with rates more than doubling in the past decade (Hirai et al., 2021). Within the U.S., Massachusetts (MA) has one of the highest OUD rates among this population (Haight et al., 2018), with 1.5% of MA residents in 2018 delivering a live birth with evidence of OUD during pregnancy (Mass.gov, 2021a). A total of 2.4% women with a live birth during 2011 to 2015 in MA (N = 274,234) had OUD during pregnancy in a study by Schiff et al., 2020 (Schiff et al., 2020).

A large treatment gap exists for pregnant and postpartum (P&P) people OUD in the U.S., as only one-third to one-half receive medications for OUD (MOUD) (Krans et al., 2019). In MA, 33.8% women with a live birth during 2011 to 2015 did not receive any MOUD treatment during pregnancy (Schiff et al., 2020). Pharmacotherapy with methadone or buprenorphine is the evidence-based treatment for P&P people with OUD (Substance Abuse and Mental Health Services Administration, 2018). Naltrexone is currently not recommended during pregnancy due to lack of clear evidence on treatment safety (Substance Abuse and Mental Health Services Administration, 2018). To date, there is little research identifying which patients with OUD will respond better to each medication (Blanco & Volkow, 2019). Hence, both medications should be accessible to all patients so that patients can work with their clinicians to determine which works best for them (Blanco & Volkow, 2019). However, the type of MOUD provided to patients is often based on logistical considerations, such as geographic access to opioid treatment programs (OTPs) to provide methadone and/or buprenorphine, or health care practitioners with waivers to prescribe buprenorphine (Blanco & Volkow, 2019). Additionally, limited availability of treatment programs and provider capacity impede

access to MOUD of any kind (Langabeer, Stotts, Cortez, Tortolero, & Champagne-Langabeer, 2020).

Access to healthcare facilities varies across space because of uneven distributions of healthcare providers and consumers, and the geographic distance between them (*spatial factors*); and varies among population groups because of their different socioeconomic and demographic characteristics (*nonspatial factors*) (Aday & Andersen, 1974; Luo & Qi, 2009). GIS-based tools including those that incorporate points of access (i.e., supply) and their travel distance or time to/from population-weighted centroids (i.e., demand) of a defined unit of analysis (e.g., census tract, ZIP Code Tabulation Area [ZCTA]) are commonly used to investigate spatial factors. Such studies, when used in conjunction with data on nonspatial factors, such as demographic characteristics and socioeconomic status, are critical to design an effective method to investigate socio-spatial access to healthcare facilities (Joseph & Phillips, 1984; Wang & Luo, 2005).

A limited number of studies report on P&P people's MOUD access in the U.S. at a macro (e.g., state or county) level (Krans et al., 2019; Reising, Horne, & Bennett, 2021; Wolf et al., 2019). Krans et al., (2019) conducted a study of pregnant women with OUD in Pennsylvania counties and found that 44.1% of pregnant women received no opioid pharmacotherapy, 27.1% used buprenorphine, and 28.8% used methadone during 2009 to 2015. Greater increases in buprenorphine use were found in geographic regions with large metropolitan centers, such as the Southwest (+24.9%) and the Southeast (+12.0%), compared to largely rural regions, such as the New West (+5.2%) (Krans et al., 2019). Reising et al., (2021) conducted a study among pregnant women on Medicaid in Illinois and found that counties with high need for treatment for maternal OUD had limited treatment services. A total of 66% of neonatal opioid withdrawal

syndrome (NOWS) cases among rural Illinois residents had no MOUD treatment services at all. Furthermore, treatment services were concentrated in 36% of Illinois' counties, leaving a large area (74% of counties) with no treatment services (Reising et al., 2021). Similarly, Wolf et al., (2019) conducted a nationwide study of the U.S. at the state level and found that NOWS was higher in states with a lower density of buprenorphine-waivered physicians (r = 0.71; 95% CI: 0.50, 0.84) (Wolf et al., 2019).

To our knowledge, this is one of the first studies to *spatially* examine MOUD access among P&P people in MA. In addition, we examined ZCTA characteristics associated with such accessibility using a range of sociodemographic variables from the American Community Survey (ACS) as well as contemporary composite scores depicting socioeconomic vulnerability (Agency for Toxic Substances and Disease Registry, 2021) and concentration of privilege (Krieger et al., 2016).

4.2 METHODS

4.2.1 Study Populations, Data Sources, and Unit of Analysis

We conducted secondary analyses of existing OTPs, buprenorphine providers, and sociodemographic data in MA, using a cross-sectional study design. All the data used were publicly available and accessed in March 2021. We compiled data at the ZCTA level from several sources: 1) sociodemographic data from ACS 2016-2020 (United States Census Bureau, 2021b); 2) data on OTPs from Substance Abuse and Mental Health Services Administration (SAHMSA) treatment locator (Substance Abuse and Mental Health Services Administration, 2021c), constituting 258 OTP facilities licensed to provide methadone/buprenorphine to treat OUD; 3) data on buprenorphine providers from buprenorphine practitioner locator (Substance Abuse and Mental Health Services Administration, 2021b), constituting 2,585 clinicians (physicians, nurse

practitioners, physician assistants, and advanced practice nurses) certified under federal law to prescribe buprenorphine through a waiver process; 4) data on drive-time from the Environmental Systems Research Institute (ESRI) streets network data (ESRI Streetmap USA, 2021); and 5) ZCTA boundaries from TIGER/Line Shapefiles from the Census Bureau (United States Census Bureau, 2021a). We excluded naltrexone as it is not recommended in pregnancy at the time this study was conducted (Caritis & Venkataramanan, 2020). The latter four data sources were used for spatial analyses to calculate geographic accessibility to the MOUD sites. The resulting accessibility indices from the spatial analyses were merged with data from the ACS for statistical analyses, to examine factors associated with geographic access to MOUD sites.

ZCTA, the geographical unit of this analysis, is defined by the U.S. Census Bureau as “the generalized areal representations of United States Postal Service (USPS) ZIP Code service areas”. It is worth noticing that ZCTAs are different from USPS ZIP Codes which are “not areal features but a collection of mail delivery routes”. ZCTAs match social and neighborhood areas better than USPS ZIP Codes (United States Census Bureau, 2020). ZCTA code is the same as ZIP Code for an area in most instances. However, ZIP Codes assigned to businesses only or single delivery point address might not have a ZCTA code, and large water bodies and large unpopulated lands do not have ZCTA code at all (United States Census Bureau, 2022b).

This manuscript follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies (Equator Network, 2019).

4.2.2 Measures

4.2.2.1 Covariates for *spatial* analyses

As part of the spatial analyses, we conducted enhanced two-step floating catchment area analysis (E2SFCA). This analysis calculates accessibility indices based on four sources of data: supply-side data, demand-side data, streets network data to calculate the proximity between supply and demand populations based on drive-time, and a catchment area (ZCTA for this study).

Supply-side data: The supply-side data consisted of the coordinates of the MOUD sites, including buprenorphine providers and OTPs. These coordinates were incorporated into the GIS system as a set of points.

Demand-side data: The demand-side data were the number of P&P people during 2016 to 2020 within each ZCTA. A P&P person is someone who is currently pregnant or gave birth within the last year (Centers for Disease Control and Prevention, 2022). For this study, P&P people referred to those who gave birth in the past 12 months during 2016 to 2020. Due to absence of publicly available data, P&P people were used as a proxy for P&P people with OUD. These data were converted to a set of points by joining them with the population-weighted ZCTA centroids which were used to calculate accessibility indices between ZCTA population centroids and MOUD providers (Dai, 2010). Using population centroids instead of geographic centroids increases the spatial accuracy (Page, Langford, & Higgs, 2019). In the U.S., populated areas of a geographic area (like ZCTA, county, etc.) are not usually located near the geographic center of that area. This mismatch between the geographic center and the population center is most apparent in large, sparsely populated areas. This variability gives rise to unreliable estimates. Population-weighted centroids are one alternative to geometric centroids in such cases (Dilts, 2020).

4.2.2.2 Outcome measures and covariates for *statistical* analyses

Outcome variables: We included four outcome variables: accessibility indices for buprenorphine providers within 30-minute drive-time, accessibility indices for buprenorphine providers within 15-minute drive-time, accessibility indices for OTPs within 30-minute drive-time, and accessibility indices for OTPs within 15-minute drive-time. The accessibility indices were calculated from the E2SFCA. The outcome variables were originally continuous in nature, but they did not fulfill the linearity assumption required for linear regression, so they were dichotomized into 0 and 1 (Vittinghoff et al., 2012), where 0 indicated indices below the state median, and 1 indicated indices equal to and above the state median.

Exposure variables: Our main exposure variable was pregnancy rate, defined as P&P people per 1,000 people aged 15 to 50 years per year for each ZCTA in MA during 2016 to 2020. This variable was dichotomized into less than, and more than or equal to the median pregnancy rate of the state of MA. It was originally continuous but was dichotomized since the linearity assumption between pregnancy rate and logit of the four outcome variables were not met. We also adjusted for a total of 13 variables to examine any association between geographic access to MOUD and ZCTA social determinants of health. These 13 variables were: Socioeconomic status Social Vulnerability Index (SVI) (Agency for Toxic Substances and Disease Registry, 2021), Minority Status and Language SVI, Housing Type and Transportation SVI, Household Composition and Disability SVI, Index of Concentration at the Extremes *(*ICE) for racialized economic segregation (Chambers et al., 2019; Krieger et al., 2017), percent White, percent foreign-born, percent with bachelor's degree or higher education, percent in labor force, percent households that received public assistance, percent single parent households, percent households with no vehicle, and urbanicity.

We calculated the SVIs and ICE variables because they were not available at the *ZCTA* level. The SVIs at ZCTA level were calculated using precalculated SVIs at census tract level available from the Center for Disease Control and Prevention (Agency for Toxic Substances and Disease Registry, 2021) using the method by Bilal et al., 2020 (Bilal et al., 2020). The SVIs were categorized into quartiles based on previous literature (Dasgupta et al., 2020; Dryden-Peterson et al., 2020), with higher quartiles representing increasing vulnerability. Each quartile increase in the *Socioeconomic status SVI* signifies that a higher proportion of the population in the ZCTA is living in poverty, is unemployed, has lower income or does not have a high school diploma. Each quartile increase in the *Minority Status and Language SVI* indicates a higher proportion of the population in the ZCTA belongs to a minority group or speaks English less than "very well." Each quartile increase in the *Housing Type and Transportation SVI* points to a higher proportion of the population in the ZCTA living in a multiunit structure, mobile homes, or group quarters, or a higher proportion of the households are overcrowded and do not have a vehicle. Each quartile increase in the *Household Composition and Disability SVI* indicates a higher proportion of the population in the ZCTA is aged ≥65 years, or ≤17 years, or >5 years with a disability, or a higher proportion of households consist of single parents.

ICE for racialized economic segregation compares White populations in the highest income quintile with non-White populations in the lowest income quintile, and was computed using the following formula:

$$ICE_i = (A_i - P_i) / T_i$$

where, A_i is equal to the number of affluent White non-Hispanic people in the i^{th} ZCTA (i.e., in the highest income quintile), P_i is equal to the number of poor persons of color in ZCTA i (i.e., in the bottom income quintile), and T_i is equal to the total population with known income level in ZCTA i (Krieger et al., 2016). The ICE was categorized into

quartile based on previous literature, with each quartile increase representing increased concentration of privilege (Chambers et al., 2019; Krieger et al., 2017).

Urbanicity was defined per the 2010 Rural-Urban Commuting Area Codes precalculated at 5-digit ZIP Code level which matched with the eligible ZCTAs (United States Department of Agriculture, 2020). ZCTAs were identified as metropolitan if they fell within a Metropolitan Statistical Area and nonmetropolitan otherwise (Bower, Thorpe Jr, Rohde, & Gaskin, 2014). Three more variables were considered for analysis but dropped due to multicollinearity based on Variance Inflation Factors of more than 6 (Vittinghoff et al., 2012). These were: percent population with limited English proficiency, percent living in poverty, and percent Hispanic.

4.2.3 Analyses

4.2.3.1 Spatial analyses

To estimate the geographic accessibility to MOUD sites, we conducted E2SFCA analyses using an E2SFCA plug-in in the Network Analyst tool (Langford M, Fry R, & Higgs G, 2015) of ArcMap 10.5.1 software (ESRI, Redlands, CA, USA). The following parameters were used in all measures: a linear decay function, 15- and- 30-minute drive-time (as a cut-off distance) to define the catchment area, geocoded locations for OTP and buprnorphine providers (MOUD sites, i.e., supply), and ZCTA population centroids with count of P&P population (i.e., demand).

There are two computational steps in the E2SFCA analysis. In the first step, a catchment area around each MOUD provider is constructed based on user-defined drive-time or distance threshold (15- and 30-minute drive-time radii for this study). A supply-to-demand ratio is then calculated using the number of MOUD providers and the number of P&P people falling within the catchment. In the second step, a similar

catchment area is constructed around each ZCTA population centroid and supply-to-demand ratio is calculated, and the sum of all supply-to-demand ratio that fall within the catchment constitutes the final accessibility indices (Page et al., 2019). The E2SFCA accessibility analysis is termed as 'Enhanced' because it uses a distance-decay function such that people become less inclined to utilize a service as their distance to it increases, until the threshold distance/time is reached, at which point the demand falls to zero (Langford M et al., 2015). The distance-decay parameter assigns less weight to those supply points which are further from the demand centre using a stepped weighting structure (Luo & Qi, 2009). A detailed rationale and description of the analysis are provided in Langford *et al*., 2019 (Langford, Higgs, & Dallimore, 2019). The accessibility indices are interpreted as a ratio of supply to demand – in our case, it is the number of MOUD sites (buprenorphine providers or OTPs) per 100 P&P people within the designated drive-time (either 15 or 30 minutes) (Langford M et al., 2015).

To portray the accessibility indices, we developed descriptive GIS maps and categorized the data into 5 quartiles in ArcGIS Pro 2.8.3 (ESRI, Redlands, CA, USA). The covariates that were statistically significant in the regression analyses were portrayed using Optimized Hotspot Analysis in ArcGIS Pro 2.8.3. Hotspots and coldspots were defined as geographically contiguous regions of ZCTAs with statistically significant Getis-Ord statistics (ESRI, 2018). The resulting maps were edited in MS Office 2010 Picture Editor for visual clarity.

4.2.3.2 Statistical analyses

We calculated descriptive statistics to assess measures of central tendency, the skewness of the data, and to inform cut points where needed. We conducted chi-squared tests between outcome variables and each categorical covariate to assess crude associations. We then conducted bivariate logistic regressions to examine the

unadjusted association between outcome variables and each continuous covariate. All the variables that were significant at $p<0.05$ for the type 3 analysis of effects in bivariate analyses were added to the multivariable models, except for the main exposure variable, which was added to the multivariable analyses even when p value was greater than or equal to 0.05. We then conducted multivariable logistic regression analyses to examine any association of pregnancy rates with geographic accessibility to MOUD sites, controlling for covariates.

In the bivariate and multivariable logistic regressions, we built two independent models that separated conceptually similar variables. **Model 1** included five covariates of composite scores: socioeconomic status SVI, minority status and language SVI, housing type and transportation SVI, household composition and disability SVI, and ICE for racialized economic segregation. **Model 2** included eight covariates from the ACS: percent White, percent foreign-born, percent with bachelor's degree or higher education, percent in labor force, percent households that received public assistance, percent single parent households, percent households with no vehicle, and urbanicity.

We then conducted a complete case analysis on 448 ZCTAs that had one or more P&P people (N=537). In this study, the missing data occurred in the outcome variable only, and in such instance, complete-case analysis and multiple imputation are equivalent, and complete-case analysis is preferred since it is easier, more efficient, and more robust (von Hippel, 2007). Statistical significance was set at $p<0.05$. All statistical analyses were conducted in SAS 9.4 (SAS®, 2021).

4.2.4 Ethical Approval

The study was approved by the Tufts Health Sciences Institutional Review Board as non-human subjects research (IRB ID STUDY00000466).

4.3 RESULTS

A total of 74,969 people aged 15 to 50 years were P&P during 2016-2020, with a median pregnancy rate of 45.0 (IQR: 27.0) per 1,000 people aged 15 to 50 years. The analysis included a total of 448 ZCTAs, after removing 89 ZCTAs with no P&P people (N=537). The P&P people count was concentrated in Eastern MA ZCTAs, which was very similar to the distribution of overdose death counts in MA during 2016 to 2020 (Massachusetts Registry of Vital Records and Statistics, 2022) (Please refer to Figure 4.1 a and b respectively).

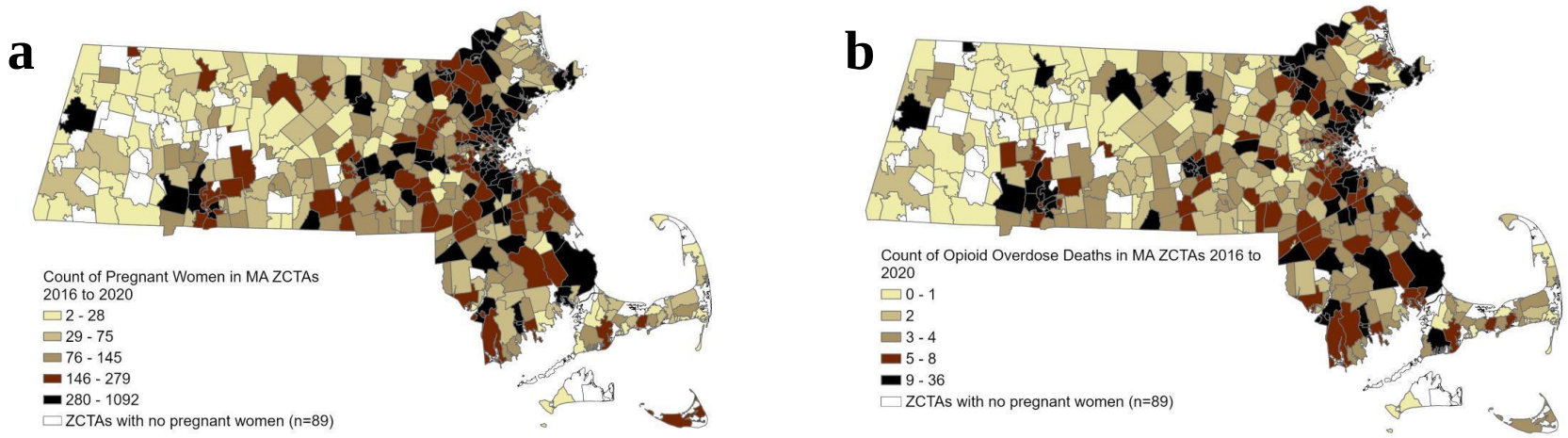

Figure 4.1 Comparison of distribution of pregnant people vs. opioid overdose deaths in each Massachusetts ZCTA
a. Count of pregnant people duing 2016-2020
b. Count of opioid overdose death duing 2016-2020

The 448 ZCTAs included in this study had a high proportion of White populations (Median: 89.8%, IQR: 16.0%, similar to state median of 90.8%) and a small proportion of Hispanic or Latino populations (Median: 4.0%, IQR: 6.0%, vs. a state median of 3.9%). A quarter of the population had a bachelor's degree or higher education (Median: 24.3%, IQR: 11.4%, similar to the state median of 24.4%) and two-thirds of the population were in the labor force (Median: 67.6%, IQR: 7.7%, vs. a state median of 67.1%). One-fifth of the households consisted of single parents (Median: 19.7%, IQR: 12.0%, equal to state median), and 12.3% (IQR: 17.6%) received public assistance (slightly higher than the state median of 11.2%). A small proportion of households did not have any vehicle (Median: 5.0%, IQR: 6.7%, vs. a state median of 4.7%). A similarly small proportion of the population was below the poverty line (Median: 6.4%, IQR: 6.8%, equal to the state median), and a slightly higher proportion was foreign-born (Median: 8.6%, IQR: 12.5% slightly higher than the state median of 8.0%). A very small proportion of population had limited English proficiency (Median: 1.7%, IQR: 4.1%, slightly higher than the state median of 1.2%) (Table 4.1).

Across 448 MA ZCTAs with one or more P&P people (N=537 ZCTAs), social vulnerability in terms of SVIs ranged between 0 (lowest vulnerability) to 1.0 (highest vulnerability) with a median of 0.43 (IQR: 0.35) for the socioeconomic status domain, a median of 0.32 (IQR: 0.40) for minority status and language domain, a median of 0.44 (IQR: 0.31) for housing type and transportation domain, and a median of 0.49 (IQR: 0.28) for household composition and disability domain. ICE for racialized economic segregation ranged from -0.26 to +0.26 (negative values indicate lower privilege and positive values indicate higher privilege), with a median value of 0.14 (IQR: 0.08), which leans in the direction of more extreme concentrations of high incomes and White populations (Table 4.1). The most socioeconomically vulnerable ZCTAs had the highest

proportion of people with no vehicle. A mean of 17.4% (SD: 14.3%) population did not own a vehicle in the fourth quartile (most vulnerable quartile), 7.7% (SD:9.0) in the third quartile, 6.6% (SD: 9.1%) in the second quartile, and 4.4% (SD: 4.4%) in the first quartile (least vulnerable quartile) (post hoc data analysis, not shown in table) of the socioeconomic status SVI.

We included 258 OTPs and 2,585 buprenorphine providers in the analysis. There was a median of 2.26 buprenorphine providers per 100 P&P people within 15-minute drive-time, and 3.00 buprenorphine providers per 100 P&P people within 30-minute drive-time. There was a median of 0.46 OTPs per 100 P&P people within 15-minute drive-time, and 0.48 OTPs per 100 P&P people within 30-minute drive-time across 448 ZCTAs in MA (Table 4.1).

Table 4.1 ZIP Code Tabulation Area characteristics and geographic access to medication for opioid use disorder sites, Massachusetts (n=448).

Variables	Median (IQR)	Mean (SD)	Minimum	Maximum
Sociodemographic characteristics of Massachusetts ZIP Code Tabulation Area				
Pregnancy rate (per 1,000 people aged 15 to 50 years) *	45.0 (27.0)	50.6 (34.5)	3.0	425.0
Percent households with no vehicle *	5.0 (6.7)	9.0 (10.9)	0.0	64.2
Percent Bachelor's degree and higher education *	24.3 (11.4)	24.2 (7.8)	6.0	52.3
Percent in labor force *	67.6 (7.7)	66.6 (6.5)	24.7	86.9
Percent households that received public assistance *	12.3 (17.6)	17.5 (16.0)	0.0	95.1
Percentage single parent households *	19.7 (12.0)	22.9 (12.4)	2.7	72.9
Percentage White *	89.8 (16.0)	84.4 (15.3)	6.8	100.0
Percentage Hispanic or Latino *	4.0 (6.0)	8.3 (12.4)	0.0	86.7
Percentage below poverty level *	6.4 (6.8)	8.9 (7.4)	0.0	50.8
Percent foreign born *	8.6 (12.5)	12.1 (10.3)	0.0	61.9
Percent population with limited English proficiency *	1.7 (4.1)	3.8 (5.9)	0.0	46.2
Socioeconomic status SVI **	0.4 (0.4)	0.4 (0.2)	0.0	1.0
Minority status and language SVI **	0.3 (0.4)	0.4 (0.3)	0.0	1.0
Housing type and transportation SVI **	0.4 (0.3)	0.4 (0.2)	0.0	1.0
Household composition and disability SVI **	0.5 (0.3)	0.5 (0.2)	0.0	0.9
ICE for racialized economic segregation *	0.1 (0.1)	0.1 (0.1)	-0.3	0.3
Geographic access to MOUD providers in each Massachusetts ZIP Code Tabulation Area (Accessibility indices)				
Buprenorphine providers within 15-minute drive-time ˜	2.3 (3.0)	3.5 (8.4)	0.0	160.9
Buprenorphine providers within 30-minute drive-time ˜	3.0 (2.6)	3.3 (2.3)	0.0	19.8
Opioid treatment programs within 15-minute drive-time ˜	0.5 (0.5)	0.6 (1.0)	0.0	20.0
Opioid treatment programs within 30-minute drive-time ˜	0.5 (0.4)	0.6 (0.4)	0.0	2.1

*** Data from ACS** 2016-2020; ** **Data from ACS** 2014-2018
˜ **Accessibility indices** from the enhanced two-step floating catchment area analyses, interpreted as *number of MOUD providers per 100 pregnant and postpartum people within designated drive-time*, data from 2021.
IQR: Interquartile range, **MOUD**: Medication for opioid use disorder, **SD**: Standard deviation, **SVI**: Social Vulnerability Index, **ZCTA**: ZIP Code Tabulation Area

Socioeconomic status SVI: Social vulnerability index, a higher score represents a higher proportion of population in the ZCTA is living in poverty, is unemployed, has lower income or does not have a high school diploma, *higher SVI scores indicate higher vulnerability in the subsequent SVIs as well*.
Minority status and language SVI: a higher score indicates a higher proportion of population in the ZCTA is minority and speaks English less than very well.
Housing type and transportation SVI: a higher score signifies a higher proportion of population in the ZCTA lives in multiunit structure, mobile homes, or group quarters, or a higher proportion of the households are overcrowded and do not have a vehicle.
Household composition and disability SVI: a higher score represents a higher proportion of population in the ZCTA is aged ≥65 years, or ≤17 years, or >5 years with a disability, or a higher proportion of households are single parent households.
ICE: Index of Concentration at the Extremes, compares White populations in the highest income quintile with non-White populations in the lowest income quintile, *higher* positive *scores indicate* extreme concentration of privilege.

4.3.1 MOUD Providers per 100 P&P People Aged 15 to 50 Years in MA ZCTAs

Eastern MA had relatively higher access to **buprenorphine providers within 15-minute drive-time**, compared to Western and Central MA. In Eastern MA, Metro Boston and parts of Barnstable County (in Cape Cod) had the highest access to buprenorphine providers within 15-minute drive-time; while Western and Central MA had large areas with lowest access to buprenorphine providers within 15-minute drive-time (Figure 4.2 a). A large portion of Worcester County in Central MA had poor access to buprenorphine providers within 30-minute drive-time also (Figure 4.2 b).

Berkshire and Hampshire counties in Western MA had large areas of low access to **OTPs within 15-minute drive-time** (Figure 4.2c). Greater Boston area had low access to OTPs within 15- and 30-minute drive-time (excluding Boston). Boston and parts of Barnstable and Bristol counties in Eastern MA had the highest access to OTPs within 15- and 30-minute drive-time (Figure 4.1c, d). A large portion of Worcester County in Central MA had highest access to OTPs within 15- and 30-minute drive-time (Figures 4.1c, d). ZCTAs that had poor access to both OTPs and buprenorphine providers within 15- and 30-minute drive-time were concentrated in Eastern MA counties: Essex, Plymouth, Norfolk, and much of Middlesex (Figures 4.2a, b, c, d).

Maps in Figures 4.3a-d depict measures that were used to calculate E2SFCA accessibility indices. Hotspot clusters of P&P people were located in Metro Boston while coldspot clusters were located in Western MA and Barnstable County ($p<0.05$). These areas have high highway and surface road access and have at least one MOUD site in each ZCTA.

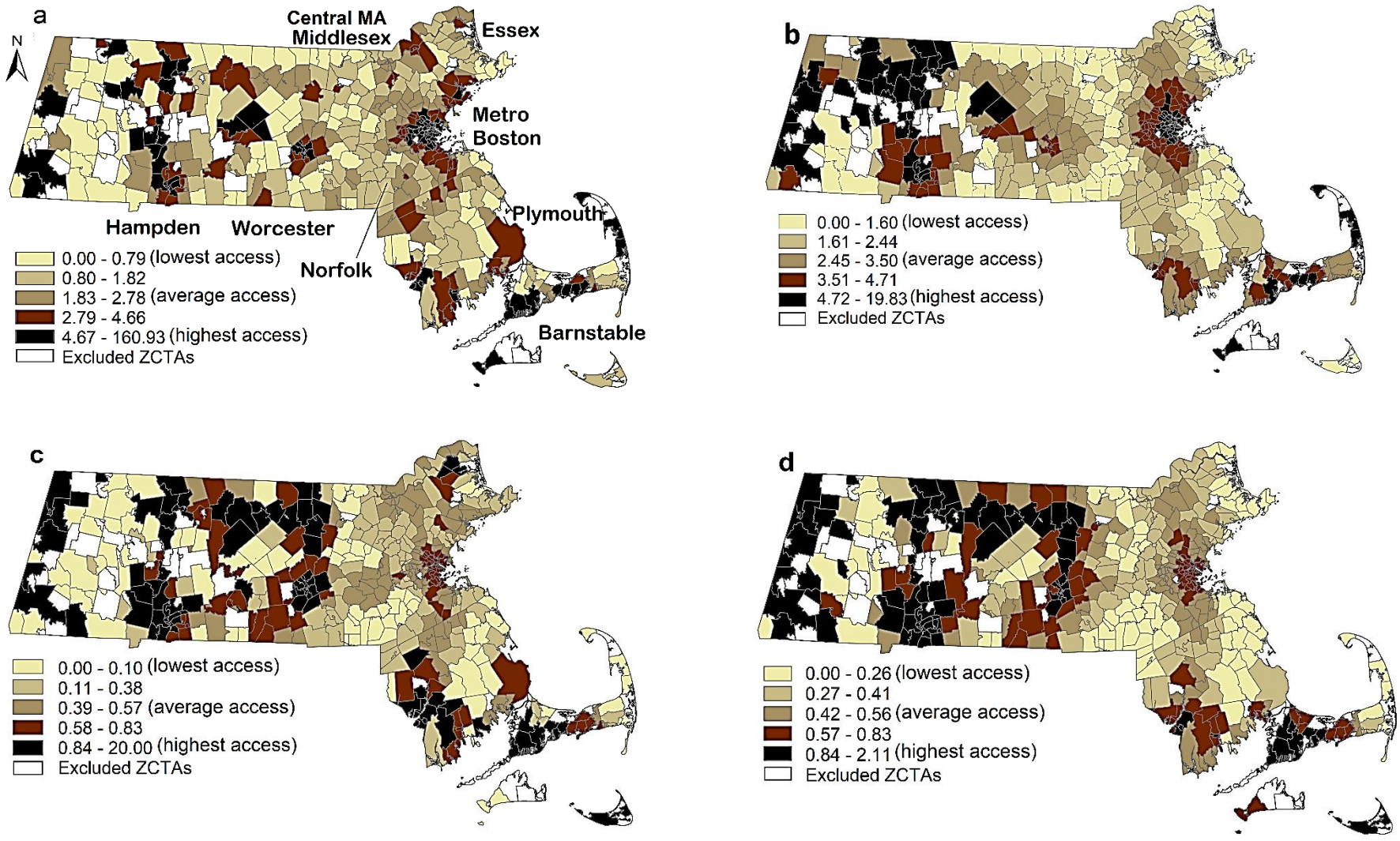

Figure 4.2 Accessibility indices calculated from the Enhanced 2-Step Floating Catchment Area Analyses, categorized into 5 quantiles, and interpreted as:

Number of buprenorphine providers per 100 people aged 15 to 50 years who gave birth in the past 12 months in Massachusetts ZIP Code Tabulation Areas within

a) **15-minute drive-time**

b) 30-minute drive-time

Number of opioid treatment programs per 100 people aged 15 to 50 years who gave birth in the past 12 months in Massachusetts ZIP Code Tabulation Areas within

c) 15-minute drive-time

d) 30-minute drive-time

Note: **ZCTA**: ZIP Code Tabulation Area; 89 ZCTAs with no P&P people were excluded.

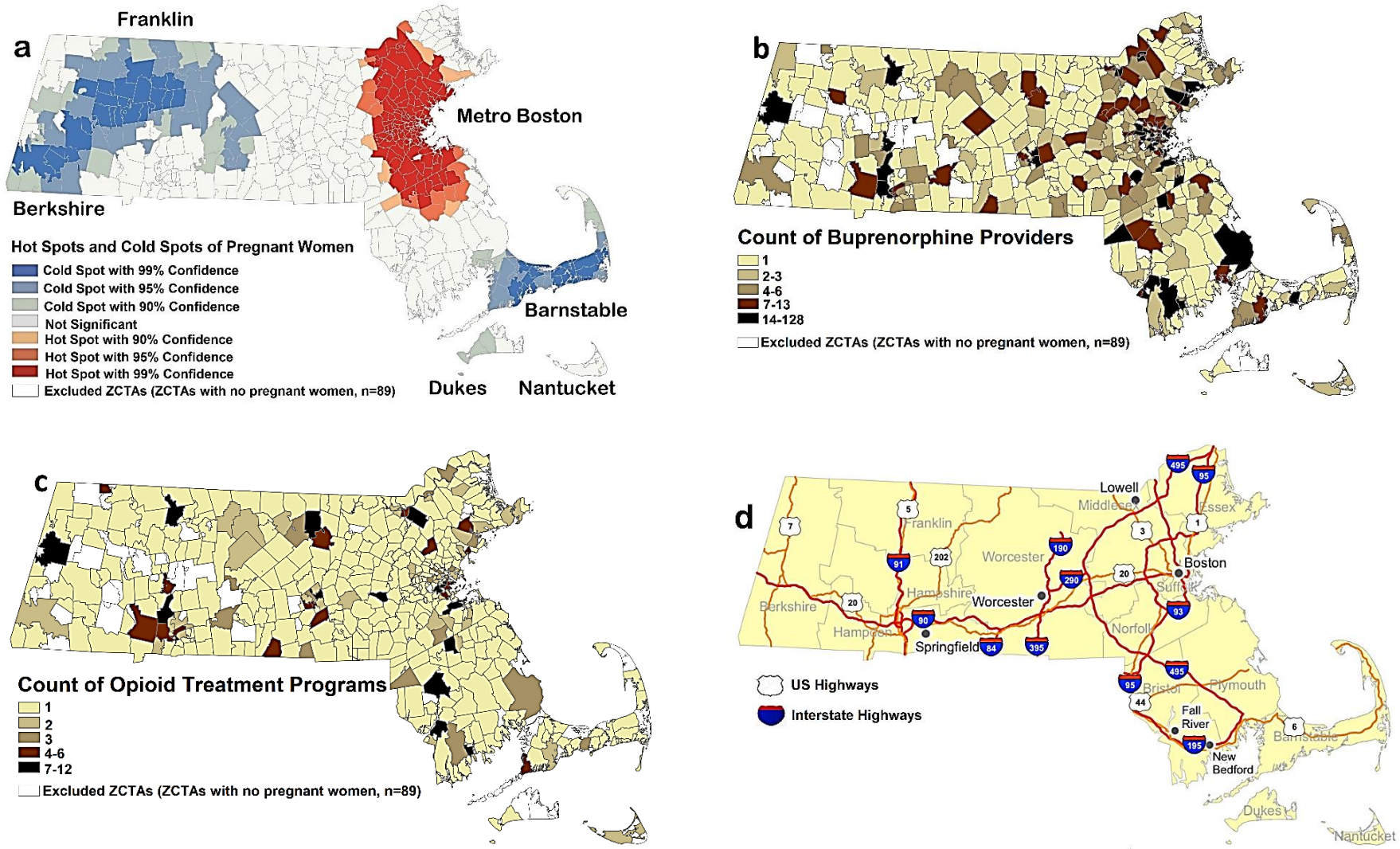

Figure 4.3 a-d. Maps of **variables used in** the calculation of accessibility indices in the **Enhanced 2-Stage Floating Catchment Area** Analyses.

a) Hot spots and cold spots of P&P people during 2016-2020, calculated using Optimized Hotspot Analysis.
b) Number of buprenorphine providers in each ZIP Code Tabulation Area (ZCTA), 2021.
c) Number of opioid treatment programs in each ZCTA, 2021.
d) MA map showing US highways and Interstate highways, sourced from Geology.com. (2021). Map of Massachusetts Cities and Roads. https://geology.com/cities-map/massachusetts.shtml (Accessed 9/22/2021)

4.3.2 Factors Associated with Access to Buprenorphine Providers Within 15- and 30-Minute Drive-Time

In bivariate analyses, all four SVI variables as a group (determined through the p values from type 3 analysis of effects, equivalent to group-wise likelihood ratio tests) exhibited significant positive associations with access to buprenorphine providers within 15- and 30-minute drive-time, such that more socioeconomically vulnerable ZCTAs were more likely to have access indices greater than or equal to the state median (Table 4.2). Furthermore, ZCTAs with greater extreme concentration of privilege were less likely to have access indices greater than or equal to the state median access to buprenorphine providers within 15- and 30-minute drive-time such that.

In multivariable analyses, factors that were independently associated with access to **buprenorphine providers within 15-minute drive-time** were: minority status and language SVI, housing type and transportation SVI, and ICE (Table 4.2). Compared to the first quartile of minority status and language SVI (least vulnerable quartile), ZCTAs in the fourth quartile (the most vulnerable quartile) were nearly 11 times more likely to have access indices greater than or equal to the state median (AOR = 10.59, 95% CI: 4.70, 23.83). Furthermore, compared to ZCTAs in the fourth quartile of ICE (the most privileged quartile) those in the first quartile (least privileged quartile) were five times more likely to have access indices greater than or equal to the state median (AOR = 4.86, 95% CI: 1.68, 14.02). In the case of access to **buprenorphine providers within 30-minute drive-time**, two covariates (minority status and language SVI, and ICE) retained their statistical significance.

Table 4. 2 Factors associated with access to **buprenorphine providers** within 15- and 30-minute drive-time from population centers in Massachusetts ZIP Code Tabulation Areas, (n= 448).

	MODEL 1			
	[#] Access within 15-minute drive-time		[#] Access within 30-minute drive-time	
	OR from bivariate models (95% CI)	Adjusted OR (95% CI)	OR from bivariate models (95% CI)	Adjusted OR (95% CI)
Pregnancy rate				
≥ State median	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
< State median	0.90 (0.62, 1.30)	1.06 (0.66, 1.67)	1.21 (0.83, 1.75)	1.40 (0.92, 2.13)
Socioeconomic status SVI				
0 to 24 percentiles (least vulnerable)	1.00	1.00	1.00	1.00
25 to 49 percentiles	**1.77 (1.03, 3.06) ***	1.46 (0.76, 2.82)	1.09 (0.64, 1.87)	1.00 (0.54, 1.85)
50 to 74 percentiles	**1.84 (1.07, 3.18) ***	0.87 (0.41, 1.85)	1.60 (0.94, 2.72) ~	1.12 (0.56, 2.23)
75 to 99 percentiles (most vulnerable)	**8.07 (4.42, 14.74) ****	0.70 (0.25, 1.99)	**3.26 (1.89, 5.65) ****	1.00 (0.39, 2.55)
Minority status and language SVI				
0 to 24 percentiles (least vulnerable)	1.00	1.00	1.00	1.00
25 to 49 percentiles	**2.46 (1.37, 4.44) ****	**2.76 (1.44, 5.31) ****	0.96 (0.56, 1.66)	0.96 (0.54, 1.71)
50 to 74 percentiles	**4.08 (2.28, 7.32) ****	**4.76 (2.45, 9.23) ****	**1.74 (1.02, 2.97) ***	**1.79 (1.01, 3.19) ***
75 to 99 percentiles (most vulnerable)	**22.00 (10.97, 44.11) ****	**10.59 (4.70, 23.83) ****	**7.28 (3.97, 13.35) ****	**5.50 (2.65, 11.43) ****
Housing type and transportation SVI				
0 to 24 percentiles (least vulnerable)	1.00	1.00	1.00	1.00
25 to 49 percentiles	**2.17 (1.21, 3.90) ****	1.31 (0.69, 2.51)	1.46 (0.85, 2.51)	1.04 (0.58, 1.88)
50 to 74 percentiles	**5.58 (3.11, 10.03) ****	1.60 (0.79, 3.25)	**2.50 (1.46, 4.30) ****	0.99 (0.52, 1.92)
75 to 99 percentiles (most vulnerable)	**12.11 (6.46, 22.72) ****	**3.94 (1.81, 8.56) ****	**3.89 (2.23, 6.79) ****	1.27 (0.64, 2.53)

	Model 1			
	[#] Access within 15-minute drive-time		[#] Access within 30-minute drive-time	
	OR from bivariate models (95% CI)	Adjusted OR (95% CI)	OR from bivariate models (95% CI)	Adjusted OR (95% CI)
Household composition and disability SVI				
0 to 24 percentiles (least vulnerable)	1.00	1.00	1.00	1.00
25 to 49 percentiles	**0.51 (0.30, 0.88) ***	0.69 (0.36, 1.33)	**0.55 (0.32, 0.94) ***	0.63 (0.35, 1.16) ~
50 to 74 percentiles	1.04 (0.61, 1.75)	1.07 (0.54, 2.13)	1.02 (0.60, 1.72)	0.96 (0.51, 1.80)
75 to 99 percentiles (most vulnerable)	**2.57 (1.48, 4.46) ****	1.85 (0.83, 4.12)	1.22 (0.72, 2.07)	0.76 (0.37, 1.54)
ICE for racialized economic segregation				
75 to 99 percentiles (most privileged)	1.00	1.00	1.00	1.00
0 to 24 percentiles (least privileged)	**14.94 (7.74, 28.86) ****	**4.86 (1.68, 14.02) ****	**5.49 (3.10, 9.73) ****	2.47 (0.95, 6.43) ~
25 to 49 percentiles	**2.97 (1.69, 5.20) ****	**2.28 (1.07, 4.86) ***	**2.86 (1.65, 4.97) ****	**2.78 (1.37, 5.65) ****
50 to 74 percentiles	**1.85 (1.05, 3.27) ***	1.54 (0.79, 2.97)	**2.08 (1.20, 3.60) ****	**1.97 (1.06, 3.65) ***

[#]**Accessibility indices** from the enhanced two-step floating catchment area analyses, dichotomized into accessibility greater than or equal to the median state level of accessibility, and accessibility lower than the median state level of accessibility.
OR: Odds ratio; **Pregnancy rate**: Number of P&P people per 1,000 women aged 15 to 50 years during 2016 to 2020.
Ref: reference category, in subsequent rows, 1.00 is the reference category
SVI: Social vulnerability index, **ZCTA**: ZIP Code Tabulation Area
Socioeconomic status SVI: each quartile increase represents a higher proportion of population in the ZCTA is living in poverty, is unemployed, has lower income or does not have a high school diploma, *higher SVI scores indicate higher vulnerability in the subsequent SVIs as well.*
Minority status and language SVI: each quartile increase indicates a higher proportion of population in the ZCTA is minority and speaks English less than very well.
Housing type and transportation SVI: each quartile increase signifies a higher proportion of population in the ZCTA lives in multiunit structure, mobile homes, or group quarters, or a higher proportion of the households are overcrowded and do not have a vehicle.
Household composition and disability SVI: each quartile increase represents a higher proportion of population in the ZCTA is aged ≥65 years, or ≤17 years, or >5 years with a disability, or a higher proportion of households are single parent households.
ICE: Index of Concentration at the Extremes compares White populations in the highest income quintile with non-White populations in the lowest income quintile, *higher positive scores indicate extreme concentration of privilege*.
**** P value** <0.01; ***** P value <0.05; **~** 0.05 ≤ P value ≤ 0.10
Note: The **reference categories** for the four different SVIs and ICE were chosen to represent the *least disadvantaged* ZCTAs in terms of least vulnerability and most privileged**.**

Table 4. 3 Factors associated with access to **buprenorphine providers** within 15- and 30-minute drive-time from population centers in Massachusetts ZIP Code Tabulation Areas (n= 448).

	MODEL 2			
	# Access within 15-minute drive-time		# Access within 30-minute drive-time	
	OR from bivariate models (95% CI)	Adjusted OR (95% CI)	OR from bivariate models (95% CI)	Adjusted OR (95% CI)
Pregnancy rate				
≥ state median	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
< state median	0.90 (0.62, 1.30)	1.04 (0.64, 1.69)	1.20 (0.83, 1.73)	1.35 (0.88, 2.07)
Urbanicity				
Nonmetropolitan ZCTAs	1.14 (0.56, 2.35)	-	2.01 (0.95, 4.28) ~	-
Metropolitan ZCTAs	1.00	-	1.00	-
Percent households with no vehicle	**1.31 (1.22, 1.40) ****	**1.15 (1.07, 1.24) ****	**1.12 (1.08, 1.16) ****	**1.08 (1.04, 1.14) ****
Percent bachelor's degree and higher education	**0.95 (0.93, 0.98) ****	1.01 (0.97, 1.06)	**0.96 (0.93, 0.98) ****	**0.95 (0.91, 0.99) ***
Percent in labor force	**0.95 (0.92, 0.98) ****	**0.92 (0.88, 0.96) ****	**0.95 (0.92, 0.98) ****	**0.95 (0.92, 0.99) ****
Percent households that received public assistance	**1.07 (1.05, 1.09) ****	1.00 (0.97, 1.03)	**1.04 (1.02, 1.05) ****	1.00 (0.98, 1.03)
Percent single parent households	**1.12 (1.09, 1.15) ****	**1.08 (1.03, 1.13) ****	**1.05 (1.03, 1.07) ****	0.99 (0.95, 1.03)
Percent White population	**0.91 (0.89, 0.93) ****	0.99 (0.93, 1.05)	**0.95 (0.93, 0.97) ****	1.01 (0.97, 1.05)
Percent foreign-born population	**1.12 (1.09, 1.15) ****	1.06 (0.98, 1.14)	**1.08 (1.05, 1.11) ****	**1.07 (1.01, 1.13) ****

#**Accessibility indices** from the enhanced two-step floating catchment area analysis, dichotomized into accessibility greater than or equal to the median state level of accessibility, and accessibility lower than the median state level of accessibility.
OR: Odds ratio; **Pregnancy rate**: Number of P&P people per 1,000 women aged 15 to 50 years during 2016 to 2020.
Ref: reference category, in subsequent rows, 1.00 is the reference category; **ZCTA**: ZIP Code Tabulation Area
**** P value** <0.01; ***** P value <0.05; **~** 0.05 ≤ P value ≤ 0.10
Note: **Urbanicity** was not included in the adjusted model since it had a P value >0.05 in the bivariate models.
Three variables: percent Hispanic population, percent population under poverty level, and percent population with limited English proficiency were excluded from analysis due to multicollinearity.

In multivariable models, access to **buprenorphine providers within 15-minute drive-time** was associated with three covariates (percent households with no vehicles, single parent households, and percent in labor force). For each 1%-point increase in households with no vehicle, the odds of having buprenorphine access indices greater than or equal to the state median increased by 15% (AOR = 1.15, 95% CI: 1.07, 1.24) and the association was highly significant ($p<0.01$) (Table 4.3).

4.3.3 Factors Associated with Access to OTPs Within 15- and 30-Minute Drive-Time

In bivariate analyses (Table 4.4), all four SVI domains as a group exhibited significant associations with access to OTPs within 15- and 30-minute drive-time, such that greater vulnerability in the SVI domains were associated with increased odds of having access indices greater than or equal to the state median. Furthermore, ICE for racialized economic segregation showed a significant association with access to OTPs within 15- and 30-minute drive-time, such that greater extreme concentration of privilege was associated with lower odds of having access indices greater than or equal to the state median.

In multivariable models, access to **OTPs within 30-minute drive-time** was associated with three variables: urbanicity, percent households with no vehicle, and percent bachelor's degree and higher education. Compared to metropolitan ZCTAs, nonmetropolitan ZCTAs were four times more likely to have access indices greater than or equal to the state median (AOR = 4.04, 95% CI: 1.65, 9.86), and this association was highly significant ($p<0.01$) (Table 4.5).

Table 4. 4 Factors associated with access to **opioid treatment programs** within 15- and 30-minute drive-time from population centers in Massachusetts ZIP Code Tabulation Areas (n= 448).

	MODEL 1			
	# Access within 15-minute drive-time		# Access within 30-minute drive-time	
	OR from bivariate models (95% CI)	Adjusted OR (95% CI)	OR from bivariate models (95% CI)	Adjusted OR (95% CI)
Pregnancy rate				
≥ State median	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
< State median	0.97 (0.67, 1.40)	1.27 (0.82, 1.95)	0.84 (0.58, 1.21)	0.98 (0.65, 1.48)
Socioeconomic status SVI				
0 to 24 percentiles (least vulnerable)	1.00	1.00	1.00	1.00
25 to 49 percentiles	1.73 (1.00, 3.01) ~	1.78 (0.96, 3.31)	1.63 (0.95, 2.79) ~	1.46 (0.81, 2.65)
50 to 74 percentiles	**2.67 (1.54, 4.62) ****	**2.17 (1.08, 4.36) ***	**1.95 (1.14, 3.34) ***	1.22 (0.62, 2.39)
75 to 99 percentiles (most vulnerable)	**7.54 (4.16, 13.65) ****	2.19 (0.84, 5.68)	**4.66 (2.65, 8.19) ****	1.17 (0.46, 2.99)
Minority status and language SVI				
0 to 24 percentiles (least vulnerable)	1.00	1.00	1.00	1.00
25 to 49 percentiles	**2.06 (1.19, 3.56) ****	**2.20 (1.22, 3.96) ****	**1.95 (1.14, 3.34) ***	**1.91 (1.08, 3.36) ***
50 to 74 percentiles	**1.85 (1.07, 3.20) ***	**2.16 (1.18, 3.95) ***	1.52 (0.88, 2.60)	1.54 (0.86, 2.75)
75 to 99 percentiles (most vulnerable)	**7.98 (4.38, 14.55) ****	**4.55 (2.20, 9.44) ****	**5.09 (2.88, 8.99) ****	**2.71 (1.36, 5.41) ****
Housing type and transportation SVI				
0 to 24 percentiles (least vulnerable)	1.00	1.00	1.00	1.00
25 to 49 percentiles	1.35 (0.79, 2.32)	0.88 (0.48, 1.59)	1.25 (0.73, 2.13)	0.88 (0.49, 1.56)
50 to 74 percentiles	**2.01 (1.18, 3.44) ***	0.65 (0.33, 1.28)	**1.79 (1.05, 3.04) ***	0.73 (0.38, 1.40)
75 to 99 percentiles (most vulnerable)	**4.68 (2.66, 8.23) ****	1.21 (0.60, 2.44)	**3.00 (1.74, 5.18) ****	0.99 (0.50, 1.96)

	Model 1			
	# Access within 15-minute drive-time		# Access within 30-minute drive-time	
	OR from bivariate models (95% CI)	Adjusted OR (95% CI)	OR from bivariate models (95% CI)	Adjusted OR (95% CI)
Household composition and disability SVI				
0 to 24 percentiles (least vulnerable)	1.00	1.00	1.00	1.00
25 to 49 percentiles	**0.46 (0.26, 0.78) ****	**0.50 (0.27, 0.92) ***	0.67 (0.40, 1.14)	0.69 (0.39, 1.24)
50 to 74 percentiles	1.15 (0.68, 1.95)	1.01 (0.54, 1.89)	1.07 (0.64, 1.81)	0.83 (0.45, 1.52)
75 to 99 percentiles (most vulnerable)	**1.87 (1.09, 3.20) ***	0.96 (0.46, 1.98)	1.60 (0.94, 2.72) ~	0.76 (0.38, 1.54)
ICE for racialized economic segregation				
75 to 99 percentiles (most privileged)	1.00	1.00	1.00	1.00
0 to 24 percentiles (least privileged)	**8.51 (4.63, 15.64) ****	**2.98 (1.13, 7.86) ***	**6.65 (3.70, 11.96) ****	**5.13 (1.97, 13.41) ****
25 to 49 percentiles	**2.28 (1.32, 3.93) ****	1.54 (0.76, 3.09)	**2.27 (1.32, 3.90) ****	**2.22 (1.12, 4.41) ***
50 to 74 percentiles	1.37 (0.79, 2.38)	1.15 (0.62, 2.13)	1.42 (0.82, 2.45)	1.38 (0.76, 2.51)

#**Accessibility indices** from the enhanced two-step floating catchment area analyses, dichotomized into accessibility greater than or equal to the median state level of accessibility, and accessibility lower than the median state level of accessibility.

OR: Odds ratio; **Pregnancy rate**: Number of P&P people per 1,000 women aged 15 to 50 years during 2016 to 2020.

Ref: reference category, in subsequent rows, 1.00 is the reference category

SVI: Social vulnerability index, **ZCTA**: ZIP Code Tabulation Area

Socioeconomic status SVI: each quartile increase represents a higher proportion of population in the ZCTA is living in poverty, is unemployed, has lower income or does not have a high school diploma, *higher SVI scores indicate higher vulnerability in the subsequent SVIs as well.*

Minority status and language SVI: each quartile increase indicates a higher proportion of population in the ZCTA is minority and speaks English less than very well.

Housing type and transportation SVI: each quartile increase signifies a higher proportion of population in the ZCTA lives in multiunit structure, mobile homes, or group quarters, and a higher proportion of the households are overcrowded and do not have a vehicle.

Household composition and disability SVI: each quartile increase represents a higher proportion of population in the ZCTA is aged ≥65 years, or ≤17 years, or >5 years with a disability, or a higher proportion of households are single parent households.

ICE: Index of Concentration at the Extremes compares White populations in the highest income quintile with non-White populations in the lowest income quintile, *higher positive scores indicate extreme concentration of privilege*.

**** P value** <0.01; ***** P value <0.05; **~** 0.05 ≤ P value ≤ 0.10

Note: Only minority status and language SVI is significantly associated (p<0.05) with access within 15-minute drive-time in the multivariable analysis using p value from the Type 3 Analysis of Effects, which means that access differs by this predictor as a group.

The **reference categories** for the four different SVIs and ICE were chosen to represent the *least disadvantaged* ZCTAs in terms of least vulnerability and most privileged**.**

Table 4. 5 Factors associated with access to **opioid treatment programs** within 15- and 30-minute drive-time from population centers in Massachusetts ZIP Code Tabulation Areas (n= 448).

	MODEL 2			
	[#] Access within 15-minute drive-time		[#] Access within 30-minute drive-time	
	OR from bivariate models (95% CI)	Adjusted OR (95% CI)	OR from bivariate models (95% CI)	Adjusted OR (95% CI)
Pregnancy rate				
≥ state median	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
< state median	0.97 (0.67, 1.40)	1.12 (0.76, 1.70)	0.84 (0.58, 1.21)	0.95 (0.63, 1.45)
Urbanicity				
Nonmetropolitan ZCTAs	1.50 (0.72, 3.13)	-	**3.24 (1.42, 7.38) ****	**4.04 (1.65, 9.86) ****
Metropolitan ZCTAs	1.00	-	1.00	1.00
Percent households with no vehicle	**1.12 (1.08, 1.16) ****	**1.10 (1.05, 1.16) ****	**1.10 (1.06, 1.13) ****	**1.13 (1.08, 1.19) ****
Percent bachelor's degree and higher education	**0.95 (0.92, 0.97) ****	0.98 (0.94, 1.02)	**0.94 (0.92, 0.96) ****	**0.94 (0.91, 0.98) ****
Percent in labor force	**0.97 (0.94, 0.99) ***	0.97 (0.94, 1.01)	**0.97 (0.94, 0.99) ***	0.98 (0.95, 1.02)
Percent households that received public assistance	**1.05 (1.03, 1.06) ****	1.00 (0.98, 1.03)	**1.04 (1.02, 1.05) ****	0.99 (0.96, 1.02)
Percent single parent households	**1.07 (1.05, 1.10) ****	**1.05 (1.01, 1.10) ~**	**1.05 (1.03, 1.07) ****	1.02 (0.98, 1.06)
Percent White population	**0.96 (0.95, 0.98) ****	1.00 (0.98, 1.03)	**0.97 (0.96, 0.99) ****	1.00 (0.98, 1.03)
Percent foreign-born population	**1.04 (1.02, 1.06) ****	0.98 (0.93, 1.03)	**1.03 (1.01, 1.05) ****	0.96 (0.92, 1.01)

[#] **Accessibility indices** from the enhanced two-step floating catchment area analyses, dichotomized into accessibility greater than or equal to the median state level of accessibility, and accessibility lower than the median state level of accessibility

OR: Odds ratio; **Pregnancy rate:** Number of P&P people per 1,000 women aged 15 to 50 years during 2016 to 2020.

Ref: reference category, in subsequent rows, 1.00 is the reference category; **ZCTA**: ZIP Code Tabulation Area

** P value <0.01; ***** P value <0.05; **~** 0.05 ≤ P value ≤ 0.10

Note: Urbanicity was not included in the adjusted model since it had a P value >0.05 in the bivariate models.

Three variables: percent Hispanic population, percent population under poverty level, and percent population with limited English proficiency were excluded from analysis due to multicollinearity.

4.3.4 Hotspots and Coldspots of Covariates

Hotspot clusters of minority status and language social vulnerability were identified in the Metro Boston area, and Eastern Hampden (in Western MA) ($p<0.05$). Minority status and language social vulnerability coldspots were located in much of Western and Central MA, some parts of Essex and Plymouth counties, and most of Barnstable County (all three counties in Eastern MA). Significant housing type and transportation SVI hotspots were located in Worcester (in Central MA) and Hampden counties (in Western MA) and in Metro Boston (Figure 4.4a-e). A hotspot is interpreted as a cluster of ZCTAs that have significantly higher concentration of events compared to the average number, and coldspots are ZCTAs that have significantly lower concentration of events compared to the average number.

Hotspots of percent White population were identified in much of Western and Central MA, Barnstable and Plymouth counties (both counties in Eastern MA), while coldspots were located in the Greater Boston area. Hotspots of households with no vehicle were located in Metro Boston area, parts of Hampden County (in Western MA), and Westport (in Eastern MA). Hotspots of single parent households were located in Eastern Hampden County, Metro Boston area and Fall River (in Southeastern MA). Coldspots of single parent household were identified in the Metro West region, west of Boston (Figures 4.5a-d).

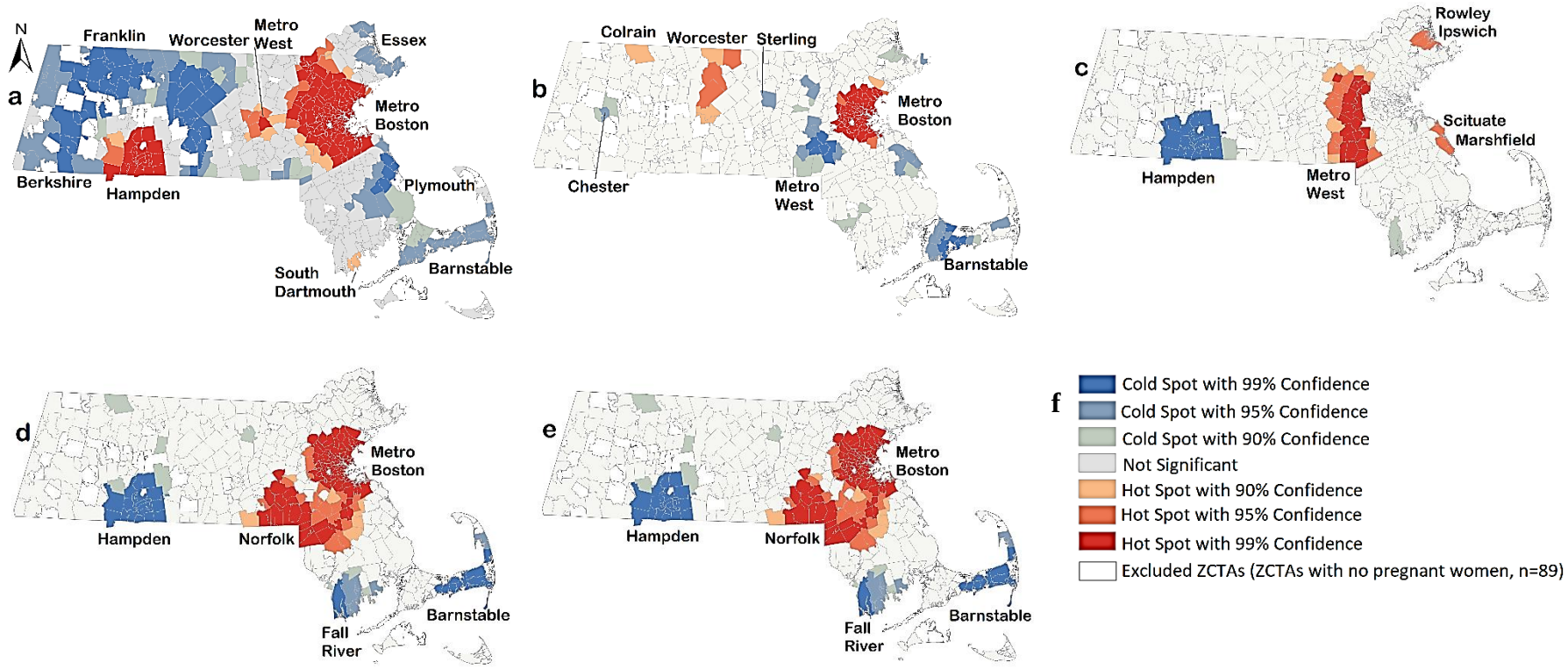

Figure 4.4 Maps of covariates that were statistically significant in the logistic regression. Red areas represent hotspots and blue areas represent coldspots, interpreted as:

a) **Minority status and language social vulnerability index**, red indicates clusters of ZCTAs with (statistically, in subsequent panels as well) significantly **higher** than the average vulnerability (i.e., *more people who are minority and speak English less than very well*), and blue indicates clusters of ZCTAs with significantly **lower** than the average vulnerability.

b) **Housing type and transportation social vulnerability index**, red depicts clusters of ZCTAs with significantly **higher** than the average vulnerability (i.e., *more people who live in multiunit structures, mobile home, or group quarters, or in households that are overcrowded or without a vehicle*), and blue indicates clusters of ZCTAs with significantly **lower** than the average vulnerability.

c) **Index of Concentration at the Extremes** for racialized economic segregation, red specifies clusters of ZCTAs with significantly **higher** than the average concentration of privilege (i.e., *more people who are White with high income*), and blue indicates clusters of ZCTAs with significantly **lower** than the average concentration of privilege (i.e., more people who are non-White with low income).

d) Proportion of population in each ZCTA with bachelor's degree or higher education, red indicates clusters of ZCTAs with significantly **higher** than the average number of people with bachelor's degree or higher education, and blue indicates clusters of ZCTAs with significantly **lower** than the average number of people with bachelor's degree or higher education.

e) Proportion of population in each ZCTA who are in the labor force, red highlghts clusters of ZCTAs with significantly **higher** than the average number of people in labor force, and blue indicates clusters of ZCTAs with significantly **lower** than the average number of people in labor force.

f) Levels of statistical significance for hotspot and coldspot clusters

Note: **ZCTA**: ZIP Code Tabulation Area

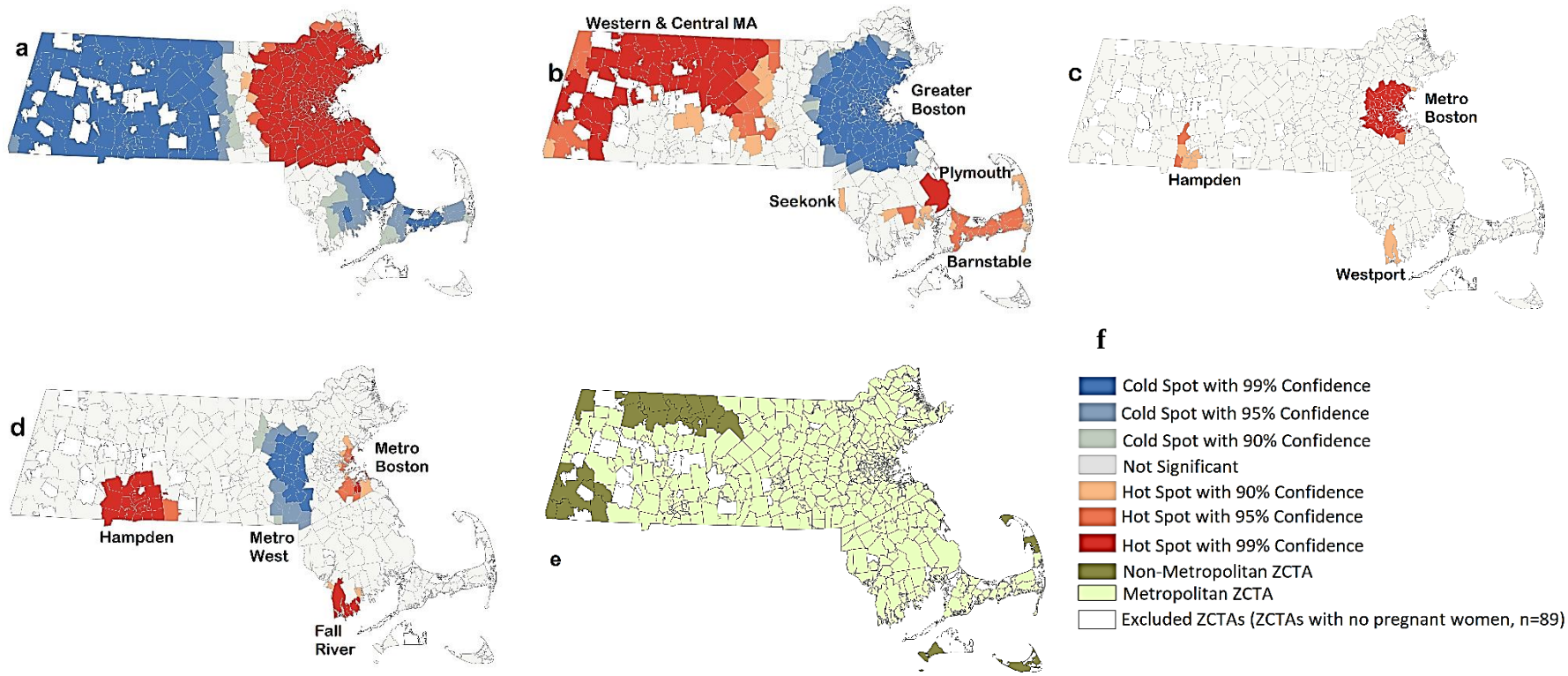

Figure 4.5 a-e. Maps of covariates that were statistically significant in the logistic regression. Reds are hotspots and blues are coldspots, interpreted as:

a) **Proportion of foreign-born population** in each ZCTA, red indicates clusters of ZCTAs with (statistically, in subsequent maps as well) significantly **higher** than the average number of foreign-born populations, and blue indicates clusters of ZCTAs with significantly **lower** than the average proportion of foreign-born population.

b) **Proportion of White population** in each ZCTA, red depicts clusters of ZCTAs with significantly **higher** than the average proportion of White population**,** and blue indicates clusters of ZCTAs with significantly **lower** than the average proportion of White population.

c) **Proportion of households with no vehicle** in each ZCTA, red specifies clusters of ZCTAs with significantly **higher** than the average proportion of households with no vehicle**.**

d) **Proportion of single parent households** in each ZCTA, red highlights clusters of ZCTAs with significantly **higher** than the average proportion of single parent households**,** blue indicates clusters of ZCTAs with significantly **lower** than the average proportion of single parent households**.**

e) **Light greens are metropolitan ZCTAs**, dark greens are nonmetropolitan ZCTAs.

f) **Levels of statistical significance** for hotspot and coldspot clusters

Note: **ZCTA**: ZIP Code Tabulation Area

4.4 DISCUSSION

We conducted a novel study of MOUD access for P&P people during 2016 to 2020 in MA, utilizing spatial and statistical analyses. We utilized data from five different publicly available sources, consisting of 74,969 P&P people in 448 ZCTAs, 258 OTPs, and 2,585 buprenorphine providers in MA. Overall, we found that ZCTAs located in most of the Western MA had poor access to both MOUD sites, disparities in the distribution of the different types of MOUDs was not uniform across space, and characteristics associated with poor access were metropolitan, less minority and language vulnerability, and higher concentration of privilege (i.e., higher proportion of White population in the highest income quintile). Our results identify specific types and locations of ZCTAs where resources should be targeted to have greatest potential of increasing treatment access specific to P&P people.

The ZCTAs identified as having poor access to both OTPs and buprenorphine providers within 15- and 30-minute drive-time for P&P people during 2016 to 2020 were concentrated in Eastern MA counties: Essex, Plymouth, Norfolk, and much of Middlesex. These same counties had the highest number of opioid-related overdose deaths in MA in 2020, with Middlesex County ranking the first (Massachusetts Department of Public Health, 2021b). A large portion of Western MA had poor access to both buprenorphine providers and OTPs within 15-minute drive-time. This is concerning because as drive-time increases, the likelihood of utilizing MOUD decreases. In a study of Spokane county in Washington, Amiri *et. al.* found that patients who lived farther than 10 miles from an OTP had 29% higher risk of missing doses of methadone compared to those residing within five miles (IRR = 1.29, 95% CI: 1.03, 1.61, p = 0.03) (Amiri et al., 2018). In another study of treatment programs for substances other than opioids in Baltimore city, Beardsley *et. al.* found that patients traveling less than one mile were 50% more likely to

complete treatment (defined as successful completion of the client's treatment goals) than patients who traveled more than one mile (Beardsley et al., 2003). Paired with our results, these prior findings highlighting the risks of greater distance and benefits of shorter distance of travel may have important clinical implications for MA.

Central MA has poor access to buprenorphine providers within 15- and 30-minute drive-time. Most of Metro Boston (except for core Boston and some of the surrounding cities) had poor access to OTPs. It is equally important to have access to both types of MOUDs, as there is limited information about which patients respond better to which MOUD, and even less knowledge in case of P&P people (Blanco & Volkow, 2019). However, methadone's supply has been limited over time, as the medication is only delivered through OTPs, which are closely regulated at the federal and state levels (Substance Abuse and Mental Health Services Administration, 2015). Drawing from policies to increase methadone access in countries like Canada and Australia, geographic methadone disparity could be mitigated through implementation of pharmacy-based methadone dispensing (Joudrey et al., 2020). Furthermore, studies have found that approximately 44% to 66% of physicians waivered to prescribe buprenorphine actually prescribe buprenorphine; of these prescribers, the majority do not prescribe to their maximum patient limit (C. Jones et al., 2015). This issue is highlighted by a recent study which found that although capacity to provide methadone and buprenorphine was highest in counties with the greatest disease burdens, the availability of methadone and buprenorphine was uneven across segregated counties, leaving many patients who do not respond to a medication without access to the other evidence-based treatment options (Goedel et al., 2020). On a positive note, relaxed federal and state MOUD guidelines during the COVID-19 pandemic, including buprenorphine initiation via telemedicine, OTPs allowing take-home doses of

methadone, prohibition of Medicaid prior authorization requirements for MOUD, among others point to increased access and decreased barriers to continuity of care (Au-Yeung et al., 2021).

Nonmetropolitan ZCTAs had four times higher odds of having good access to OTPs within 30-minute drive-time, compared to metropolitan ZCTAs. We used E2SFCA to calculate these accessibility indices and such high access indices are expected for large ZCTAs with small population because unlike the traditional methods, E2SFCA takes into account both the drive-time to service and the service demand (Page et al., 2019). E2SFCA indices are a measure of relative accessibility based on the number of MOUD providers, the number of people giving birth in the past 12 months, their proximity based on drive-time using highways, roads and local roads, and a catchment area (ZCTA for this study). The nonmetropolitan ZCTAs were located in the western part of MA (Berkshire and Franklin), and eastern part of MA (Nantucket, Dukes and Barnstable), which have good road access, including interstate highways and US highways. For example: Interstates I-90 and I-91, and US Highways 5, 7, and 20 pass through the western part of MA (Berkshire and Franklin), and US Highway 6 passes through Barnstable. These nonmetropolitan ZCTAs have significantly lower than the average number of P&P people (i.e., coldspots of P&P people). Moreover, all these ZCTAs have at least one OTP and one buprenorphine provider. Hence, as the demand is low and the supply is high, and the road access is good, the nonmetropolitan ZCTAs have higher odds of good accessibility indices compared to the metropolitan ZCTAs. Our findings corroborate those from a recent study of 3,142 U.S. counties, in which micropolitan counties had lower risk of having low MOUD provider capacity than metropolitan counties (Haffajee et al., 2019).

ZCTAs with the highest minority status and language vulnerability were more likely to have good access to both types of MOUDs. The findings of these statistical analyses were supported by spatial analyses, which show that Boston and surrounding areas, and Eastern Hampden (in Western MA) have greater access to buprenorphine providers and OTPs, depicted by our accessibility indices. Furthermore, the same areas have highly vulnerable populations, indicated by hotspot clusters of minority status and language SVI. This is a very encouraging finding that indicates more equitable distribution of MOUD resources for P&P people in MA, which might be partially explained by the 'not in my backyard' phenomena, wherein there is locally organized resistance to unwanted proposed developments including methadone clinics, as such clinics and their clients are highly stigmatized (Erika, 2022). Also, compared to the rest of the U.S., New England has higher availability of treatment providers for both methadone and buprenorphine (Massachusetts Department of Public Health, 2018).

4.5 STRENGTHS AND LIMITATIONS

The study has a number of strengths. The use of publicly available data which are consistently available for all states in the U.S., makes this study replicable in other states. Additionally, we used population representative data, including a comprehensive list of buprenorphine providers and OTPs in MA from the SAMHSA treatment locator, which is a federal body working towards reducing the impact of substance use and mental illness on American communities, which increased the validity of this study.

However, this study has several limitations. First, due to lack of publicly available data, we used data on P&P people as a proxy for P&P people with OUD, which may be less representative and underestimate the accessibility to MOUD sites. The accessibility indices are interpreted as the number of MOUD sites (buprenorphine providers or OTPs)

per 100 P&P people within the designated drive-time. As there were higher number of P&P people compared to P&P people with OUD in each ZCTA, this would underestimate the accessibility indices. The underestimation of accessibility indices is similar across all the ZCTAs so the comparison of accessibility among ZCTAs of MA would not be affected. Furthermore, the distribution of this proxy population across MA ZCTAs was compared with the distribution of opioid overdose by juxtaposing the maps and the distribution was similar. From a service planning perspective, the use of proxy population would be similar to planning a primary care physician's office based on the total number of adult population in the community, and not just the sick populations. On the positive side, using this proxy population makes the study replicable in other states as the data are consistently available for all states in the U.S.

The second limitation is that, the supply of buprenorphine providers might not have been correctly estimated. The available data are based on a provider limit of 100 patients, instead of the current 250, underestimating the supply, and underestimating the accessibility. Also, the supply and the resulting accessibility could be further underestimated as these data do not include some buprenorphine-waivered clinicians who do not consent to be on the buprenorphine list. Alternatively, some buprenorphine-waivered providers who agree to be included on the buprenorphine list do not actively prescribe buprenorphine, and do not have a full MOUD patient load, thus overestimating the accessibility. Furthermore, patients may access treatment across state-lines, which means that even if their residential ZCTA had low MOUD access, they were still able to access MOUD.

Another study limitation is that the E2SFCA accessibility indices might become extreme in the case of large sized ZCTAs, as the floating catchment areas become less reliable due to the increased variability in the population centroid (Dilts, 2020). This is

because the indices are calculated based on the distance between providers and population centroids. If the population centroid lies near to the provider, it will have a high index, whereas if the population centroid lies far away from the provider, it will have a low index (Bryant Jr & Delamater, 2019). However, the use of a decay method in the calculation of the accessibility indices in this study increased the validity of the findings.

Furthermore, individuals may use public transportation to commute to treatment facilities, and our analysis did not account for different transport modalities, due to data unavailability. Since the data from each ZCTA applied to all residents in that ZCTA, it can help us in understanding the context in which an individual lives, but not whether that data apply to any specific individual in the dataset. Previous studies have noted that ZCTA level measurements tend to detect smaller effects compared to block group and tract measures. Also, our findings might not be generalizable to non-binary pregnant people, nor to populations outside of MA.

4.6 CONCLUSION

Accessibility to MOUDs for P&P people in MA was better for ZCTAs that were more vulnerable in terms of minority status and language, that had less extreme concentration of privilege, and that were nonmetropolitan. Efforts should be concentrated in increasing access to MOUDs overall, and in improving access to both types of MOUDs, so people can choose the MOUD that works best for them. Future studies should be conducted using data on P&P people with OUD, which can be analyzed from private data available from the Public Health Data Warehouse at the MA Department of Public Health. Also, dependent on funding availability, studies could contact each MOUD site to verify whether they are operational, and use private data on

public transportation routes, in addition to the drive-time data used in this study, to achieve even greater precision of salient measures.

4.7 ROLE OF THE FUNDING SOURCE

The Tufts Initiative on Substance Use and Addiction provided funding support for this study (PI: Stopka). The funder has no role in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

Chapter 5: Discussion

Community - a confluence of the social, economic, political, physical, and built environments - is fundamental to our understanding of health and health inequities, and even more so for P&P people with OUD, who are a highly vulnerable population. Disadvantaged populations may not seek healthcare because of limited availability and accessibility of MOUD providers, and concerns about stigma and confidentiality, as well as other higher priorities such as unfulfilled social needs. The community where a P&P person lives may present a risk environment that can influence substance use patterns given regular exposures to substance use in the community around them. At the same time, it is possible that socioeconomically disadvantaged locations might have lower access to MOUD, compounding the issue, and resulting in worse health outcomes.

This dissertation addressed the contemporary epidemic of OUD among P&P people. P&P people with OUD have more than doubled in number in the past decade (Hirai et al., 2021), and MA has one of the highest OUD rates within this population in the U.S. (Neonatal Quality Improvement Collaborative of Massachusetts, 2017). Less than half of the P&P population receive MOUD, such as buprenorphine and methadone (Krans et al., 2019), an effective evidence-based treatment for OUD within this population (Higgins et al., 2019; National Institute on Drug Abuse, 2017; Substance Abuse and Mental Health Services Administration, 2018). Geographic access to MOUDs varies across communities and access is influenced by social determinants of health. And it is important to remember that P&P people with OUD have additional treatment needs beyond MOUD, e.g., clinical services and social support. The overarching aim of this dissertation was to identify and characterize locations of high OUD burden among

P&P people in MA and their access to holistic services, including MOUD, with an emphasis on communities and their social determinants of health.

5.1 Burden of OUD and Access to MOUD

In this study, high-risk areas for maternal OUD rates were concentrated in Central and Western MA indicated by hotspots of OUD rates. Additionally, a large portion of Western and Central MA had hotspots of socioeconomically vulnerable ZCTAs. This means that the population-adjusted risk of maternal OUD was concentrated in these more vulnerable ZCTAs, which demand more OUD treatment locations. However, a large portion of Western MA had poor access to MOUDs (both buprenorphine and methadone) within 15-minute drive-times, while Central MA had poor access to buprenorphine providers within 15- and 30-minute drive-times. This is concerning because as drive-time increases, the likelihood of utilizing MOUD decreases. In a study of Spokane county in Washington, Amiri *et al.* found that patients who lived further than 10 miles from an OTP had 29% higher risk of missing doses of methadone compared to those residing within five miles (IRR = 1.29; 95% CI: 1.03 to 1.61, $p = 0.03$) (Amiri et al., 2018). In another study of treatment programs for substances other than opioids in Baltimore city, Beardsley *et al.* found that patients traveling less than one mile were 50% more likely to complete treatment (defined as successful completion of the client's treatment goals) than patients who traveled more than one mile (Beardsley, Wish, Fitzelle, O'Grady, & Arria, 2003). Paired with my results, these prior findings highlighting the risks of greater travel distances and benefits of shorter distances may have important clinical and public health implications for MA.

5.2 Social Determinants of Health Associated with OUD High-risk Areas

One of the pertinent social determinants of health associated with OUD high-risk ZCTAs was metropolitan status. In my analyses focused on MA, nonmetropolitan ZCTAs had four times higher odds of having good access to OTPs within 30-minute drive-times, compared to metropolitan ZCTAs. I used E2SFCA to calculate these accessibility indices and high access indices were expected for large ZCTAs with small population because unlike the traditional methods, E2SFCA takes into account both the drive-time to service and the service demand (Page et al., 2019). The E2SFCA indices were a measure of relative accessibility based on the number of MOUD providers (i.e., supply of services), the number of P&P people with OUD (demand for services), their proximity based on drive-times using highways, roads and local roads, and a catchment area (ZCTA for this study). The nonmetropolitan ZCTAs were largely located in the western (Berkshire and Franklin Counties) and eastern parts of MA (Nantucket, Dukes and Barnstable Counties), which had good road access, including interstate highways and U.S. highways. For example: Interstates I-90 and I-91, and U.S. Highways 5, 7, and 20 pass through the western part of MA (Berkshire and Franklin Counties), and U.S. Highway 6 passes through Barnstable. These nonmetropolitan ZCTAs had significantly lower than the average number of P&P people (i.e., coldspots of P&P people). Moreover, all these ZCTAs had at least one OTP and one buprenorphine provider during my study perioid. Hence, as the demand for MOUD treatment was low and the supply was high, and the road access was good, the nonmetropolitan ZCTAs had higher odds of good accessibility indices compared to the metropolitan ZCTAs. My findings corroborate those from a recent study of 3,142 U.S. counties, in which micropolitan counties had lower risk of having low MOUD provider capacity than metropolitan counties (Haffajee et al., 2019).

Another social determinant of health associated with access to OUD treatment among P&P people was their nativity status. Foreign-born people had less access to MOUD treatment compared to U.S.-born populations, as noted in Chapter 3. This is of concern because previous studies found that foreign-born women's risk of substance use during pregnancy increased as immigrant women acculturated to the U.S. (Harley & Eskenazi, 2006; Hernandez et al., 2020). Hence this population should not be overlooked in the design of interventions for at-risk people (Perreira & Cortes, 2006). Future research should comprehensively examine the unmet health needs and predictors of access to treatment and care among foreign-born P&P people with OUD (Adigun et al., 2021) as the foreign-born population accounted for more than 44.9 million or 13.7% of the U.S. population in 2019 and has grown each year with approximately 1.2 million new migrants entering the U.S. annually (Batalova et al., 2021).

Additionally, throughout the scoping review, I found that addressing the social determinants of health was an important strategy to improve access to needed treatment and care among P&P people with OUD. Some salient strategies to improve treatment access were: providing social support including childcare, transportation, housing, and nutrition; facilitating access to WIC and vocational services; and reducing financial barriers through treatment being covered by Medicaid, provision of private funding, reduced program fees for pregnant women, and paid maternity leave. Other prominent strategies were: providing support for violence and trauma; and free or facilitated transportation to and from the program. I also found that providing such services in a non-judgmental approach improved their access to treatment and care for OUD.

5.3 Effective Model Components That Meet the Holistic Needs of P&P People with OUD

Substance use among P&P people is a highly polarized topic, and maternal OUD has been stigmatized and criminalized at various socioecological levels, including the state and national policy level. For example, MA requires mandatory reporters to report pregnant people who receive MOUD to the Department of Children and Families (Massachusetts Office of the Child Advocate, 2020). Such policies can deter pregnant patients with OUD from seeking timely prenatal care and can hinder disclosure of drug use to providers. Decreasing stigma and criminalization will help P&P people feel more comfortable accessing care, which will ensure a safer pregnancy for the mother and child (Fonti et al., 2016). In the scoping review, I found that providing training and education to the care team (including clinicians and non-clinicians) improved their attitudes towards patients with OUD and their job satisfaction. This is in line with the results of a scoping review by Park *et al.,* which recommended strategies to achieve stigma reduction in two major ways: the first was to normalize MOUD so that it would no longer be considered as a tool for 'substituting one addiction with another' and the second was to emphasize OUD as a chronic disease, a mainstream medical issue just like diabetes that needs long-term care and support, which can be managed at the primary care level (Park et al., 2020). My scoping review reported that non-judgmental care from providers facilitated access to well-coordinated and high-quality care. My scoping review also identified a need to bolster patient-provider relationships that are built on trust, are free of stigma, and that empower patients to make their own decisions; and improve policies and regulations to reduce stigma around opioid use and MOUD, so that P&P people with OUD can access high quality care.

Also, P&P people should be able to choose the MOUD that works best for them because, to date, there is little research identifying the types of patients with OUD that will respond better to each medication, and because both medications have their own advantages and limitations (Blanco & Volkow, 2019). Both buprenorphine and methadone are first-line therapy for OUD during P&P period and the choice between the two medications should be based on joint decision-making between the patient and the clinician (Substance Abuse and Mental Health Services Administration, 2018). However, such decisions are often primarily based on geographic access to specific types of MOUD (Blanco & Volkow, 2019). Methadone is only offered at OTPs; buprenorphine can be offered in OTPs and office-based settings (Substance Abuse and Mental Health Services Administration & National Survey of Substance Abuse Treatment Services, 2020). OTPs are understaffed and underfunded, and patients may have to wait for months to be admitted (Amiri, McDonell, Denney, Buchwald, & Amram, 2021). Most buprenorphine prescribers are located in urban areas, and the availability is low in rural areas. Also, MOUD providers frequently do not treat pregnant people, even when they are accepting new patients (Patrick, Buntin, et al., 2019).

In this study, I found that access to methadone and buprenorphine varied by location and by socioeconomic vulnerability in MA. Drawing from policies to increase methadone access in countries like Canada and Australia, geographic methadone disparities could be mitigated through implementation of pharmacy-based methadone dispensing (Joudrey et al., 2020). It is important to bear in mind that the availability of MOUD providers does not ensure access to MOUD. Studies have found that approximately 44% to 66% of physicians waivered to prescribe buprenorphine actually prescribe buprenorphine; of these prescribers, the majority do not prescribe to their maximum patient limit (Jones et al., 2015). This issue was highlighted by a recent U.S.

study which found that although capacity to provide methadone and buprenorphine was highest in counties with the greatest disease burdens, counties with highly segregated African American and Hispanic/Latino communities had more facilities to provide methadone per capita, while counties with highly segregated White communities had more facilities to provide buprenorphine per capita. Such uneven availability of methadone and buprenorphine based on the racial/ethnic composition of the community left many patients who did not respond to a medication without access to the other evidence-based treatment options (Goedel et al., 2020). On a positive note, relaxed federal and state MOUD guidelines during the COVID-19 pandemic, including buprenorphine initiation via telemedicine, OTPs allowing take-home doses of methadone, prohibition of Medicaid prior authorization requirements for MOUD, among others, pointed to increased access and decreased barriers to continuity of care (Au-Yeung et al., 2021).

In addition to MOUD access, P&P people with OUD have a wide range of needs, including clinical services like obstetric, gynecologic, pediatric, psychiatric, and lactation services, as well as social supports like childcare, transportation, housing, and nutrition. Implementing a comprehensive women-centered model, which encompasses this wide range of needs, benefits the mother and child in terms of **increased preventative care for mothers** (e.g., postpartum visits, use of long-acting reversible contraception), **enhanced neonatal health** (e.g., lower rates for and duration of NOWS, shorter neonatal intensive care unit and hospital lengths of stay), and **increased initiation and continuation of breastfeeding at discharge** (Paterno et al., 2019; Singh et al., 2020). Improving access to and retention of patients in quality care should be the cornerstone of a public health and clinical response to the OUD epidemic.

5.4 Strengths, Limitations, and Future Studies

A particular strength of this study is the generalizability of findings arising from the use of population-representative public and private data. Both Chapters 3 and 4 utilized data from the latest ACS, which is a nationally representative sample of all populations in the U.S. Chapter 2 utilized comprehensively linked administrative data with a near census of the MA population, and Chapter 3 utilized a comprehensive list of methadone and buprenorphine providers across the state of MA. Additionally, most of the data used in this study are consistently available for all U.S. states, making this study replicable elsewhere.

This thesis has several limitations. Firstly, the external validity and generalizability might be limited due to data limitations. For instance, due to lack of publicly available data on OUD among P&P people in MA, and the delay in access to the PHD from MDPH due to the COVID-19 pandemic, Chapter 4 utilized P&P people in MA as a proxy to P&P people with OUD, which may be less representative. This may have resulted in underestimation of the accessibility indices, as there were fewer P&P people with a history of OUD compared to P&P people in every ZCTA. The underestimation of accessibility indices was similar across all the ZCTAs so the relative comparison of accessibility across MA ZCTAs would not be affected. To further assess potential underestimations, the distribution of this proxy population across MA ZCTAs was compared with the distribution of opioid overdose by juxtaposing maps of the two measures and the distributions were similar. From a service planning perspective, the use of a proxy population would be similar to planning the opening of a primary care physician's office based on the total number of adult populations in the community, and not just the sick populations. On the positive side, using this proxy population makes the

study replicable in other states, as the data are consistently available for all states in the U.S.

This dissertation used ZCTA as the unit of analysis, mainly because it was the smallest spatial unit of residence available in the PHD Warehouse for analyses, due to data privacy and confidentiality concerns. The data from each ZCTA applied to all residents in that ZCTA, which can help us in understanding the context in which an individual lives, but not whether that data apply to any specific individual in the dataset. Previous studies have noted that ZCTA-level measurements tend to detect smaller effects compared to block group and tract measures.

The COVID-19 pandemic might have impacted the number of P&P people with OUD, by increasing the number of people using substances due to increased stress, and by hindering data collection procedures. Also, the COVID-19 pandemic might have increased access to MOUD providers due to relaxed federal and state MOUD guidelines, including buprenorphine initiation via telemedicine, Opioid Treatment Programs allowing take-home doses of methadone, and prohibition of Medicaid prior authorization requirements for MOUD.

Due to the COVID-19 pandemic, access to the PHD Warehouse was delayed by 18 months. It was a big and complex dataset, consisting of administrative data from more than two dozen agencies, with approximately 1.5 billion records in the APCD dataset alone. The PHD Warehouse was being continuously updated along with its 400-page data dictionary with hundreds of variables. Understanding the different datasets and the variables and resolving how to join these complex datasets was time-intensive and arduous. Additionally, analyses focused on the dataset took several hours to run and needed to be analyzed on-site to ensure confidentiality and privacy protections for the people represented in the data. In similar future research, at least several months

should be dedicated to read and understand the data comprehensively, and close coordination and intense guidance from the MDPH would be a must.

Future studies should focus on the most vulnerable populations including foreign-born people; those experiencing homelessness, trauma, and violence; and non-binary pregnant persons, which might affect OUD and related treatment access among P&P people.

5.5 Disclaimer

While the work in Chapter 3 analyzed the data provided by the Massachusetts Department of Public Health (MDPH) PHD Warehouse, the methods, analyses, and results do not represent the perspectives of MDPH.

Chapter 6: References

Abraham, A. J., Andrews, C. M., Yingling, M. E., & Shannon, J. (2018). Geographic disparities in availability of opioid use disorder treatment for Medicaid enrollees. *Health services research, 53*(1), 389-404. doi: https://doi.org/10.1111/1475-6773.12686

Aday, L. A., & Andersen, R. (1974). A framework for the study of access to medical care. *Health services research, 9*(3), 208. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/4436074. (Accessed September 23, 2020)

Adigun, S., Barroso, C., Mixer, S., Myers, C., & Anderson, J. (2021). Minding the Gaps: Health Care Access for Foreign-born People in the US: An Integrative Review. *Journal of health care for the poor and underserved, 32*(4), 1653-1674. doi:10.1353/hpu.2021.0158

Admon, L. K., Bart, G., Kozhimannil, K. B., Richardson, C. R., Dalton, V. K., & Winkelman, T. N. (2019). Amphetamine-and opioid-affected births: incidence, outcomes, and costs, United States, 2004–2015. *American journal of public health, 109*(1), 148-154. doi:10.2105/AJPH.2018.304771

Agency for Toxic Substances and Disease Registry. (2021). CDC/ATSDR SVI Data and Documentation Download. Retrieved from https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html. (Accessed July 23, 2021)

American Society of Addiction Medicine. (2020). Buprenorphine Waiver Management. Retrieved from https://www.asam.org/advocacy/practice-resources/buprenorphine-waiver-management. (Accessed September 20, 2020)

Amiri, S., Lutz, R., Socías, M. E., McDonell, M. G., Roll, J. M., & Amram, O. (2018). Increased distance was associated with lower daily attendance to an opioid treatment program in Spokane County Washington. *Journal of substance abuse treatment, 93*, 26-30. doi:https://doi.org/10.1016/j.jsat.2018.07.006

Amiri, S., McDonell, M. G., Denney, J. T., Buchwald, D., & Amram, O. (2021). Disparities in access to opioid treatment programs and office-based buprenorphine treatment across the rural-urban and area deprivation continua: a US nationwide small area analysis. *Value in Health, 24*(2), 188-195.

An Act Requiring Certain Reports For Opiate Overdoses. (2015). Chapter 55. The 192nd General Court of the Commonwealth of Massachusetts. Retrieved from https://malegislature.gov/laws/sessionlaws/acts/2015/chapter55. (Accessed February 17, 2022)

Angelotta, C., Weiss, C. J., Angelotta, J. W., & Friedman, R. A. (2016). A moral or medical problem? The relationship between legal penalties and treatment practices for opioid use disorders in pregnant women. *Women's Health Issues, 26*(6), 595-601.

Arksey, H., & O'Malley, L. (2005). Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology, 8*(1), 19-32. doi:10.1080/1364557032000119616

Au-Yeung, C., Blewett, L., & Winkelman, T. (2021). Increasing Access to Medications for Opioid Use Disorder: Policy Strategies During and After COVID-19 Pandemic. *The Milbank Memorial Fund*. Retrieved from https://www.milbank.org/wp-content/uploads/2021/10/Au-Yeung_Brief_5.pdf. (Accessed November 20, 2020)

Batalova, J., Hanna, M., & Levesque, C. (2021). Frequently Requested Statistics on Immigrants and Immigration in the United States. Retrieved from

https://www.migrationpolicy.org/article/frequently-requested-statistics-immigrants-and-immigration-united-states-2020. (Accessed February 1, 2022)
Beardsley, K., Wish, E. D., Fitzelle, D. B., O'Grady, K., & Arria, A. M. (2003). Distance traveled to outpatient drug treatment and client retention. *Journal of substance abuse treatment, 25*(4), 279-285. doi:10.1016/s0740-5472(03)00188-0
Bell, J., Towers, C. V., Hennessy, M. D., Heitzman, C., Smith, B., & Chattin, K. (2016). Detoxification from opiate drugs during pregnancy. *American journal of obstetrics and gynecology, 215*(3), 374. e371-374. e376.
Bilal, U., Barber, S., Tabb, L., & Diez-Roux, A. V. (2020). Spatial Inequities in COVID-19 Testing, Positivity, Incidence and Mortality in 3 US Cities: a Longitudinal Ecological Study. *medRxiv*. doi:https://doi.org/10.1101/2020.05.01.20087833
Blanco, C., & Volkow, N. D. (2019). Management of opioid use disorder in the USA: present status and future directions. *The Lancet, 393*(10182), 1760-1772. doi:https://doi.org/10.1016/S0140-6736(18)33078-2
Bower, K. M., Thorpe Jr, R. J., Rohde, C., & Gaskin, D. J. (2014). The intersection of neighborhood racial segregation, poverty, and urbanicity and its impact on food store availability in the United States. *Preventive medicine, 58*, 33-39. doi:10.1016/j.ypmed.2013.10.010
Boyars, L., & Guille, C. (2018). Treatment of perinatal opioid use disorder. *Obstetrics and Gynecology Clinics, 45*(3), 511-524.
Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology, 3*(2), 77-101.
Bronfenbrenner, U. (1989). *Ecological systems theory. In R. Vasta (Ed.), Six theories of child development: Revised formulations and current issues* (Vol. 6): Jessica Kingsley Publishers.
Bryant Jr, J., & Delamater, P. L. (2019). Examination of spatial accessibility at micro-and macro-levels using the enhanced two-step floating catchment area (E2SFCA) method. *Annals of GIS, 25*(3), 219-229.
Campbell, S. M., Roland, M. O., & Buetow, S. A. (2000). Defining quality of care. *Social science & medicine, 51*(11), 1611-1625.
Caritis, S. N., & Venkataramanan, R. (2020). Naltrexone use in pregnancy: a time for change. *American journal of obstetrics and gynecology, 222*(1), 1-2. doi:https://doi.org/10.1016/j.ajog.2019.08.041
Carroll, K. M., Chang, G., Behr, H., Clinton, B., & Kosten, T. R. (1995). Improving treatment outcome in pregnant, methadone-maintained women: results from a randomized clinical trial. *American Journal on Addictions, 4*(1), 56-59.
Center for Behavioral Health Statistics and Quality. (2018). 2017 National Survey on Drug Use and Health: Detailed Tables. Substance Abuse and Mental Health Services Administration, Rockville, MD. Retrieved from https://www.samhsa.gov/data/sites/default/files/cbhsq-reports/NSDUHDetailedTabs2017/NSDUHDetailedTabs2017.pdf. (Accessed September 23, 2021)
Centers for Disease Control and Prevention. (2022). Pregnant and Postpartum Women. Retrieved from https://www.cdc.gov/hearher/pregnant-postpartum-women/index.html. (Accessed June 2, 2022)

Centers for Medicare and Medicaid Services. (2020). Maternal Opioid Misuse (MOM) Model. Retrieved from https://innovation.cms.gov/innovation-models/maternal-opioid-misuse-model. (Accessed on May 19, 2020)

Centre for Reviews and Dissemination. (2009). Systematic Reviews: CRD's Guidancefor Undertaking Reviews in Health Care. Retrieved from https://www.york.ac.uk/media/crd/Systematic_Reviews.pdf. (Accessed September 13, 2019)

Chambers, B. D., Baer, R. J., McLemore, M. R., & Jelliffe-Pawlowski, L. L. (2019). Using index of concentration at the extremes as indicators of structural racism to evaluate the association with preterm birth and infant mortality—California, 2011–2012. *Journal of urban health, 96*(2), 159-170. doi:https://doi.org/10.1007/s11524-018-0272-4

Chang, G., Carroll, K. M., Behr, H. M., & Kosten, T. R. (1992). Improving treatment outcome in pregnant opiate-dependent women. *Journal of substance abuse treatment, 9*(4), 327-330.

Chesnokova, A., French, B., Weibe, D., Camenga, D. R., & Yun, K. (2015). Association between neighborhood-level smoking and individual smoking risk: Maternal smoking among Latina women in Pennsylvania. *Public Health Reports, 130*(6), 672-683.

Cochran, G., Hruschak, V., Abdullah, W., Krans, E., Douaihy, A. B., Bobby, S., . . . Tarter, R. (2018). Optimizing pregnancy treatment interventions for moms (OPTI-Mom): A pilot study. *Journal of addiction medicine, 12*(1), 72.

Colquhoun, H. L., Levac, D., O'Brien, K. K., Straus, S., Tricco, A. C., Perrier, L., . . . Moher, D. (2014). Scoping reviews: time for clarity in definition, methods, and reporting. *Journal of clinical epidemiology, 67*(12), 1291-1294.

Commonwealth of Massachusetts. (2015). An act requiring certain reports for opiate overdoses. Retrieved from https://malegislature.gov/Laws/SessionLaws/Acts/2015/Chapter55. (Accessed January 18, 2022)

Crane, D., Marcotte, M., Applegate, M., Massatti, R., Hurst, M., Menegay, M., . . . Williams, S. (2019). A statewide quality improvement (QI) initiative for better health outcomes and family stability among pregnant women with opioid use disorder (OUD) and their infants. *Journal of substance abuse treatment, 102*, 53-59.

Criteria from American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders* (Fifth ed.). Washington, DC: American Psychiatric Association.

Dai, D. (2010). Black residential segregation, disparities in spatial access to health care facilities, and late-stage breast cancer diagnosis in metropolitan Detroit. *Health & place, 16*(5), 1038-1052. doi:https://doi.org/10.1016/j.healthplace.2010.06.012

Dasgupta, S., Bowen, V. B., Leidner, A., Fletcher, K., Musial, T., Rose, C., . . . Pevzner, E. (2020). Association between social vulnerability and a county's risk for becoming a COVID-19 hotspot—United States, June 1–July 25, 2020. *Morbidity and Mortality Weekly Report, 69*(42), 1535. doi:10.15585/mmwr.mm6942a3

DeWeerdt, S. (2019). Tracing the US opioid crisis to its roots: Understanding how the opioid epidemic arose in the United States could help to predict how it might spread to other countries 2019. Retrieved from https://www.nature.com/articles/d41586-019-02686-2 (Accessed on April 26, 2021)

Digital Solution Foundry and EPPI-Centre. (2020). EPPI-Mapper, Version 1.2.5. EPPI-Centre, UCL Social Research Institute, University College London.

Dilts, T. (2020). Mapping with Population-Weighted Centroids. Retrieved from https://www.esri.com/about/newsroom/arcuser/popcentroids/. (Accessed June 3, 2022)

Drug Addiction Treatment Act of 2000. (2000). Pub. L. No.106-310, 114 Stat. 1101. Retrieved from http://www.gpo.gov/fdsys/pkg/PLAW-106publ310/pdf/PLAW-106publ310.pdf. (Accessed April 12, 2021)

Dryden-Peterson, S., Velásquez, G. E., Stopka, T. J., Davey, S., Lockman, S., & Ojikutu, B. (2020). SARS-CoV-2 Testing Disparities in Massachusetts. *medRxiv*, 2020.2011.2002.20224469. doi:10.1101/2020.11.02.20224469

Equator Network. (2019). The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Retrieved from https://www.equator-network.org/reporting-guidelines/strobe/. (Accessed August 9, 2021)

Erika. (2022). Not In My Backyard: 8 Things (2022) You Need to Know. Retrieved from https://gokcecapital.com/not-in-my-backyard/ (accessed June 5, 2022)

ESRI. (2018). Optimized Hot Spot Analysis. Retrieved from https://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-statistics-toolbox/optimized-hot-spot-analysis.htm. (Accessed February 8, 2021)

ESRI Streetmap USA. (2021). CA: Environmental Systems Research Institute. Retrieved from https://www.esri.com/en-us/arcgis/products/arcgis-streetmap-premium/overview?rsource=%2Fdata%2Fstreetmap. (Accessed March 3, 2021)

Fallin-Bennett, A., Elswick, A., & Ashford, K. (2020). Peer support specialists and perinatal opioid use disorder: Someone that's been there, lived it, seen it. *Addictive behaviors, 102*, 106204.

Feng, J., Iser, J. P., & Yang, W. (2016). Medical encounters for opioid-related intoxications in Southern Nevada: sociodemographic and clinical correlates. *BMC Health Services Research, 16*(1), 438. doi:10.1186/s12913-016-1692-z

Fill, M., Miller, A., Wilkinson, R., Warren, M., Dunn, J., Schaffner, W., & Jones, T. (2018). Educational disabilities among children born with neonatal abstinence syndrome. *Pediatrics, 142*(3).

Finch, B. K., Vega, W. A., & Kolody, B. (2001). Substance use during pregnancy in the state of California, USA. *Social science & medicine, 52*(4), 571-583. doi:10.1016/S0277-9536(00)00161-1

Fonti, S., Davis, D., & Ferguson, S. (2016). The attitudes of healthcare professionals towards women using illicit substances in pregnancy: A cross-sectional study. *Women and Birth, 29*(4), 330-335.

Friedmann, P. D., D'Aunno, T. A., Jin, L., & Alexander, J. A. (2000). Medical and psychosocial services in drug abuse treatment: Do stronger linkages promote client utilization? *Health services research, 35*(2), 443.

Gabrielson, S. M. B., Carwile, J. L., O'Connor, A. B., & Ahrens, K. A. (2020). Maternal opioid use disorder at delivery hospitalization in a rural state: Maine, 2009–2018. *Public Health (Elsevier), 181*, 171-179. doi:10.1016/j.puhe.2019.12.014

Godwin, M., Green, S., Jones, H., & Robbins, S. S. (2020). Perinatal Substance Use Disorders Treatment. *N C Med J, 81*(1), 36-40. doi:10.18043/ncm.81.1.36

Goedel, W. C., Shapiro, A., Cerdá, M., Tsai, J. W., Hadland, S. E., & Marshall, B. D. (2020). Association of racial/ethnic segregation with treatment capacity for opioid use disorder

in counties in the United States. *JAMA network open, 3*(4), e203711-e203711. doi:10.1001/jamanetworkopen.2020.3711
Goodman, D. (2015). Improving access to maternity care for women with opioid use disorders: colocation of midwifery services at an addiction treatment program. *Journal of midwifery & women's health, 60*(6), 706-712.
Green, B. N., & Johnson, C. D. (2015). Interprofessional collaboration in research, education, and clinical practice: working together for a better future. *Journal of Chiropractic Education, 29*(1), 1-10.
Guagliardo, M. F. (2004). Spatial accessibility of primary care: concepts, methods and challenges. *International journal of health geographics, 3*(1), 1-13.
Guille, C., Simpson, A. N., Douglas, E., Boyars, L., Cristaldi, K., McElligott, J., . . . Brady, K. (2020). Treatment of Opioid Use Disorder in Pregnant Women via Telemedicine: A Nonrandomized Controlled Trial. *JAMA network open, 3*(1), e1920177-e1920177.
Gulliford, M., Figueroa-Munoz, J., Morgan, M., Hughes, D., Gibson, B., Beech, R., & Hudson, M. (2002). What does' access to health care'mean? *Journal of health services research & policy, 7*(3), 186-188.
Guttmacher. (2019). Substance Use During Pregnancy. Retrieved from https://www.guttmacher.org/state-policy/explore/substance-use-during-pregnancy. (Accessed April 23, 2022)
Habibzadeh, F. (2017). How to report the results of public health research. *Journal of Public Health and Emergency, 1*, 90.
Haffajee, R. L., Lin, L. A., Bohnert, A. S., & Goldstick, J. E. (2019). Characteristics of US counties with high opioid overdose mortality and low capacity to deliver medications for opioid use disorder. *JAMA network open, 2*(6), e196373-e196373. doi:10.1001/jamanetworkopen.2019.6373
Haight, S., Ko, J., Tong, V., Bohm, M., & Callaghan, W. (2018). Opioid Use Disorder Documented at Delivery Hospitalization — United States, 1999–2014. *MMWR Morb Mortal Wkly Rep, 67*, 845–849.
Hand, D. J., Short, V. L., & Abatemarco, D. J. (2017). Treatments for opioid use disorder among pregnant and reproductive-aged women. *Fertility and Sterility, 108*(2), 222-227.
Harley, K., & Eskenazi, B. (2006). Time in the United States, social support and health behaviors during pregnancy among women of Mexican descent. *Social science & medicine, 62*(12), 3048-3061.
Harrell, F. E. (2001). *Regression modeling strategies: with applications to linear models, logistic regression, and survival analysis* (Vol. 608): Springer.
Hedges, L. V., & Citkowicz, M. (2015). Estimating effect size when there is clustering in one treatment group. *Behavior Research Methods, 47*(4), 1295-1308.
Hernandez, M., von Sternberg, K., & Velasquez, M. M. (2020). Alcohol use and problems among Latinas at risk of an alcohol-exposed pregnancy: The role of acculturation and interpersonal factors. *Journal of ethnicity in substance abuse*, 1-14.
Higgins, T. M., Goodman, D. J., & Meyer, M. C. (2019). Treating perinatal opioid use disorder in rural settings: Challenges and opportunities. *Preventive medicine, 128*, 105786.
Hirai, A. H., Ko, J., Y.,, Owens, P. L., Stocks, C., & Patrick, S. W. (2021). Neonatal abstinence syndrome and maternal opioid-related diagnoses in the US, 2010-2017. *Jama, 325*(2), 146-155. doi:110.1001/jama.2020.24991.

Hobbs, S. D., & Medinus, A. (2020). Demographic Differences in Massachusetts All Payer Claims Data (MA APCD) Before and After Gobeille. Retrieved from https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiom8iNkeT3AhWjpIkEHbiLDAIQFnoECAcQAQ&url=https%3A%2F%2Fwww.chiamass.gov%2Fassets%2Fuploads%2FDEMOGRAPHIC-IMPACT-OF-GOBEILLE.pdf&usg=AOvVaw24hcq6RgKcuYbQKUTUIOwh. (Accessed May 16, 2022)

Hodgins, F. E., Lang, J. M., Malseptic, G. G., Melby, L. H., & Connolly, K. A. (2019). Coordinating Outpatient Care for Pregnant and Postpartum Women with Opioid Use Disorder: Implications from the COACHH Program. *Maternal and child health journal, 23*(5), 585-591.

Hogg, W., Rowan, M., Russell, G., Geneau, R., & Muldoon, L. (2008). Framework for primary care organizations: the importance of a structural domain. *International Journal for Quality in Health Care, 20*(5), 308-313.

Jansson, L. M., Svikis, D. S., Velez, M., Fitzgerald, E., & Jones, H. E. (2007). The impact of managed care on drug-dependent pregnant and postpartum women and their children. *Substance use & misuse, 42*(6), 961-974.

Jones, C., Campopiano, M., Baldwin, G., & McCance-Katz, E. (2015). National and state treatment need and capacity for opioid agonist medication-assisted treatment. *American journal of public health, 105*(8), e55-e63. doi:10.2105/AJPH.2015.302664

Jones, H., Haug, N., Silverman, K., Stitzer, M., & Svikis, D. (2001). The effectiveness of incentives in enhancing treatment attendance and drug abstinence in methadone-maintained pregnant women. *Drug and alcohol dependence, 61*(3), 297-306.

Jones, H., Haug, N., Stitzer, M., & Svikis, D. (2000). Improving treatment outcomes for pregnant drug-dependent women using low-magnitude voucher incentives. *Addictive behaviors, 25*(2), 263-267.

Joseph, A. E., & Phillips, D. R. (1984). *Accessibility and utilization: geographical perspectives on health care delivery*. New York: Happer & Row Publishers.

Joshi, C., Russell, G., Cheng, I.-H., Kay, M., Pottie, K., Alston, M., . . . Lo, W. (2013). A narrative synthesis of the impact of primary health care delivery models for refugees in resettlement countries on access, quality and coordination. *International journal for equity in health, 12*(1), 88.

Joshi, C., Skeer, M., Chui, K., & Stopka, T. J. (2022). Spatial and nonspatial factors associated with access to medication for opioid use disorder among pregnant women in Massachusetts: A cross-sectional study. Manuscript submitted for publication.

Joshi, C., Skeer, M. R., Chui, K., Neupane, G., Koirala, R., & Stopka, T. J. (2021). Women-centered drug treatment models for pregnant women with opioid use disorder: A scoping review. *Drug and alcohol dependence, 226*, 108855. doi:https://doi.org/10.1016/j.drugalcdep.2021.108855

Joudrey, P. J., Chadi, N., Roy, P., Morford, K. L., Bach, P., Kimmel, S., . . . Calcaterra, S. L. (2020). Pharmacy-based methadone dispensing and drive time to methadone treatment in five states within the United States: A cross-sectional study. *Drug and alcohol dependence, 211*, 107968. doi:https://doi.org/10.1016/j.drugalcdep.2020.107968

Kahn, L., Mendel, W., Fallin, K., Borngraber, E., Nochajski, T., Rea, W., & Blondell, R. (2017). A parenting education program for women in treatment for opioid-use disorder at an outpatient medical practice. *Social Work in Health Care, 56*(7), 649-665.

Kaiser Family Foundation. (2019). Expanding Postpartum Medicaid Coverage. Retrieved from https://www.kff.org/womens-health-policy/issue-brief/expanding-postpartum-medicaid-coverage/

Kaiser Family Foundation. (2020). Status of State Medicaid Expansion Decisions: Interactive Map. Retrieved from https://www.kff.org/medicaid/issue-brief/status-of-state-medicaid-expansion-decisions-interactive-map/

Klaman, S. L., Isaacs, K., Leopold, A., Perpich, J., Hayashi, S., Vender, J., . . . Jones, H. E. (2017). Treating women who are pregnant and parenting for opioid use disorder and the concurrent care of their infants and children: literature review to support national guidance. *Journal of addiction medicine, 11*(3), 178.

Knudsen, H. K. (2015). The supply of physicians waivered to prescribe buprenorphine for opioid use disorders in the United States: a state-level analysis. *Journal of Studies on Alcohol and Drugs, 76*(4), 644-654. doi:https://doi.org/10.15288/jsad.2015.76.644

Koob, G. F., & Volkow, N. D. (2016). Neurobiology of addiction: a neurocircuitry analysis. *The Lancet Psychiatry, 3*(8), 760-773.

Korthuis, P. T., McCarty, D., Weimer, M., Bougatsos, C., Blazina, I., Zakher, B., . . . Chou, R. (2017). Primary care–based models for the treatment of opioid use disorder: A scoping review. *Annals of Internal Medicine, 166*(4), 268-278.

Krans, E., Bobby, S., England, M., Gedekoh, R., Chang, J., Maguire, B., . . . English, D. (2018). The Pregnancy Recovery Center: A women-centered treatment program for pregnant and postpartum women with opioid use disorder. *Addictive behaviors, 86*, 124-129. doi:10.1016/j.addbeh.2018.05.016

Krans, E., Kim, J., Chen, Q., Rothenberger, S., James, A., Kelley, D., & Jarlenski, M. (2021). Outcomes associated with the use of medications for opioid use disorder during pregnancy. *Addiction, 116*(12), 3504-3514.

Krans, E., Kim, J., James, A., Kelley, D., & Jarlenski, M. (2019). Medication-Assisted Treatment Use Among Pregnant Women With Opioid Use Disorder. *Obstetrics and gynecology, 133*(5), 943-951. doi:10.1097/AOG.0000000000003231

Krieger, N., Feldman, J. M., Waterman, P. D., Chen, J. T., Coull, B. A., & Hemenway, D. (2017). Local residential segregation matters: stronger association of census tract compared to conventional city-level measures with fatal and non-fatal assaults (total and firearm related), using the index of concentration at the extremes (ICE) for racial, economic, and racialized economic segregation, Massachusetts (US), 1995–2010. *Journal of urban health, 94*(2), 244-258. doi:10.1007/s11524-016-0116-z

Krieger, N., Waterman, P. D., Spasojevic, J., Li, W., Maduro, G., & Van Wye, G. (2016). Public health monitoring of privilege and deprivation with the index of concentration at the extremes. *American journal of public health, 106*(2), 256-263.

Laken, M. P., McComish, J. F., & Ager, J. (1997). Predictors of prenatal substance use and birth weight during outpatient treatment. *Journal of substance abuse treatment, 14*(4), 359-366.

Lander, L. R., Gurka, K. K., Marshalek, P. J., Riffon, M., & Sullivan, C. R. (2015). A comparison of pregnancy-only versus mixed-gender group therapy among pregnant women with opioid use disorder. *Social Work Research, 39*(4), 235-244.

Lander, L. R., Marshalek, P., & Sullivan, C. R. (2016). Medication-assisted treatment for pregnant women: An interdisciplinary group based model. *Journal of Groups in Addiction & Recovery, 11*(3), 182-193.

Langabeer, J. R., Stotts, A. L., Cortez, A., Tortolero, G., & Champagne-Langabeer, T. (2020). Geographic proximity to buprenorphine treatment providers in the US. *Drug and alcohol dependence, 213*, 108131. doi:https://doi.org/10.1016/j.drugalcdep.2020.108131

Langford M, Fry R, & Higgs G. (2015). USW-FCA2: An ArcGIS add-In tool to compute Enhanced Two-Step Floating Catchment Area accessibility scores. Retrieved from https://www.researchgate.net/publication/287198887_USW-FCA2_An_ArcGIS_add-In_tool_to_compute_Enhanced_Two-Step_Floating_Catchment_Area_accessibility_scores. (Accessed January 21, 2020)

Langford, M., Higgs, G., & Dallimore, D. J. (2019). Investigating spatial variations in access to childcare provision using network-based Geographic Information System models. *Social Policy & Administration, 53*(5), 661-677. doi:https://doi.org/10.1111/spol.12419

Lind, J. N., Interrante, J. D., Ailes, E. C., Gilboa, S. M., Khan, S., Frey, M. T., . . . Razzaghi, H. (2017). Maternal use of opioids during pregnancy and congenital malformations: a systematic review. *Pediatrics, 139*(6).

Lo-Ciganic, W. H., Donohue, J. M., Kim, J. Y., Krans, E. E., Jones, B. L., Kelley, D., . . . Jarlenski, M. P. (2019). Adherence trajectories of buprenorphine therapy among pregnant women in a large state Medicaid program in the United States. *Pharmacoepidemiology and drug safety, 28*(1), 80-89.

Lopian, K. M., Chebolu, E., Kulak, J. A., Kahn, L. S., & Blondell, R. D. (2019). A retrospective analysis of treatment and retention outcomes of pregnant and/or parenting women with opioid use disorder. *Journal of substance abuse treatment, 97*, 1-6.

Luo, W., & Qi, Y. (2009). An enhanced two-step floating catchment area (E2SFCA) method for measuring spatial accessibility to primary care physicians. *Health & place, 15*(4), 1100-1107. doi:10.1016/j.healthplace.2009.06.002

Mackey, K., Veazie, S., Anderson, J., Bourne, D., & Peterson, K. (2019). Evidence brief: barriers and facilitators to use of medications for opioid use disorder.

Martínez-Mesa, J., González-Chica, D., Duquia, R., Bonamigo, R., & Bastos, J. (2016). Sampling: how to select participants in my research study? *Anais brasileiros de dermatologia, 91*(3), 326-330. doi:10.1590/abd1806-4841.20165254

Massachusetts Department of Public Health. (2017). An Assessment of Fatal and Nonfatal Opioid Overdoses in Massachusetts (2011 – 2015). Retrieved from https://www.mass.gov/files/documents/2017/08/31/legislative-report-chapter-55-aug-2017.pdf. (Accessed May 2, 2022)

Massachusetts Department of Public Health. (2018). Opioid-related overdose deaths continue to decline in Massachusetts. Retrieved from https://www.mass.gov/news/opioid-related-overdose-deaths-continue-to-decline-in-massachusetts. (Accessed September 15, 2021)

Massachusetts Department of Public Health. (2019). Governor Baker Signs Legislation Ending Civil Commitments at MCI-Framingham for Substance Use Disorder Retrieved from https://www.mass.gov/news/governor-baker-signs-legislation-ending-civil-commitments-at-mci-framingham-for-substance-use. (Accessed April 23, 2022)

Massachusetts Department of Public Health. (2021a). Neonatal abstinence syndrome dashboard. Retrieved from https://dphanalytics.hhs.mass.gov/ibmcognos/bi/?pathRef=.public_folders%2FMEPHTN%2Fdph%2FNAS-dashboard%2FNAS%2BDashboard%2BNew%2BData%2Bv6a%2F2022-05-16T15%253A02%253A23.705Z. (Accessed May 31, 2022).

Massachusetts Department of Public Health. (2021b). Number of Opioid-Related Overdose Deaths, All Intents by County, MA Residents: 2010-2020. Retrieved from https://www.mass.gov/doc/opioid-related-overdose-deaths-by-county-november-2021/download. (Accessed September 21, 2021)

Massachusetts Department of Public Health. (2021c). PHD 2.0 Analytic Data Dictionaries. Retrieved from https://www.mass.gov/doc/phd-20-analytic-data-dictionaries-v2-112021/download. (Accessed January 18, 2022)

Massachusetts Department of Public Health. (2021d). PHD Datasets Brief Descriptions. Retrieved from https://www.mass.gov/doc/phd-datasets-brief-descriptions-v2-112021/download. (Accessed January 18, 2022)

Massachusetts Department of Public Health. (2022a). Opioid-related Overdose Deaths among MA Residents – November 2021 Retrieved from https://www.mass.gov/doc/opioid-related-overdose-deaths-among-ma-residents-november-2021/download (Accessed May 13, 2022)

Massachusetts Department of Public Health. (2022b). PHD 2.0 Analytic Data Dictionaries v3 2.2022. Retrieved from https://www.mass.gov/doc/phd-20-analytic-data-dictionaries-v3-22022/download. (Accessed June 5, 2022)

Massachusetts Department of Public Health. (2022c). State Office of Rural Health Rural Definition Retrieved from https://www.mass.gov/service-details/state-office-of-rural-health-rural-definition. (Accessed on June 1, 2022)

Massachusetts Office of the Child Advocate. (2020). The Mandated Reporter Commission. Retrieved from https://www.mass.gov/doc/mandated-reporter-commission-status-report/download. (Accessed on April 26, 2021)

Massachusetts Registry of Vital Records and Statistics. (2022). Massachusetts Death Certificates 2020.

Metz, T. D., Rovner, P., Hoffman, M. C., Allshouse, A. A., Beckwith, K. M., & Binswanger, I. A. (2016). Maternal deaths from suicide and overdose in Colorado, 2004–2012. *Obstetrics and gynecology, 128*(6), 1233.

Meyer, M., Benvenuto, A., Howard, D., Johnston, A., Plante, D., Metayer, J., & Mandell, T. (2012). Development of a substance abuse program for opioid-dependent nonurban pregnant women improves outcome. *Journal of addiction medicine, 6*(2), 124-130.

Meyers, D. J., Hood, M. E., & Stopka, T. J. (2014). HIV and hepatitis C mortality in Massachusetts, 2002–2011: spatial cluster and trend analysis of HIV and HCV using multiple cause of death. *PLoS One, 9*(12), e114822. doi:https://doi.org/10.1371/journal.pone.0114822

Mittal, L., & Suzuki, J. (2017). Feasibility of collaborative care treatment of opioid use disorders with buprenorphine during pregnancy. *Substance abuse, 38*(3), 261-264.

National Academy for State Health Policy. (2016). Massachusetts Becomes First State to Pass Statewide Cap on First-Time Opioid Prescriptions. Retrieved from https://nashp.org/massachusetts-becomes-first-state-to-pass-statewide-cap-on-first-time-opioid-prescriptions/. (Accessed February 23, 2022)

National Institute on Drug Abuse. (2014a). America's addiction to opioids: heroin and prescription drug abuse. Bethesda (MD): NIDA. Retrieved from https://archives.drugabuse.gov/testimonies/2014/americas-addiction-to-opioids-heroin-prescription-drug-abuse. (Accessed September 23, 2021)

National Institute on Drug Abuse. (2014b). Drugs, Brains, and Behavior: The Science of Addiction. Retrieved from https://www.drugabuse.gov/sites/default/files/soa_2014.pdf. (Accessed September 23, 2020)

National Institute on Drug Abuse. (2017). Treating Opioid Use Disorder During Pregnancy. Retrieved from https://nida.nih.gov/publications/treating-opioid-use-disorder-during-pregnancy (Accessed May 25, 2022)

National Institute on Drug Abuse. (2021). The Federal Responses to the Drug Overdose Epidemic. Retrieved from https://nida.nih.gov/about-nida/legislative-activities/testimony-to-congress/2021/the-federal-responses-to-the-drug-overdose-epidemic. (Accessed February 22, 2022)

National Institute on Drug Abuse. (September 2009). InfoFacts: Treatment approaches for drug addiction. Retrieved from http://www.drugabuse.gov/publications/drugfacts/treatment-approaches-drugaddiction. (Accessed September 23, 2020)

Neonatal Quality Improvement Collaborative of Massachusetts. (2017). Improving the Care of Substance-Exposed Newborns and their Families:A Massachusetts Quality Improvement Initiative. Retrieved from https://b21a2104-8467-430f-9b8f-1e89273454a5.filesusr.com/ugd/55ea1e_29a50555bf874d92b0b250898583de67.pdf. (Accessed September 23, 2020)

Niles, J. K., Gudin, J., Radcliff, J., & Kaufman, H. W. (2021). The opioid epidemic within the COVID-19 pandemic: drug testing in 2020. *Population Health Management, 24*(S1), S-43-S-51.

NVIVO. (2020). Retrieved from https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/about/nvivo

Ochalek, T. A., Cumpston, K. L., Wills, B. K., Gal, T. S., & Moeller, F. G. (2020). Nonfatal opioid overdoses at an urban emergency department during the COVID-19 pandemic. *Jama, 324*(16), 1673-1674.

Ostrach, B., & Leiner, C. (2019). "I didn't want to be on Suboxone at first…"–Ambivalence in Perinatal Substance Use Treatment. *Journal of addiction medicine, 13*(4), 264-271.

Pagano, A. (2014). Barriers to drug abuse treatment for Latino migrants: Treatment providers' perspectives. *Journal of ethnicity in substance abuse, 13*(3), 273-287. doi:10.1080/15332640.2014.886320

Page, N., Langford, M., & Higgs, G. (2019). Measuring spatial accessibility to services within indices of multiple deprivation: implications of applying an enhanced two-step floating catchment area (E2SFCA) approach. *Applied Spatial Analysis and Policy, 12*(2), 321-348.

Palombi, L. C., St Hill, C. A., Lipsky, M. S., Swanoski, M. T., & Lutfiyya, M. N. (2018). A scoping review of opioid misuse in the rural United States. *Annals of epidemiology, 28*(9), 641-652.

Park, J. N., Rouhani, S., Beletsky, L., Vincent, L., Saloner, B., & Sherman, S. G. (2020). Situating the Continuum of Overdose Risk in the Social Determinants of Health: A New Conceptual Framework. *Milbank Q, 98*(3), 700-707.

Paterno, M. T., Jablonski, L., Klepacki, A., & Friedmann, P. D. (2019). Evaluation of a Nurse-Led Program for Rural Pregnant Women With Opioid Use Disorder to Improve Maternal–Neonatal Outcomes. *Journal of Obstetric, Gynecologic & Neonatal Nursing, 48*(5), 495-506.

Patrick, S., Buntin, M., Martin, P., Scott, T., Dupont, W., Richards, M., & Cooper, W. (2019). Barriers to accessing treatment for pregnant women with opioid use disorder in Appalachian states. *Substance abuse, 40*(3), 356-362. doi:10.1080/08897077.2018.1488336

Patrick, S., Davis, M., Lehmann, C., & Cooper, W. (2015). Increasing incidence and geographic distribution of neonatal abstinence syndrome: United States 2009 to 2012. *J Perinatol. , 35*(8), 650–655.

Patrick, S., Faherty, L., Dick, A., Scott, T., Dudley, J., & Stein, B. (2019). Association Among County-Level Economic Factors, Clinician Supply, Metropolitan or Rural Location, and Neonatal Abstinence Syndrome. *Jama, 321*(4), 385-393.

Penchansky, R., & Thomas, J. W. (1981). The concept of access: definition and relationship to consumer satisfaction. *Medical care*, 127-140.

Perreira, K. M., & Cortes, K. E. (2006). Race/ethnicity and nativity differences in alcohol and tobacco use during pregnancy. *American journal of public health, 96*(9), 1629-1636.

Petry, N. M. (2011). Contingency management: what it is and why psychiatrists should want to use it. *The psychiatrist, 35*(5), 161-163.

Pope, C., Ziebland, S., & Mays, N. (2000). Qualitative research in health care. Analysing qualitative data. *BMJ, 320*(7227), 114-116.

Powell, D., Williams, A., Larsen, K., Perkins, D., Roland, M., & Harris, M. (2008). Coordinating primary health care: an analysis of the outcomes of a systematic review. *Medical Journal of Australia, 188*, S65-S68.

Radel, L., Baldwin, M., Crouse, G., Ghertner, R., & Waters, A. (2018). Substance use, the opioid epidemic, and the child welfare system: Key findings from a mixed methods study. *Office of the Assistant Secretary for Planning and Evaluation*.

Reising, V. A., Horne, A., & Bennett, A. C. (2021). The interaction of neonatal abstinence syndrome and opioid use disorder treatment availability for women insured by medicaid. *Public Health Nursing, 38*(1), 98-105.

Research Data Assistance Center. (2016). Introduction to Medicaid: Overview of the Medicaid Program. Retrieved from https://www.resdac.org/videos/overview-medicaid-program. (Accessed September 23, 2020)

Rhyan, C. (2017). The potential societal benefit of eliminating opioid overdoses, deaths, and substance use disorders exceeds $95 billion per year. *Altarum, November*.

Rodriguez, C. E., & Klie, K. A. (2019). *Pharmacological treatment of opioid use disorder in pregnancy.* Paper presented at the Seminars in perinatology.

Rose-Jacobs, R., Trevino-Talbot, M., Vibbert, M., Lloyd-Travaglini, C., & Cabral, H. J. (2019). Pregnant women in treatment for opioid use disorder: Material hardships and psychosocial factors. *Addictive behaviors, 98*, 106030.

Rosenblatt, R. A., Andrilla, C. H. A., Catlin, M., & Larson, E. H. (2015). Geographic and specialty distribution of US physicians trained to treat opioid use disorder. *The Annals of Family Medicine, 13*(1), 23-26. doi:https://doi.org/10.1370/afm.1735

Rosenblum, A., Cleland, C. M., Fong, C., Kayman, D. J., Tempalski, B., & Parrino, M. (2011). Distance traveled and cross-state commuting to opioid treatment programs in the United States. *Journal of environmental and public health, 2011*.

Rubenstein, E., Young, J. C., Croen, L. A., DiGuiseppi, C., Dowling, N. F., Lee, L. C., . . . Daniels, J. (2019). Brief Report: Maternal Opioid Prescription from Preconception Through

Pregnancy and the Odds of Autism Spectrum Disorder and Autism Features in Children. *J Autism Dev Disord, 49*(1), 376-382. doi:10.1007/s10803-018-3721-8

SAS®. (2021). Retrieved from https://www.sas.com/en_us/curiosity.html?utm_source=other&utm_medium=cpm&utm_campaign=non-cbo-us&dclid=&gclid=CjwKCAjwuvmHBhAxEiwAWAYj-Lk1GbsLSY3_fYxPPFJKSbhHglLHaGE9_RyLErJ2JkUeMm3A93rWFBoC-osQAvD_BwE. (Accessed July 27, 2021)

Schiff, D. M. (2019). Racial and Ethnic Disparities in the Utilization of Medication for Opioid Use Disorder in the Year Prior to Delivery in Massachusetts. Retrieved from https://amersa.org/wp-content/uploads/2019/oral/racial-use.pdf. (Accessed September 23, 2021)

Schiff, D. M., Nielsen, T., Hoeppner, B. B., Terplan, M., Hansen, H., Bernson, D., . . . Selk, S. (2020). Assessment of Racial and Ethnic Disparities in the Use of Medication to Treat Opioid Use Disorder Among Pregnant Women in Massachusetts. *JAMA network open, 3*(5), e205734. doi:10.1001/jamanetworkopen.2020.5734

Short, V. L., Hand, D. J., MacAfee, L., Abatemarco, D. J., & Terplan, M. (2018). Trends and disparities in receipt of pharmacotherapy among pregnant women in publically funded treatment programs for opioid use disorder in the United States. *Journal of substance abuse treatment, 89*, 67-74.

Shreffler, J., Shoff, H., Thomas, J. J., & Huecker, M. (2021). Brief Report: The Impact of COVID-19 on Emergency Department Overdose Diagnoses and County Overdose Deaths. *The American Journal on Addictions, 30*(4), 330-333.

Silverman, K., Svikis, D., Robles, E., Stitzer, M. L., & Bigelow, G. E. (2001). A reinforcement-based therapeutic workplace for the treatment of drug abuse: six-month abstinence outcomes. *Experimental and clinical psychopharmacology, 9*(1), 14.

Singh, R., Rothstein, R., Ricci, K., Visintainer, P., Shenberger, J., Attwood, E., & Friedmann, P. (2020). Partnering with parents to improve outcomes for substance exposed newborns—a pilot program. *Journal of Perinatology, 40*(7), 1041-1049.

Sloboda, Z., Glantz, M. D., & Tarter, R. E. (2012). Revisiting the concepts of risk and protective factors for understanding the etiology and development of substance use and substance use disorders: Implications for prevention. *Substance use & misuse, 47*(8-9), 944-962.

Smid, M. C., Stone, N., Baksh, L., Debbink, M. P., Einerson, B. D., Varner, M. W., . . . Clark, E. A. (2019). Pregnancy-associated death in Utah: contribution of drug-induced deaths. *Obstetrics and gynecology, 133*(6), 1131.

Society of Actuaries. (2019). Economic Impact of Non-Medical Opioid Use in the United States. Retrieved from https://www.soa.org/globalassets/assets/files/resources/research-report/2019/econ-impact-non-medical-opioid-use.pdf. (Accessed September 23, 2020)

Sordo, L., Barrio, G., Bravo, M. J., Indave, B. I., Degenhardt, L., Wiessing, L., . . . Pastor-Barriuso, R. (2017). Mortality risk during and after opioid substitution treatment: systematic review and meta-analysis of cohort studies. *BMJ, 357*.

Stein, B. D., Dick, A. W., Sorbero, M., Gordon, A. J., Burns, R. M., Leslie, D. L., & Pacula, R. L. (2018). A population-based examination of trends and disparities in medication treatment for opioid use disorders among Medicaid enrollees. *Substance abuse, 39*(4), 419-425.

Stein, B. D., Gordon, A. J., Dick, A. W., Burns, R. M., Pacula, R. L., Farmer, C. M., . . . Sorbero, M. (2015). Supply of buprenorphine waivered physicians: the influence of state policies. *Journal of substance abuse treatment, 48*(1), 104-111. doi:10.1016/j.jsat.2014.07.010

Stewart, R. D., Nelson, D. B., Adhikari, E. H., McIntire, D. D., Roberts, S. W., Dashe, J. S., & Sheffield, J. S. (2013). The obstetrical and neonatal impact of maternal opioid detoxification in pregnancy. *American journal of obstetrics and gynecology, 209*(3), 267. e261-267. e265.

Stopka, T. J., Krawczyk, C., Gradziel, P., & Geraghty, E. M. (2014). Use of spatial epidemiology and hot spot analysis to target women eligible for prenatal women, infants, and children services. *American journal of public health, 104*(S1), S183-S189.

Substance Abuse and Mental Health Services Administration. (2009). *Substance Abuse Treatment: Addressing the Specific Needs of Women. Treatment Improvement Protocol (TIP) Series, No. 51. HHS Publication No. (SMA) 13-4426. Rockville, MD: Substance Abuse and Mental Health Services Administration.*

Substance Abuse and Mental Health Services Administration. (2013). A Standard Framework for Levels of Integrated Healthcare. Retrieved from https://www.pcpcc.org/sites/default/files/resources/SAMHSA-HRSA%202013%20Framework%20for%20Levels%20of%20Integrated%20Healthcare.pdf . (Accessed on August 10, 2020)

Substance Abuse and Mental Health Services Administration. (2015). Federal guidelines for opioid treatment programs. HHS publication no (SMA) PEP15-FEDGUIDEOTP. Rockville, MD: Substance Abuse and Mental Health Services Administration.

Substance Abuse and Mental Health Services Administration. (2016). A collaborative approach to the treatment of pregnant women with opioid use disorder. Retrieved from http://store.samhsa.gov/. (Accessed on February 19, 2020)

Substance Abuse and Mental Health Services Administration. (2018). *Clinical Guidance for Treating Pregnant and Parenting Women With Opioid Use Disorder and Their Infants*(Vol. HHS Publication No. (SMA) 18-5054). Retrieved from https://store.samhsa.gov/product/Clinical-Guidance-for-Treating-Pregnant-and-Parenting-Women-With-Opioid-Use-Disorder-and-Their-Infants/SMA18-5054. (Accessed September 23, 2020)

Substance Abuse and Mental Health Services Administration. (2021a). Become a Buprenorphine Waivered Practitioner. Retrieved from https://www.samhsa.gov/medication-assisted-treatment/become-buprenorphine-waivered-practitioner. (Accessed September 23, 2021)

Substance Abuse and Mental Health Services Administration. (2021b). Buprenorphine Practitioner Locator. Retrieved from https://www.samhsa.gov/medication-assisted-treatment/practitioner-program-data/treatment-practitioner-locator. (Accessed March 3, 2021)

Substance Abuse and Mental Health Services Administration. (2021c). SAMHSA treatment locator. Retrieved from https://findtreatment.samhsa.gov/locator. (Accessed March 3, 2021)

Substance Abuse and Mental Health Services Administration, & National Survey of Substance Abuse Treatment Services. (2020). Data on Substance Abuse Treatment Facilities. Rockville, MD: Substance Abuse and Mental Health Services Administration, 2021.

Sutter, M. B., Watson, H., Bauers, A., Johnson, K., Hatley, M., Yonke, N., & Leeman, L. (2019). Group prenatal care for women receiving medication-assisted treatment for opioid use disorder in pregnancy: an interprofessional approach. *Journal of midwifery & women's health, 64*(2), 217-224.

Svikis, D. S., Lee, J. H., Haug, N. A., & Stitzer, M. L. (1997). Attendance incentives for outpatient treatment: effects in methadone-and nonmethadone-maintained pregnant drug dependent women. *Drug and alcohol dependence, 48*(1), 33-41.

Terplan, M., Longinaker, N., & Appel, L. (2015). Women-centered drug treatment services and need in the United States, 2002-2009. *American journal of public health, 105*(11), e50-e54. doi:10.2105/AJPH.2015.302821

The American College of Obstetricians and Gynecologists. (2017). Opioid Use and Opioid Use Disorder in Pregnancy: ACOG Committee Opinion. Retrieved from https://www.acog.org/Clinical-Guidance-and-Publications/Committee-Opinions/Committee-on-Obstetric-Practice/Opioid-Use-and-Opioid-Use-Disorder-in-Pregnancy?IsMobileSet=false#neonatal. (Accessed September 23, 2020)

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., . . . Straus, S. E. (2018). PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Annals of Internal Medicine, 169*(7), 467-473. doi:10.7326/m18-0850

Tuten, M., Svikis, D. S., Keyser-Marcus, L., O'Grady, K. E., & Jones, H. E. (2012). Lessons learned from a randomized trial of fixed and escalating contingency management schedules in opioid-dependent pregnant women. *The American journal of drug and alcohol abuse, 38*(4), 286-292.

United States Census Bureau. (2020). ZIP Code Tabulation Areas (ZCTAs). Retrieved from https://www.census.gov/programs-surveys/geography/guidance/geo-areas/zctas.html. (Accessed July 26, 2021)

United States Census Bureau. (2021a). 2020 TIGER/Line® Shapefiles: ZIP Code Tabulation Areas. Retrieved from https://www.census.gov/cgi-bin/geo/shapefiles/index.php?year=2020&layergroup=ZIP+Code+Tabulation+Areas. (Accessed March 1, 2021)

United States Census Bureau. (2021b). Explore Census Data Retrieved from https://data.census.gov/cedsci/. (Accessed March 22, 2021)

United States Census Bureau. (2022a). Quick Facts Massachusetts. Retrieved from https://www.census.gov/quickfacts/fact/map/MA/POP060210. (Accessed on June 1, 2022)

United States Census Bureau. (2022b). ZIP Code Tabulation Areas (ZCTAs). Retrieved from https://www.census.gov/programs-surveys/geography/guidance/geo-areas/zctas.html. Accessed July 4, 2022

United States Department of Agriculture. (2020). Rural-Urban Commuting Area Codes. Retrieved from https://www.ers.usda.gov/data-products/rural-urban-commuting-area-codes/. (Accessed January 19, 2021)

US Census Bureau. Census regions and divisions of the United States. Retrieved from https://www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf. (Accessed September 23, 2020)

Vittinghoff, E., Glidden, D., Shiboski, S., & McCulloch, C. (2012). *Regression Methods in Biostatistics: Linear, Logistic, Survival, and Repeated Measures Models* (Second ed.).

von Hippel, P. T. (2007). 4. Regression with missing Ys: an improved strategy for analyzing multiply imputed data. *Sociological Methodology, 37*(1), 83-117.

Wainwright, J. J., Mikre, M., Whitley, P., Dawson, E., Huskey, A., Lukowiak, A., & Giroir, B. P. (2020). Analysis of drug test results before and after the US declaration of a national emergency concerning the COVID-19 outbreak. *Jama, 324*(16), 1674-1677.

Wang, F., & Luo, W. (2005). Assessing spatial and nonspatial factors for healthcare access: towards an integrated approach to defining health professional shortage areas. *Health & place, 11*(2), 131-146.

Welle-Strand, G. K., Skurtveit, S., Tanum, L., Waal, H., Bakstad, B., Bjarkø, L., & Ravndal, E. (2015). Tapering from Methadone or Buprenorphine during Pregnancy: Maternal and Neonatal Outcomes in Norway 1996-2009. *European Addiction Research, 21*(5), 253-261. doi:10.1159/000381670

Wilder, C., Lewis, D., & Winhusen, T. (2015). Medication assisted treatment discontinuation in pregnant and postpartum women with opioid use disorder. *Drug and alcohol dependence, 149*, 225-231.

Winkelman, T., Chang, V., & Binswanger, I. (2018). Health, polysubstance use, and criminal justice involvement among adults with varying levels of opioid use. *JAMA network open, 1*(3), e180558.

Winkelman, T., Villapiano, N., Kozhimannil, K., Davis, M., & Patrick, S. (2018). Incidence and costs of neonatal abstinence syndrome among infants with Medicaid: 2004–2014. *Pediatrics, 141*(4), e20173520.

Wolf, E. R., Tong, S. T., Sabo, R. T., Woolf, S. H., Abbinanti, K., Pecsok, J., & Krist, A. H. (2019). A state-level study of opioid use disorder treatment access and neonatal abstinence syndrome. *BMC pediatrics, 19*(1), 1-8.

World Health Organization. (2010). Framework for Action on Interprofessional Education & Collaborative Practice (WHO/HRH/HPN/10.3). Retrieved from https://apps.who.int/iris/bitstream/handle/10665/70185/WHO_HRH_HPN_10.3_eng.pdf;jsessionid=FAE8F5F608E8FB533790655373934AFD?sequence=1. (Accessed September 23, 2020)

World Health Organization. (2014). Guidelines for the Identification and Management of Substance Use and Substance Use Disorders in Pregnancy. Geneva, Switzerland: WHO Document Production Services. Retrieved from https://apps.who.int/iris/bitstream/handle/10665/107130/9789241548731_eng.pdf?sequence=1. (Accessed September 23, 2020)

Yazdy, M. M., Desai, R. J., & Brogly, S. B. (2015). Prenatal exposures and short and long term developmental outcomes: prescription opioids in pregnancy and birth outcomes: a review of the literature. *Journal of pediatric genetics, 4*(2), 56.

Yu, J., Clark, L. P., Chandra, L., Dias, A., & Lai, T.-F. M. (2009). Reducing cultural barriers to substance abuse treatment among Asian Americans: A case study in New York City. *Journal of substance abuse treatment, 37*(4), 398-406. doi:10.1016/j.jsat.2009.05.006