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Barriers to Prenatal Care in the Context of Maternal Methamphetamine Use and Congenital Syphilis in Los Angeles County, 2011-2020

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Community Health Sciences

by

Eunhee Park

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ABSTRACT OF THE DISSERTATION

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Doctor of Philosophy in Community Health Sciences

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Professor Jennifer Ann Wagman, Chair

Congenital syphilis is preventable, yet rising public health crisis in the United States, particularly in Los Angeles County (LAC). This intersecting epidemics of sexually transmitted infections (STI), substance use, and structural inequities disproportionately affect pregnant and birthing persons. This dissertation examines the barriers to prenatal care in the context of methamphetamine use and its contribution to the increasing rates of congenital syphilis between 2011 and 2020.

Guided by a Reproductive Justice framework and Syndemic theory, this study utilized STI surveillance data and administrative data to measure burden of methamphetamine and examines how it is associated with congenital syphilis prevention barriers that are at individual, institutional, and community levels. Analytic methods included multivariate logistic regression, structural equation modeling, and spatiotemporal Bayesian modeling using integrated Nested Laplace Approximation. These methods evaluated the association between methamphetamine use and lack of syphilis treatment/prenatal care in the context of pregnancy, Syndemic risk, and policy change.

Chapter Two assessed whether pregnancy status moderated the association between methamphetamine use and syphilis treatment (Aim 1). Chapter Three applied structural equation modeling to identify how Syndemic factors mediated the relationship between methamphetamine use and lack of prenatal care, with attention to racial disparities (Aim 2). Chapter Four mapped spatiotemporal trends in CS rates across LAC Health Districts, accounting for methamphetamine-related arrests and social vulnerability (Aim 3).

Findings indicated that persons of reproductive potential (PRP) who are pregnant had 50% less likelihood of getting syphilis treatment compared to non-pregnant counterparts (Aim 1). Latinx birthing persons experienced high Syndemic burdens, and methamphetamine use was pronounced among Black birthing persons (Aim 2). Upward trends in methamphetamine use and prenatal care gaps emerged following policy change in 2015 (Aim 3).

This dissertation aims to identify how individual and structural level determinants of health interact to shape reproductive health outcomes among pregnant persons with diagnosed (and undiagnosed) syphilis. It underscores the urgent need to integrate STI care and harm reduction approaches in conjunction with sexual and reproductive health services in areas most affected by congenital syphilis.

The dissertation of Eunhee Park is approved.

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University of California, Los Angeles

2025

DEDICATION

To every person who carries the sacred right,

to have a child,

to choose not to, and

to raise children in communities that cherish their health, safety, and dignity.

I am deeply grateful to my husband, parents, family, friends, collogues, mentors, and especially to my two sons, who remind me every day why this work matters.

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LIST OF ACRONYMS

ACS	American Community Survey
AIC	Akaike's Information Criterion
AUC	Area Under the Curve
BIC	Bayesian Information Criterion
CDC	Center of Disease Control and Prevention
CFI	Comparative Fit Index
CI	Confidence Interval
CPO	Conditional Predictive Ordinate
CS	Congenital Syphilis
DCFS	Department of Child and Family Services
DHSP	Division of HIV and STD Programs
DIC	Deviance Information Criterion
DPH	Department of Public Health
DUA	Data Use Agreement
FTA-ABS	Fluorescent Treponemal Antibody Absorption Test
HD	Health District
INLA	Integrated Nested Laplace Approximation
LAC	Los Angeles County
LRT	Likelihood Ratio Test
MCH	Maternal and Child Health
Meth	Methamphetamine
MMRIA	Maternal Mortality Review Information Application
OR	Odds Ratio
P&S Syphilis	Primary and Secondary Syphilis
PHN	Public Health Nurse
PNC	Prenatal Care
PRP	Persons of Reproductive Potential, assigned female at birth aged 15 to 44
PTSD	Post-Traumatic Stress Disorder
RMSEA	Root Mean Square Error of Approximation
ROC	Receiver Operating Characteristic
RPR	Rapid Plasma Reagin
RR	Relative Risk
RW2	Second-order Random Walk
SEM	Structural Equation Modeling
SPA	Service Planning Areas
SRMR	Standardized Root Mean Square Residual
STD	Sexually Transmitted Disease
STI	Sexually Transmitted Infection
SVI	Social Vulnerability Index
YLL	Years of Life Lost

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Park E. Barriers to prenatal care in the context of maternal methamphetamine use and congenital syphilis in Los Angeles County, 2011-2020. 16th International Women’s and Children’s Health and Gender (InWomen’s) Group Conference. [Oral Presentation] Online. May 31, 2024.

Chapter 1. Introduction

Once considered an infection nearing elimination, congenital syphilis (CS) has re-emerged, unfolding into a new epidemic since early 2010s, even with penicillin being the definitive and effective treatment for syphilis.[1–3] To Address this public health crisis and elevate it as a national priority, the National Syphilis and Congenital Syphilis Syndemic Federal Task Force has been established as of November 15, 2023.[4] The Department of Health and Human Services aims to reduce CS rate as a critical part of *Health People 2030* objectives. It aims to achieve a significant reduction in the CS rate, targeting 33.9 cases per 100,000 live births by 2030, down from the baseline rate of 48.5 cases per 100,000 live births in 2019.[5] In comparison to the national average CS rate, California has a CS rate nearly twice as high, at 114.9 cases per 100,000 live births, while Los Angeles County surpasses the California average with a rate of 125.8 cases per 100,000 live births.[6]

CS results from the vertical transmission of the bacterium, *Treponema pallidum*, from a pregnant person with untreated or inadequately treated syphilis to the fetus during pregnancy via the placenta, or to the infant during delivery through contact with syphilitic lesions in the birth canal.[6,7] It can result in miscarriage, stillbirth, infant death, or severe medical issues for the newborn that includes, but not limited to, bone damage, severe anemia, enlarged liver and spleen, jaundice, nerve problems causing blindness, deafness, meningitis, or skin rashes.[8,9] While CS is easily preventable by treating maternal syphilis infection with a benzathine penicillin G regimen at least 30 days before delivery (98% efficacious in CS prevention),[6] some pregnant persons are not able to get the syphilis treatment during pregnancy. Factors associated with CS cases include maternal substance use,[10–12] lack of prenatal care (PNC),[12–20] maternal history of incarceration,[21–24] homelessness,[11,20,25] and being Black or Hispanic.[7,13,14,18,26,26–29] Therefore, CS crisis is seen as a stark illustration of deep-rooted reproductive health inequities in the United States.[7,21,25,27,28,30–33] Given its entanglement with multiple systems of inequities, including housing instability, criminalization of substance use during pregnancy, and limited access to in Los Angeles County, methamphetamine (meth) use represents a critical Syndemic factor driving CS risk. From a The Reproductive Justice perspective, substance use should not preclude access to respectful, timely, and adequate PNC. Guided by Syndemic theory, this dissertation centers meth use not as an individual behavior, but as a marker of deeper structural inequities that shape reproductive health outcomes.

This dissertation is organized into an introduction and three chapters, each chapter corresponding to one of the study's three research aims, followed by a discussion synthesizing study findings. The introductory section presents background information, defines key concepts, outlines the public health significance of CS, and details the theoretical and methodological frameworks guiding the study. Following chapters aligns with each research aim and the chapter is structured with its own introduction, methods, results, and discussion sections. Chapter Two addresses Aim 1 and examines whether pregnancy status moderates the association between meth use and syphilis treatment among persons of reproductive potential. Chapter Three focuses on Aim 2 and investigates the pathways between maternal meth use, Syndemic burden, and prenatal care utilization among birthing people of infants born with CS, with a focus on racial disparities. Chapter Four presents Aim 3, which uses spatiotemporal analysis to assess trends in CS across health districts in Los Angeles County from 2011 to 2020, in relation to structural factors such as social vulnerability and meth-related arrests. Chapter five synthesizes key findings across all aims, highlights cross-cutting themes, addresses study limitations, and offers public health implications for stakeholders. This study aims to provide a comprehensive, multilevel analysis of how meth use, social vulnerability, and systemic inequities shape factors associated with CS to inform targeted, person-centered interventions aimed at reversing the rising CS trend.

1. Definition of Key Terms and Concepts

Syphilis

Treponema pallidum is a spirochaete bacterium with various subspecies that causes syphilis through sexual exposure or vertical transmission during pregnancy.[8] *Treponema pallidum* is known for its invasiveness and immune evasiveness.[9] Syphilis has a long latent period during which patients have no signs or symptoms, but can remain infectious.[8] Despite the availability of simple diagnostic tests and the effectiveness of treatment with a single dose of long-acting penicillin, syphilis is re-emerging as a global public health problem.[3] Syphilis typically advances through a series of stages that may span weeks, months, or even years as shown in Figure 1.

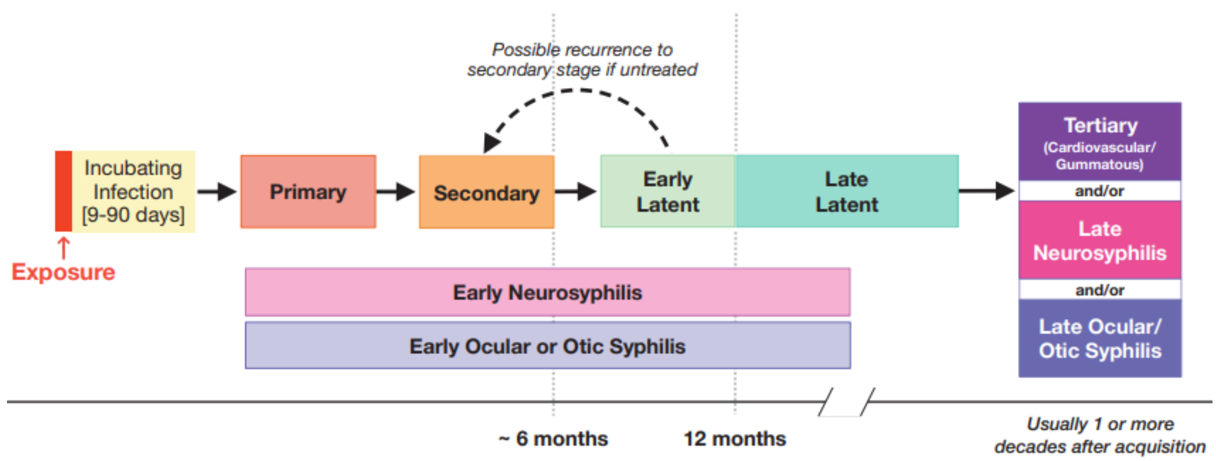


Figure 1. The Natural History of Untreated Syphilis

Note: Schematic drawing of the natural history of untreated syphilis. Reprinted from *The Diagnosis, Management, and Prevention of Syphilis. An Update and Review* (p.3), by New York City STD Prevention Training Center (2019)

Stages of Syphilis

Primary Syphilis: A single sore, called a chancre appears during the primary stage and there might be multiple sores in some cases.[34] The sore appears where the bacteria entered the body and it's typically painless and may go unnoticed, especially if it's inside the mouth or genital region.[6] The sore lasts for 3-6 weeks and heals on its own regardless of whether the person receives treatment or not.[34] However, without treatment, the person will progress to the next stage.[34]

Secondary Syphilis: Symptoms for the secondary stage include skin rashes, fever, swollen lymph nodes, fatigue, sore throat, weight loss, hair loss, headaches, and muscle aches and they last for a few weeks after the original sore heals.[34] These symptoms will also resolve with or without treatment, but without treatment, the infection will continue to progress.

Latent (hidden) Syphilis: After the secondary stage, *Treponema pallidum* become dormant and the infected person has no visible symptoms during this time.[6] This latent period can last for years.[34] The disease can either stay latent for life or progress to the tertiary stage.[34]

Tertiary (late) Syphilis: This is the most severe stage and can occur years or even decades after the initial infection.[34] Complications at this stage can affect multiple organs, including the heart, brain, and nerves that could lead to paralysis, numbness, gradual blindness, dementia, and even death.[34]

Congenital Syphilis: CS occurs when a pregnant person with syphilis passes the bacteria to her unborn child. This can result in miscarriage, stillbirth, or severe medical issues for the newborn that includes, but not limited to, bone damage, severe anemia, enlarged liver and spleen, jaundice, nerve problems causing blindness or deafness, meningitis, or skin rashes.[6,35]

Diagnosis of Syphilis During Pregnancy

Prenatal syphilis diagnosis utilizes a combination of treponemal and non-treponemal tests. Treponemal tests (e.g., *Treponema Pallidum* Particle Agglutination (TP-PA) test, Fluorescent Treponemal Antibody Absorption test (FTA-ABS), *Treponema Pallidum* Enzyme Immunoassay (TP-EIA), *Treponema Pallidum* Chemiluminescence Assay (TP-CIA) identify antibodies against *Treponema Pallidum* and Non-treponemal Tests (e.g., Venereal disease research laboratory (VDRL), Rapid Plasma Reagin (RPR) identify antibodies from cellular damage due to infection.[35] Treponemal tests generally remain positive for life, even after successful treatment, while a negative result indicates no infection.[35] In pregnant women with no syphilis risk factors, a negative treponemal test followed by a positive non-treponemal test is likely a false positive, which can occur due to various infections (Epstein-Barr virus, hepatitis, HIV, varicella, measles, tuberculosis, malaria, endocarditis), specific health conditions (lymphoma, connective tissue disorders), pregnancy, and drug use.[1,35]

Syphilis Treatment During Pregnancy

Treatment ranges from a single dose to three weekly doses depending on the stage of syphilis infection. Specifically, early-stage syphilis (primary, secondary, and early latent) requires only a single dose of 2.4 million units of benzathine penicillin G, while late latent, unknown duration, or tertiary syphilis is treated with three doses of penicillin G administered weekly for three weeks.[35] Timely identification and treatment of partners are critical to preventing reinfection in pregnant women after initial treatment of perinatal syphilis.[28]

For pregnant women with risk factors for syphilis infection (multiple sex partners, drug use, housing insecurity), holistic, nonjudgmental, and enhanced outpatient preventative strategies are recommended by the Center of Disease Control and Prevention (CDC).[36–39] This approach includes prenatal screening for syphilis at the first point of medical contact (i.e., emergency rooms, pregnancy testing sites, primary care clinics, vaccination clinics, mental health clinics, and detention facilities), targeted education for front-line healthcare providers on diagnosis and follow-up of pregnant patients at risk of syphilis infection, and consistent monitoring of public and private laboratories to ensure the prompt and thorough reporting of perinatal syphilis.[35] In addition, mobile clinics for substance use and HIV testing may serve as high-impact locations for screening at-risk populations that may otherwise not seek timely PNC.[1,35]

Methamphetamine

While the opioid epidemic has garnered worldwide attention, increasing meth use has drawn less scrutiny.[40–43] Meth is a highly addictive illicit substance and a potent central nervous system stimulant. Meth produces a rapid, pleasurable rush with euphoria, heightened attention, decreased appetite, and increased energy.[44] Immediate physiological responses after meth use are similar to those produced by the "fight-or-flight" response and include increased blood pressure, body temperature, heart rate, and breathing rate.[45] Negative side effects include stroke, cardiac arrhythmia, stomach cramps, and shaking, as well as increased anxiety, insomnia, aggression, paranoia, and hallucinations.[45] Chronic meth use is associated with mental disorders like depression and psychosis; cognitive and neurological deficits; cardiovascular and renal dysfunctions; transmission of HIV, viral hepatitis, and sexually transmitted infections; and increased mortality.[46–48]

Meth was called as a blue collar drug as the use was limited to Caucasian men who were truck drivers and construction workers in 1980's because it was known to enhance job performance or ability to perform in monotonous, and physically exhausting occupations.[49,50] The meth supply expanded in 1990's as large laboratories in Southern California and Northern Mexico produced pure and potent form of meth at a lower price expanding its consumer basis to Latinxs, Asian/Pacific Islanders, Native Americans, gay and bisexual men, incarcerated population, women, and adolescents.[50] Many federal laws passed to restrict precursor chemicals of meth and those laws include the following: the Comprehensive Drug Abuse Prevention and Control Act in 1970; Chemical Diversion and Trafficking Act in 1989; Domestic Chemical Diversion Control Act in 1995; and Combat Methamphetamine Epidemic Act in 2015.[51,52] However, each restriction was followed by adaptation of drug production and it wasn't effective at lowering meth use.[51] Chronic users typically consume 0.7 to 1 gram of meth a day which costs them about $55 to $70 dollars.[53] In Los Angeles County (LAC), meth-related emergency department visits tripled between 2011 and 2020 and the rate of meth overdose death increased from 2.1 per 100,000 population to 13.4 during the same period.[54] In addition, California's Proposition 47, passed in 2014 and implemented in 2015, reclassified simple drug possession from a felony to a misdemeanor, ending incarceration for most nonviolent drug possession cases.[55] While aimed at reducing mass incarceration, this policy shift coincided with a rise in meth-related harms, including diminished entry points for court-mandated treatment.[55]

2. Epidemiology of Congenital Syphilis Epidemic

Syphilis rates have been sharply rising among men, women, and newborns across the United States since the historic lows in 2000-2001. From 2011 and 2020, rates of primary and secondary (P&S) syphilis, which represent the most contagious stages of syphilis, showed an escalation of 280%, increasing from 4.5 to 12.6 cases per 100,000 population.[56] In 2020, the rate of increase in P&S syphilis was higher for women compared to men, with women experiencing a 36.2% rise, in contrast to the 8.7% increase observed among men.[56]

Cases of CS increased by an alarming 656% from 2011 to 2020, escalating from 9.1 to 59.7 cases per 100,000 live births.[57] Racial and ethnic disparities are associated with risk for syphilis infection, lack of PNC, and untreated syphilis that result in unprevented congenital syphilis. In 2020, the CS rates are notably high among American Indian or Alaska Native populations at 190.6 cases per 100,000 live births, followed by Native Hawaiian or other Pacific Islanders at 187.4 cases, and Black at 134.9 cases.[58] In California, Blacks presents the highest CS rate, with 416.2 cases per 100,000 live births, followed by American Indian and Alaska Native (361.5 cases) and Hispanic (117.1). Hispanics accounted for over 50% of the CS cases in the state, with 227 reported cases out of 483 total reported CS cases in 2020.[59]

Substance Use During Pregnancy and Barriers to Prenatal Care

Pregnant women who use substance use need treatment, not criminalization.[60] Since 2010, the crisis of addiction and overdose began to impact pregnant women.[61,62] From 2010 to 2019, drug overdoses accounted for 1,586 deaths and 83,969 Years of Life Lost (YLL) in perinatal women, making it the third leading cause of YLL in this population.[63] Fear of criminal punishment prevents many pregnant women from seeking care they need.[62,64,65] Many states treat drug use during pregnancy as child abuse or a criminal offense, which can lead to fines, loss of custody, or incarceration.[66–68] From 2011 to 2017, there was annual increase of 10,000 children placed in foster care, with parental substance use linked to at least half of these cases.[69]

Moreover, there are considerable inequalities within the child welfare system. Black pregnant women are more likely to be referred to the child welfare system and less likely to be reunited with their infants than pregnant white women, and Black children are overrepresented in this child welfare system.[70] These punitive policies cause pregnant women to fear disclosing their substance use to their health care providers or to avoid seeking treatment for a substance use disorder and PNC that includes syphilis screening and treatment services.[19,20,32,71] Oni et al. (2022) identified five themes in relation to the disclosure and subsequent management and treatment of substance use during pregnancy that help understand barriers to PNC (Figure 2).[72]

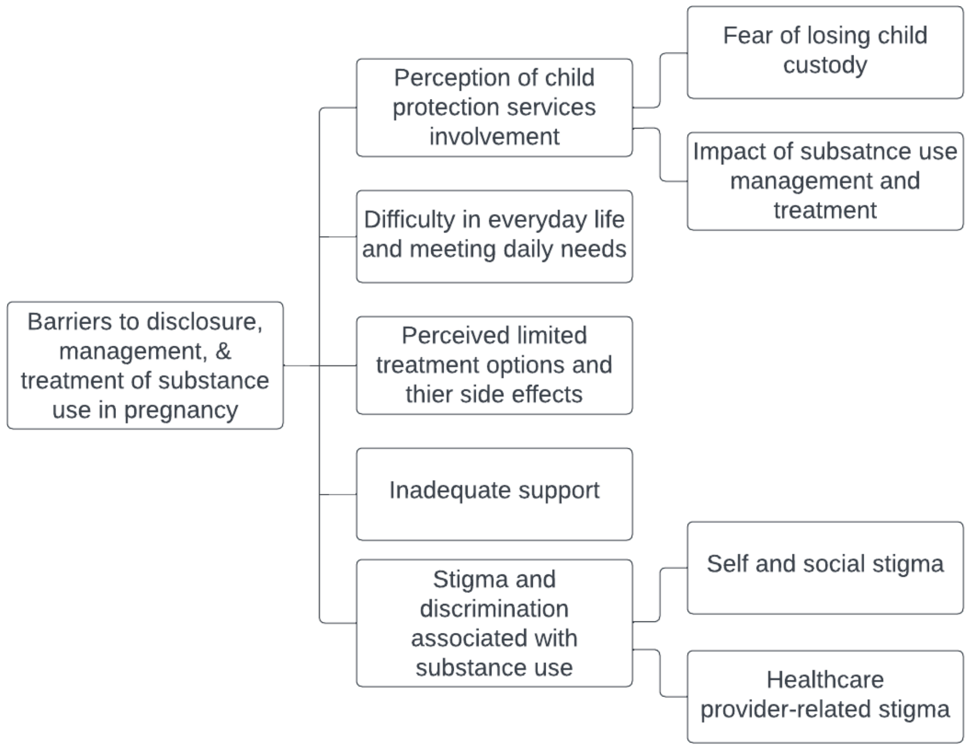


Figure 2. Barriers to Disclosure and Management/Treatment of Substance Use & Prenatal Care in Pregnancy, Adapted from Oni et al, 2022[72]

Maternal Methamphetamine Use and Congenital Syphilis

Meth use is associated with increased risk of contracting sexually transmitted diseases (STD), including syphilis and HIV. A large body of research demonstrates significant associations between meth use and increased risk of syphilis transmission among men who have sex with men by focusing on high-risk sexual behaviors;[22,73–75] however, little is known about heterosexual transmission and its impact during pregnancy and birth outcomes. The CDC report has shown emerging trends in the co-occurrence of heterosexual syphilis transmission and illicit substances, particularly meth use in 2013-2017.[76] The study conducted by Plotzker et al. (2022) in California also found statistically significant association between CS and homelessness (odds ratio [OR], 2.5) and meth use (OR, 2.1).[11] Importantly, the associations were not significant among those who received PNC, indicating the importance of PNC in CS prevention. Authors noted that the study data didn't include Los Angeles and San Francisco, and the observed association can differ in large metropolitan areas.

The previous research highlights the need for further investigation into the relationship between illicit substances, especially meth use, and female syphilis cases, particularly concerning missed opportunities in CS prevention. The co-occurrence of syphilis transmission and meth use among persons of reproductive potential suggests a synergistic effect increasing CS risk in infants. Additionally, the significance of PNC in preventing CS is underscored, emphasizing the importance of researching ways to enhance access to PNC among at-risk populations. Longitudinal studies can provide insights into how these associations evolve over time. Considering social determinants of health alongside health behaviors can provide valuable insights for shaping public health and policy responses aimed at understanding the barriers preventing pregnant persons who use meth and are living with syphilis from accessing PNC. There is a pressing need to study the temporal changes in meth use among birthing persons of infants born with syphilis and to conduct a thorough examination in large metropolitan cities like Los Angeles. This approach has the potential to uncover variations in the context of meth use and syphilis and congenital syphilis, thereby advancing our understanding of the intricate interplay between these intersecting epidemics.

Congenital Syphilis in Los Angeles County

The CS cases is geographically concentrated to only 5% of counties having CS cases in the United States.[77] In 2020, California had the second highest number of CS cases (N=481), after Texas (N=561) and the fifth highest CS rate (114.5 per 100,000 live births).[57] The CS cases in California in 2020 represents over 12-fold increase compared to 2011. LAC accounted for 23.5% CS cases in California, with a total of 113 CS cases, the highest number among all counties.[59] CS in LAC increased by 7.5-fold between 2011 and 2020 (15 to 113 CS cases), with the 6-fold increase in syphilis among women of reproductive age (206 to 1,213 syphilis cases).[78] Responding to this challenge, the LAC Department of Public Health (DPH) initiated a strategic plan entitled, "Eliminating Congenital Syphilis in Los Angeles County: A Call to Action" and highlighted heterosexual syphilis and drug use as "intersecting epidemics."[78]

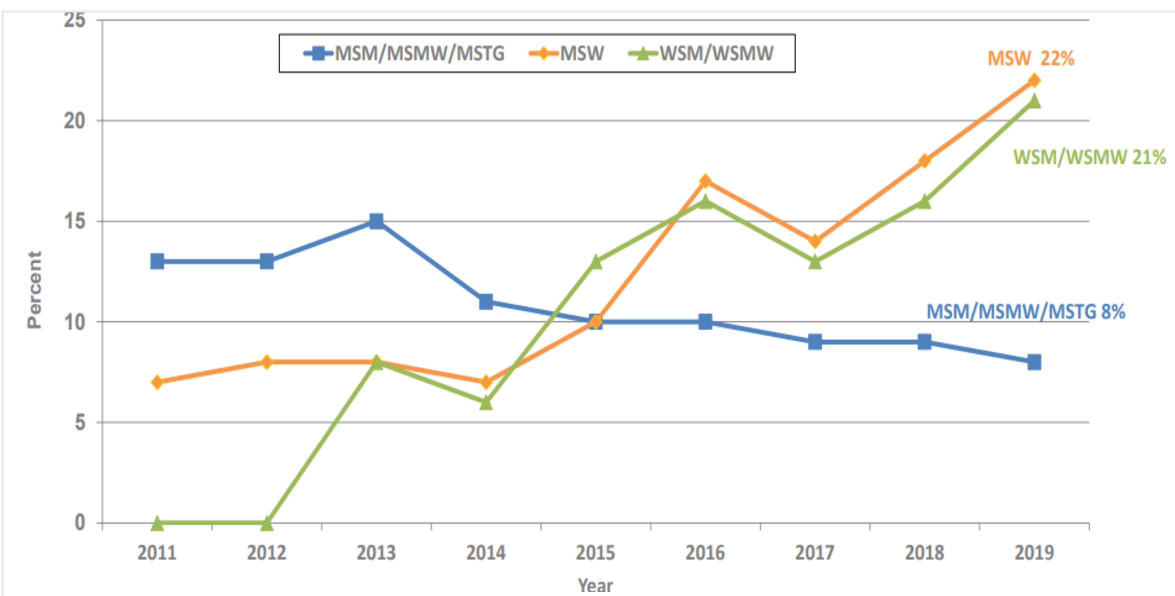


Figure 3. Shift of Methamphetamine Use Trends Among Early Syphilis Cases by MSW, WSM/WSMW, and MSM/MSMW/MSTG in Los Angeles County, 2010-2019
*Early syphilis include primary, secondary, and early latent syphilis cases. Date as of 3/12/2021. Of 25,937 early syphilis incidents with a qualifying interview, 23,804 (91.8%) responded with yes/no to meth use during the past 12 months and are included in the figure. Percent missing ranged from 6.2% to 10.3%. Note: MSW(Men who have Sex with Women); WSM (Women who have Sex with Men); WSMW(Women who have Sex with Men and Women); MSM(Men who have Sex with Men); MSMW(Men who have Sex with Men and Women); MSTG(Men who have Sex with Trans Gendered person)

These intersecting epidemics are reflected in syphilis surveillance data in Figure 3, which show that in 2015 the rates of meth use in men who have sex with women (orange line) and women who have sex with men/women who have sex with men and women (green line) surpassed the rate in Men who have Sex with Men (MSM, blue line). In LAC, up to two third of mothers with CS infants reported actively using substances, primarily meth, in the past 12 months.

There are significant racial disparities in rates of CS. In California, Black mothers had the delivery with highest CS rate (416.2 per 100 000 live births), and Hispanics mothers had the highest number of deliveries CS cases (227 cases out of 483) in 2020.[10] Similar to the trends in national and state, racial disparities in LAC is observed. The majority of CS cases in LAC were born from Hispanic mothers (61%), followed by Black mothers (16%) in 2020.[78]

3. Public Health Significance

CS is preventable and its resurgence points to missed opportunities in public health programs. To address this problem, we must first obtain an accurate and full picture of syphilis-related disease burden due to meth use specific to Persons of Reproductive Potential (assigned female at birth aged between 15 and 44, PRP), pregnant persons, and birthing persons of infants born with CS. This burden is not evenly distributed, Black and Latinx birthing persons, may be disproportionately affected due to the compounding impacts of structural racism, which heightens both vulnerability to meth-related harms and barriers to timely diagnosis and treatment. This study aims to provide evidence for CS prevention programs that is safe for vulnerable population who cannot access necessary PNC due to their existing vulnerabilities and barriers to access PNC services due to those vulnerabilities. Furthermore, syphilis screening and treatment should happen wherever pregnant persons present – an emergency room, substance use treatment facility, jail, or STD clinics. Preliminary study conducted in the neighboring Kern County showed that meth use was associated with the stigma around substance use during pregnancy, fear of being reported to authorities, and having their children removed by government agencies like the Department of Children and Family Services.[19,20,37] This study aims to offer new insights into understanding how structural racism and social determinants of health can negatively impact birth outcomes by analyzing substance use among pregnant persons with syphilis infection, its impact on PNC access, and birth outcomes.

The study is innovative in its use of existing STD surveillance data, which is rarely leveraged for maternal and child health (MCH) research study. Few data sources in the field of substance use provide a representative sample from a major metropolitan area that captures meth use alongside related health burdens—such as barriers to syphilis treatment, limited PNC access, and adverse birth outcomes. This is the first study to utilize representative surveillance data from LAC that comprehensively examines meth-related syphilis disease burden. The application of Syndemic Theory is also novel in this context, particularly in estimating the mediating effect of Syndemic factors in the association between meth use and lack of PNC. Moreover, the study advances public health research by identifying the gendered impact of substance use and its distinct burdens during pregnancy which often differs significantly from those experienced by non-pregnant people. Although the surveillance data span 2011 to 2020, this period captures a critical decade marked by sharp increases in CS cases, rising meth use among PRP, and key policy changes—including the implementation of California's Proposition 47 in 2015.[55]

Understanding trends and spatial disparities during this formative period provides essential context for interpreting recent patterns and for designing interventions as CS rates continue to climb nationally and locally. The findings generate timely, data-driven insights that inform public health planning, policy development, and intervention strategies to address CS prevention and maternal health equity.

4. Theoretical Framework

I approach the intersection of CS and Syndemic of meth use through the lens of Reproductive Justice and structural racism to understand the underlying mechanisms of multiple CS risk factors (i.e., meth use, child protective services, incarceration, mental health problems, racial disparity in CS). Racial disparities observed in CS are not merely a consequence of individual health behaviors but are reflective of broader systemic issues that include access to healthcare, socioeconomic status, social institutions, and the interplay of structural racism that further marginalize pregnant people of color. By embedding this study within the framework of Reproductive Justice, my dissertation aims to provide insights that could inform public health policy and practice, moving towards a reduction of CS and equitable reproductive health.

Reproductive Justice

Reproductive Justice offers a crucial perspective on understanding sexual and reproductive health including MCH, by emphasizing the social, political, and economic conditions that shape reproductive decision-making and care access.[79,80] It expands beyond the right to choose, asserting the fundamental right to have children, to not have children, and to parent children in safe environments.[81]

At the core of Reproductive Justice is recognition that health disparities are deeply racialized. Women of color, particularly Black, and Latinx women, face systemic and institutional barriers to reproductive healthcare, including limited access to prenatal and postnatal care, contraception, and safe abortion services.[81,82] These inequities are not simply individual level problems but are embedded in broader systems of structural racism, which continue to shape health risk and outcomes.[83,84]

The framework also examines the role of the criminal justice system undermining reproductive autonomy, especially for communities of color.[85] Incarcerated individuals face compounded barriers to healthcare and experience the trauma of family separation, often without meaningful pathway to recovery and reintegration.[67,85] The Reproductive Justice framework acknowledges the historical context of reproductive control as ongoing forms of racial violence and state control over bodily autonomy.[85,86]

Therefore, in this dissertation, race is not conceptualized as an individual-level biological or cultural characteristic, but rather as a proxy for exposure to racialized social systems. The framing is particularly relevant for PRP, pregnant persons, and birthing persons living with untreated syphilis who are affected by meth-related Syndemic. These Syndemic conditions shaped by structural racism include housing instability, child welfare involvement, incarceration, and lack of PNC. Guided by Reproductive Justice principles, my analyses center the systemic roots of rising CS and aims to inform evidence-based public health responses that are equity-driven and community-specific.

Defining Study Population

This dissertation intentionally uses terms such as female, women, mother, persons of reproductive potential, and birthing persons in ways that reflect both the constraints of available surveillance data and the values of Reproductive Justice. "Female" is used when referencing biological sex assigned at birth in medical and public health surveillance systems, such as in CDC case definitions for syphilis. The term "woman" is used to acknowledge gendered experiences in health—especially in contexts of systemic barriers, stigma, and care access. However, understanding that gender is socially constructed and not interchangeable with sex, the analysis integrates inclusive language practices. Where appropriate, terms such as "birthing person" and "Persons of Reproductive Potential (assigned female at birth aged between 15 and

44, PRP)" are used in places of traditional classification like "mother," "women of reproductive age," or "females aged 15-44." This language reflects a person-first, equity-driven approach that acknowledges the diverse identities of those affected by syphilis, meth, and reproductive health system in the context of CS. By adopting more inclusive language throughout the analysis, the study affirms that public health language should evolve to reflect both precision and respect for identity.

Table 1. Defining Study Population

Medical and Surveillance Setting to Address Sexual and Reproductive Health	Reproductive Justice Framework	This Study
Female refers to biological sex at birth and its characteristics. It is often used in medical and surveillance contexts.	Recognized as a biomedical classification, but cautioned against when used to erase gender identity or reduce individuals to reproductive function	Used in alignment with STD surveillance definitions when referencing data sources (e.g., female syphilis cases)
Woman/Women refers to adult females in demographic data collection, social construct of how woman is defined in certain society.	Acknowledges gender as a social and cultural construct; emphasizes lived experience, social roles, and intersecting identities	Used when discussing gendered experiences, including stigma, criminalization, and systemic barriers—particularly in relation to women of color
Woman/Women of reproductive age refers to biological born female(s) aged between 15 and 44.	Critiqued for centering biological potential for reproduction; Reproductive Justice calls for inclusive terms that consider autonomy, identity, and structural context	Replaced with "persons of reproductive potential (PRP)" to promote inclusivity, particularly when gender identity data are unavailable to include others don't identify with women but able to get pregnant and give births
Mother is a social and medical term for a person who has given birth	Recognized as relational and identity-based, but can exclude or misgender individuals who do not identify with this role or language	Replaced with "birthing persons" to specify the context of vertical transmission of congenital syphilis. "Mother" used to reflect societal narratives.

Structural Racism and its Impact on Birth Outcomes

Aimed at addressing the urgent issue of racism within maternal health, the Conceptual Model of Racism and Inequities in Maternal Morbidity and Severe Maternal Mortality outlines the roles of structural racism, interpersonal racism, and discrimination in contributing to disparities in maternal mortality, particularly affecting Black, Latinx, and Indigenous women in the United States. This framework serves as a crucial tool for comprehending, defining, and ultimately addressing the multifaceted impacts of structural racism and health disparities in CS. The conceptual model, Figure 4, was developed by the CDC Maternal Mortality Review Information Application (MMRIA) Racism & Discrimination Working Group in 2022.

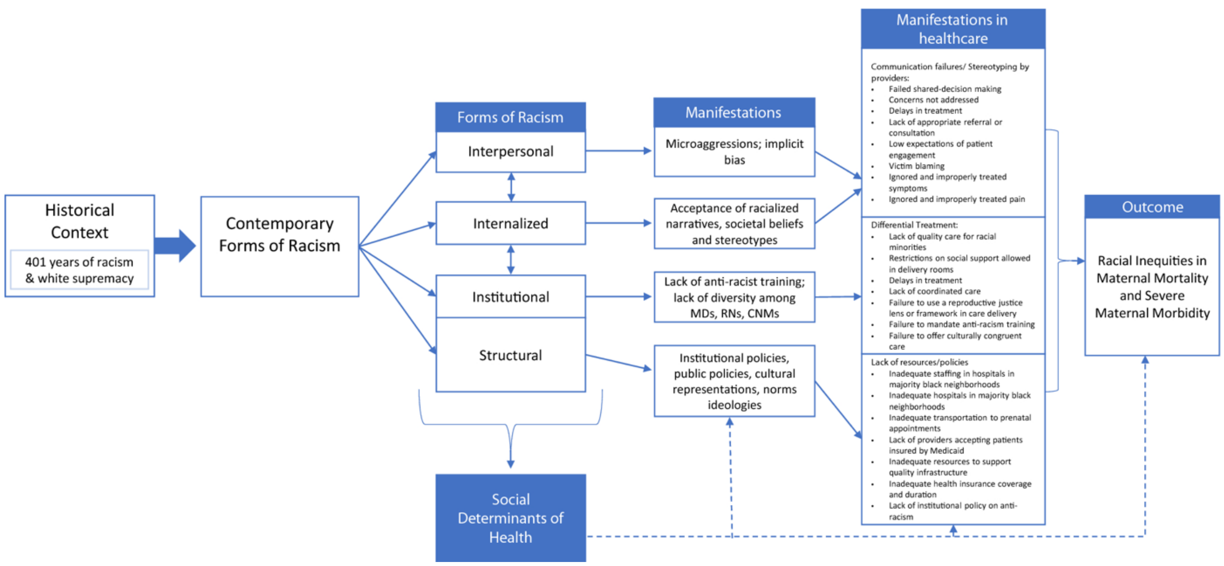


Figure 4. Conceptual Model of Racism and Inequities in Maternal Morbidity and Severe Maternal Mortality, developed by CDC's Mortality Review Information Application (MMRIA) Racism & Discrimination Working Group

To further explore the racial disparities observed in CS cases in LAC, I incorporated key constructs from the Figure 4 and expanded upon them in conceptual framework illustrated in Figure 5.

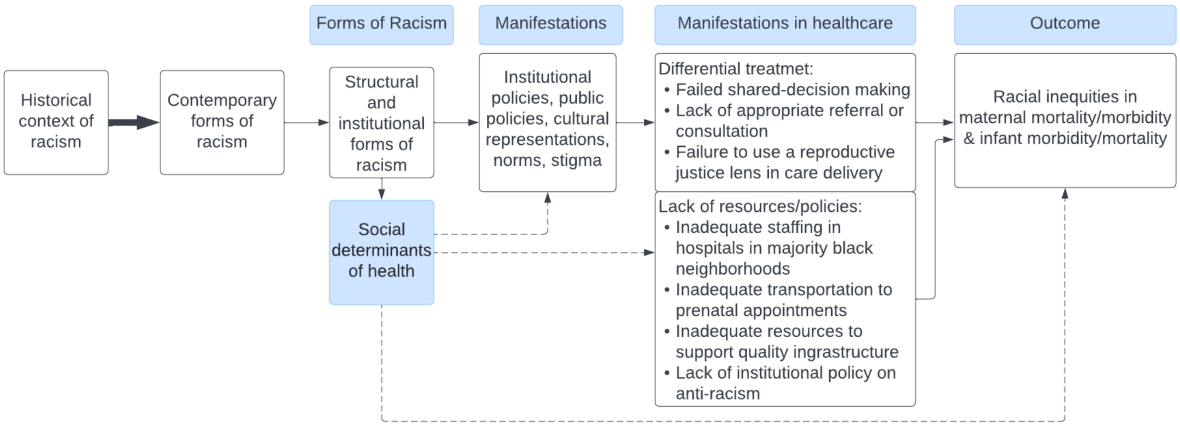


Figure 5. Adapted Model with Selected Constructs from the Conceptual Model of Racism and Inequities in Maternal Morbidity and Severe Maternal Mortality

Syndemic Theory

The Syndemic Theory considers how two or more epidemics co-occur, interact and exacerbate health outcomes in a population, by focusing on disease-disease and social condition-disease interactions for analysis of biosocial connections.[87–89] The term Syndemic or synergistic epidemic is originally coined by Merill Singer to explain how substance abuse, violence, and AIDS are mutually intertwined epidemics that put Black women at disproportionate risk of HIV.[88] The Syndemic involves the adverse interaction between diseases and health conditions of all types and emerge under conditions of health inequalities caused by poverty, stigmatization, stress, or structural violence.[87] Figure 6 depicts the adaptation of the Syndemic Theory to model the "intersecting epidemics" of syphilis and meth use and how the adverse interaction results in CS.

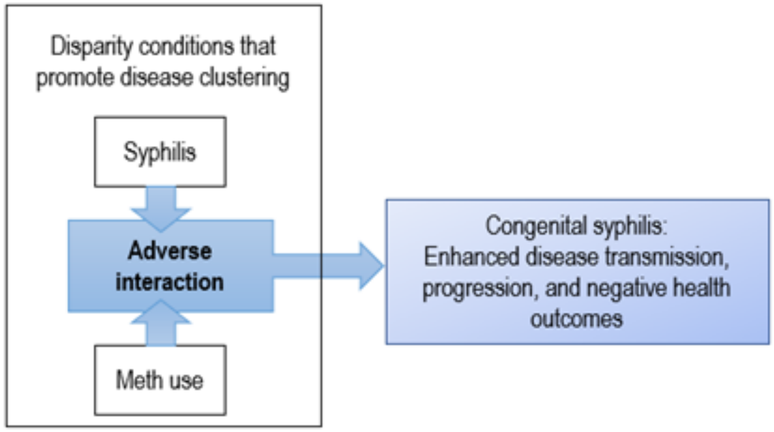


Figure 6. Application of Syndemic Theory to Congenital Syphilis

Integrated Conceptual Framework

Based on the Reproductive Justice lens, I developed the conceptual framework by integrating Structural Racism, Syndemic Theory, and the Health Service Utilization Framework. The Health Service Utilization Framework was developed by Andersen and Newman[90] and later developed by Adays framework[91,92] to focus on vulnerable population. My conceptual framework is developed to address the specific barriers to PNC utilization faced by to Black and Latinx women (Figure 7**)**. The model identifies three determinants that impede care utilization. The three components of the model are (1) *Predisposing* characteristics that exist before an onset of syphilis (e.g., age, race, marital status, pregnancy, homelessness, history of incarceration, history of Child and Family Services involvement); (2) *Enabling* factors that affect an individual's ability to secure health services in the community (e.g., community resources); (3) *Need* characteristics include the actual health problem in the population. The adverse interaction between maternal meth use and syphilis infection is highlighted in blue to show its Syndemic effect. Together these factors may lead to lack of PNC utilization among pregnant persons with syphilis resulting in CS. Due to the impact of structural and institutional disparities that disproportionately affect Black and Hispanic pregnant people, the model shows how it leads to racial disparities in CS.

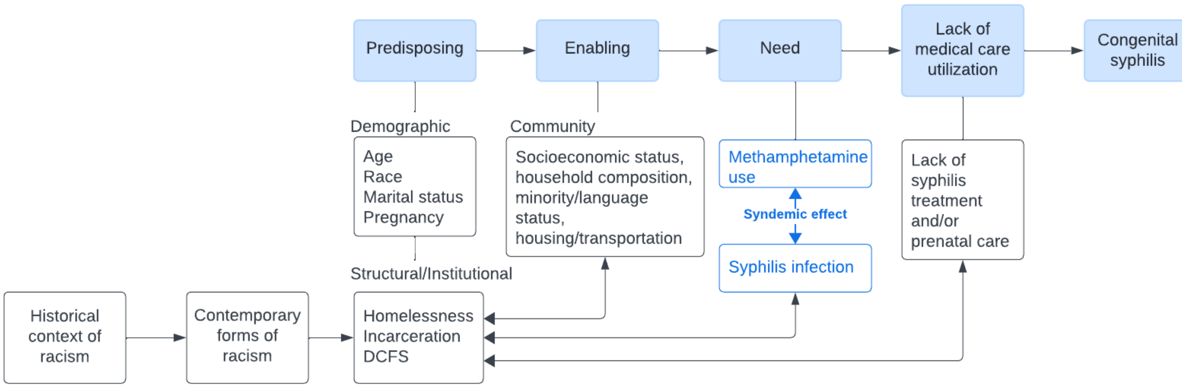


Figure 7. Integrated Model to Conceptualize How Racism Operates and Results in Inequities in Congenital Syphilis

This framework illustrates how structural racism perpetuates systemic inequities in homelessness, incarceration, and involvement with the Department of Child and Family Services (DCFS), which may intersect with community-level vulnerabilities and Syndemic effects of meth use and syphilis infection, significantly hindering access to PNC utilization and subsequent syphilis diagnosis and treatment. It also shows how incarceration and involvement with DCFS may amplify the fear of punitive social systems and the stigma associated with meth use and syphilis, potentially dissuading Black women from seeking essential PNC services and syphilis treatment. Moreover, through the broader lens of racism, it sheds light on the differential treatment and attitudes Black women encounter due to their socioeconomic circumstances, housing situations, or criminal records, influencing both their healthcare access and quality. Latinx women may face distinct barriers, including language barriers, limited health literacy, and immigration status, which may lead to delayed or avoided care. These structural challenges can further compound mistrust in healthcare and public health system, especially in contexts where interactions with authorities or institutions feel unsafe or surveilled. Therefore, a multifaceted analysis is pivotal for developing targeted, evidence-based interventions that improve maternal healthcare access and quality for both Black and Latinx PRP, pregnant persons, and birthing persons. Addressing these distinct, yet interconnected, barriers is critical to reducing disparities reflected in syphilis and CS surveillance data and promoting reductive justice for communities most impacted by meth-related Syndemic burdens.

5. Research Aims and Approach

Research Aims

The overarching aim of this dissertation is to measure meth-related Syndemic burdens contributing to the ongoing CS crisis in LAC, with the goal of informing more equitable and effective prevention programs. Through a multilevel framework, the study investigates the intersection of meth use and related Syndemic conditions. Using STD surveillance and publicly available administrative data from 2011 to 2020, the study addresses three specific aims: (1) to assess whether pregnancy status moderates the association between meth use and syphilis treatment; (2) to evaluate how Syndemic risk factors mediate the relationship between meth use and PNC utilization, with attention to racial disparities; and (3) to map spatiotemporal trends in CS across health districts in relation to structural conditions, including the Social Vulnerability Index (SVI) and meth-related arrest rates. By situating CS within the broader landscape of systemic inequities, this dissertation highlights how missed opportunities for prevention are not solely the result of individual behavior, but are deeply embedded in structural vulnerabilities, racialized sexual and reproductive health environment, and place-based disparities.

Figure 8 illustrates each research aim to its population of focus, level of analysis, and primary outcome. Aim 1 evaluates whether pregnancy moderates the relationship between meth use and syphilis treatment among PRP. Aim 2 assesses whether meth use among pregnant individuals is associated with missed PNC, either directly or through a Syndemic burden of co-occurring social and behavioral risks. Aim 3 shifts to the district level, using spatial and Bayesian methods to examine how structural conditions—particularly social vulnerability and policy change related to drug use—contribute to geographic disparities in CS burden. Figure 8 highlights the study's multilevel structure, showing how individual and contextual risk factors intersect across time and space to drive one of the most preventable and stark manifestations of maternal and child health system failure: CS. The integration of structural equation modeling, multilevel logistic regression, and Bayesian spatiotemporal modeling enables a comprehensive analysis of risk pathways, reinforcing the study's central argument: that preventing CS requires addressing the compounding effects of substance use, structural vulnerability, and systemic inequities in both health care delivery and policy surrounding it.

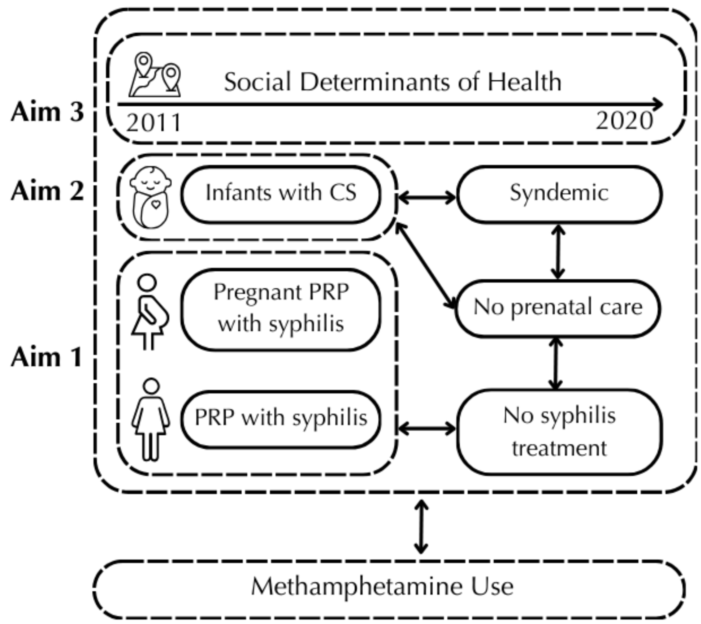


Figure 8. Illustration of Three Research Aims

Aim 1. To assess whether pregnancy status moderates the relationship between methamphetamine use and syphilis treatment among people of reproductive potential diagnosed with syphilis in Los Angeles County.

Chapter Two examines the association between meth use and syphilis treatment, and whether pregnancy status moderates this association. By assessing the moderation effects, the analysis provides insight into how pregnancy status shapes the impact of substance use on access to syphilis treatment.

Aim 2. To examine racial disparities in the relationship between maternal meth use, Syndemic burden, and prenatal care utilization among birthing persons of infants born with syphilis.

Using structural equation modeling (SEM), Chapter Three analyzes whether Syndemic risk factors—homelessness, mental health problems, DCFS referrals, and incarceration—mediate the association between meth use and lack of PNC. Multi-group SEM is used to assess whether these pathways differ across racial groups. This analysis aims to compare how structural vulnerabilities operate differently across racial groups to shape access to PNC during pregnancy.

Aim 3. To analyze spatiotemporal trends in congenital syphilis rates across Health Districts in Los Angeles County from 2011 to 2020, in relation to social vulnerability and meth-related arrests.

Chapter 3 uses Bayesian spatiotemporal modeling to assess changes in relative risk of CS over time and space, integrating administrative data on meth-related female arrest rates and district-level SVI scores. The analysis identifies geographic patterns of elevated risk and informs place-based intervention strategies that address structural determinants of CS.

Data Source

Federal and California laws mandate the reporting of all cases of syphilis and CS by providers and laboratories to the local health department.[93] Upon receipt of a case report and/or positive laboratory result, the Division of HIV and STD Programs (DHSP) in the Los Angeles County Department of Public Health (LAC DPH) opens the case and assigns it to a field services investigators who work on (1) primary, secondary, and early latent syphilis cases reported throughout the county and (2) syphilis cases arising from custody settings.[94] Public Health Nurses (PHNs) further investigate (1) CS cases and (2) syphilis cases diagnosed among pregnant females by conducting phone interviews and reviewing medical records sent from each hospital reporting CS cases.[94] The CS records include urine toxicology test result for substance use, social worker's interview notes detailing maternal risk factors such as homelessness during pregnancy, substance use, mental health, and referral to child protection services. The PHNs are (1) determining the stage of the syphilis infection, (2) verifying that the index patient received appropriate treatment, (3) eliciting name and location information for sexual and/or cluster (non–sex partners who would benefit from an examination) contacts, and (4) ensuring that recent contacts are notified and treated.[94] All reported cases of syphilis and CS undergo the standardized procedure.[94]

Table 2 summarizes the study population derived from DHSP syphilis and CS surveillance data between 2011 and 2020. A total of 5,765 syphilis cases constitutes the primary analytic sample for Aim 1. Among these, 1,607 cases were identified as pregnant at the time of syphilis diagnosis, allowing for comparisons between pregnant and non-pregnant individuals. For Research Aims 2 and 3, the analytic sample was based on 414 reported CS cases during the same period.

Table 2. Research Aims and Approach

Component	Aim 1. Meth Use – Syphilis Treatment	Aim 2. Meth Use – Prenatal Care	Aim 3. Time & Space – Congenital Syphilis Rate
Population	Persons of Reproductive Potential (PRP) aged 15–44 years diagnosed with syphilis	Birthing persons of infants diagnosed with congenital syphilis at birth	Infants born with congenital syphilis at birth
Study Period	1/1/2011 – 12/31/2020	1/1/2011 – 12/31/2020	1/1/2011 – 12/31/2020
Geographic Scope	Los Angeles County, excluding Long Beach & Pasadena	Los Angeles County, excluding Long Beach & Pasadena	Los Angeles County, excluding Long Beach & Pasadena

Data Source	PRP syphilis surveillance records from the Los Angeles County Department of Public Health	Congenital syphilis surveillance records from the Los Angeles County Department of Public Health	Congenital syphilis surveillance records from LACDPH; CDC Social Vulnerability Index (SVI); meth-related arrest data from Los Angeles County; population and birth data from the American Community Survey (ACS)
Total Sample Size	N = 5,765 (Pregnant = 1,670; non-pregnant = 4,095)	N =414	N = 26
Outcome Variable	Syphilis treatment status (Yes/No)	Prenatal care (Yes/No)	Rate of congenital syphilis
Key Exposure Variables	Pregnancy status, methamphetamine use, homelessness, incarceration, race/ethnicity, syphilis stage	Latent Syndemic indicator	Social Vulnerability Index
Exclusion Criteria	Individuals outside the 15–44 age range; missing pregnancy status or outcome data	Missing outcome data	Long Beach and Pasadena Health Districts
Unit of Analysis	Individual-level case records	Individual-level case records	Health Districts in Los Angeles County

Ethical Considerations

Secondary data analysis of public health surveillance data, especially when dealing with sensitive topics such as STDs, including syphilis, necessitates rigorous ethical considerations. This is particularly critical when the data involve vulnerable populations, including pregnant individuals with histories of substance use, housing instability, incarceration, and other social determinants of health. The ethical conduct of the research is therefore a central component of study design and implementation.

The surveillance data used in this study were originally collected for public health monitoring purposes by the LAC DPH, and this project was conducted in close collaboration with DHSP within the LAC DPH. One of my dissertation committee members serves as the Medical Director of LAC DPH DHSP, offering direct insight and oversight into the ethical handling and applied utility of the data. I met biweekly with DHSP colleagues to review study progress, ensure alignment with local surveillance protocols, and share emerging findings as detailed in the Data Use Agreement (DUA) between UCLA and LAC DPH. The deidentified datasets were shared following the DUA between LAC DPH and UCLA (MTA2024-00000339) and the research protocol was approved by UCLA IRB (IRB #23-000126) and SMART IRB Reliance Agreement (SMARTIRB #8919).

The knowledge generated from this study has the potential to inform policy, interventions, and programs targeting CS and its related risk factors—particularly in the context of PNC delivery, substance use prevention and treatment, and STD services. Ultimately, this research could inform the development of evidence-based, equity-centered interventions that benefit populations at risk for untreated syphilis and CS in LAC, particularly pregnant people and their infants.

Chapter 2. Moderation Effect of Pregnancy on the Association Between Methamphetamine Use and Syphilis Treatment Among Persons of Reproductive Potential (Aim 1)

1. Introduction

Syphilis has re-emerged as a significant public health problem in the United States over the past decade, with especially alarming increases among women of reproductive age and in cases of congenital syphilis (CS).[3] After reaching historic lows in the early 2000s, syphilis rates have rebounded dramatically.[1] Nationally, primary and secondary syphilis diagnoses in women more than doubled between 2013 and 2017, and the number of infants born with syphilis surged nearly sevenfold from 2012 to 2021.[1] California has been at the epicenter of this resurgence: from 2012 to 2021, early syphilis cases in women climbed over 1,100%, accompanied by a 1,500% increase in CS cases (from just 33 cases in 2012 to 528 in 2021).[59] In Los Angeles County (LAC) specifically, syphilis and CS have risen to crisis levels. Only 6 CS cases were reported in LAC in 2012, whereas 112 cases were recorded in 2020 – the highest annual total in decades. This surge in CS corresponds with the overall uptick in syphilis among women and highlights a major public health failure in preventing mother-to-child transmission.[25]

One hypothesized driver of these worsening trends is the intersection of syphilis with the ongoing methamphetamine (meth) epidemic. National surveillance data indicate that by 2017, 16.6% of women diagnosed with primary or secondary syphilis reported meth use, up from only 6.2% a few years prior.[76] In California's recent CS cases, substance use has been a common theme: in 2018, over half of pregnant women with syphilis reported meth use, and roughly half experienced recent homelessness or incarceration.[11] These co-occurring issues suggest that many women acquiring syphilis and unable to receive syphilis treatment during pregnancy are living in very challenging social circumstances.[12,21,23,25] Meth use can directly and indirectly impede access to timely sexually transmitted infection (STI) treatment – directly through its physiologic and cognitive effects that reduce healthcare engagement, and indirectly via stigma and marginalization in healthcare settings.[22] When coupled with pregnancy, these challenges are heightened. Pregnant people who use drugs may avoid care for fear of judgment or child protective services involvement, which in turn increases the risk of untreated syphilis and CS.[11,19,20] Thus, meth use in pregnancy represents a convergence of risks that is highly relevant to public health efforts to eliminate CS.

From a The Reproductive Justice perspective, the ongoing rise of CS in communities burdened by substance use, poverty, and structural inequities is especially concerning. The Reproductive Justice framework asserts that all individuals have the right to maintain bodily autonomy, to have children or not, and to parent children in safe, healthy environments.[80] The profile of many women affected by syphilis in LAC – disproportionately women of color facing housing instability, criminal justice involvement, and addiction – reflects deep structural racism and social injustice that impede their ability to access care and have healthy pregnancies. Rather than viewing syphilis in isolation, a The Reproductive Justice lens locates this issue within broader systems of inequality, highlighting the moral imperative to address barriers such as stigma, lack of healthcare access, and punitive approaches to substance use in pregnancy. Additionally, the overlapping epidemics of meth use, unstable housing, and syphilis can be understood through Syndemic theory. A Syndemic occurs when two or more epidemics co-occur in a population, exacerbating one another through intertwined social and environmental factors.[88] In this case, the meth epidemic and the syphilis/CS epidemic in LAC form a Syndemic risk condition that each risk condition fueling the other's impact in vulnerable populations. Women who use meth may be more likely to acquire syphilis and less likely to get treated, leading to more CS-affected births; conversely, the burdens of syphilis and unplanned pregnancy may further marginalize these women, worsening substance use and related harms. Understanding this interplay is critical for developing integrated interventions that address both infection and its root causes.

Despite recognition of these intersecting issues, there is a paucity of research examining how pregnancy itself influences the relationship between substance use and STI outcomes. Pregnancy is a unique period that can either facilitate care engagement through routine prenatal visits and motivation to protect the fetus or, alternatively, introduce new barriers (such as fear of legal consequences or intensified stigma for pregnant people use drugs or struggling with addiction). It remains unclear whether being pregnant attenuates or amplifies the negative impact of meth use on receiving syphilis treatment. Most surveillance and epidemiologic studies have described risk factors for CS or rising meth use among women, but none to our knowledge have explicitly tested pregnancy as a moderator of the association between drug use and treatment outcomes. This represents a critical gap in understanding how to target interventions: if pregnancy offers an opportunity to better engage pregnant persons who use drugs in care, that strategy should be bolstered; if not, it signals an urgent need for improved services and support during pregnancy.

To address this gap, the present study examines whether pregnancy status moderates the relationship between meth use and syphilis treatment among Persons of Reproductive Potential (PRP) in LAC. Using 2011–2020 county surveillance data on PRP aged 15–44 diagnosed with syphilis (including both pregnant and non-pregnant PRP), I examine if the effect of meth use on the likelihood of receiving adequate syphilis treatment differs by pregnancy status. I hypothesize that pregnancy may alter this association – for instance, pregnancy could potentially mitigate some barriers to treatment (via prenatal care opportunities and public health follow-up), or conversely, pregnancy could compound the challenges for women who use meth. By grounding the study question in a The Reproductive Justice and Syndemic framework, any observed differences may reflect underlying structural conditions. The findings from this moderation analysis can inform whether pregnancy should be considered a key context in tailoring interventions for PRP with syphilis who use meth, ultimately to improve treatment rates and prevent adverse outcomes like CS.

2. Methods

Study Design and Population

This study utilized a retrospective secondary analysis of syphilis surveillance data from LAC, excluding cases from the independent jurisdictions of Long Beach and Pasadena. The dataset was managed by the Division of HIV and STD Programs (DHSP) within the LAC Department of Public Health (LAC DPH). In accordance with federal and state reporting laws, all syphilis diagnoses were mandatorily reported by healthcare providers and laboratories.[95] Deidentified, line-listed case reports from 2011 to 2020 were extracted for analysis, including demographic, clinical, and behavioral characteristics.

The study population included all persons of reproductive potential (PRP)—defined as females at birth aged 15 to 44 years—diagnosed with syphilis between January 1, 2011, and December 31, 2020. Pregnant and non-pregnant individuals were distinguished based on clinical records (Figure 9). PRP syphilis cases were eligible for inclusion if they met the following criteria: (1) identified as female, (2) aged 15–44 years, (3) resided in LAC excluding Long Beach and Pasadena, and (4) were diagnosed with syphilis or delivered a CS-affected infant during the study period.

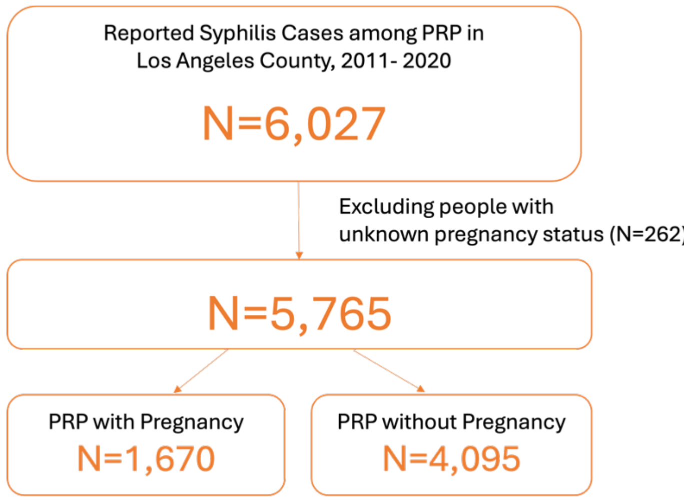


Figure 9. Aim 1 Study Population Flow Chart

Missing data were monitored throughout the data preparation process. The final merged dataset was examined for internal consistency, range errors, and omissions. The rate of missingness was calculated for each primary variable. Where data were missing on key variables—such as meth use (~17% missing)—a multiple imputation strategy was implemented using the Monte Carlo method in SAS. Five imputed datasets were generated, and the results were pooled to account for within- and between-imputation variability.

Outcome Variable

The primary outcome variable—syphilis treatment—was based on adherence to CDC guidelines and dichotomized as "yes" (if the treatment meets the guidelines) and "no" (if it does not). The specific treatment regimen varies depending on the patient's pregnancy status, and this variation was incorporated into how the outcome variable was defined.

Independent Variable

The independent variable, meth use in the past 12 months, was coded as a binary categorical variable with responses of "yes" if the individual had a positive urine toxicology result for amphetamines or self-reported meth use during the case investigation process, and "no" if neither condition was met. Meth use was hypothesized to be associated with decreased likelihood of syphilis treatment due to reduced engagement with healthcare services, increased stigma and discrimination in medical settings, and social instability that could create barriers to accessing syphilis treatment.

Moderator

Pregnancy status was identified based on medical records and interview notes and coded as a binary variable ("yes" or "no") for the analysis. The moderation effect of pregnancy was examined by interaction term (meth use*pregnancy status). Then, the odds ratios were stratified by pregnancy status, which allowed for identifying distinct patterns in treatment outcome between pregnant and non-pregnant individuals. It was hypothesized that pregnancy further impeded syphilis treatment due to fears and challenges in disclosing, managing, and treating substance use during pregnancy; increased clinical complexities in managing both syphilis and pregnancy; and heightened concerns about adverse outcomes, such as the criminalization of substance use during pregnancy and the potential loss of child custody.

Covariates

Several covariates were included to control for potential confounders. Age was categorized into six ordinal groups: 15–19, 20–24, 25–29, 30–34, 35–39, and 40–44 years. Race and ethnicity were categorized as White, Black, Latinx, Asian, Native Hawaiian or Pacific Islander (NHPI), American Indian or Alaska Native (AIAN), Two or More Races, Other, and Unknown. Syphilis disease stage was classified as Primary & Secondary, Early Latent, or Late Latent/Unknown, based on clinical documentation.

Additional social determinants were included as covariates. Homelessness was coded as "yes" if the individual was reported as living outdoors, in shelters, or in vehicles. Incarceration history was coded as "yes" if the individual was incarcerated at the time of testing or had been incarcerated within the 12 months preceding diagnosis. Both variables were treated as binary indicators.

Conceptual Framework

As shown in Figure 10, pregnancy status functioned as a moderator in the relationship between meth use and syphilis treatment. This analytic focus was rooted in The Reproductive Justice theory, which recognized that pregnant individuals, particularly those who used substances, faced heightened surveillance and systemic barriers that could differentially impact treatment access and outcomes. The model posited that meth use reduced the likelihood of receiving syphilis treatment, with this effect potentially intensified by the added social scrutiny and fear of punitive consequences experienced during pregnancy.

Meth use in the past 12 months served as the independent variable. The dependent variable was receipt of syphilis treatment in accordance with CDC guidelines, categorized as a binary outcome. The framework also incorporated key covariates, including age, race, syphilis stage, homelessness, and incarceration history. These factors were known to influence healthcare engagement and were included in the statistical models to account for potential confounding.

Reflecting the conceptual framework, the statistical models consisted of a series of nested logistic regressions. Model 1 tested the unadjusted association between meth use and treatment. Model 2 adjusted for demographic covariates (age and race), while Model 3 added syphilis stage to account for clinical syphilis stage. Model 4 further included structural vulnerability indicators, specifically homelessness and incarceration history. Interaction terms between meth use and pregnancy status were added to assess moderation. Odds ratios and confidence intervals were estimated, and model fit was evaluated using AIC, BIC, McFadden's R^2, and deviance comparisons.

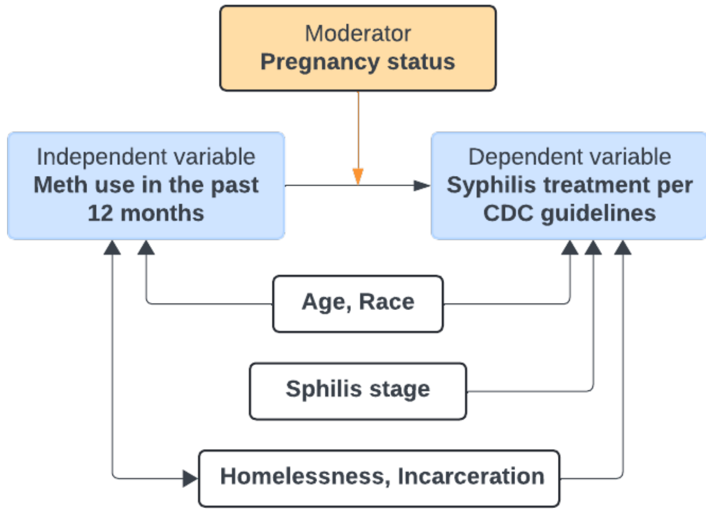


Figure 10. Aim 1 Conceptual Framework

Statistical Analyses

Descriptive statistics were first generated to summarize the demographic characteristics of the study population. Differences in categorical variables between groups were assessed using chi-square tests.

To determine whether pregnancy status modifies the association between meth use and the odds of receiving adequate syphilis treatment, a moderation analysis was performed. Two logistic regression models were compared: a main effects model and an interaction model that included the interaction term (meth use × pregnancy). A Likelihood Ratio Test (LRT) assessed whether adding the interaction term significantly improved model fit. If the interaction was statistically significant ($p < 0.05$), stratified analyses by pregnancy status were conducted to estimate separate odds ratios for each subgroup. Logistic regression equations were used as below, where ***p*** represents the probability of receiving syphilis treatment.

- Main Effect Model

$$log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 METH + \sum_{j=1}^{6} \beta_j AGE_j + \sum_{k=1}^{9} \beta_k RACE_k + \sum_{l=1}^{3} \beta_l STAGE_l$$

$$+\beta_2 HOMELESSNESS + \beta_3 INCARCERATION$$

$$+ \beta_4 PREGNANCY$$

- Interaction Model

$$log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 METH + \sum_{j=1}^{6} \beta_j AGE_j + \sum_{k=1}^{9} \beta_k RACE_k + \sum_{l=1}^{3} \beta_l STAGE_l$$

$$+\beta_2 HOMELESSNESS + \beta_3 INCARCERATION$$

$$+ \beta_4 PREGNANCY + \beta_5 METH * PREGNANCY$$

Coefficients in the statistical model are:

- β_0 : Intercept
- β_1 : Coefficient for methamphetamine use ($METH$)
- β_j *for j = 1, 2…6*: Coefficients for the age group dummy variables (AGE_j)
- β_k *for k = 1. 2…9*: Coefficients for the race dummy variables ($RACE_k$)
- β_l *for l = 1, 2, 3*: Coefficients for the syphilis stage dummy variables ($STAGE_l$)
- β_2: Coefficients for homelessness ($HOMELESSNESS$)
- β_3: Coefficients for incarceration history ($INCARCERATION$)
- β_4: Coefficients for pregnancy status ($PREGNANCY$)
- β_5: Coefficients for interaction ($METH * PREGNANCY$)

The impact of meth use on syphilis treatment was examined using a series of nested multivariate logistic regression models: an unadjusted model (Model 1); a model adjusted for demographic variables (Model 2; age and race); a model further adjusted for clinical syphilis stage (Model 3; categorized as Primary & Secondary, Early Latent, and Late Latent); and a full model additionally adjusted for social vulnerabilities (Model 4; homelessness and incarceration) for both pregnant and non-pregnant PRP.

Model 1 (Unadjusted Model)

$$log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 METH$$

$METH$ is a binary indicator for meth use.

Model 2 (Adjusted for Demographics: Age and Race)

$$log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 METH + \sum_{j=1}^{6} \beta_j AGE_j + \sum_{k=1}^{9} \beta_k RACE_k$$

AGE_j represents dummy variables for the different age groups with 40-44 years old PRP as the reference group, and $RACE_k$ represents dummy variables for the racial categories with White as the reference.

Model 3 (Further Adjusted for Syphilis Stage)

$$log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 METH + \sum_{j=1}^{6} \beta_j AGE_j + \sum_{k=1}^{9} \beta_k RACE_k + \sum_{l=1}^{3} \beta_l STAGE_l$$

$STAGE_l$ denotes dummy variables for syphilis stage (e.g., Primary & Secondary, Early Latent, with Late Latent or Unknown as the reference).

Model 4 (Further Adjusted for Social Vulnerabilities)

$$log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 METH + \sum_{j=1}^{6} \beta_j AGE_j + \sum_{k=1}^{9} \beta_k RACE_k + \sum_{l=1}^{3} \beta_l STAGE_l$$

$$+\beta_2 HOMELESSNESS + \beta_3 INCARCERATION$$

In this final model, $HOMELESSNESS$ and $IN\boldsymbol{CARCERATION}$ are binary indicators for homelessness and incarceration history, respectively. Each coefficient is exponentiated to obtain the odds ratio, and the corresponding 95% confidence interval is also exponentiated. For any given coefficient with standard error $SE(coefficient)$:

The odds ratio is calculated as:

$$Odds\ Ratio = \ e^{coefficient}$$

The 95% confidence interval for the coefficient is:

$$coefficient \pm 1.96\ \times\ SE(coefficient)$$

Exponentiating these limits yields the 95% confidence interval for the odds ratio:

$$(e^{coefficient-1.96\times SE(coefficient)}, e^{coefficient+1.96\times SE(coefficient)})$$

A multiple imputation approach was employed to handle missing data. Sensitivity analyses were conducted using bootstrapped confidence intervals to assess the robustness of the results. Model fit was assessed using AIC and BIC values. Multicollinearity was assessed using pairwise Pearson correlations via PROC CORR. All statistical analyses were performed using SAS statistical software (version 9.4, SAS Institute Inc).

3. Results

Descriptive Characteristics by Pregnancy Status

A total of 5,765 persons of reproductive potential (PRP) aged 15–44 diagnosed with syphilis in LAC from 2011–2020 were included in the analysis. Of these, 1,670 (29.0%) were pregnant at the time of diagnosis, and 4,095 (71.0%) were non-pregnant. Table 2 summarized the demographic and clinical characteristics of syphilis cases by pregnancy status. Overall, pregnant individuals were slightly younger on average than their non-pregnant counterparts. The median age in the pregnant group was 27 years (interquartile range, IQR ≈ 23–32), compared to 29 years (IQR ≈ 24–36) in the non-pregnant group. Age distribution significantly differed by pregnancy status ($\chi^2 = 181.81$, $p < .0001$). Pregnant individuals were more concentrated in the 20–29 age range, with 26.2% aged 20–24 and 29.0% aged 25–29, whereas non-pregnant individuals included a greater proportion of older individuals, with 13.2% aged 40–44 compared to only 3.2% among those who were pregnant.

Racial distribution significantly varied between groups ($\chi^2 = 10.98$, $p = .001$). The racial/ethnic distribution was similar between groups and reflected the disproportionate burden of syphilis and approximately two-thirds of cases in both groups were among Black and Latina women, while White and Asian/Pacific Islander women accounted for smaller fractions. Latinx individuals represented the majority in both groups, comprising 57.2% of the pregnant group and 48.0% of the non-pregnant group. Non-pregnant individuals had higher proportions of White individuals (13.6% vs. 9.5%) and a greater percentage of cases with unknown race (7.9% vs. 3.9%).

Syphilis stage at diagnosis significantly differed ($\chi^2 = 53.35$, $p < .0001$). Pregnant individuals were more frequently diagnosed at the Early Latent stage (27.1% vs. 20.9%) and less often at the Primary & Secondary stage (11.7% vs. 18.5%) compared to non-pregnant individuals. The majority in both groups were diagnosed at the Late Latent or Unknown stage.

Indicators of social and behavioral vulnerabilities were observed in both pregnant and non-pregnant individuals, reflecting the Syndemic conditions surrounding substance use and syphilis in LAC. Meth use within the past 12 months, as recorded through case investigations, was reported in 11.7% of pregnant individuals and 10.0% of non-pregnant individuals, a difference that approached but did not reach statistical significance ($\chi^2 = 3.39$, $p = 0.066$). There was consistent presence of meth use across both groups highlighted its continued relevance as a behavioral health concern.

Housing instability and incarceration were also notable. Homelessness was significantly less prevalent among pregnant individuals (5.7%) than among non-pregnant individuals (15.0%; $\chi^2 = 95.23$, $p < .0001$). In contrast, incarceration history was reported by 13.2% of pregnant individuals compared to 15.9% of non-pregnant individuals, a difference that reached statistical significance ($\chi^2 = 6.44$, $p = 0.011$), though modest in magnitude. Despite differences in specific indicators, both groups exhibited elevated levels of social vulnerability. Importantly, pregnant individuals had a higher overall rate of syphilis treatment completion (76.9%) compared to non-pregnant individuals (58.7%; $\chi^2 = 170.12$, $p < .0001$), suggesting greater linkage to care during pregnancy, potentially due to prenatal screening protocols and coordinated public health efforts. Collectively, these findings demonstrated that pregnant and non-pregnant PRP affected by syphilis in LAC were not categorically different subpopulations. Instead, they shared a common risk environment shaped by substance use, housing insecurity, and criminal justice system involvement, with pregnancy offering a potential point of in-depth analysis.

Table 3. Pregnancy Status among Persons of Reproductive Potential (PRP) aged 15-44 years in Los Angeles County (N=5,765)

	Yes (N=1,670)		No (N=4,095)		χ2	P-value
	N	%	N	%		
Age Group***					181.81	<.0001
15-19	146	8.74	320	7.81		
20-24	438	26.23	812	19.83		
25-29	485	29.04	933	22.78		
30-34	351	21.02	788	19.24		
35-39	197	11.80	702	17.14		
40-44	53	3.17	540	13.19		
Race***					10.98	0.001
White	158	9.46	558	13.63		
Black	379	22.69	996	24.32		
Latinx	955	57.19	1965	47.99		
Asian	94	5.63	155	3.79		
NHPI	6	0.36	12	0.29		
AIAN	2	0.12	14	0.34		
Two or more	1	0.06	2	0.05		
Other	10	0.60	69	1.68		
Unknown	65	3.89	324	7.91		
Syphilis Stage***						
Primary & Secondary	196	11.74	758	18.51	53.35	<.0001
Early Latent	453	27.13	855	20.88		
Late Latent or Unknown	1021	61.14	2482	60.61		
Homelessness***					95.23	<.0001
No	1575	94.31	3481	85.01		
Yes	95	5.69	614	14.99		
Incarceration Status/History*						
No	1449	86.77	3445	84.13	6.44	0.011
Yes	221	13.23	650	15.87		
Methamphetamine Use						
No	1475	88.32	3684	89.96	3.39	0.066
Yes	195	11.68	411	10.04		
Syphilis treatment***					170.12	<.0001
No	386	23.11	1691	41.29		
Yes	1284	76.89	2404	58.71		

Note. Statistical significance is denoted for p < 0.001 (***).

Trends in Methamphetamine Use

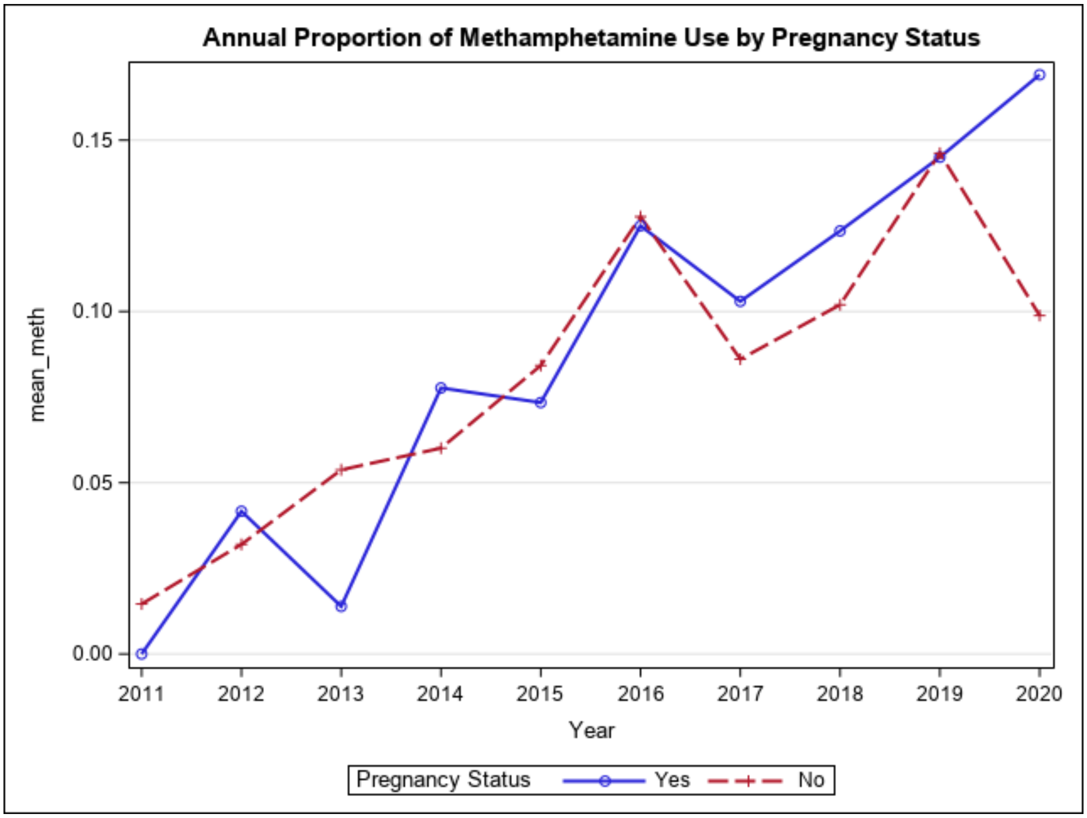


Figure 11. Trends in Methamphetamine Use Among Syphilis Cases by Pregnancy Status

Figure 11 illustrated the annual proportion of meth use among PRP with syphilis cases in LAC from 2011 to 2020, stratified by pregnancy status. The y-axis represented the proportion of individuals reporting meth use, while the x-axis showed each year of the study period. The solid blue line with denoted pregnant individuals, and the dashed red line represented non-pregnant individuals of reproductive potential. Meth use increased substantially over the study period among PRP with reported syphilis cases in LAC, with rising prevalence observed in both pregnant and non-pregnant PRP. Meth use rose steadily from 2011 to 2020 for both groups, with particularly steep increases occurring after 2015. Among pregnant PRP (blue line), the prevalence of meth use began near 0% in 2011 and increased more sharply over time, eventually surpassing the prevalence observed among non-pregnant PRP by 2017. By 2020, approximately

17% of pregnant PRP with syphilis cases reported meth use, compared to about 10% of non-pregnant PRP cases, suggesting a shift in the burden of meth use toward the pregnant population after 2016. The consistent increase, particularly among pregnant individuals—highlighted the need for integrated, low-barrier, and stigma-informed care models to engage pregnant PRP with syphilis and co-occurring meth use.

Moderation Analysis: Pregnancy Status as an Effect Modifier

A moderation analysis was conducted to determine whether pregnancy status moderates the association between meth use and the odds of receiving adequate syphilis treatment. In the main effect model (without interaction term), both meth use ($\beta = -0.19$, $p < 0.001$) and pregnancy status ($\beta = -0.59$, $p < 0.001$) were statistically significant, indicating that each factor independently influences the odds of syphilis treatment. When the interaction term (meth use × pregnancy status; $\beta = 0.85$, $p < 0.001$) was added, model fit improved significantly according to Wald $\chi^2 = 14.29$ ($p < 0.001$) and reductions in the AIC (from 5866.29 to 5854.17) and -2 Log Likelihood (from 5826.29 to 5812.17). Notably, meth use ($\beta = -1.61$, $p < 0.001$) and pregnancy status ($\beta = -0.69$, $p < 0.001$) remained significant in the interaction model, suggesting a robust moderation effect.

	Main Effect Model				Interaction Model			
	β	SE	OR	95% CI	β	SE	OR	95% CI
Meth Use	–0.19***	0.05	0.83	0.76–0.91	–1.61***	0.20	0.20	0.13–0.31
Pregnancy	–0.59***	0.07	0.55	0.48–0.63	–0.69***	0.09	0.50	0.42–0.61
Meth Use × Pregnancy					0.85***	0.22	2.34	1.53–3.57
AIC	5866.29				5854.17			
–2 Log Likelihood	5826.29				5812.17			

Figure 12. Moderation Analysis: Logistic Regression Predicting Syphilis Treatment

Note. OR = odds ratio; CI = confidence interval; SE = standard error; ***$p < 0.001$

Multivariate Logistic Regression of Methamphetamine Use and Syphilis Treatment, Stratified by Pregnancy Status

Given that the moderation analysis demonstrated a significant interaction between pregnancy status and meth use, stratified logistic regression models were estimated separately for non-pregnant and pregnant PRP. The results of these subgroup analyses were presented in Tables 4 and 5, respectively.

Non-pregnant PRP

As shown in Table 4, meth use was initially associated with higher odds of receiving syphilis treatment among non-pregnant persons of reproductive potential in the unadjusted model (Model 1), with an odds ratio of 1.30 (95% CI: 1.04–1.64). This association remained nearly identical after adjusting for age and race in Model 2 (OR = 1.31, 95% CI: 1.04–1.64), suggesting demographic variables did not confound the relationship. However, once syphilis stage was included in Model 3, the association attenuated (OR = 1.08, 95% CI: 0.83–1.40), and the confidence interval crossed the null value, indicating a non-significant relationship.

In the final model (Model 4), which added indicators of structural vulnerability, homelessness and incarceration, the association between meth use and syphilis treatment remained non-significant (OR = 1.05, 95% CI: 0.80–1.37). Notably, homelessness emerged as a significant predictor of treatment (OR = 1.88, 95% CI: 1.50–2.37), indicating higher odds of treatment among those who reported experiencing homelessness. It could be due to existing harm reduction services adjacent to services for homelessness and people experiencing homelessness may receive STI screening, diagnosis, and treatment services. This counterintuitive result aligns with prior studies suggesting that engagement with the public health or shelter system may increase contact with STI care. In contrast, recent incarceration was not significantly associated with treatment, potentially due to heterogeneity in care access during custody or challenges in continuity of care post-release.

Table 4. Non-pregnant PRP: Methamphetamine Use & Syphilis Treatment Logistic Regression

	Model 1		Model 2		Model 3		Model 4	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Methamphetamine use	**1.30**	**1.04 , 1.64**	**1.31**	**1.04 , 1.64**	1.08	0.83 , 1.40	1.05	0.80 , 1.37
Age Group								
15-19			**0.99**	**0.73 , 1.33**	**0.71**	**0.51 , 0.99**	0.72	0.51 , 1.01
20-24			1.03	0.81 , 1.30	0.85	0.65 , 1.10	0.84	0.65 , 1.10
25-29			0.97	0.77 , 1.22	0.85	0.66 , 1.10	0.84	0.65 , 1.08
30-34			0.92	0.73 , 1.16	0.78	0.60 , 1.01	0.77	0.60 , 1.01
35-39			0.96	0.76 , 1.23	0.94	0.72 , 1.23	0.93	0.71 , 1.21
40-44			Ref.		Ref.		Ref.	
Race								
AI/AN			0.38	0.13 , 1.11	0.56	0.17 , 1.80	0.58	0.18 , 1.88
Other			0.87	0.51 , 1.46	0.83	0.46 , 1.51	0.89	0.49 , 1.63
Asian			**2.54**	**1.60 , 4.05**	**3.40**	**2.09 , 5.55**	**3.31**	**2.02 , 5.41**
Black			0.98	0.78 , 1.23	0.85	0.66 , 1.10	0.88	0.68 , 1.13
Latinx			1.02	0.83 , 1.25	1.15	0.91 , 1.44	1.16	0.93 , 1.46
NHPI			1.48	0.40 , 5.54	1.53	0.37 , 6.42	1.59	0.38 , 6.69
Two or more			0.47	0.03 , 7.59	0.31	0.01 , 8.60	0.34	0.01 , 9.56
Unknown			0.76	0.57 , 1.02	0.93	0.68 , 1.28	0.99	0.72 , 1.37
White			Ref.		Ref.		Ref.	
Syphilis Stage								
P&S					**16.55**	**12.09 , 22.65**	**16.40**	**11.97 , 22.46**
EL					**11.87**	**9.11 , 15.46**	**11.74**	**9.01 , 15.30**
LL/UNK					Ref.		Ref.	
Homelessness							**1.88**	**1.50 , 2.37**
Incarceration							1.08	0.88 , 1.33
AIC	5163.277		5155.977		4230.721		4203.665	
BIC	5175.912		5250.740		4338.119		4323.698	
-2 Log Likelihood	5159.277		5125.977		4196.721		4165.665	

Note: AIC = Akaike Information Criterion, BIC: Bayesian Information Criterion
Model 1: Unadjusted model. Model 2: Adjusted for demographic variables (age, race).
Model 3: Further adjusted for clinical stage (syphilis stage).
Model 4: Full main effect model, additionally adjusted for social vulnerabilities (homelessness, incarceration).

Model fit improved incrementally across specifications. Model 4 achieved the lowest AIC (4203.665) and BIC (4323.698), suggesting superior fit relative to prior models. These improvements indicate that adding clinical and structural variables enhanced explanatory power, even though the initial association between meth use and treatment lost statistical significance. From a theoretical perspective, these findings do not support a Syndemic and structural vulnerability lens—underscoring that substance use does not predict treatment outcomes.

Pregnant PRP

In contrast, among pregnant PRP, both Model 1 and Model 2 demonstrated that meth use was associated with decreased odds of treatment (OR: 0.56, 95% CI: 0.40–0.77 and OR: 0.56, 95% CI: 0.40–0.78, respectively). As shown in Table 5, this association remained significant even after adjusting for syphilis stage in Model 3 (OR: 0.49, 95% CI: 0.34–0.69), and in Model 4 with additional adjustments for social vulnerabilities such as homelessness and incarceration (OR: 0.50, 95% CI: 0.35–0.73). The magnitude of reduction, approximately 50% lower odds of treatment among pregnant PRP using meth compared to those do not use meth was consistent across all model specifications. This suggested that meth use among pregnant PRP may represent a distinct risk profile compared to other population with syphilis, characterized by additional or unmeasured barriers to treatment access due to pregnancy.

Additionally, age groups 15–19 and 20–24 exhibited stronger associations with treatment (OR: 3.51, 95% CI: 1.63–7.58 and OR: 1.88, 95% CI: 1.00–3.52, respectively), while racial differences in treatment were evident, with Asian and Latinx individuals showing higher odds of treatment compared to White pregnant PRP. Syphilis stage continued to be an important predictor of treatment, as those diagnosed with Primary & Secondary and Early Latent syphilis stages had higher treatment odds compared to Late Latent syphilis stage. Social vulnerabilities such as homelessness and incarceration were not statistically significantly in Model 4.

Table 5. Pregnant PRP: Methamphetamine Use & Syphilis Treatment Logistic Regression

	Model 1		Model 2		Model 3		Model 4	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Methamphetamine use	**0.56**	**0.40 , 0.77**	**0.56**	**0.40 , 0.78**	**0.49**	**0.34 , 0.69**	**0.50**	**0.35 , 0.73**
Age Group								
15-19			**3.51**	**1.63 , 7.58**	**3.03**	**1.36 , 6.72**	**3.10**	**1.39 , 6.91**
20-24			1.88	1.00 , 3.52	1.71	0.89 , 3.29	1.74	0.90 , 3.36
25-29			1.62	0.87 , 3.02	1.52	0.80 , 2.91	1.55	0.81 , 2.96
30-34			1.33	0.71 , 2.49	1.31	0.68 , 2.53	1.34	0.69 , 2.58
35-39			1.38	0.71 , 2.68	1.47	0.73 , 2.94	1.48	0.74 , 2.98
40-44			Ref.		Ref.		Ref.	
Race								
AI/AN			N/A		N/A		N/A	
Other			0.45	0.12 , 1.68	0.50	0.12 , 2.03	0.49	0.12 , 2.00
Asian			**2.16**	**1.14 , 4.12**	**3.01**	**1.55 , 5.82**	**2.97**	**1.53 , 5.75**
Black			1.08	0.71 , 1.65	1.06	0.68 , 1.66	1.07	0.69 , 1.66
Latinx			**1.61**	**1.10 , 2.35**	**1.75**	**1.17 , 2.61**	**1.75**	**1.17 , 2.61**
NHPI			N/A		N/A		N/A	
Two or more			N/A		N/A		N/A	
Unknown			0.73	0.39 , 1.35	0.82	0.43 , 1.57	0.82	0.43 , 1.58
White			Ref.		Ref.		Ref.	
Syphilis Stage								
P&S					**7.29**	**4.06 , 13.09**	**7.33**	**4.08 , 13.18**
EL					**5.13**	**3.60 , 7.32**	**5.12**	**3.59 , 7.30**
LL/UNK					Ref.		Ref.	
Homelessness							1.10	0.64 , 1.87
Incarceration							0.88	0.61 , 1.27
AIC	1797.711		1781.774		1635.869		1639.291	
BIC	1808.552		1863.083		1728.019		1742.282	
-2 Log Likelihood	1793.711		1751.774		1604.869		1601.291	

Note: AIC = Akaike Information Criterion, BIC: Bayesian Information Criterion
Model 1: Unadjusted model.
Model 2: Adjusted for demographic variables (age, race).
Model 3: Further adjusted for clinical stage (syphilis stage).
Model 4: Full main effect model, additionally adjusted for social vulnerabilities (homelessness, incarceration).

Sensitivity Analyses and Model Evaluation

Sensitivity analyses were conducted using bootstrapped confidence intervals to assess the robustness of model estimates. The direction and magnitude of the meth–pregnancy interaction remained consistent, supporting the stability of the primary findings. The correlations among predictors were uniformly low (all Pearson correlation $r < 0.15$), suggesting minimal shared variance and indicating that multicollinearity was not a significant concern in the model. Model fit was assessed by comparing Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values. Model 4 achieved the lowest AIC/BIC, suggesting higher explanatory power relative to Models 1 to 3.

Multiple Imputation to Account for Missing Methamphetamine Use Data

Missing meth use data (17%) were addressed using SAS PROC MI, which employed a Monte Carlo method for multiple imputation.[96–98] This procedure replaces missing values with plausible estimates based on the observed data distribution, resulting in several complete datasets. Each dataset was analyzed, and the results were combined with PROC MIANALYZE following Rubin's rules, accounting for both within- and between-imputation variability. This approach reduced bias and enhanced the validity and robustness of the findings. After five imputations, the Model 4's adjusted odds ratios remained consistent: 1.19 (95% CI: 0.94–1.52) for non-pregnant PRP and 0.52 (95% CI: 0.36–0.75) for pregnant PRP, reinforcing the reliability of the results (Table 6).

Table 6. Comparing Odds Ratios of Logistic Regression Model 4 and Multiple Imputation

	Non-Pregnant PRP				Pregnant PRP			
	Model 4		M.I.		Model 4		M.I.	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Methamphetamine use	1.05	0.80 , 1.37	0.86	0.68 , 1.11	**0.50**	**0.35 , 0.73**	**0.52**	**0.36 , 0.75**
Age Group								
15-19	0.72	0.51 , 1.01	0.83	0.61 , 1.14	**3.10**	**1.39 , 6.91**	**3.10**	**1.39 , 6.91**
20-24	0.84	0.65 , 1.10	0.98	0.77 , 1.25	1.74	0.90 , 3.36	1.74	0.90 , 3.36
25-29	0.84	0.65 , 1.08	0.91	0.72 , 1.15	1.55	0.81 , 2.96	1.55	0.81 , 2.96
30-34	0.77	0.60 , 1.01	0.88	0.69 , 1.11	1.34	0.69 , 2.58	1.34	0.69 , 2.58
35-39	0.93	0.71 , 1.21	0.91	0.71 , 1.16	1.48	0.74 , 2.98	1.48	0.74 , 2.98
40-44	Ref.		Ref.		Ref.		Ref.	
Race								
AI/AN	0.58	0.18 , 1.88	0.91	0.18 , 1.88	N/A		N/A	
Other	0.89	0.49 , 1.63	0.68	0.49 , 1.63	0.49	0.12 , 2.00	0.49	0.12 , 2.00
Asian	**3.31**	**2.02 , 5.41**	**3.34**	**2.02 , 5.41**	**2.97**	**1.53 , 5.75**	**2.97**	**1.53 , 5.75**
Black	0.88	0.68 , 1.13	1.09	0.68 , 1.13	1.07	0.69 , 1.66	1.07	0.69 , 1.66
Latinx	1.16	0.93 , 1.46	1.50	0.93 , 1.46	**1.75**	**1.17 , 2.61**	**1.75**	**1.17 , 2.61**
NHPI	1.59	0.38 , 6.69	3.17	0.38 , 6.69	N/A		1.39	0.14 , 13.62
Two or more			0.69	0.03 , 16.22	N/A		N/A	
Unknown	0.99	0.72 , 1.37	0.93	0.69 , 1.24	0.82	0.43 , 1.58	0.81	0.42 , 1.58
White	Ref.		Ref.		Ref.		Ref.	
Syphilis Stage								
P&S	**16.40**	**11.97 , 22.46**	**8.12**	**6.59 , 10.01**	**7.33**	**4.08 , 13.18**	**7.33**	**4.08 , 13.18**
EL	**11.74**	**9.01 , 15.30**	**7.86**	**6.44 , 9.59**	**5.12**	**3.59 , 7.30**	**5.12**	**3.60 , 7.30**
LL/UNK	Ref.		Ref.		Ref.		Ref.	
Homelessness	**1.88**	**1.50 , 2.37**	**0.64**	**0.52 , 0.77**	1.10	0.64 , 1.87	0.91	0.54 , 1.56
Incarceration	1.08	0.88 , 1.33	0.97	0.80 , 1.18	0.88	0.61 , 1.27	1.13	0.79 , 1.63

M.I.: Multiple Imputation. The Fully Conditional Specification (FCS) method was used for multiple imputation to handle missing data, allowing each variable to be imputed using a separate regression model. To account for uncertainty in the imputation process, five imputed datasets were generated (nimpute=5), and results were pooled to produce valid statistical inferences.

4. Discussion

This study analyzed 5,765 syphilis cases among PRP in LAC from 2011 to 2020, to examine how meth use is associated with syphilis treatment and how the association is moderated by pregnancy status. Over the study period, meth use prevalence increased substantially among both pregnant and non-pregnant PRP, with pregnant individuals surpassing non-pregnant counterparts after 2016, peaking at over 17% in 2020. This notable shift underscores a growing public health concern regarding substance use during pregnancy and its implications for maternal and child health. Overall, pregnant PRP were primarily younger and Latinx, diagnosed more frequently at the Early Latent syphilis stage, and had lower rates of homelessness and incarceration compared to non-pregnant individuals. Importantly, pregnant PRP had significantly higher syphilis treatment rates (76.9%) compared to non-pregnant PRP (58.7%), suggesting that prenatal care potentially facilitated greater access to treatment overall.

The moderation analysis demonstrated that pregnancy significantly modified the relationship between meth use and syphilis treatment. Among pregnant PRP, meth use was consistently associated with reduced odds of receiving treatment (OR = 0.50, 95% CI: 0.35–0.73), even after multiple imputation for missing data (OR = 0.52, 95% CI: 0.36–0.75). Conversely, meth use was not significantly associated with odds of treatment among non-pregnant PRP in fully adjusted models. These differential findings highlight that pregnancy and meth specific factors, potentially including stigma, surveillance, and systemic barriers, may uniquely complicate treatment access for substance-using pregnant PRP.

Interpreting these findings through The Reproductive Justice and Syndemic frameworks clarifies the intersectional vulnerabilities faced by pregnant PRP who use substances. The Reproductive Justice framework underscores how pregnant persons using substances are disproportionately subject to intensified surveillance and social condemnation, potentially exacerbating systemic and structural barriers to timely and appropriate healthcare.[79] The Syndemic framework further illustrates how co-occurring factors—substance use, homelessness, and incarceration—compound and mutually reinforce negative health outcomes.[87] However, the significant positive association observed between homelessness and higher treatment odds in some models among non-pregnant PRP may reflect the impact of targeted public health interventions. This paradoxical finding suggested that when harm reduction services are integrated within homelessness service environments, they may facilitate access to syphilis treatment among individuals experiencing homelessness.

Racial disparities further complicated the landscape of syphilis treatment access, although not always in the expected direction. Among PRP, both Asian and Latinx individuals exhibited significantly higher odds of receiving treatment compared to their White counterparts. A similar pattern was observed among non-pregnant PRP, where Asian individuals also had elevated odds of treatment relative to Whites. These findings diverged from the initial hypotheses grounded in structural racism frameworks, which anticipated that racial minority groups would face greater barriers to care. One possible interpretation is that, within this specific population of syphilis cases, many of whom experience overlapping Syndemic vulnerabilities such as housing instability, substance use, and late-stage diagnosis, the marginal effects of race may be attenuated by the severity of shared structural disadvantage. However, the consistently higher odds of treatment among Asian PRP, even within this high-risk sample, suggest a distinct pattern that warrants further investigation. This may reflect differential patterns of healthcare utilization, cultural norms surrounding engagement with public health services, or targeted outreach strategies that are more effective in reaching certain subgroups. Alternatively, it may indicate variation in provider behavior, case management follow-up, or prioritization protocols across demographic lines. These findings underscore the complexity of interpreting racial disparities in healthcare outcomes within highly marginalized populations and point to the importance of intersectional approaches that consider how race interacts with other social determinants that shape treatment trajectories.

Syphilis stage at diagnosis emerged as a consistent predictor of treatment outcomes across both pregnant and non-pregnant PRP. Those diagnosed at the primary and secondary stages demonstrated significantly higher odds of receiving adequate treatment compared to individuals diagnosed at the late latent or unknown stages. This pattern is likely attributable to the presence of visible and sometimes painful symptoms associated with early-stage syphilis, such as chancres, mucocutaneous lesions, and rashes, which increase the likelihood that individuals will seek clinical care. Moreover, symptomatic infections are more easily recognized by healthcare providers, prompting earlier diagnosis and initiation of treatment. By contrast, individuals in the late latent or unknown stage are often asymptomatic and may only be identified through routine screening protocols, such as prenatal care, incarceration intake, or contact tracing. The absence of symptoms in these later stages can result in missed opportunities for timely diagnosis, particularly among populations who do not routinely access preventive or sexual health services.

Limitations

Several methodological limitations must be noted. First, because syphilis surveillance data were originally intended for public health monitoring rather than research, certain variables (especially meth use) were subject to reporting biases and incomplete documentation. Although multiple imputation methods addressed data missingness (17% for meth use), residual confounding remained possible. Second, the dichotomous measurement of meth use precluded detailed analyses of substance use patterns or co-occurring substance dependencies. Third, the study lacked qualitative or context-specific data, limiting deeper exploration of personal decision-making processes, barriers to care, and stigma experiences. Lastly, results derived from LAC might not generalize to other settings with different demographic compositions, health systems, or policy contexts.

Implications

The results of this study highlighted a concerning and growing disparity in syphilis treatment among pregnant individuals who use meth. Even after accounting for demographic and structural factors, meth use remained a significant barrier to treatment among pregnant PRP, underscoring the need for targeted, supportive interventions. These findings illustrated how substance use, stigma, and system-level barriers continue to shape maternal health outcomes in ways that are both preventable and actionable.

These findings call for comprehensive, multi-sectoral responses that center trauma-informed, harm reduction-based approaches, and recognize the rights and dignity of pregnant individuals who use substances. Interventions must embed structural competency into public health practice, clinical training, and policy design, with a specific focus on dismantling systemic racism and shifting from surveillance-based to support-based models of care.[99,100] Addressing CS and maternal substance use disparities demands not only improving treatment access but also advancing The Reproductive Justice—ensuring that all people, particularly those most structurally marginalized, can parent with dignity, access healthcare without fear, and live in safe, supported communities.

To advance equitable MCH outcomes, coordinated actions are needed across public health, clinical, policy, and research sectors. Public health practitioners should prioritize low-barrier, trauma-informed prenatal care models that integrate syphilis screening with substance use support, while strengthening cross-sector partnerships among STD programs, maternal health services, and behavioral health providers.[101] Enhancing surveillance systems to capture nuanced behavioral health data can also support early intervention and more effective care coordination. Clinicians play a key role and should routinely screen for meth use during pregnancy in nonjudgmental, confidential settings and receive training in stigma reduction and culturally responsive care. Policymakers must align criminal justice reforms, such as Proposition 47[102] (that will be discussed in Chapter Three), with investments in harm reduction, prenatal outreach, and integrated substance use services, while also enacting protections against punitive responses (e.g., mandatory child welfare referrals) that deter care-seeking. Researchers should conduct qualitative and mixed-methods studies to explore care engagement among pregnant individuals who use meth and examine how provider bias and institutional mistrust may shape disparities in STI treatment and maternal health access.

Chapter 3. Maternal Methamphetamine Use, Syndemic Burden, and Prenatal Care Utilization to Understand Missed Opportunities to Prevent Congenital Syphilis (Aim 2)

1. Introduction

Prenatal care (PNC) is a cornerstone of maternal and child health (MCH), reducing risks associated with adverse birth outcomes and facilitating early detection and treatment of infectious diseases, including syphilis.[103] However, significant disparities in PNC access persist, particularly among populations affected by substance use and structural vulnerabilities.[104] Methamphetamine (meth) use during pregnancy has become increasingly prevalent in California and nationally, contributing to rising rates of congenital syphilis (CS).[11] Meth use is often compounded by Syndemic risk factors—such as homelessness, mental health disorders, incarceration history, and involvement with child protective services—that create substantial barriers to care.[105]

The Reproductive Justice framework situates these barriers within broader systems of structural inequity, emphasizing the right to have children, to not have children, and to parent children in safe and supportive environments.[80] From this perspective, lack of PNC among substance-using pregnant individuals is not solely a matter of individual behavior but reflects overlapping systems of oppression and punitive responses to substance use in pregnancy.

This study aimed to investigate the direct and indirect associations between meth use and lack of PNC among birthing persons of infants diagnosed with CS in Los Angeles County (LAC) from 2011 to 2020. Specifically, it examined whether meth use independently predicted lack of PNC and whether this association was mediated by Syndemic burden. Logistic regression and structural equation modeling (SEM) were used to identify predictors and explore pathways linking meth use, Syndemic risks, and PNC access, with a focus on racial disparities informed by structural racism and The Reproductive Justice theories.

2. Methods

Dataset

Data were derived from the CS surveillance dataset managed by the Division of HIV and STD Programs (DHSP) in the Los Angeles County Department of Public Health (LAC DPH). For this study, deidentified, line-listed CS case reports from 2011 to 2020 were extracted, excluding cases reported from the cities of Pasadena and Long Beach, which operate their own health departments. The dataset included demographic and clinical information for both the birthing parents and the infants.

Under the guidance of LAC DPH epidemiologists, I conducted a detailed review of both paper-based and web-based clinical and public health records between February 2022 and December 2024 to enhance the completeness of Syndemic-related variables. This review covered all 414 CS cases included in the study. Medical records and public health investigator notes were systematically examined to collect available data on key maternal risk factors, including substance (e.g., meth, heroin, cocaine, opiates, and cannabis) use, mental health problems (ranging from depression and anxiety to bipolar disorder, schizophrenia, and episodic psychosis), homelessness, incarceration history, and Department of Children and Family Services (DCFS) referrals. Further details regarding CS case investigation and reporting procedures are provided in the Introduction's Data Source section.

Outcome Variable

PNC access served as the primary outcome variable for this study and was operationalized as a dichotomous measure (yes/no). PNC access was determined based on documented receipt of any PNC prior to delivery, as recorded in medical records and public health case investigations. Cases where no PNC was received prior to delivery were classified as having no PNC access.

Access to PNC was a critical indicator of CS prevention. In this study, PNC access was conceptualized as being shaped not only by individual-level vulnerabilities, but also by broader social and structural determinants, including systemic inequities, barriers to healthcare, and social vulnerability within communities. This conceptualization aligned with Syndemic theory, which recognizes the interplay between multiple co-occurring conditions and structural forces in exacerbating adverse health outcomes. Therefore, PNC access was hypothesized to be influenced by a constellation of individual behaviors, and social determinants that collectively create or hinder opportunities for timely and adequate PNC that enables maternal syphilis screening, diagnosis, and treatment.

Independent Variable

Maternal meth use was measured as a dichotomous variable (0 = No, 1 = Yes) and was treated as a key independent predictor in this study. Importantly, while a broader Syndemic variable was constructed from indicators of homelessness, mental health problems, child/family service referrals, and incarceration history, maternal meth use was examined separately to elucidate its unique impact on PNC utilization among pregnant people diagnosed with syphilis. This approach was informed by a The Reproductive Justice framework, which calls for an analysis that centers the lived experiences of marginalized populations and examines how intersecting systems of oppression (e.g., racial, economic, and social inequities) shape healthcare access. By isolating meth use as a stand-alone predictor, this study aims to better understand how substance use contributes to the structural barriers in PNC, independent of other co-occurring risk factors.

Syndemic Variables

To quantify the cumulative burden of interrelated psychosocial and structural risk factors among birthing persons of infants diagnosed with CS, a latent variable for Syndemic burden was constructed using SEM. This latent construct captures the co-occurrence and interaction of multiple adversities, in alignment with Syndemic theory, which posits that intersecting conditions mutually reinforce each other to exacerbate health outcomes among structurally marginalized populations. The Syndemic latent variable was inferred from four binary observed indicators:

1. Homelessness in the 12 months prior to delivery,
2. Incarceration history in the past 12 months,
3. Referral to the DCFS for suspected maltreatment or neglect, and
4. Mental health problems documented at birth or at the surveillance record.

Each indicator was coded as 1 = presence of the condition and 0 = absence. These indicators were specified as reflective indicators in the SEM, with the assumption that they are manifestations of an underlying, unmeasured Syndemic construct. Standardized factor loadings ranged from 0.47 to 0.66, all statistically significant at $p < 0.001$, indicating that each observed variable contributed meaningfully to the latent factor.

The factor scores derived from the latent construct were then used as a continuous, weighted measure of Syndemic burden in subsequent path analyses. These scores reflect not just the number of conditions present, but also the relative contribution of each risk factor based on its loading in the SEM model—offering a more refined alternative to simple count-based indices.

Model fit was evaluated using chi-square, Comparative Fit Index (CFI), Tucker–Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). Finally, a multi-group SEM was also conducted to examine whether mediation pathways varied by maternal race. The SEM was conducted by utilizing the "lavaan" package in R (4.4.2 version) with maximum likelihood estimation.

SEM was particularly well-suited for this study, given its capacity to model complex relationships among both observed and latent variables while accounting for measurement error.[106] Surveillance data often suffer from limitations such as underreporting, missing information, and inconsistently measured constructs, challenges that SEM can partially mitigate by explicitly modeling measurement error.[107] In this study, SEM enabled the creation of a theory-driven latent Syndemic variable, integrating multiple co-occurring risk factors into a single construct grounded in Syndemic theory. Furthermore, SEM allowed for the testing of mediation pathways, such as whether Syndemic burden mediated the relationship between meth use and lack of PNC. This analytical approach provided a robust framework for evaluating synergistic risks and identifying indirect pathways of harm, enhancing the interpretability and theoretical coherence of findings.

Study Population Characteristics

Maternal age was categorized into seven groups (15–19, …, 45–54 years) to capture age-related effect on healthcare access and risk profiles. Marital status was classified into three categories: Single/Divorced, Married, and Other/Unknown. This variable serves as a proxy for social support and household stability, known to be associated with access to PNC and maternal health outcomes. Self-reported race was measured with six categories: White, Black, Latinx, Asian, Native Hawaiian & Pacific Islander, and Other/Unknown. Race is included to assess potential disparities in health outcomes and access to care, informed by The Reproductive Justice framework that informs racial/ethnic differences in MCH due to racism.

Covariates

Marital status was included as a covariate in the logistic regression models predicting the absence of PNC to control for potential confounding related to social support systems.[108,109] Birthing persons without a partner may face increased barriers to healthcare access, such as reduced emotional, logistical, or financial support—factors that are known to influence engagement in prenatal services.[110]

Analyses

Descriptive statistics were first used to summarize maternal demographic and clinical characteristics by maternal meth use. Chi-square tests were conducted to assess differences in categorical variables, with statistical significance set at $p < 0.05$.

To examine associations between key variables, pairwise Cramer's V statistics were calculated. Cramer's V, a measure of association for nominal variables, ranges from 0 (no association) to 1 (perfect association) and was used to assess clustering of risk factors. These associations provided context for the potential interrelationships among Syndemic conditions and informed subsequent modeling strategies.

To understand both direct and indirect mechanisms influencing PNC utilization among those who missed to prevent CS, both logistic regression and SEM was utilized following Rijnhart et al. (2017) methods.[111] Three logistic regression analyses were conducted to estimate the association between maternal meth use and no PNC. An unadjusted logistic regression model was first estimated, followed by a multivariate model incorporating Syndemic factors (homelessness, mental health problems, referrals to DCFS, incarceration history, and marital status). An interaction model included interaction terms to test whether the effect of meth use on PNC was modified by Syndemic factors. Model comparisons were based on likelihood ratio tests, Akaike's Information Criterion (AIC), and Bayesian Information Criterion (BIC). The multivariate model was selected as the best-fitting model based on these criteria. Odds ratios (ORs) with 95% confidence intervals (CIs) were derived using exponentiated regression coefficients. Model diagnostics included calculation of predicted probabilities, construction of a confusion matrix, and derivation of the receiver operating characteristic (ROC) curve with corresponding area under the curve (AUC).

- **Logistic Regression Model 1**
  - Included only meth use

$$log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 METH$$

- **Logistic Regression Model 2**
  - Incorporated meth use and all Syndemic risk factors)

$$log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 METH + \beta_2 HOMELESSNESS + \beta_3 INCARCERATION$$

$$+\beta_4 DCFS + \beta_5 MENTAL\ HEALTH$$

- **Logistic Regression Model 3**
  - Added the interaction between meth use and the Syndemic risk factors to Model 2

$$log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 METH$$

$$+ \sum_{k=2}^{6} \beta_k Syndemic\ Factors_{k,i}$$

$$+ \sum_{k=2}^{6} \beta_{1k} RACE_k (Meth_i * Syndemic\ Factors_{k,i})$$

Based on the logistic regression, Structural Equation Modeling (SEM) was specified to test potential mediation by a latent "Syndemic factors" variable. Two SEM specifications were estimated, including a mediation model that examined: (1) the direct effect of meth use on no PNC; (2) the indirect effect of meth use through the latent Syndemic construct. Only groups with ≥40 observations were included to ensure sufficient sample size for stable parameter estimates.

Step 1. A latent variable, Syndemic factors, was defined by homelessness, mental health problems, child/family service referrals, and incarceration history. The structural model regressed absence of PNC on maternal meth use, marital status, and the latent Syndemic factor.

Step 2. In this step, the latent factor was regressed on maternal meth use. Then, absence of PNC was regressed on maternal meth use, the latent factor, and marital status, thereby explicitly testing for mediation.

Step 3. A multi-group SEM by maternal race was conducted to examine whether the mediation structure varied across racial groups. After filtering out groups with insufficient cases (less than 40 cases), group-specific models were estimated and compared.

Statistical analyses were conducted using R version 4.5.0 (R Core Team, 2025). SEM was employed using lavaan package.[112] All statistical analyses were performed within RStudio (R.app GUI 1.81) using R Markdown.

3. Results

Population Characteristics

A total of 414 infants diagnosed with congenital syphilis were included in this analysis. Birthing parents were divided into two groups based on meth use, with 43.5% identified as individuals who used meth. Among those who did not use meth, 26.9% were aged 20–24 years, compared to just 15% in the meth-use group. Conversely, in the 25–29 age range, 37.8% of birthing parents who used meth were represented, versus 20.1% among those who did not use meth. The largest racial/ethnic group was Latinx in both groups, although the distribution differed significantly ($\chi^2 = 20.6127$; $p < 0.01$). Among birthing parents who used meth, 55.0% identified as Latinx, compared to 47.9% in the non–meth-use group. Late latent syphilis was the most common stage of infection overall: 66.7% of birthing parents in the meth-use group had late latent syphilis, compared to 55.1% of those who did not use meth. Meanwhile, early latent infection was more prevalent among individuals who did not use meth (36.6% vs. 24.7%). Notable disparities were observed in the Syndemic factors (i.e., homelessness, mental health conditions, DCFS (Department of Children and Family Services) referrals, and incarceration histories ($p < 0.0001$). More than half (53.3%) of individuals who used meth experienced homelessness, versus 12.0% among those who did not use meth. Mental health problems were reported by 21.1% of parents who used meth, compared to 2.1% of those who did not. Referrals to DCFS were 4.7 times higher in the meth-use group (31.7% vs. 6.8%), and more than two times higher in histories of incarceration (58.9% vs. 20.5%).

Lack of PNC was significantly more prevalent in the meth-use group (63.3% vs. 38.9%; $\chi^2 = 24.3192$; $p < 0.0001$), underscoring a critical PNC access gap. Approximately 93–95% of infants survived to birth or neonatal discharge, and stillbirth or neonatal death rates were 5 to 7%, substantially higher than the national neonatal mortality rate of 0.28%, highlighting the risk of CS.[113]

Table 7. Maternal Demographic and Clinical Characteristics (N=414)

	No Meth Use		Meth Use			
	n=234	%	n=180	%	χ^2 Statistics	*P*-value
Age Group***					27.6840	0.0003
15-19	21	8.97	9	5.00		
20-24	63	26.92	27	15.00		
25-29	47	20.09	68	37.78		
30-34	48	20.51	47	26.11		
35-39	25	10.68	16	8.89		
40-44	16	6.84	5	2.78		
45-54	3	1.28	0	0.00		
Marital Status***					20.8768	0.0003
Single/Divorced	141	60.26	139	77.22		
Married	47	20.09	15	8.33		
Other/Unknown	23	9.83	26	14.44		
Race**					20.6127	0.0022
White	26	11.11	26	14.44		
Black	66	28.21	44	24.44		
Latinx	112	47.86	99	55.00		
Asian	23	9.83	2	1.11		
Native Hawaiian & Pacific Islander	1	0.43	2	1.11		
Other/Unknown	6	2.56	7	3.89		
Syphilis Stage*					6.6157	0.0366
Primary & Secondary	19	8.37	15	8.62		
Early Latent	83	36.56	43	24.71		
Late Latent	125	55.07	116	66.67		
Syndemic Factors						
Homelessness***	28	11.97	96	53.33	82.9828	<.0001
Mental Health Problems***	5	2.14	38	21.11	39.3532	<.0001
Referred to DCFS***	16	6.84	57	31.67	43.1849	<.0001
History of Incarceration ***	48	20.51	106	58.89	64.1380	<.0001
Non-Treponemal Test						
1st Trimester***	112	47.86	58	32.22	24.8213	<.0001
28-32 Weeks of Gestation	56	23.93	36	20.00	5.8631	0.0533
Delivery	199	95.22	176	97.78	2.1839	0.3356
No Prenatal Care***	91	38.89	114	63.33	24.3192	<.0001
Birth Outcome					0.6462	0.4222
Alive	218	93.16	171	95.00		
Stillborn/Neonatal Death	16	6.84	9	5.00		

DCFS: Department of Children and Family Services.

Note: If 20% or more of the expected cell counts were less than 5, the Likelihood Ratio Chi-Square test was used instead of the Pearson Chi-Square test for better reliability. Statistical significance is denoted as follows: $p < 0.05$ (*), $p < 0.01$ (**), $p < 0.001$ (***).

Correlation Analysis

Cramer's V values, which ranged from 0 (no association) to 1 (perfect association), provided insight into the clustering of risk factors and informed the statistical modeling. In this analysis, the strongest association appeared between maternal meth use and homelessness (0.44), indicating that meth use was more closely tied to homelessness than to other factors. Among the Syndemic indicators, intercorrelations generally fell below 0.4, suggesting that although these variables clustered into a risk profile, each captured distinct dimensions of risk. Notably, the association between homelessness and mental health problems (0.38) was the highest among the indicators that constituted the latent Syndemic factor.

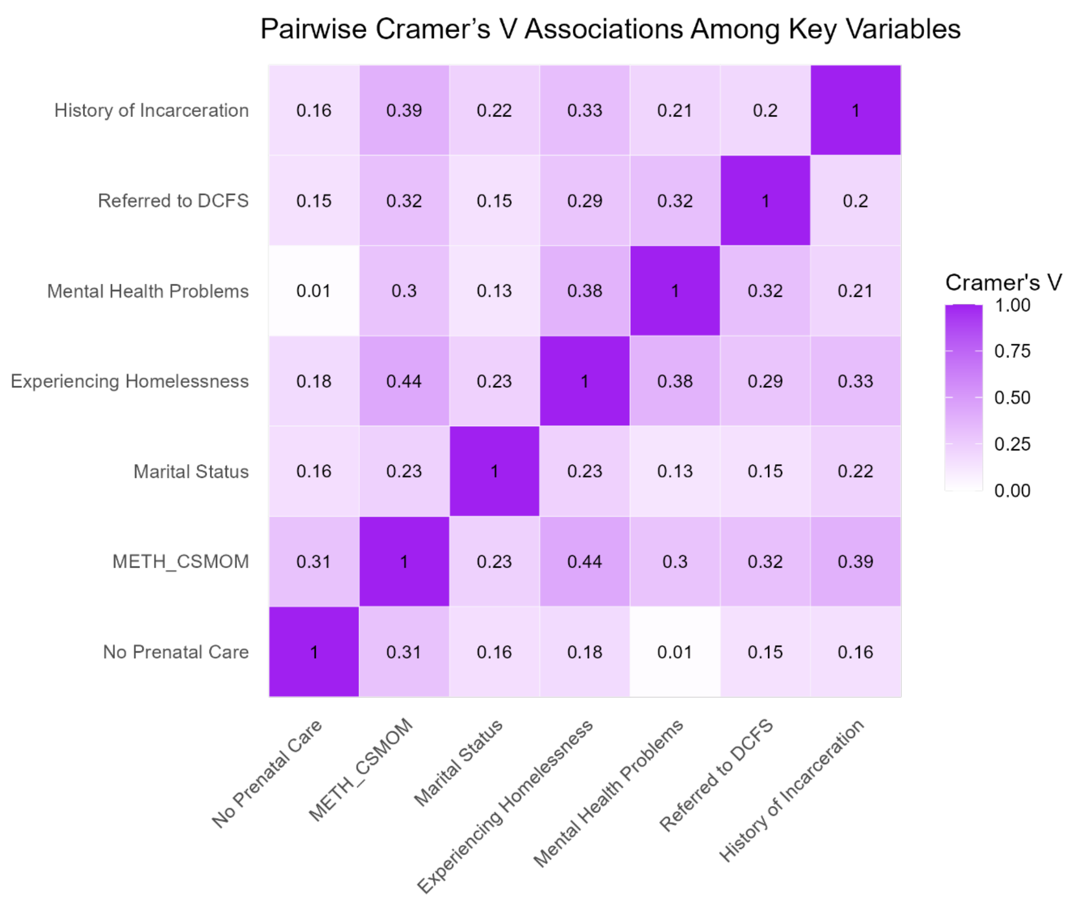


Figure 13. Pairwise Cramer's V Associations Among Key Variables

Logistic Regression

Meth use was associated with a 2.71-fold increase in the odds of no PNC (95% CI: 1.82, 4.07) in the unadjusted model. In the multivariate model—adding homelessness, mental health status, DCFS involvement, incarceration history, and marital status—the odds ratio for meth use rose to 3.11 (95% CI: 1.90, 5.13), while none of the added covariates were statistically significant, apart from a slightly protective effect of mental health (OR=0.42, 95% CI: 0.20, 0.89). The interaction model produced an even higher odds ratio for meth use (OR=4.73, 95% CI: 2.41, 9.49), though none of the interaction terms were significant. Information criteria and McFadden's R^2 indicated that the multivariate model offered the best balance of improved fit (reduction in residual deviance from 503.30 to 491.01, $p = 0.031$) and parsimony (lowest AIC of 505.01), outperforming both the basic (AIC = 507.30) and interaction (AIC = 508.18) models.

Table 8. Odds Ratios from Logistic Regression Models for No Prenatal Care

Variable	Unadjusted OR	Unadjusted 95% CI	Multivariate Model 1 OR	Multivariate Model 1 95% CI	Multivariate Model 2 OR	Multivariate Model 2 95% CI
(Intercept)	0.64	0.49 , 0.83	0.36	0.25 , 0.52	0.32	0.21 , 0.48
Meth	**2.71**	**1.82 , 4.07**	**3.11**	**1.90 , 5.13**	**4.73**	**2.41 , 9.49**
Homelessness			1.38	0.81 , 2.37	1.16	0.43 , 2.94
Mental health problems			**0.42**	**0.08 , 0.98**	0.53	0.05 , 4.43
DCFS referrals			1.60	0.88 , 2.94	3.01	0.82 , 12.81
Incarceration			1.21	0.75 , 1.96	1.79	0.86 , 3.68
Marital Status			1.09	1.00 , 1.19	1.09	1.00 , 1.19
Meth*Homelessness					1.18	0.37 , 3.84
Meth*Mental Health					0.81	0.08 , 9.71
Meth*DCFS					0.40	0.08 , 1.76
Meth*Incarceration					0.47	0.18 , 1.25
df	389		384		380	
Model Comparison ANOVA χ^2 (*p*-value)			0.031*		0.306	
AIC	507.30		505.01		508.18	
BIC	515.24		532.79		551.84	
McFadden's R^2	0.069		0.091		0.100	

Accordingly, the multivariate model was chosen for further diagnostic assessment, and its performance was summarized by the confusion matrix, overall accuracy, and ROC analysis. In the confusion matrix, rows represent predicted classes (0 = negative, 1 = positive) and columns represent actual classes (0 = negative, 1 = positive), yielding 150 true negatives, 70 false negatives, 58 false positives, and 113 true positives. This corresponds to an accuracy of 67.3% (95% CI: 0.624–0.719), with a sensitivity of 61.8% and a specificity of 72.1%. The Kappa statistic (0.34) suggests fair agreement beyond chance, while a balanced accuracy of 66.9% accounts for potential class imbalance. Among predicted positives, 66.1% are truly positive (PPV), and among predicted negatives, 68.2% are correctly classified (NPV). Compared to the No Information Rate of 53.2% (assuming a constant prediction of the majority class), the model shows substantial improvement. Finally, the ROC curve, which plots sensitivity against 1–specificity, yields an AUC of 0.704, indicating moderate discriminative ability—if a positive and negative case are chosen at random, the model score is higher for the positive case about 70.4% of the time.

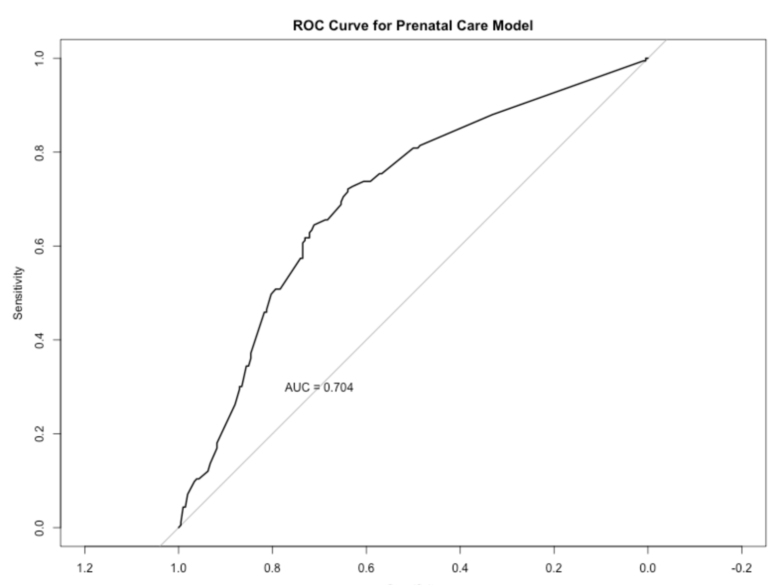


Figure 14. Receiver Operating Characteristic (ROC) Curve for Prenatal Care Prediction Model

Structural Equation Modeling for Mediation Effect of Syndemic Factors

A SEM approach was used to examine whether a latent Syndemic construct mediated the relationship between meth use and PNC access. The model converged successfully after 32 iterations using maximum likelihood estimation (ML) and Non-Linear Minimization using Bounds (NLMINB) optimization algorithm, estimating 12 free parameters based on 414 observations.

The latent construct, Syndemic, was specified to include four observed indicators: homelessness in the past 12 months, mental health issues reported by health care providers or self-reported, referrals made to Department of Child and Family Services (as known as Child Protective Services) involvement after birth, and incarceration in the past 12 months. Factor loadings were all statistically significant ($p < 0.001$), with standardized estimates ranging from 0.472 to 0.662, indicating that each indicator contributed meaningfully to the latent variable.

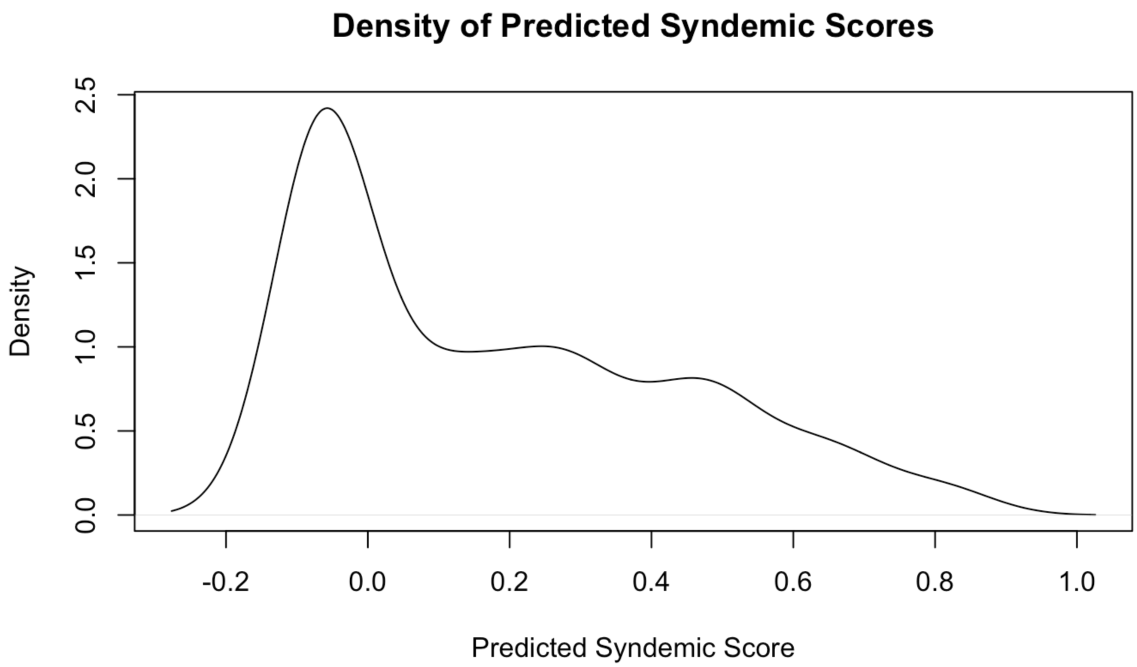


Figure 15. Kernel Density Plot of Latent Syndemic Scores

Figure 15 illustrated the overall distribution of predicted Syndemic scores derived from the SEM. The density plot showed a right skewed distribution, with the highest concentration of scores occurring near zero. This pattern suggested that while a large proportion of birthing parent experienced low levels of Syndemic burden, there remained a meaningful subset with moderate to high levels of co-occurring psychosocial and structural risk factors. The multimodal shape (i.e., A primary peak near zero, showing that many individuals had low Syndemic burden. At least one or two additional smaller humps around 0.3 and 0.6, suggesting other groups with moderate to higher Syndemic scores) of the distribution further indicated the presence of subgroups with varying degrees of Syndemic vulnerability within the study population.

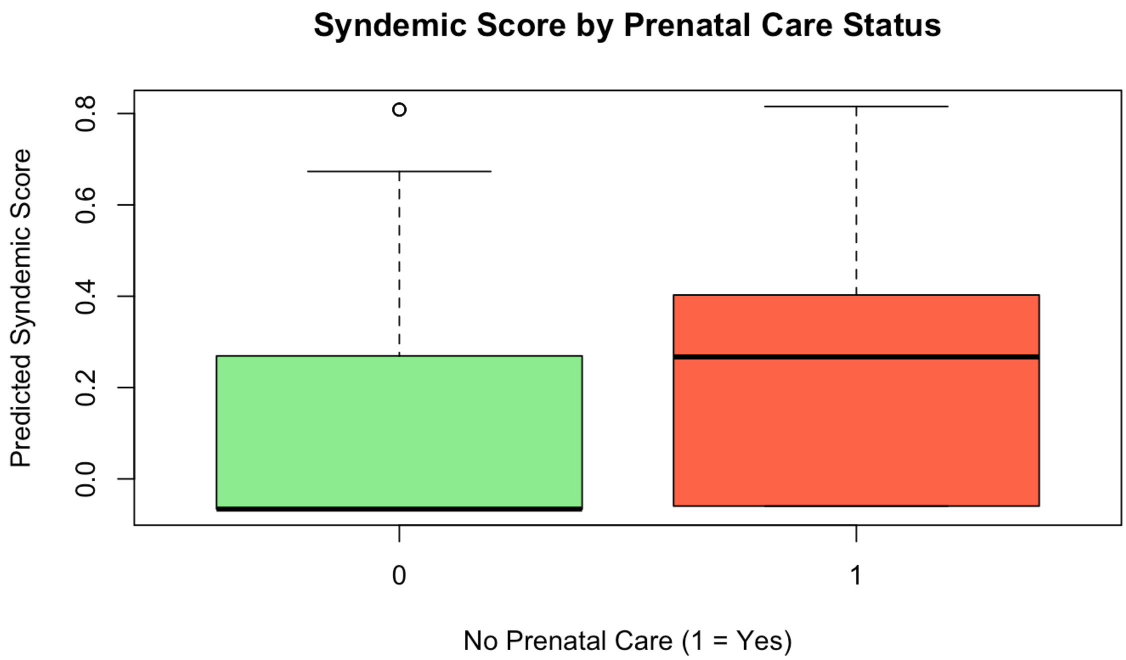


Figure 16. Distribution of Predicted Syndemic Scores by Prenatal Care Utilization

Figure 16 presented a boxplot comparing predicted Syndemic scores by PNC status. Birthing parents who did not receive PNC (coded as 1) had higher median Syndemic scores and a wider interquartile range compared to those who did receive PNC (coded as 0). This difference suggested that greater Syndemic burden was associated with lower likelihood or PNC utilization. The results highlighted the potential role of Syndemic factors, such as substance use, housing instability, and mental health issues, in shaping barriers to timely and adequate PNC during pregnancy.

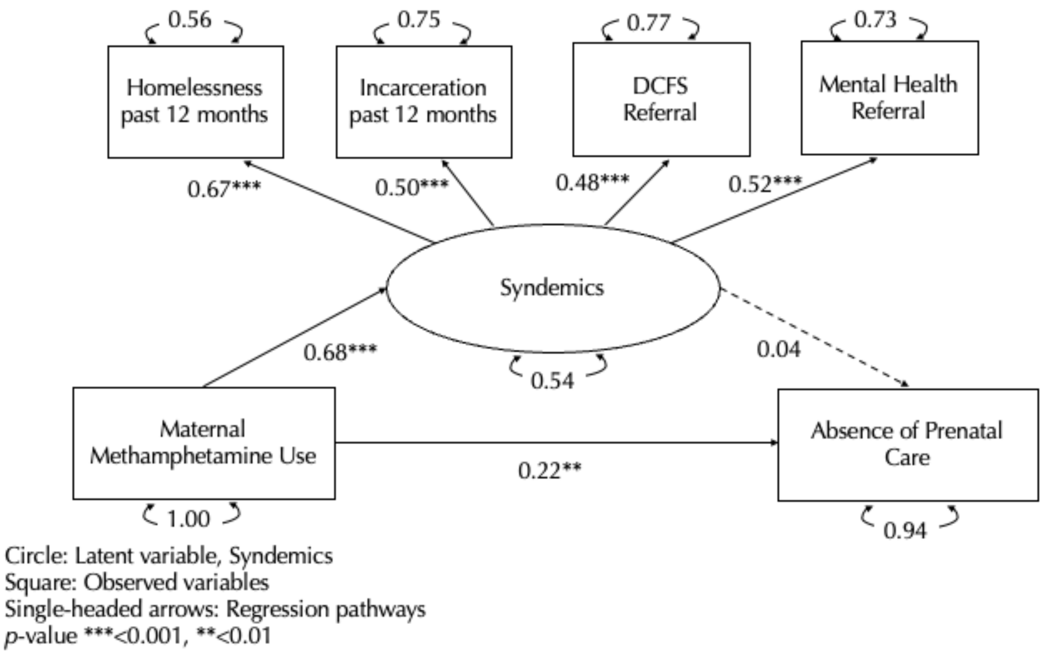


Figure 17. Structural Equation Model of Syndemic Mediation Between Methamphetamine Use and Absence of Prenatal Care
Note: This path diagram illustrates the hypothesized mediation model examining the effect of maternal meth use on absence of prenatal care via a latent Syndemics construct. The latent variable Syndemics was defined by four observed indicators: homelessness, incarceration, referral to child welfare (DCFS), and mental health issues in the past 12 months. Solid arrows represent significant paths ($p < 0.001$), and dashed arrows indicate non-significant paths. While meth use was significantly associated with both the Syndemics construct and absence of prenatal care, the indirect path through Syndemics was not statistically significant, indicating no mediation effect. $\chi^2(8) = 20.168$, $p = 0.010$, CFI = 0.965, RMSEA = 0.061, SRMR = 0.037

In the SEM model shown in Figure 17, meth use was positively associated with the latent variable Syndemics ($\beta = 0.678$, $z = 10.740$, $p < 0.001$), indicating that individuals using meth were more likely to experience multiple co-occurring vulnerabilities. Meth use also showed a significant direct effect on the likelihood of not receiving PNC ($\beta = 0.217$, $z = 2.761$, $p = 0.006$). However, the hypothesized indirect pathway through the Syndemic latent variable was not supported. The path from Syndemic to absence of PNC was not significant and the indirect effect of meth use on PNC via Syndemics was also nonsignificant. The total effect of meth use on the absence of PNC remained statistically significant ($\beta = 0.268$, $p < 0.001$), suggesting that the relationship was driven primarily by a direct pathway of meth use. All residual variances of observed variables were statistically significant, indicating adequate measurement reliability.

These results suggest that while meth use is strongly associated with increased Syndemic burden and independently predicts lack of PNC, the hypothesized mediation via the Syndemic construct was not statistically supported in this sample. Model fit was assessed using multiple indices. The chi-square test for model fit was statistically significant ($\chi^2(8) = 20.843$, $p = 0.008$), indicating some deviation from a saturated model. However, the Comparative Fit Index (CFI = 0.962) and the Tucker-Lewis Index (TLI = 0.928) both exceeded the conventional threshold of 0.90, suggesting good comparative fit. The Root Mean Square Error of Approximation (RMSEA = 0.064; 90% CI: 0.031–0.098) and the Standardized Root Mean Square Residual (SRMR = 0.039) further supported an acceptable overall model fit.

Multi-Group Structural Equation Modeling by Maternal Race

To examine the distribution of Syndemic risk factors associated with missed PNC among birthing persons of infants born with CS, the analytic sample was stratified by birthing person's race (Table 9). Most birthing persons identified as Latinx (51%), followed by Black (27%), White (13%), and Asian (6%). Latinx and Black birthing persons experienced high levels of unmet PNC, with nearly half lacking any documented PNC. In comparison, lower prevalence was observed among Asian participants. Meth use and structural vulnerabilities were also more prevalent among Latinx and Black individuals. Meth use affected 47% of Latinx and 40% of Black birthing persons. Histories of homelessness (29% Latinx, 33% Black), DCFS involvement (18% Latinx, 18% Black), and incarceration (37% Latinx, 43% Black) further illustrated the Syndemic clustering in these groups.

Analysis of cumulative Syndemic burden showed that approximately 60% of Latinx, 64% of Black, and 73% of White birthing persons experienced one or more co-occurring risk factors, compared to only 8% among Asian participants. While Syndemic exposure were prevalent among White individuals, the higher concentration of structural vulnerabilities, such as homelessness, DCFS involvement, and incarceration, among Latinx and Black birthing persons showed compounding forms of marginalization in women of color. These disparities underscore the structural inequities disproportionately affecting Latinx and Black communities, which may exacerbate barriers to timely PNC and adequate syphilis treatment, contributing to increased risk of CS.

Table 9. Distribution of Syndemic Risk Factors by Maternal Race among Birthing Persons of Infants Diagnosed with Congenital Syphilis, Los Angeles County, 2011-2020 (N=414)

	Latinx		Black		White		Asian		
	N	%	N	%	N	%	N	%	χ^2 test
	211	**50.97**	**110**	**26.57**	**52**	**12.56**	**25**	**6.04**	p-value
No PNC	104	49.29	54	49.09	30	57.69	9	36.00	0.008
Meth use	99	46.92	44	40.00	26	50.00	2	8.00	0.557
Homelessness	61	28.91	36	32.73	22	42.31	2	8.00	0.074
Mental health	20	9.48	12	10.91	8	15.38	0	0.00	0.336
DCFS ref	37	17.54	20	18.18	13	25.00	1	4.00	0.420
Incarceration	79	37.44	47	42.73	21	40.38	2	8.00	0.075
Number of risk factors									
0	85	40.28	40	36.36	14	26.92	23	92.00	
1	34	16.11	23	20.91	10	19.23	0	0.00	
2	41	19.43	20	18.18	11	21.15	0	0.00	
3	29	13.74	14	12.73	12	23.08	1	4.00	
4	15	7.11	11	10.00	3	5.77	1	4.00	
5	6	2.84	2	1.82	2	3.85	0	0.00	

Note: DCFS = Department of Children and Family Services; PNC = Prenatal Care; "Number of risk factors" includes meth use, homelessness, mental health condition, DCFS referral, and incarceration. Additional racial groups not shown due to small cell sizes: NHPI (n = 3), Other (n = 1), and Unknown (n = 12). Percentages are calculated within each racial group.

To examine whether the Syndemic mediation model functioned differently across racial groups, multi-group SEM was performed for White (n = 52), Black (n = 110), and Latinx (n = 210) among birthing mothers of infants born with CS. Black birthing parents were disproportionately represented among CS cases (27%), accounting for a significantly higher share of cases relative to their proportion in the general birthing population (7%).

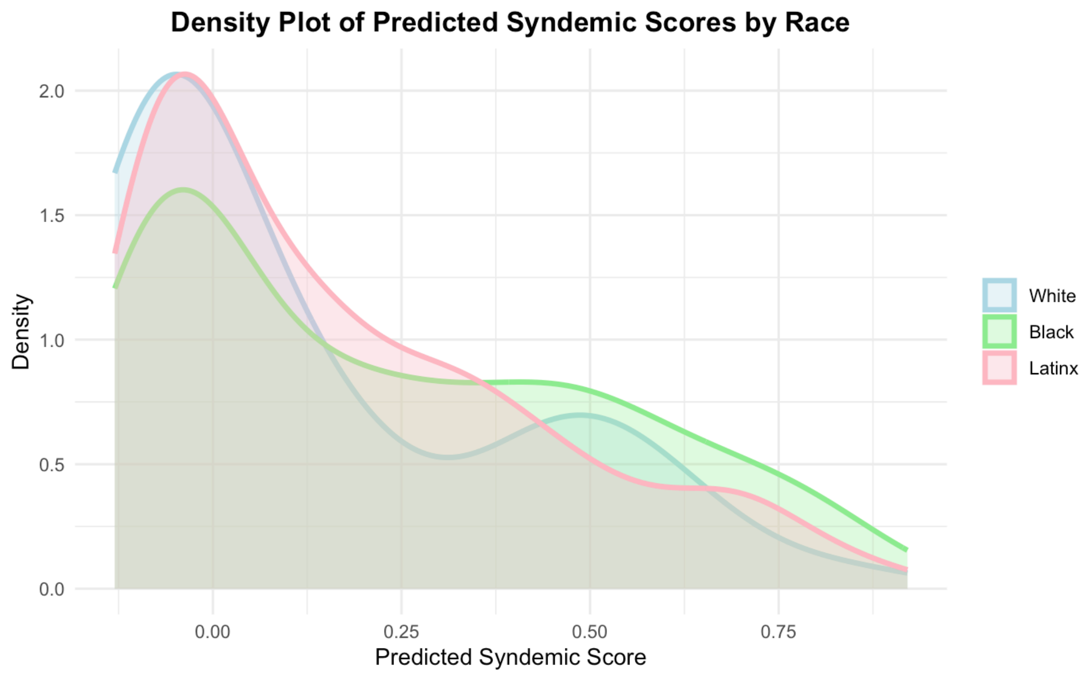


Figure 18. Kernel Density Plot of Latent Syndemic Scores by Maternal Race

Figure 18 presented a kernel density plot comparing the distribution of predicted Syndemic scores across three maternal race groups: White (blue), Black (green), and Latinx (red). The plot showed the density of Syndemic scores on the y-axis, with the predicted Syndemic scores on the x-axis. Each racial group was represented by its own density curve, with shaded area indicating the distribution within each group. The plot revealed notable differences in the distribution of Syndemic scores by maternal race. Black birthing parents showed higher Syndemic score then both the White and Latinx birthing parents, as indicated by the higher density in the green curve with higher Syndemic scores. Latinx birthing parents had slightly a slightly more even distribution, with a broader range of Syndemic scores. In contrast, the White group showed the lowest density of higher Syndemic scores, indicating that White birthing parents had lower predicted Syndemic burdens compared to the other racial groups. Overall, the plot suggested that maternal race may be associated with different levels of cumulative risk factors, underscoring the need for SEM stratified maternal race.

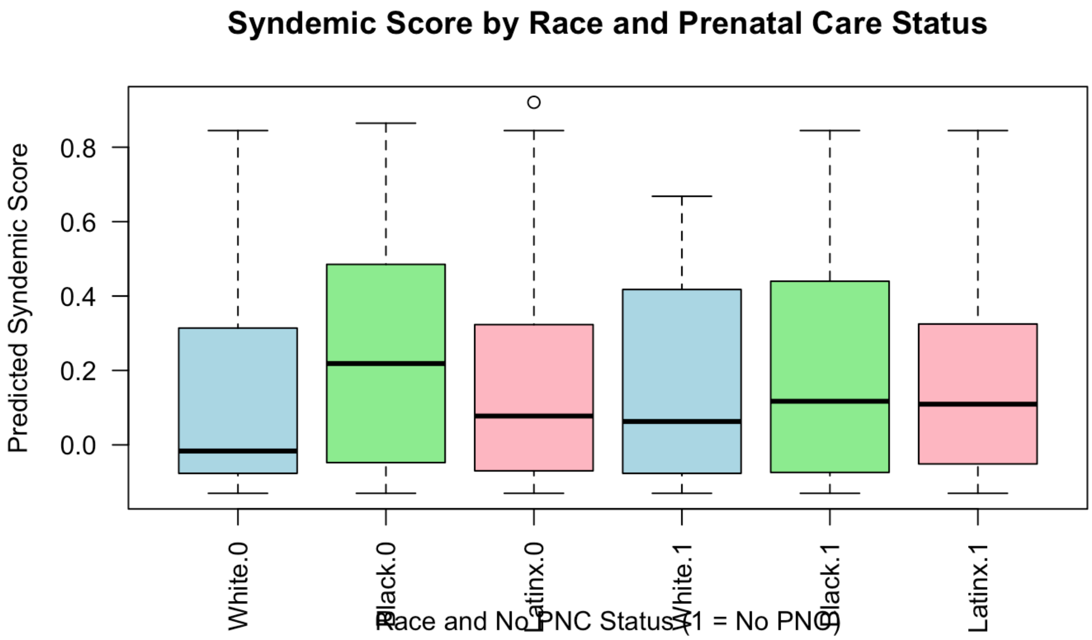


Figure 19. Boxplot of Predicted Syndemic Scores by Maternal Race and Prenatal Care

The Figure 19 illustrated the distribution of predicted Syndemic scores by maternal race and PNC status. The x-axis represented PNC status where 0 denoted receipt of any PNC during pregnancy and 1 denoted absence of PNC. The y-axis displayed the predicted Syndemic scores and each box shoewed the interquartile range, with the horizontal lime mkaring the median. Among those who received PNC, Black birthing parents had the highest median Syndemic scores, followed by White and Latinx groups. In the no PNC group, both White and Black individuals showed increased Syndemic scores compared to their counterparts who received care, suggesting that higher Syndemic burden is associated with no PNC. The Latinx group demonstrated relatively consistent Syndemic scores regardless of PNC status, indicating a different pattern of association. It implied that the relationship between Syndemic burden and PNC may vary by race, highlighting the need for race-specific pathways through SEM.

Model 1 Structural model

$\eta_i = \mathbf{0.678^{***}}\ \mathbf{M_i} + \zeta_i$

$Y_i = \mathbf{0.217^{***}}\ \mathbf{M_i} + 0.037\ \eta_i + \varepsilon_i$

Model 2 Structural model, Adding marital status (Z_{1i}), and age group (Z_{2j}):

$\eta_i = \mathbf{0.666^{***}}\ \mathbf{M_i} + \zeta_i$

$Y_i = \mathbf{0.262^{***}}\ \mathbf{M_i} + 0.057\ \eta_i + 0.091\ Z_{1i} + 0.087\ Z_{2j} + \varepsilon_i$

Model 3 Structural Model, by Birthing Persons' Race

Black birthing persons: $\eta_i = \mathbf{0.572^{***}}\ \mathbf{M_i} + \zeta_i$; $Y_i = \mathbf{0.501^{***}}\ \mathbf{M_i} - 0.211\ \eta_i + 0.088\ Z_{1i} + 0.030\ Z_{2j} + \varepsilon_i$

Latinx birthing persons: $\eta_i = \mathbf{0.688^{***}}\ \mathbf{M_i} + \zeta_i$; $Y_i = 0.059\ M_i + \mathbf{0.336^{*}}\ \boldsymbol{\eta_i} + 0.018\ Z_{1i} + 0.070\ Z_{2j} + \varepsilon_i$

White birthing persons: $\eta_i = 0.620\ M_i + \zeta_i$; $Y_i = \mathbf{0.597}\ \mathbf{M_i^{*}} - 0.493\ \eta_i - 0.043\ Z_{1i} + 0.157\ Z_{2j} + \varepsilon_i$

η_i = Syndemic, M_i = Meth use, Y_i = No Prenatal Care, Z_{1i} = marital status, Z_{2j} = age group

Note. Syndemic burden (η_i) is a latent variable predicted by meth use (M_i). Prenatal care status (Y_i) was regressed on M_i and η_i. Z_{1i} = marital status, Z_{2j} = age group. Standardized coefficients shown. Benchmarks for effect size estimation: small ≈ .10; medium ≈ .30; large ≥ .50 (Cohen, 1988)[114]
* indicates $p < .05$; **, $p < .01$; ***, $p < .001$.

Figure 20. Structural Equation Models Examining the Relationship Between Methamphetamine Use, Syndemic Burden, and Prenatal Care by Maternal Race

The equations above summrazied three SEMs assessing the realtionship between meth use (M_i), syndemic burden (η_i), and lack of PNC (Y_i), with covariates including marital status (Z_{1i}) and age group (Z_{2j}). In Model 1, established the base structure, wher emeth use predicted the latent Syndemic variable, and both variables predicted lack of PNC. Model 2 incorporated demographic covariates (marital status, and age group) to assess to adjust the pathway from syndemic burden to PNC. Model 3 stratified the analysis by maternal race revealing differences in the strength and singificance of pathways across groups. Full standardized model estimates and corresponding fit indices for all three models were presented in Appendices 2B to 2E.

In Model 1, meth use significantly predicted symdeic burden ($\beta = 0.678^{***}$) and was directly associated with no PNC ($\beta = 0.217^{***}$). After adjusting for marital status and age in Model 2, the coefficients slightly attenuated but remained significant, suggesting these covariatels contributed additional explanatory power without fully accoounting for the effect of meth use. Model 3 showed racial differents in pathways. Among Black birthing persons, meth use was strongly associated with syndemic burden (β = 0.572***), and syndemeic burden had a strong and significant association with no prental care (β = 0.501***), indicating an indirect risk pathway. For Latinx birthing persons, the direct effect of meth use on PNC was not significant, but syndemic burden significantly predicted care access (β = 0.336*), suggesting a stronger mediating role of syndemic factors compared to other racial groups. Among White birthing persons, meth use was directly assocaited with no PNC ((β = 0.597*), whereas the syndemic burden path was not signficant, implying a predominant direct pathway between meth and no PNC.

Model Fit Assessment

Model fit was assessed using multiple indices, including the chi-square test, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR).[115] These indices were evaluated against conventional thresholds to determine model adequacy and to guide the interpretation of structural path.[114,116]

Model 1 and Model 2 (Pooled Sample)

Model 1 and 2, estimated using maximum likelihood with NLMINB optimization, demonstrated acceptable to good fit. Both models yielded statistically significant chi-square values (Model 1: $\chi^2(8) = 20.17$, $p = .010$; Model 2: $\chi^2(16) = 33.19$, $p = .007$), which may reflect sensitivity to sample size, a common limitation of the chi-square statistic.[116] Therefore, additional fit indices were examined to provide a more reliable assessment.

Model 1 had excellent fit, with a CFI of 0.965 and TLI of 0.935, both exceeding the convenetional 0.90 threshold. The RMSEA was 0.061, falling within the acceptable range (≤ 0.08). The SRMR was 0.037, indicating low residual error. Model 2 also demonstrated strong fit, with a CFI of 0.950 and TLI of 0.922. The RMSEA improved slightly to 0.052. The SRMR remained low at 0.039. These indicators collectively suggested that both models adequately captured the observed data and that the latent structure of Syndemic variable as a mediating variable was well-supported.

Model 3 (Stratified by Birthing Person's Race)

Model 3 stratified the SEM by maternal race and included 57 estimated parameters. In contrast to Models 1 and 2, Model 3 demonstrated poor overall fit. The Model chi-square test was statistically significant ($\chi^2(48) = 110.51$, $p < .001$) and RMSEA value was 0.105 (90% CI: 0.079, 0.131), well above the convenetional cutoff for acceptable fit.

Comparative fit indices were below standard benchmarks (CFI = 0.816 and TLI = 0.713), indicating marginal fit. In contrast, the SRMR value of 0.067 ramained below the 0.08 threshold, suggesting acceptable standarized residuals. Model misfit appeared to be driven primarily by the White subgroup ($\chi^2 = 57.54$, n = 52), which had the smallest sample size. In contrast, the Black ($\chi^2 = 23.71$, n = 110) and Latix ($\chi^2 = 29.25$, n = 211) subgroups showed relatively better fit, albeit not optimal. The overall model included 57 parameters, increasing the risk of overfitting, particualrly given the small sample size in some subgroups.

Implications for Model Fit Assessment

The findings from Models 1 and 2 indicated strong global and residual fit, leading to the reliable interpretation of structural relationships in the pooled sample. However, the relatively poor fit of Model 3 required caution in interpreting race-stratified pathways. Several considerations may account for the observed discrepancies in model performance. First, the small sample size in the White subgroup likely contributed to instability in parameter estimation, inflated chi-square values, and overall model misfit. Second, the stratified model included a substantial increase in the number of free parameters (from 14 in Model 2 to 57 in Model 3), increasing the likelihood of overfitting and convergence issues, particularly given the limited sample size in the White subgroup.[114] Despite poor global fit in Model 3, the SRMR value remained within the acceptable range, suggesting that standardized residuals were modest. This discrepancy implied that subgroups pathways may remain interpretable, particularly for the Black and Latinx groups with larger sample sizes.

Model 1 and 2 provided a well-fitting framework for evaluating the direct and Syndemic factor mediated relationships between meth use and PNC in the overall sample. Model 3 showed exploratory insights into racialized differences in these pathways; however, its limited fit, especially in the White subgroup, constrained definitive conclusions. Despite these limitations, the stratified analysis contributed to the growing literature emphasizing differing effects of Syndemic factors across racial groups, as discussed in the Introduction and theoretical framework. These findings align with qualitative evidence suggesting that structural racism and context-specific social determinants, such as immigration status, fear of DCFS, stigma, and differential access to culturally competent care shape the cumulative burden of risk experienced among pregnant people using substances. In particular, the stronger mediating role of Syndemic burden among Latinx birthing persons highlights how overlapping structural vulnerabilities may uniquely impede PNC access, reinforcing the need for services addressing not just syphilis treatment, but wrap-around service addressing multiple barriers faced by pregnant PRP with syphilis.

4. Discussion

In this chapter, I examined PNC utilization among birthing persons of infants born with CS in LAC and found that meth use was significantly associated with lack of PNC. Mothers who reported meth use had more than three times higher odds of not receiving PNC compared to those who did not use meth. The structural equation modeling further revealed that meth use had a direct effect ($\beta = 0.27$, $p < 0.001$) on absence of PNC. The results showed that meth use had its unique pathways that deters PNC utilization. The SEM analysis provided a novel methodological approach to understanding congenital syphilis prevention gaps, revealing a complex network of interrelated factors. The latent Syndemic construct was strongly loaded by multiple observed variables, with meth use showing the strongest loading (0.67), followed closely by homelessness (0.66), and then incarceration, DCFS referral, and mental health problems. Interestingly, while these factors clustered together meaningfully as a Syndemic, their impact on PNC was primarily associated with meth use specifically, with the direct path from the Syndemic latent variable to absence of PNC being non-significant (β=0.057) in Model 2. This suggests that meth use functions as a critical nexus point as a component of the broader Syndemic and as the predominant direct barrier to healthcare engagement.

In the multi-group SEM, Syndemic burden mediated the relationship between meth use and lack of PNC specifically for Latinx birthing persons, but not for Black or White groups. This suggests that meth use was likely bound up with a constellation of other co-occurring problems, and it was this combined Syndemic stress that ultimately led to lack of PNC. In contrast, for Black birthing parents, the link between meth use and PNC may have been more direct and influenced by different factors outside the measured Syndemic index. Several plausible interpretations emerge from the literature. Latinx communities include many immigrants, and although immigration status and documentation were not measured in the study, these factors likely underlie the observed mediation. Meth use in a Latinx birthing parents' life may be a marker for several social marginalization, possibly involving lack of documentation, recent immigration, or acculturated stress. For instance, a Latinx person using meth during pregnancy might be also undocumented, uninsured, and living in fear of deportation, with resulting high stress and mental health. These overlapping adversities form a Syndemic context in which access PNC become extraordinarily difficult. Black birthing person, on the other hand, do not face immigration barriers (their structural challenges then to revolve around structural racism, which may not be fully captured by Syndemic mediator variable). Thus, the Syndemic mediator likely captured unique Latinx pregnant person specific burdens, such as economic insecurity, trauma, and chronic stress linked to immigration, that were not as prevalent or not measured for other racial groups.

The prominence of the Syndemic pathway for Latinx birthing persons highlights how structural vulnerability and culture intertwine in this group. Latinx immigrants often occupy disadvantaged social positions (low wage jobs, precarious housing, exclusion from public services) that predispose them to multiple simultaneous health risks. These compounding factors could manifest as a high Syndemic score, which in turn powerfully deters engagement in PNC. The Latinx-specific cultural and structural barriers (immigration fears, language obstacles, etc.) likely intensified the mediating effect, making the meth → Syndemic → no PNC pathway statistically significant.

The findings in this chapter highlighted the complex interplay between meth use, Syndemic conditions, and PNC in the context CS in LAC. The interview notes from social workers and public health nurses provided critical insights that complement the findings, underscoring the multifaceted challenges faced by the mother in this case. One notable challenge was the underreporting of mental health conditions, as these are not officially part of the conditions typically reported in surveillance systems. As a result, the actual prevalence and impact of mental health disorders may be significantly underestimated. There were reported a history of depression, anxiety, bipolar disorder, schizophrenia, and Post-Traumatic Stress Disorder (PTSD). Additionally, other licit substance like tobacco and alcohol use was documented and it could have contributed to the birthing person's inability to consistently engage in PNC. Other documented barriers to PNC included transportation barriers, recent immigration status, and lack of insurance, which highlighted systemic gaps in healthcare access. Moreover, domestic violence and history of sex trafficking could be other factors that hindered one’s ability to access care and support.

Significant racial and ethnic disparities emerged in this analysis, with Black and Latinx birthing parents disproportionately represented among those with no PNC. These findings align with the Reproductive Justice framework, which emphasizes how racialized and gendered power dynamics result in unequal access to healthcare resources. Rather than viewing meth-using or homeless pregnant individuals as "irresponsible," our results highlight how systemic failures in providing addiction treatment, housing, and unbiased care contributed to these disparities. The patterns observed reflect the complex, intersectional social realities by which structural oppression influences sexual and reproductive health.

While this study offers valuable insights, several limitations warrant consideration. As a cross-sectional analysis of surveillance data, we cannot establish causality or directionality beyond temporal sequencing of pregnancy events. The surveillance data, though population-based, contained limited variables and potential misclassification, particularly regarding sensitive information-like substance use and mental health problems. Additionally, generalizability may be limited to similar urban settings with comparable demographic and service landscapes. However, these limitations are balanced by key strengths, including the comprehensive dataset encompassing an entire population of cases in a diverse metropolitan area and the theory-based application of SEM to test Syndemic effect in CS context.

Findings from Research Aim 2 highlight the urgent need for targeted interventions addressing meth use among pregnant persons, while simultaneously addressing the Syndemic conditions that foster substance use. Practical implications include implementing outreach strategies with community health workers, co-locating prenatal services with substance use treatment, and adopting trauma-informed care approaches that build trust with vulnerable populations. Policy recommendations center on eliminating punitive approaches to substance use in pregnancy, which our data suggest drives affected individuals away from care. The SEM results suggest that while comprehensive interventions addressing multiple Syndemic factors remain important, special emphasis should be placed on substance use treatment and harm reduction approaches as the most direct pathway to improving PNC engagement and preventing CS, especially for Latinx and Black pregnant people.

Chapter 4. Spatiotemporal Trends in Congenital Syphilis in Los Angeles County from 2011 to 2020 (Aim 3)

1. Introduction

Building on the findings from Aims 1 and 2, this study examines the spatial-temporal trends in methamphetamine (meth) use in Los Angeles County (LAC) from 2011 to 2020 among birthing persons of fetus or infants diagnosed with congenital syphilis (CS) at birth. Understanding the temporal and geographical patterns of CS is crucial, given the established association between meth use and reduced access to syphilis treatment among pregnant persons of reproductive potential (PRP)—a factor that may hinder efforts to prevent CS.

Understanding the spatiotemporal dynamics of CS is critical for guiding public health interventions. Sexually Transmitted Infection (STI) is often localized, and certain communities or neighborhoods may bear a disproportionate burden due to underlying social determinants of health.[77] In line with Tobler's first law of geography – "near things are more related than distant things" – neighboring areas often share risk factors and disease rates.[117] Similarly, STI diagnosed in close temporal proximity may be related through ongoing transmission or common trends. By examining patterns across space and time, public health officials can identify hotspots of persistent high syphilis incidence and detect emerging clusters, enabling targeted responses.

This study presents a comprehensive spatiotemporal analysis of CS in LAC from 2011 through 2020. I utilized health district (HD) levels to map incidence patterns, evaluate spatial clustering, and assess temporal trends. I applied a Bayesian modeling approach – the Integrated Nested Laplace Approximation (INLA) – to jointly model spatial and temporal effects on syphilis incidence, yielding smoothed estimates of risk by location and year. To illuminate the role of social determinants of health, I integrated the Centers for Disease Control and Prevention

(CDC) Social Vulnerability Index (SVI) into my analysis. The SVI provides four theme-based measures of community vulnerability (Socioeconomic status, Household composition/disability, Minority status/language, and Housing/transportation characteristics). I examine how these social vulnerabilities correlate with CS rates and whether high socially vulnerable (i.e., high SVI scores) areas overlap with identified CS clusters.

By combining epidemiologic data with spatial analysis and community-level social indicators, this study aims to clarify where and when syphilis impacts have been greatest in LAC, and how underlying social vulnerability may be associated these patterns. The findings can inform more effective, geographically focused public health interventions to curb the spread of syphilis and prevent CS.

2. Methods

This ecological longitudinal study examined CS cases in LAC from 2011 to 2020 at the HD level. HD shapefiles were obtained from the Los Angeles County Department of Public Health (LACDPH). Analyses incorporated multiple data sources, including surveillance case records, census-based indicators, and law enforcement data, to assess spatial and temporal variation in CS incidence and associated social and structural risk factors (Figure 21).

Data Sources and Integration

Case-level CS data was obtained from LACDPH surveillance records and aggregated to HD-year units. Meth-related arrest records obtained from publicly available data from LAC Crime Report between 2011 and 2020, then spatially joined to HDs. To calculate the rate of case-level incidences, denominators were utilized for standardization, derived from the American Community Survey (ACS) 5-year estimates, specifically using 2020 ACS data to calculate CS rates (CS cases per total births per HD), PRP syphilis rates (female PRP syphilis cases per PRP female population per HD), and female arrest rates related to meth (female meth-related arrests per female adult population per HD). 2020 ACS population estimates were employed to provide stability to the calculations, reflecting HD-level differences and reducing sensitivity to annual population fluctuations. HD spatial data were obtained from the LAC GIS Data Portal. SVI data, sourced from CDC were aggregated to HD by spatially joining and calculating HD-level means across four domains: socioeconomic status, household composition and disability, minority status and language, and housing type and transportation.

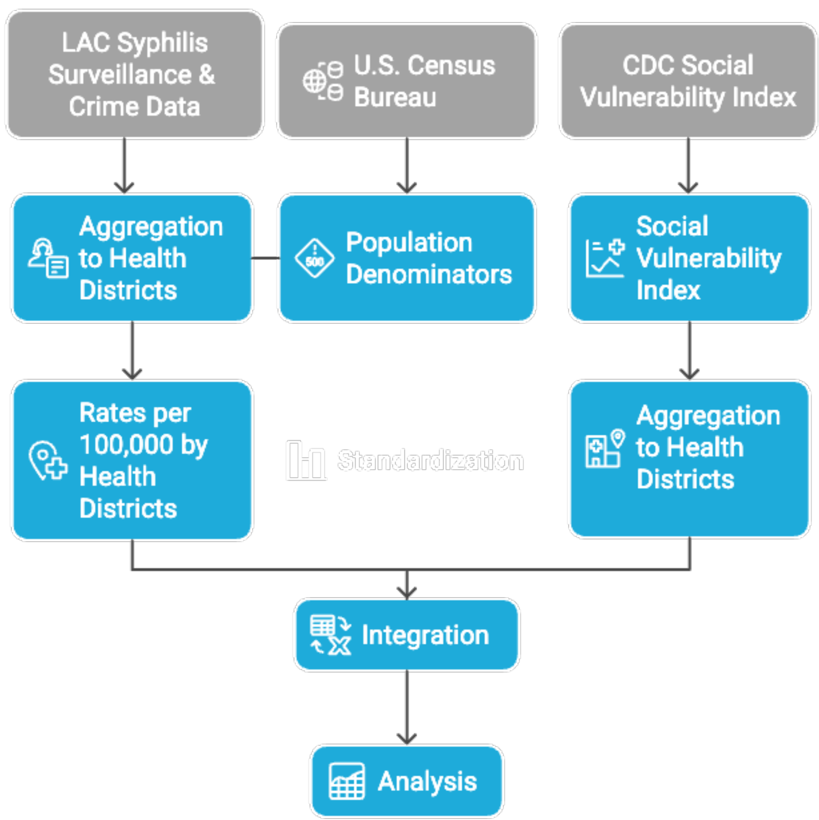


Figure 21. Data Integration Process

Unit of Spatial Data Analysis

In LAC, a HD refers to one of the 26 geographically defined areas used for organizing and delivering public health services. Detailed maps and location of the HD is described in Appendix 3A and 3B. These districts are subdivisions of larger Service Planning Areas (SPAs) and serve as operational units for localized health planning. This study uses HD as the unit of analysis because they offer a granular, policy-relevant scale for monitoring trends, targeting interventions, and allocating resources. The LACDPH, including its HIV and STD programs, routinely uses HDs to track progress and disparities across communities, making them a meaningful geographic framework for examining CS and maternal risk patterns at the local level.

Outcome Variable

The primary outcome for the analysis was CS rates, aggregated by HD-year units. Expected case rates were derived from annual live births at the HD level, standardized relative to the 2020 birth counts to ensure comparability over time. Incidence rates were subsequently calculated and reported per 100,000 live births.

Temporal Trends and Relative Risks

To analyze temporal trends and geographic disparities in CS outcomes, meth use, PNC access, and maternal vulnerabilities, descriptive and spatial visualizations were first generated. The *ggplot2* package in R was used to create dual-axis plots, illustrating annual trends in meth-related arrest rates alongside the prevalence of maternal risk factors, such as lack of PNC and housing instability, among birthing persons with CS. These plots included 95% confidence intervals to reflect estimation uncertainty. Geographic patterns were visualized using faceted choropleth maps depicting HD-level CS rates over time. CS rates were standardized to 2020 birth counts to enable cross-temporal and spatial comparisons. Additional maps illustrated geographic variation in SVI domain scores and meth-related female arrest rates across HDs to understand implications of Proposition 47.

To estimate spatial-temporal patterns in CS incidence more rigorously, the study employed Bayesian hierarchical modeling using the Integrated Nested Laplace Approximation (INLA) approach that was used by Medeiros et al. (2002).[118] A negative binomial distribution was specified to model CS case counts, with the number of births in each HD-year unit included as an offset term to adjust for population size. Temporal random effects were included in all models using both a second-order random walk (RW2) to capture structured temporal trends and an independent and identically distributed (iid) effect to account for unstructured temporal noise. The initial model specification included only these temporal effects to establish baseline estimates of relative risk (RR), using 2011 as the reference year.

A series of progressively complex models were developed to evaluate the impact of structural determinants on CS risk. The first adjusted model introduced spatial random effects via the Besag-York-Mollié 2 (BYM2) structure, regulated with Penalized Complexity (PC) priors, and incorporated fixed effects for each of the four SVI themes: (1) socioeconomic vulnerability, (2) household composition and disability, (3) minority status and language, and (4) housing and transportation. A subsequent model added meth-related female arrest rates as an additional covariate. The final, fully adjusted model incorporated all previously included variables along with the annual count of female syphilis cases by HD, also entered as a fixed effect. All covariates were included using log-link functions, and their associations with CS counts were interpreted as multiplicative effects on RR.

Model performance was assessed using the Deviance Information Criterion (DIC), Watanabe-Akaike Information Criterion (WAIC), Conditional Predictive Ordinate (CPO), and mean log scores. Pseudo R^2 values were calculated to assess explanatory power, with results indicating low variance explained by fixed effects, consistent with the presence of substantial unmeasured heterogeneity captured by spatial and temporal random effects. Posterior RR and 95% confidence intervals (CIs) were extracted for each HD-year combination and consistently referenced to the baseline year of 2011 to support comparative interpretation of temporal trends.

Sensitivity analyses were conducted by removing meth arrest rates to isolate the influence of female syphilis case counts and SVI scores on CS risk, allowing for the evaluation of the robustness and independent contributions of these covariates across model specifications.

Software

All analyses were conducted in R (version 4.2.2), using the *INLA* package (version 22.05.07) for Bayesian modeling. Spatial data management and visualization were performed using *sf, tmap, dplyr, tidyverse, ggplot2, binom, spdep, writexl, and patchwork*.

3. Results

Temporal Trends in Congenital Syphilis Relative Risk

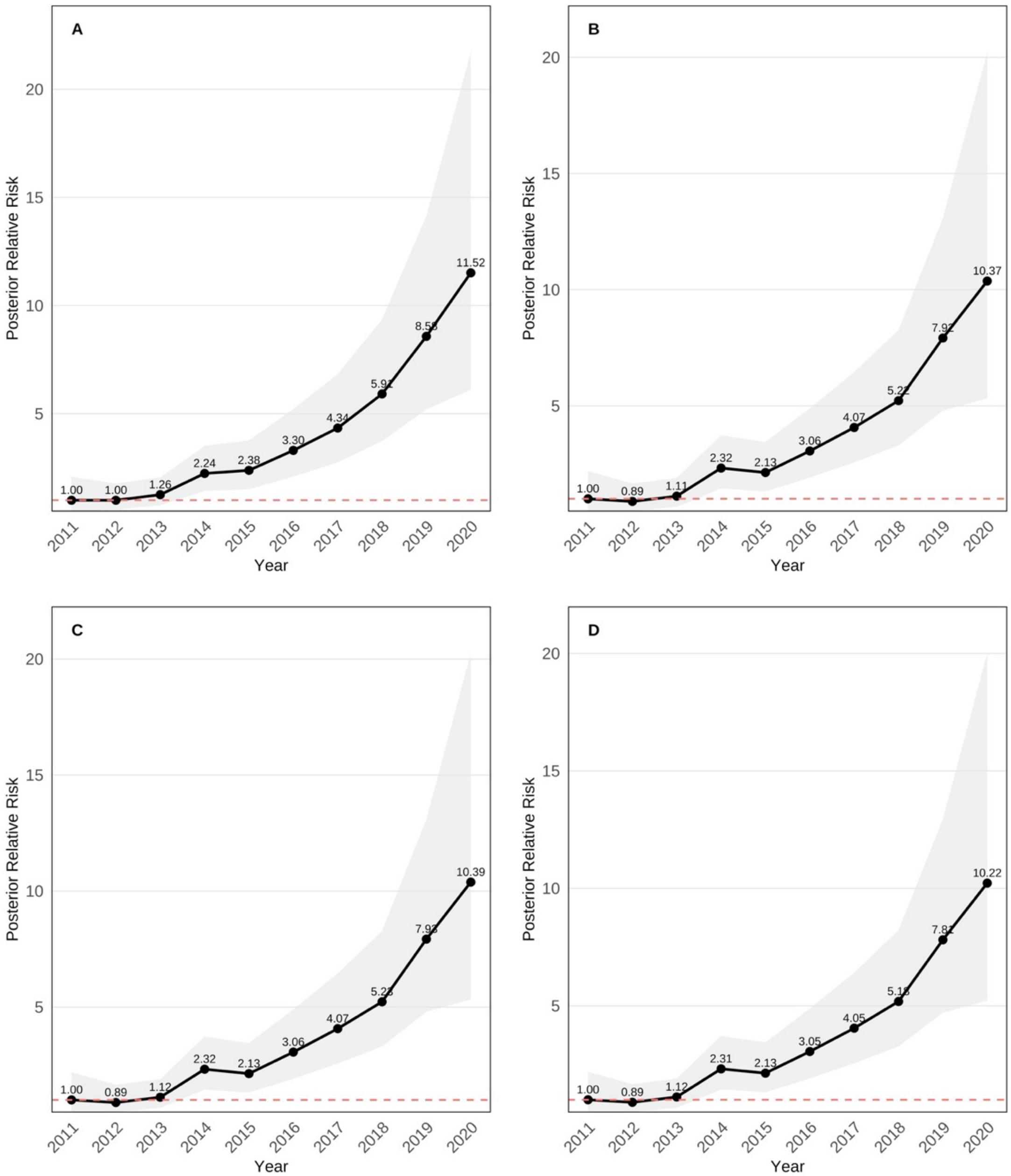
Panel A: Unadjusted Temporal Trend

The unadjusted model (Panel A) revealed a steep and continuous increase in the posterior RR of congenital syphilis over the study period. Relative to the reference year of 2011 (RR = 1.00), risk remained stable through 2012 (RR = 1.00) but began to rise in 2013 (RR = 1.26), accelerating sharply after 2015. The RR increased to 5.94 in 2018 and more than doubled in just two years, peaking at 11.52 in 2020. The widening 95% CIs in the later years reflect increased variability, likely due to rising case counts and spatial clustering.

Panel B: Adjusted for Health District-Level Mean SVI

Adjusting for the average SVI by HD (Panel B) resulted in a slightly attenuated trend, particularly in earlier years. After a dip below the reference level in 2012 (RR = 0.89), the RR rose steadily, reaching 7.93 in 2019 and 10.37 in 2020. These findings suggest that some portion of the unadjusted increase observed in Panel A was attributable to underlying social vulnerability, although substantial risk remained after adjustment.

Temporal trends in congenital syphilis relative risk in Los Angeles County (2011–2020)



Note: Reference Year: 2011 (RR=1.00)
A. Unadjusted temporal trend.
B. Adjusted for Health District-level mean SVI
C. Adjusted for Health District-level mean SVI + meth-related female arrest rate
D. Adjusted for Health District-level mean SVI + meth-related female arrest rate + female (15-44 year-old) syphilis cases
Shaded areas represent 95% credible intervals

Panel C: Adjusted for SVI and Methamphetamine-Related Female Arrest Rate

In Panel C, the model was further adjusted to include both SVI and the meth-related arrest rate among females. This adjustment yielded RR estimates closely aligned with those in

Panel B, though slightly higher in the final years. The RR in 2019 was 7.93, increasing to 10.39 in 2020, indicating that meth-related arrests contributed marginally to explaining the temporal increase but did not fully account for the observed risk. The early years again showed suppressed RR estimates (e.g., RR = 0.89 in 2012), suggesting covariate control reduced early variability.

Panel D: Fully Adjusted Model (SVI, Meth-Related Arrests, Female Syphilis Cases)

The fully adjusted model in Panel D incorporated SVI, meth-related female arrest rates, and the annual number of female (ages 15–44) syphilis cases at the HD level. This model produced a trend similar to Panel C, with slightly reduced RR in the final year (RR = 10.22 in 2020). While this adjustment accounted for a meaningful portion of the variance, it did not fully attenuate the steep temporal increase. The 95% CI narrowed slightly compared to earlier models, suggesting greater model precision due to inclusion of key covariates.

Across all models, the RR of CS increased dramatically over the study period, with particularly steep rises beginning in 2015 and continuing through 2020. Adjustments for structural (SVI), meth-related arrests, and female syphilis rate covariates reduced the magnitude of RR estimates slightly but did not eliminate the upward trend. This indicated that while structural and meth- and syphilis-related risk condition indicators contributed to the temporal escalation, additional unmeasured factors played a role in the rise of CS in LAC.

Model Diagnostics and Sensitivity Analysis

To assess the association between risk conditions in the community level (i.e., social vulnerability, meth-related arrests, and female syphilis rate in HD) and CS over time, I compared four Bayesian hierarchical models using the INLA framework. Model 1 included only temporal random effects, while Model 2 added fixed effects for the CDC SVI scores. Model 3 included meth-related arrest rates, and Model 4 further incorporated female syphilis rates in each HD. Model comparison using the DIC and WAIC indicated that Model 2 provided the best balance between model fit and parsimony (DIC = 787.7; WAIC = 789.1), with a relative model weight of 54% (DIC) and 50% (WAIC). Models 3 and 4 showed slightly higher DIC/WAIC values, suggesting modest additional explanatory value from meth use and female syphilis indicators. Predictive performance, evaluated using the CPO and mean log score, further supported Model 2 as the most accurate, yielding the lowest mean log score (1.58) and the lowest proportion of poorly predicted observations (1.2%).

All models exhibited substantial overdispersion, with Pearson Chi-square-to-degrees-of-freedom ratios exceeding 100,000, affirming the appropriateness of the negative binomial specification. Despite the inclusion of multiple theoretically relevant covariates at the HD level, variance explained by the fixed effects remained low across models, as indicated by pseudo R^2 values ranging from 0.00002 (Model 1) to 0.00004 (Model 4). This suggests that unmeasured factors—likely captured by the spatial and temporal random effects—account for most of the variation in CS risk across districts and years.

Taken together, these results indicate that adjusting for structural vulnerability factors improves model fit and predictive accuracy, with limited marginal gains from meth-related enforcement or female syphilis indicators. Future work may benefit from including other external factors like policy implementation and meth-related environmental factors specific to each HD.

Syndemic Risk Trends Among Birthing Persons of Infants Born with Congenital Syphilis

Figure 22 displayed temporal trends in Syndemic and structural risk factors among birthing persons of infants born with CS in LAC from 2011 to 2020. During this time, the prevalence of key indicators—including meth use, homelessness, incarceration, and lack of PNC—increased substantially, reflecting a growing Syndemic burden among affected individuals.

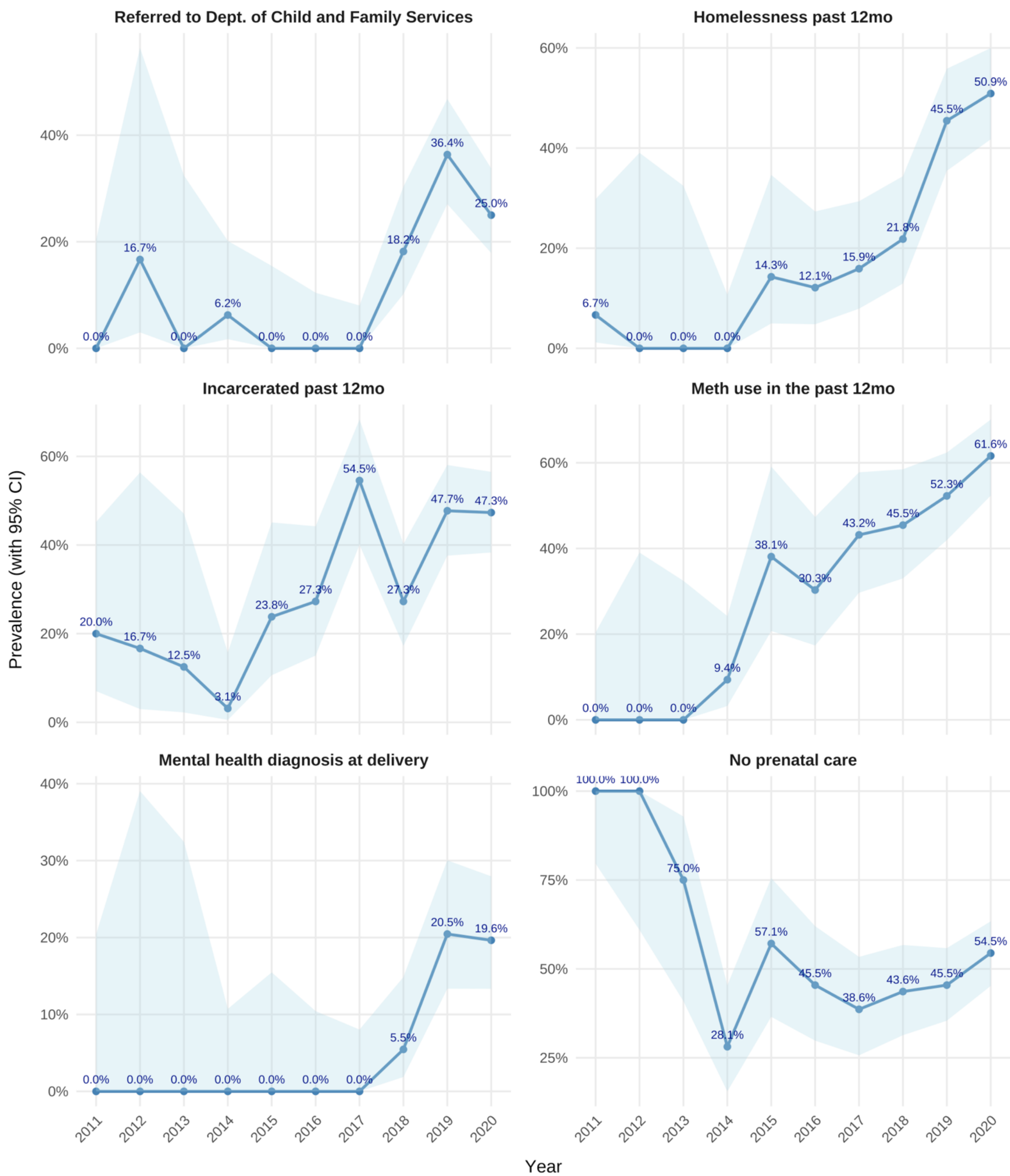


Figure 22. Temporal Trends in Maternal Risk Factors Among CS Birthing Persons

Meth use rose markedly from 11.5% in 2014 to 61.6% in 2020, while homelessness increased from 7.7% to 50.9% over the same period. Incarceration in the past 12 months rose from 26.9% in 2014 to nearly half of all cases (47.3%) by 2020. After an initial decline in lack of PNC, from 23.1% in 2014, rates began to rebound, stabilizing between 45–55% from 2016 through 2020. Referrals to the Department of Child and Family Services (DCFS) and mental health diagnoses at delivery also rose in the latter part of the period, with DCFS referrals peaking at 36.4% in 2018 and mental health diagnoses exceeding 20% in both 2019 and 2020.

It is important to note that maternal characteristic data were inconsistently collected prior to 2014, and mental health data fields contained substantial missingness throughout the study period. As such, trends before 2014 and in variables with limited reporting (e.g., mental health) should be interpreted with caution, as early-year estimates likely underestimate the true prevalence of these risk factors.

Trends in Risk Profiles of CS-Affected Birthing Persons Following Proposition 47

The Figure 23 illustrated temporal trends in (1) meth use prevalence, (2) lack of PNC prevalence among birthing persons with CS, and (3) meth-related arrests count among females in LAC between 2011 and 2020. The left y-axis represents the prevalence (%) among CS birthing persons for meth use and no PNC, while the right y-axis represents the annual count of meth-related arrests among females. A vertical shaded band highlights the passage of Proposition 47 in November 2014, which reclassified certain drug possession offenses from felonies to misdemeanors.[102]

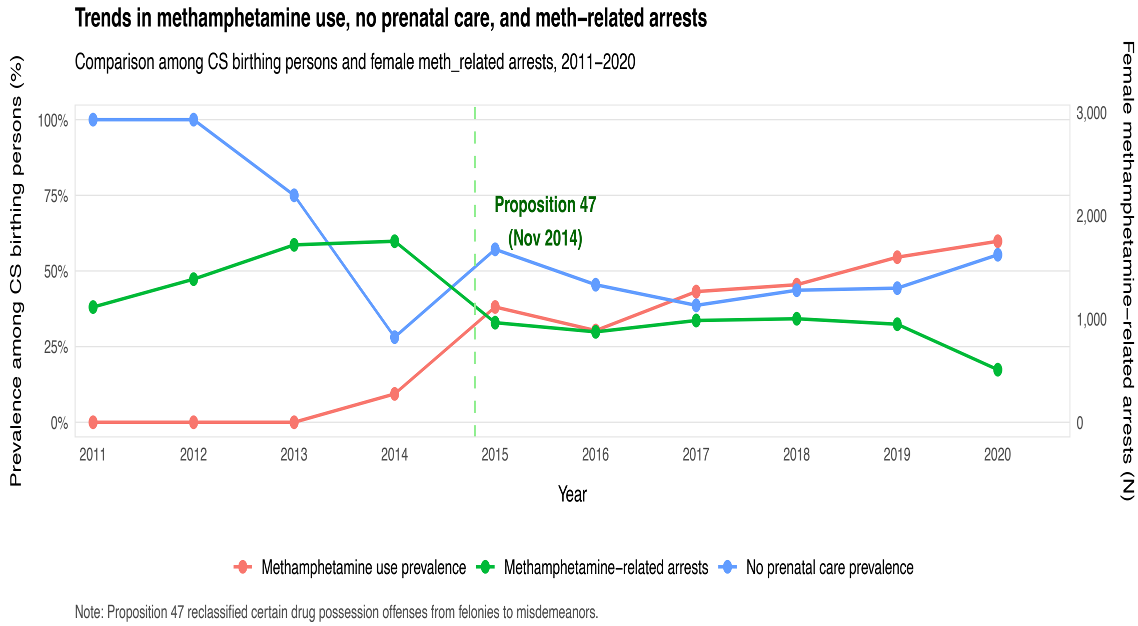


Figure 23. Trends in Methamphetamine Use, Prenatal Care, and Methamphetamine-Related Arrests

Meth use prevalence (red line) increased substantially over the decade. It remained near 0% between 2011 and 2013 but rose sharply following 2014, reaching over 60% by 2020. This increase appeared to begin immediately after the implementation of Proposition 47. No PNC prevalence (blue line) was highest in 2011–2012 (near 100%) but declined through 2014, reaching a low of approximately 30%, before gradually increasing again to 55% by 2020. This trend stabilized after 2015 but remained elevated. Meth-related arrests among females (green line) increased steadily from 2011 to 2014, peaking just prior to the enactment of Proposition 47. Arrests declined sharply in 2015 and remained lower through 2020, ending at fewer than 1,000 arrests annually, compared to nearly 2,000 in 2014.

These temporal trends suggested complex and potentially unintended consequences following the enactment of Proposition 47. Although the policy aimed to reduce incarceration and redirect resources toward treatment, the observed post-2014 divergence—marked by declining meth-related arrests alongside increasing meth use and persistently high no PNC prevalence among CS birthing persons—raised important public health concerns. The decoupling of criminal justice enforcement from behavioral health outcomes suggested that the reduction in arrests may have reflected successful decarceration efforts but was not accompanied by sufficient investments in harm reduction, substance use treatment, or prenatal outreach services.

The increase in meth use—from less than 10% in 2014 to over 60% in 2020—and the rebound in no PNC prevalence after 2015 highlighted persistent barriers to timely and culturally competent care, particularly among populations facing co-occurring structural vulnerabilities. These findings underscored the need for targeted reinvestment of savings from criminal justice reform into comprehensive, wrap-around services for reproductive-age women who use substances. Integrated models of care that combines prenatal services, behavioral health support, housing stability, and peer navigation could better address the Syndemic risks experienced by this population. Furthermore, public health surveillance and early intervention systems must remain responsive to shifts in the risk environment that follow major policy changes, particularly in communities disproportionately impacted by drug-related criminalization and limited healthcare access.

Ultimately, the post–Proposition 47 period underscored a critical policy lesson: decriminalization alone was insufficient to improve maternal and child health outcomes without simultaneous, equity-centered expansion of community-based care systems.

Social Vulnerability Across Los Angeles County Health District

Analysis of the SVI across LAC HD revealed substantial disparities in structural vulnerability, with distinct patterns across each of the four thematic domains—socioeconomic status, household composition and disability, minority status and language, and housing and transportation—as well as the composite SVI index. Based on the composite SVI, the highest-ranking (most vulnerable) districts were South (HD 69, 0.97), Southeast (HD 72, 0.95), Compton (HD 12, 0.91), San Antonio (HD 58, 0.87), and East LA (HD 16, 0.85). These five districts ranked in the top quintile across the county and reported some of the highest CS rates during the study period, suggesting a strong correlation between place-based vulnerability and disease burden.

In the socioeconomic domain (Theme 1), which includes poverty, unemployment, income, and educational attainment, the top five most vulnerable districts were South (0.98), Southeast (0.98), Compton (0.86), San Antonio (0.83), and East LA (0.81). These same districts also experienced elevated CS case counts and rates from 2015 onward. The lowest socioeconomic vulnerability was observed in West (HD 84, 0.37).

In the household composition and disability domain (Theme 2), which accounts for the proportion of elderly, children, and persons with disabilities, the most vulnerable districts included South (0.89), Compton (0.84), Southeast (0.81), San Antonio (0.78), and East LA (0.79). Districts with the lowest vulnerability in this domain included Hollywood-Wilshire (HD 34, 0.29) and West (HD 84, 0.29).

The minority status and language domain (Theme 3) ranked South (0.99), Compton (0.96), East LA (0.95), Southeast (0.95), and El Monte (HD 23, 0.90) as the most vulnerable. These districts reflect areas with a high proportion of non-English speakers and racial/ethnic minority residents. Notably, several of these same districts also exhibited consistently high CS rates. The lowest values in this category were found in Glendale (HD 27, 0.47) and West (HD 84, 0.44).

For the housing and transportation domain (Theme 4), which reflects housing crowding, lack of vehicle access, and housing cost burden, the top five most vulnerable districts were South (0.81), Compton (0.82), San Antonio (0.77), Southeast (0.78), and Southwest (HD 75, 0.77). These structural barriers likely compound risks associated with timely PNC access. In contrast, West (0.52) showed the lowest housing-related vulnerability.

Overall, spatial patterns in the thematic and composite SVI maps aligned closely with the geographic distribution of CS burden. Districts that ranked among the top five in three or more SVI domains, South (HD 69, SVI = 0.97, CS rate = 21.97 per 100,000 births in 2020), Southeast (HD 72, SVI = 0.95, CS rate = 68.79), Compton (HD 12, SVI = 0.91, CS rate = 11.88), exhibited among the highest CS rates in the county. Notably, Southeast (HD 72) reported the highest CS rate overall, while South (HD 69) and East LA (HD 16) also exceeded 20 and 10 cases per 100,000 births, respectively, in multiple years. Conversely, districts with low composite SVI scores such as West (HD 84, SVI = 0.38, CS rate = 5.89) and Torrance (HD 79, SVI = 0.58, CS rate = 8.24) had among the lowest reported CS burdens during the study period. These districts also fell in the lowest quartiles across most SVI themes, reflecting greater socioeconomic stability, better housing access, and lower minority population. This alignment underscores the importance of social vulnerability as a determinant of CS outcomes and highlights specific districts—particularly South (HD 69), Southeast (HD 72), and Compton (HD 12)—as priority areas for targeted, equity-focused public health interventions aimed at improving prenatal syphilis prevention and care access.

Table 10. Summary of CDC Social Vulnerability Index (SVI) Themes by Health District (HD)

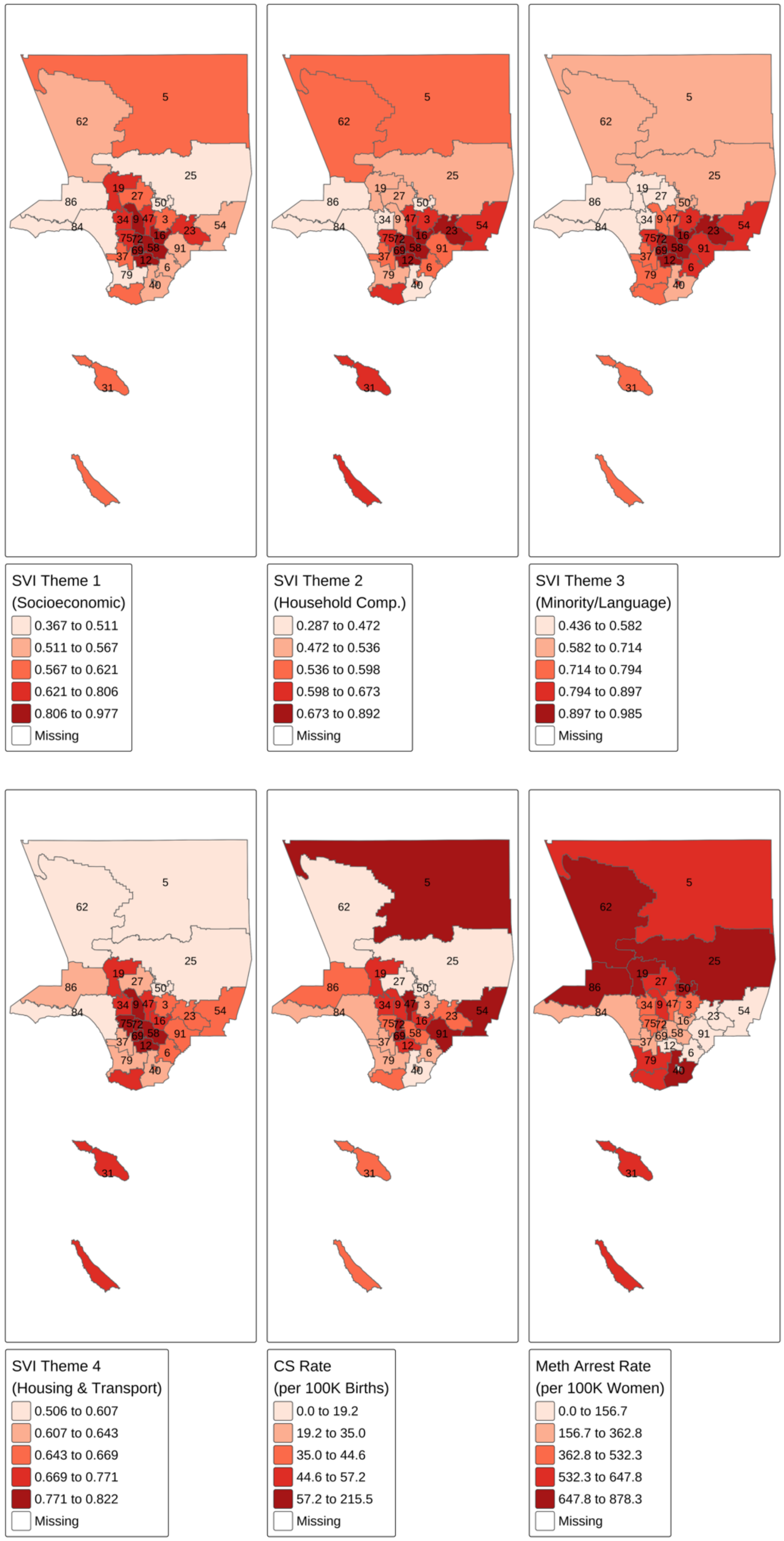
HD	HD name	Socioeconomic	Household & Disability	Minority & Language	Housing & Transportation	SVI
3	Alhambra	0.61	0.63	0.85	0.65	0.68
5	Antelope Valley	0.58	0.56	0.58	0.51	0.57
6	Bellflower	0.55	0.55	0.79	0.64	0.62
9	Central	0.82	0.47	0.74	0.82	0.79
12	Compton	0.86	0.84	0.96	0.82	0.91
16	East LA	0.81	0.79	0.95	0.72	0.85
19	East Valley	0.62	0.49	0.55	0.67	0.61
23	El Monte	0.63	0.67	0.90	0.66	0.72
25	Foothill	0.45	0.53	0.64	0.54	0.52
27	Glendale	0.58	0.53	0.47	0.64	0.59
31	Harbor	0.57	0.60	0.71	0.77	0.67
34	Hollywood-Wilshire	0.64	0.29	0.58	0.73	0.60
37	Inglewood	0.59	0.59	0.77	0.61	0.63
40	Long Beach	0.52	0.41	0.64	0.61	0.54
47	Northeast	0.67	0.63	0.75	0.74	0.73
50	Pasadena	0.37	0.42	0.61	0.51	0.43
54	Pomona	0.55	0.61	0.82	0.66	0.66
58	San Antonio	0.83	0.78	0.94	0.77	0.87
62	San Fernando	0.51	0.54	0.64	0.57	0.56
69	South	0.98	0.89	0.99	0.81	0.97
72	Southeast	0.98	0.81	0.95	0.78	0.95
75	Southwest	0.80	0.65	0.89	0.77	0.80
79	Torrance	0.49	0.52	0.72	0.64	0.58
84	West	0.37	0.29	0.44	0.52	0.38
86	West Valley	0.51	0.46	0.49	0.61	0.53
91	Whittier	0.56	0.57	0.86	0.66	0.66

Spatial Distribution of Social Vulnerability, Congenital Syphilis Rates, and Methamphetamine-related Arrests Across Los Angeles County Health Districts

Figure 24 presented a series of choropleth maps illustrating the spatial distribution of social vulnerability, CS rates, and meth-related arrest rates across HD in LAC. The top row displayed four domains of the CDC Social Vulnerability Index (SVI): socioeconomic status, household composition and disability, minority status and language, and housing and transportation. Districts in the southern and eastern regions—including South (HD 69), Southeast (HD 72), Compton (HD 12), East LA (HD 16), and San Antonio (HD 58)—consistently exhibited the highest levels of vulnerability, with values falling in the top quintiles across multiple domains. For example, Southeast and South scored above 0.95 in the socioeconomic and minority/language domains, indicating high concentrations of poverty and linguistic isolation. These districts also showed elevated housing and transportation-related challenges, such as overcrowding and limited access to vehicles.

The bottom row showed the spatial distribution of CS rates per 100,000 live births and female meth-related arrest rates. Districts with the highest CS rates—including Southeast (HD 72), Northeast (HD 47), Pomona (HD 54), and Central (HD 9)—also corresponded with high SVI scores, reinforcing the relationship between structural vulnerability and adverse maternal and child health outcomes. Meth-related arrest rates were highest in Antelope Valley (HD 5), East Valley (HD 19), and Central (HD 9), with rates exceeding 647 per 100,000 adult women. The co-occurrence of high social vulnerability, elevated substance use enforcement, and increased CS incidence in several overlapping districts supported a Syndemic framework, in which interacting social, structural, and behavioral risk factors contributed to heightened disease burden. These spatial patterns underscored the need for geographically targeted public health responses that integrated structural interventions, substance use services, and PNC access in areas of greatest need.

Figure 24. Spatial Distribution in Social Vulnerability Index (SVI), Congenital Syphilis, and Methamphetamine-related Arrest in Los Angeles County



Between 2011 and 2020, the total number of CS cases in LAC increased with both the number of affected HD and the number of reported CS cases rising over time. In the early years of the study period (2011–2014), CS cases were relatively infrequent and broadly dispersed, with most districts reporting only 1 to 3 cases per year. For example, in 2011, only nine Health Districts reported any CS cases, and no district reported more than three. However, by 2014, localized increase in CS cases began to emerge. Notably, Pomona (HD 54) experienced a significant jump to 9 cases, and Southeast (HD 72) reported four cases, both marking early indicators of geographic clustering and rising local transmission.

From 2016 onward, the geographic and numerical expansion of CS cases became more pronounced. By 2017, Northeast (HD 47, 7 cases) and El Monte (HD 23, 5 cases) showed elevated counts. The upward trend continued into 2018–2020, with sharp increases in total CS counts. In 2020, Southeast (HD 72) reported 15 cases, the highest single-year count in any HD during the study period. Other high-burden HD in 2020 included Antelope Valley (HD 5, 10 cases), Northeast (HD 47, 10 cases), Pomona (HD 54, 7 cases), and Southwest (HD 75, 7 cases). Bellflower (HD 6) and West Valley (HD 86) exceeded five cases for the first time. By the end of the decade, more than 20 of the 26 HD were reporting annual CS case counts greater than three, indicating a substantial broadening of the CS geographic coverage in LAC. This increase in both frequency and spatial distribution reflected the expanding geographic footprint of CS cases across LAC during the study period.

The rising CS case counts and rates within historically underserved districts—such as Southeast (HD 72), Northeast (HD 47), Antelope Valley (HD 5), and Pomona (HD 54) corresponded with elevated levels of social vulnerability. These districts exhibited high or moderately SVI scores, particularly in domains related to socioeconomic status, minority and language barriers, and housing and transportation instability. For example, Southeast had one of the highest overall SVI scores (0.95), with particularly elevated socioeconomic (0.98) and minority/language (0.95) vulnerability. Similarly, Northeast and Pomona demonstrated consistently high domain scores across multiple dimensions. These patterns suggest that structural disadvantages—such as poverty, housing insecurity, and limited access to culturally and linguistically appropriate care—may have contributed to the persistent and geographically concentrated burden of CS.

4. Discussion

This study identified significant temporal and spatial trends in CS across LAC between 2011 and 2020, highlighting structural determinants underlying the observed disparities. The temporal analysis revealed a substantial rise in CS risk, notably accelerating post-2015, with the unadjusted model indicating a RR increase from stable levels in 2011 (RR=1.00) to a peak of 11.52 in 2020. Adjustments for SVI moderately attenuated this trend (RR=10.37 in 2020), suggesting that structural vulnerabilities partially explained increased risk, yet substantial unexplained risk persisted. Incorporating meth-related arrest rates and female syphilis cases further refined risk estimates, although these factors only marginally altered the temporal pattern, underscoring additional unmeasured factors influencing CS incidence. Despite comprehensive covariate adjustment, model diagnostics indicated significant residual overdispersion, reflecting limitations inherent in utilizing aggregated data and potential unmeasured individual-level factors.

The study highlighted increasing Syndemic vulnerabilities among birthing persons affected by CS. Meth use prevalence escalated markedly from 11.5% in 2014 to 61.6% in 2020, accompanied by increased homelessness (7.7% to 50.9%) and incarceration rates (26.9% to

47.3%). While female meth-related arrests declined following Proposition 47, meth use and lack of PNC increased, suggesting that criminal justice reform may inadvertently create service gaps if not paired with public health infrastructure. The temporal alignment with Proposition 47's implementation underscored complex, potentially unintended policy effects: reductions in female meth-related arrests did not coincide with declines in substance use or improved PNC access, indicating a critical gap in care provision.

Spatial analyses identified pronounced geographic disparities in CS rates, closely mirroring patterns in social vulnerability. High SVI districts, notably South (HD 69), Southeast (HD 72), Compton (HD 12), and East LA (HD 16), consistently demonstrated elevated CS rates, suggesting structural barriers—such as poverty, linguistic isolation, housing instability, and limited transportation—significantly contributed to localized disease burdens. Emerging hot spots were also detected in Pomona, Whittier, and Antelope Valley, signaling areas where resources and interventions should be prioritized to prevent further CS increase. In contrast, lower vulnerability areas (e.g., West, Torrance) maintained relatively lower CS rates, emphasizing the role structural factors play in health disparities. Overall, CS risk increased approximately tenfold from 2011 and 2020 across health districts, even after adjusting for structural factors, underscoring the epidemic's widespread and accelerating nature.

Study limitations included potential biases from surveillance data, missing or inconsistently reported maternal characteristic data prior to 2014, and absence of comprehensive individual-level risk behavior data. Despite these constraints, the findings robustly illustrated the impact of structural determinants on CS trends that were closely associated with time and place.

These findings reaffirm that time and place matter. Strategic resource allocation should prioritize geographic hotspots and areas with persistent social vulnerability to ensure that high-risk districts receive targeted investment. These results underscore the necessity of targeted, equity-focused interventions addressing structural barriers and Syndemic vulnerabilities. Effective public health responses should integrate substance use treatment, PNC, and supportive services, particularly in structurally disadvantaged districts, to mitigate the persistent and growing CS epidemic in Los Angeles County.

Chapter 5. Conclusion

This dissertation examined the intersection between methamphetamine (meth) use, prenatal care (PNC) access, and congenital syphilis (CS) across individual and structural levels in Los Angeles County (LAC) from 2011 to 2020. Guided by PNC, structural racism, and syndemic theoretical frameworks, the study conducted descriptive epidemiology and hypothesis testing, offering insights into understanding the rise of CS in LAC in the context of maternal and child health (MCH) disparities.

Aim 1 established that pregnancy status significantly moderated the relationship between meth use and syphilis treatment. Specifically, pregnant individuals using meth were significantly less likely to receive recommended syphilis treatment compared to their non-pregnant counterparts, highlighting pregnancy itself as a critical context for healthcare barriers. These findings underscored the complex dynamics of stigma, systemic inequities, and healthcare access barriers faced by pregnant individuals who use substances.

In Aim 2, meth use had a significant association with lack of PNC utilization among birthing persons with infants diagnosed with CS. Structural equation modeling revealed direct associations between meth use and reduced PNC access, although Syndemic factors (homelessness, incarceration, mental health, child welfare involvement) did not significantly mediate this relationship. This result pointed to substance use, particularly meth, as a pivotal, yet independently significant risk factor for absence of PNC, that could be exacerbated by pregnancy-specific stigma and punitive systems. When stratified by race, however, Syndemic burden significantly predicted lack of PNC among Latinx birthing parents, suggesting that unmeasured, group-specific factors, such as immigration-related fear, language barriers, and distrust of institutions, may contribute to disparities in care utilization.

Aim 3 expanded the analysis to a spatiotemporal perspective, revealing marked geographic and temporal increases in CS incidence across LAC. Bayesian hierarchical models highlighted that health district (HD)-level structural vulnerabilities, captured by the Social Vulnerability Index (SVI), explained some of the increases in CS risk, yet substantial unexplained variability suggested other unmeasured structural determinants. Meth-related female arrest rates and female syphilis cases further marginally contributed to risk prediction, underscoring the interplay of structural, behavioral, and geographic contexts in shaping conditions for the rise of CS in LAC between 2011 and 2020. The study also found that areas with higher CS risk, such as South LA, Pomona, and Whittier, were those with the higher SVI scores, reinforcing the spatial alignment between social vulnerability and CS.

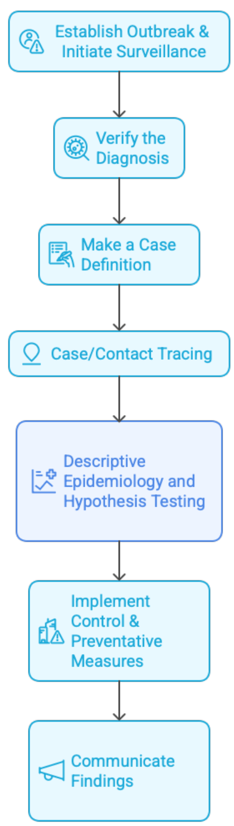


Figure 25. The Seven Epidemiological Principles in Outbreak Response. Adapted from Malange et al. (2023).[119]

Overall, this dissertation demonstrated how integrating descriptive epidemiology and hypothesis-driven analyses could illuminate the multilevel mechanisms underlying CS epidemic in LAC. As described in the Seven Epidemiological Principles for Outbreak Response (Figure 25), the study presented the importance of continuously monitoring pregnant populations and rapidly responding with tailored interventions that illuminates the importance of reaching pregnant people who use meth and providing safe and quality care for birthing persons and infants born with syphilis person-centered holistic care to prevent repeated cases and effective intervention for postpartum recovery program that includes housing, mental health, substance cessation, family care programs. Findings emphasized the urgent need for systemic change to address structural determinants of health, reduce stigma, and enhance PNC engagement through trauma-informed, low-barrier services. Public health practitioners, clinicians, policymakers, and researchers alike must collaborate to dismantle barriers, foster structural competency, and prioritize equity-focused solutions, thereby advancing Reproductive Justice and improving perinatal health outcomes for structurally marginalized populations. Findings emphasized the urgent need to move beyond individual-level behavioral approaches by implementing integrated, trauma-informed, and place-based public health interventions that address the root cause of risk, including housing insecurity, lack of insurance, stigma in healthcare, and limited access to transportation.

To address the structural inequities and Syndemic burdens that contribute to CS and limited PNC utilization, this study recommends a multi-sector approach grounded in Reproductive Justice and public health equity. For pregnant persons who use substances, it is critical to offer confidential, non-punitive PNC services that reduce fear of surveillance, criminalization, or loss of custody due to one urine test result. Traditional punitive approaches have been shown to deter care-seeking behavior, particularly among those already experiencing layered stigma due to substance use. Confidentiality protections and compassionate engagement by providers can improve trust in healthcare systems and facilitate timely PNC and syphilis-related care during pregnancy. In addition, expanding integrated service delivery models, such as co-located services, mobile clinics, and peer navigation programs, is essential to lowering logistical and psychological barriers to PNC. These models have proven effective in reaching hard-to-reach populations and can be tailored to meet the unique needs of communities with high CS burden.

Healthcare providers and clinical systems play a vital role in preventing CS by implementing culturally responsive care. Training for providers, including prenatal, substance use, and STI care, should include education on the intersecting stigmas and fear of criminalization and DCFS faced by pregnant people who use substances. Healthcare systems must invest in community-based infrastructures that may include expanding clinical hours, increasing bilingual staff, developing partnership with trusted community-based organizations, and ensuring sustained resources for wraparound services, such as housing, mental health, and substance use treatment.

For policymakers, prioritizing reproductive and perinatal health equity requires deliberate investment in postpartum and MCH services for families affected by CS. Policy action should include allocating funding to support integrated care models that connect prenatal, substance use, and social services under one system of care. Policymakers should ensure that programs avoid punitive consequences that deter care engagement and instead emphasize harm reduction, family support, and long-term health for both birthing persons and infants. Funding structures should support innovation in outreach (e.g., mobile PNC, community navigators, doulas) and sustain public health infrastructure in underserved areas with persistent CS burden.

Researchers need to build on these findings by investigating averted CS cases and identifying protective factors that enable successful PNC engagement among persons of reproductive potential who are diagnosed with syphilis. A strength-based approach helps illuminate community strengths, resilience factors, and effective interventions that could be scaled across settings. Researchers should map existing service ecosystems to identify fragmentation, redundancies, and critical service gaps that hinder timely access to care. Collaborative research across public health, clinical care, and social service sectors is necessary to develop more comprehensive, systems-level strategies for addressing CS. Additionally, future research should aim to incorporate under-measured social determinants, such as immigration status, transportation access, intimate partner violence, and experiences of discrimination, that contribute to missed care opportunities but are not well captured in surveillance data.

This study had several limitations inherent to the use of public health surveillance data. First, the dataset was restricted to individuals who were tested for syphilis and whose cases were formally reported to the LACDPH. As such, the study likely underestimated the true prevalence of syphilis, CS, and meth use—particularly among those less likely to access care or be reached by routine disease investigation protocols. Data collection involved multiple stages and personnel—testing, reporting, data entry, and case interviewing—introducing opportunities for error and inconsistencies that may have affected data quality. Prior research using California syphilis surveillance data (excluding Los Angeles and San Francisco) has shown that stigmatized variables, such as substance use or criminal justice involvement, were often left blank or coded as "refused," leading to further underestimation of these characteristics.[11] These patterns of missingness may have reduced the sensitivity of observed associations and introduced potential bias.

Additionally, the surveillance data lacked key information on structural and social determinants of health—such as transportation barriers, immigration status, housing instability, fear of losing child custody, or experiences of stigma and discrimination in healthcare—which are critical for understanding barriers to PNC and syphilis treatment. These limitations constrained the ability to fully capture the lived experiences and healthcare trajectories of persons most at risk for CS outcomes. Although sensitivity analyses, including multiple imputation, were used to address missing data, residual confounding due to unmeasured variables likely remained.

Despite these limitations, the study had several notable strengths. First, it presented a novel, theory-informed epidemiologic investigation of meth use, social vulnerability, and CS outcomes among persons of reproductive potential in LAC over a decade-long period (2011–2020). The integration of a Reproductive Justice framework—developed in dialogue with qualitative insights from prior research—was a foundational strength. This lens guided both the construction of research questions and the interpretation of findings, helping to ensure that the study did not simply describe statistical trends but instead centered the lived experiences of pregnant individuals navigating intersecting vulnerabilities. The framework was particularly critical for contextualizing how substance use during pregnancy may lead to heightened surveillance, criminalization, and institutional involvement, compounding existing social inequities.

Second, the study's multilevel approach allowed for simultaneous analysis of individual-level risk factors (e.g., meth use, incarceration history, homelessness, PNC access) and health district–level structural conditions (e.g., Social Vulnerability Index scores, meth-related arrest rates). This framework supported a more holistic understanding of how person-level behaviors are embedded within broader spatial, structural, and policy environments. Third, the use of advanced statistical methodologies—including Bayesian spatiotemporal modeling using Integrated Nested Laplace Approximation (INLA), Structural Equation Modeling (SEM), and mediation analysis—enhanced the study's analytic rigor and interpretive depth, allowing for the identification of both direct and indirect pathways of risk. Fourth, the study considered policy implications, particularly the unintended consequences of Proposition 47, which reclassified certain drug offenses. By assessing how changes in criminal justice policy may influence PNC access and CS risk, the study offered timely, data-driven insights for public health decision-making.

This dissertation aimed to advance the field of descriptive epidemiology and hypothesis-driven research by explicitly integrating theoretical frameworks, particularly Reproductive Justice, Syndemic theory, and Structural Racism, into its analytic design and interpretation. It underscored the importance of building Reproductive Justice considerations into every phase of the study, especially examining outcomes that disproportionately impact Latinx and Black pregnant people. Rather than reinforcing surveillance or punitive responses, epidemiological tools and findings should be leveraged to identify critical intervention points to engage marginalized population in care, persons of reproductive potential with syphilis and pregnant people who use substances, address systemic barriers, and reduce subsequent harms related to CS and its Syndemic drivers.

Appendices

Chapter 1 Appendices

Appendix 1A. Number of Syphilis and Congenital Syphilis Cases and Percent Change in Rates Compared to the Previous Year

Year	N, Syphilis cases among female aged 15-44	N, Female aged 15-44	100,000 person-year	Percent change
2011	206	2,611,677	7.89	N/A
2012	177	2,615,827	6.77	-14.21
2013	264	2,614,887	10.10	49.21
2014	348	2,632,605	13.22	30.93
2015	399	2,630,111	15.17	14.76
2016	490	2,598,814	18.85	24.29
2017	717	2,599,411	27.58	46.29
2018	938	2,569,341	36.51	32.35
2019	1,262	2,540,215	49.68	36.08
2020	1,213	2,553,515	47.50	-4.38
Year	**N, Congenital syphilis cases**	**N, Total live births**	**100,000 person-year**	**Percent change**
2011	15	130,313	11.51	N/A
2012	6	131,697	4.56	-60.42
2013	8	128,526	7.00	53.70
2014	32	130,150	24.59	251.12
2015	21	124,941	18.41	-25.13
2016	33	122,941	30.91	67.91
2017	44	116,850	41.08	32.90
2018	55	109,893	49.14	19.62
2019	88	107,202	82.09	67.05
2020	112	98,021	115.28	40.44

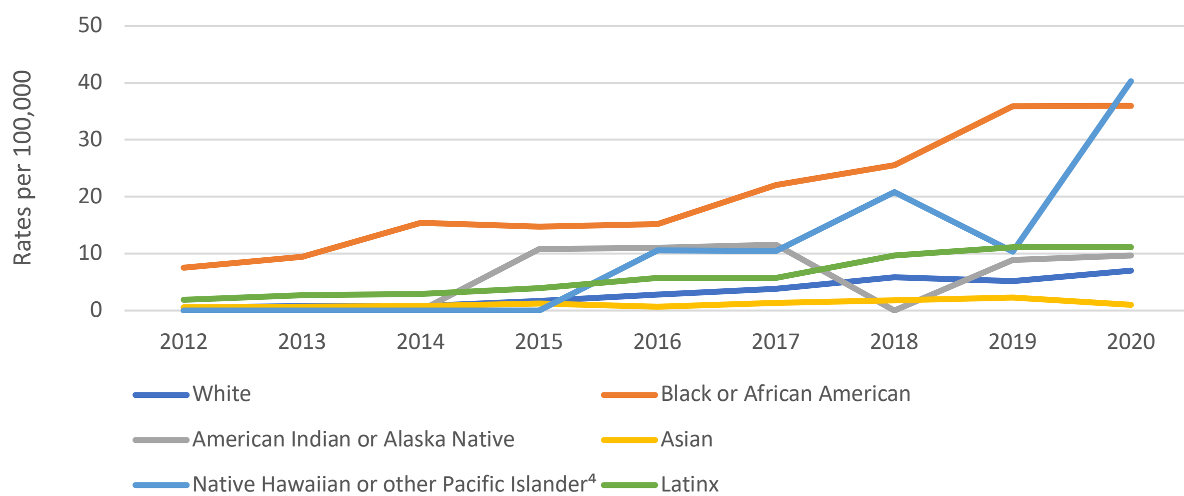
Appendix 1B. Types of Illicit Substance Use in the Past 12 months among Females Aged 15-44 with Reported Syphilis Cases in Los Angeles County 2011-2020 (N=6,014)

	Crack		Cocaine		Meth		Nitrate	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Yes	62	1.03	93	1.54	615	10.18	7	0.12
No	4426	73.27	4377	72.45	3883	64.28	4435	73.41
Missing	1553	25.71	1571	26.01	1543	25.54	1599	26.47

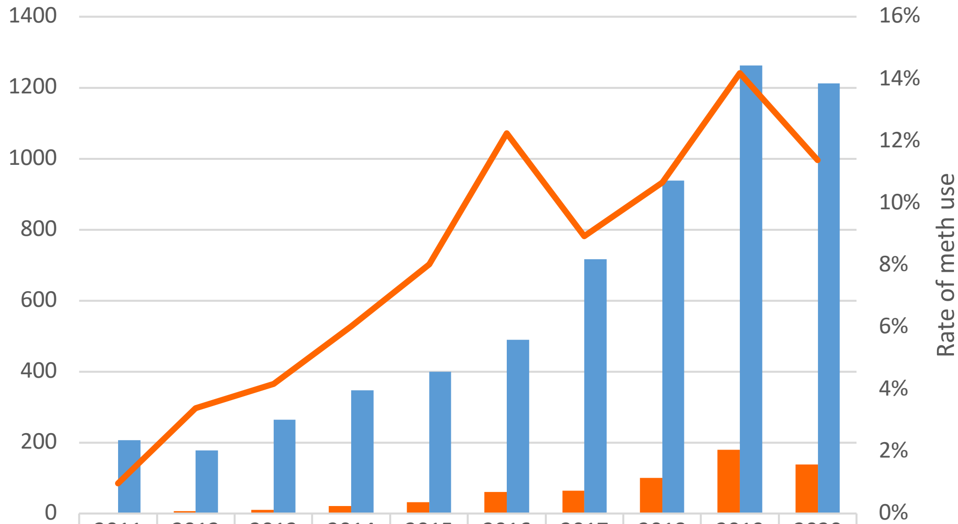
Appendix 1C. Meth Use Among Persons of Reproductive Potential (PRP; Assigned Females at Brith who Aged 15 to 44 years are old), Pregnant Persons, and Birthing Parents of Infants born with Congenital Syphilis in Los Angeles County 2011-2020

	Meth use among PRP (N=6,014)		Meth use among pregnant persons (N=1,407)		Meth use among birthing parents (N=414)	
Year	**n**	**%**	**n**	**%**	**n**	**%**
2011	2	0.03	0	0.00	0	0.00
2012	6	0.10	2	0.14	0	0.00
2013	11	0.18	1	0.07	0	0.00
2014	21	0.35	7	0.50	2	0.48
2015	32	0.53	6	0.43	8	1.93
2016	60	0.99	14	1.00	11	2.65
2017	64	1.06	21	1.49	20	4.82
2018	100	1.66	27	1.92	25	6.02
2019	179	2.96	46	3.27	44	10.60
2020	138	2.28	54	3.84	40	9.64

Appendix 1D. Rates of Early Female Syphilis Cases by Race in Los Angeles County 2012-2020



Appendix 1E. Annual Trends of Methamphetamine Use (N=614) among Persons of Reproductive Potential (PRP; Assigned Females at Brith who Aged 15 to 44 years are old) with Reported Syphilis Cases (N=6,014) in Los Angeles County 2011-2020



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
No. of meth use	2	6	11	21	32	60	64	100	179	138
Syphilis cases	206	177	264	348	399	490	717	938	1,262	1,213
Rate of meth use	0.97%	3.39%	4.17%	6.03%	8.02%	12.24%	8.93%	10.66%	14.18%	11.38%

Chapter 2 Appendices

Appendix 2A. Count of Syndemic Factors in Congenital Syphilis Cases in Los Angeles County 2011-2020 (N=414)

Year	CS	Meth use	Heroin use	Cocaine use	Opiates use	Cannabis use	Homeless ness	DCFS	Mental illness
2011	15	0	0	0	0	0	0	0	0
2012	6	0	0	1	0	1	0	1	0
2013	8	0	0	0	0	0	0	0	0
2014	32	2	0	0	0	0	0	2	0
2015	21	8	0	3	1	5	3	0	0
2016	33	11	1	0	1	7	0	0	0
2017	44	20	0	5	0	9	2	0	0
2018	55	25	2	2	1	7	8	10	3
2019	88	44	3	4	5	23	35	30	16
2020	112	40	0	3	1	19	35	13	14
Total	**414**	**150**	**6**	**18**	**9**	**71**	**83**	**56**	**33**

Note: CS. Congenital Syphilis, DCFS. Department of Children and Family Services

Appendix 2B. Structural Equation Model (SEM) Parameter Estimates

SEM Model 1 (12 Parameters, N = 414)

Model 1 Measurement Model

X_{1i} = Homelessness, X_{2i} = Mental health problems, X_{3i} = DCFS referrals, X_{4i} = Current or History of incarceration, with residuals $\delta_1 \ldots \delta_4$

$X_{1i} = 1.000 + \delta_1$
$X_{2i} = 0.477 + \delta_2$
$X_{3i} = 0.504 + \delta_3$
$X_{4i} = 0.518 + \delta_4$

Model 1 Structural model

η_i = Syndemic, M_i = Meth use, Y_i = No Prenatal Care, with residuals ζ_i, ε_i:

$\eta_i = \mathbf{0.678^{***}\ M_i} + \zeta_i$
$Y_i = \mathbf{0.217^{***}\ M_i} + 0.037\ \eta_i + \varepsilon_i$

SEM Model 2 (14 Parameters, N = 414)

Model 2 Measurement Model

X_{1i} = Homelessness, X_{2i} = Mental health problems, X_{3i} = DCFS referrals, X_{4i} = Current or History of incarceration, with residuals $\delta_1 \ldots \delta_4$

$X_{1i} = 1.000 + \delta_1$
$X_{2i} = 0.513 + \delta_2$
$X_{3i} = 0.472 + \delta_3$
$X_{4i} = 0.503 + \delta_4$

Model 2 Structural model, Adding marital status (Z_{1i}), and age group (Z_{2j}):

η_i = Syndemic, M_i = Meth use, Y_i = No Prenatal Care, with residuals ζ_i, ε_i:

$\eta_i = \mathbf{0.666^{***}\ M_i} + \zeta_i$
$Y_i = \mathbf{0.262^{***}\ M_i} + 0.057\ \eta_i + 0.091\ Z_{1i} + 0.087\ Z_{2j} + \varepsilon_i$

SEM Model 3, by Birthing Persons' Race (57 Parameters, N = 373)

Model 3 Measurement Model

X_{1i} = Homelessness, X_{2i} = DCFS referrals, X_{3i} = Current or History of incarceration, X_{4i} = Mental health problems, with residuals $\delta_1 \ldots \delta_4$

Black birthing persons	Latinx birthing persons	White birthing persons
$X_{1i} = 1.000 + \delta_1$	$X_{1i} = 1.000 + \delta_1$	$X_{1i} = 1.000 + \delta_1$
$X_{2i} = 0.423 + \delta_2$	$X_{2i} = 0427 + \delta_2$	$X_{2i} = 0.360 + \delta_2$
$X_{3i} = 0.336 + \delta_3$	$X_{3i} = 0.541 + \delta_3$	$X_{3i} = 0.389 + \delta_3$
$X_{4i} = 0.555 + \delta_4$	$X_{4i} = 0.451 + \delta_4$	$X_{4i} = 0.703 + \delta_4$

Model 3 Structural Model

η_i = Syndemic, M_i = Meth use, Y_i = No Prenatal Care, Z_{1i} = marital status, Z_{2j} = age group

Black birthing persons: $\eta_i = \mathbf{0.572^{***}\ M_i} + \zeta_i$; $Y_i = \mathbf{0.501^{***}\ M_i} - 0.211\ \eta_i + 0.088\ Z_{1i} + 0.030\ Z_{2j} + \varepsilon_i$
Latinx birthing persons: $\eta_i = \mathbf{0.688^{***}\ M_i} + \zeta_i$; $Y_i = 0.059\ M_i + \mathbf{0.336^{*}\ \eta_i} + 0.018\ Z_{1i} + 0.070\ Z_{2j} + \varepsilon_i$
White birthing persons: $\eta_i = 0.620\ M_i + \zeta_i$; $Y_i = \mathbf{0.597\ M_i^{*}} - 0.493\ \eta_i - 0.043\ Z_{1i} + 0.157\ Z_{2j} + \varepsilon_i$

Note: Parameter estimates are fully standardized (Std.all) and the significance marked *p < .05, **p < .01, ***p < .001.

Appendix 2C. Fit Indices and Standardized Parameter Estimates for SEM Model 1 (12 Parameters, N = 414)

Estimator: Maximum Likelihood		
Optimization method: NLMINB		
Number of model parameters	12	
Observation	414	
Test statistic	20.168	
DF	8	
P-value (Chi-square)	0.010	*Modest misfit*
Model Test Baseline Model		
Test statistic	364.577	
DF	15	
P-value	0.000	
User Model versus Baseline Model		
Comparative Fit Undex (CFI)	0.965	*Good fit*
Tucker-Lewis Index (TLI)	0.935	Good fit
Loglikelihood and Information Criteria		
Loglikelihood user model (H0)	-925.903	
Loglikelihood unrestricted model (H1)	-952.819	
Akaike (AIC)	1949.806	
Bayesian (BIC)	1998.116	
Sample-size adjusted Bayesian (SABIC)	1960.037	
Root Mean Square Error of Approximation:		
RMSEA	0.061	*Acceptable*
90% confidence interval - lower	0.028	
90% confidence interval - upper	0.094	
P-value H_0: RMSEA <= 0.05	0.260	
P-value H_0: RMSEA >=0.08	0.187	
Standardized Root Mean Square Residual:		
(SRMR)	0.037	*Good fit*
Parameter Estimates		
Standard errors: Standard		
Information: Expected		
Information saturated (h1) model: Structured		

	Estimate	**Std.Err**	**z-value**	**Std.lv**	**Std.all**	**P(>|z|)**	
Factor Loadings for Syndemic factors =~							
Homelessness	1.000	0.305	0.666				*fixed for scale definition*
Mental health problems	0.596	0.080	7.475	0.182	0.477	0.000	*modest association with factor*
DCFS referrals	0.798	0.102	7.799	0.244	0.504	0.000	*large association with factor*
Incarceration	0.518	0.065	7.962	0.158	0.518	0.000	*large association with factor*
Structural path							
Meth use -> Syndemic	0.417	0.039	10.740	1.367	**0.678***	**0.000**	*large*
Meth use -> No PNC	0.219	0.079	2.761	0.219	**0.217**	**0.006**	*small-medium*
Syndemic -> No PNC	0.061	0.151	0.401	0.019	0.037	0.688	*not significant*
Residual variances (unexplained proportion)							
Homelessness	0.117	0.012	9.810	0.117	0.556	0.000	
Mental health problems	0.112	0.009	12.751	0.112	0.772	0.000	
DCFS referrals	0.174	0.014	12.491	0.174	0.746	0.000	
Incarceration	0.068	0.006	12.340	0.068	0.732	0.000	
No PNC	0.235	0.016	14.376	0.235	0.941	0.000	
Syndemic	0.050	0.010	5.196	0.541	0.541	0.000	

Note. Configural model fit: $\chi^2(8) = 20.17$, p = .010; CFI = 0.965; TLI = 0.935; RMSEA = 0.061 (90% CI = 0.028–0.094); SRMR = 0.037; AIC = 1949.81; BIC = 1998.17. Model diagnostics: χ^2 test: non-significant (p ≥ .05) indicates close fit; here p = .010 suggests modest misfit that is offset by other indices.
CFI/TLI: ≥ .90 = good fit. RMSEA: ≤ .06 = close fit; .06–.08 = reasonable; > .10 = poor. SRMR: ≤ .08 = acceptable.
Parameter estimates are fully standardized (Std.all) and the significance marked *$p < .05$, **$p < .01$, ***$p < .001$. positive vs. negative denotes direction. Benchmarks (Cohen, 1988): small ≈ .10; medium ≈ .30; large ≥ .50

Appendix 2D. Fit Indices and Standardized Parameter Estimates for SEM Model 2 (14 Parameters, N = 414)

Estimator: Maximum Likelihood		
Optimization method: NLMINB		
Number of model parameters	14	
Obs	414	
Test statistic	33.193	
DF	16	
P-value (Chi-square)	0.007	*Modest misfit*
Model Test Baseline Model		
Test statistic	370.375	
DF	25	
P-value	0.000	
User Model versus Baseline Model		
Comparative Fit Undex (CFI)	0.950	*Good fit*
Tucker-Lewis Index (TLI)	0.922	*Good fit*
Loglikelihood and Information Criteria		
Loglikelihood user model (H0)	-926.834	
Loglikelihood unrestricted model (H1)	-910.238	
Akaike (AIC)	1881.668	
Bayesian (BIC)	1937.230	
Sample-size adjusted Bayesian (SABIC)	1892.809	
Root Mean Square Error of Approximation:		
RMSEA	0.052	*Acceptable*
90% confidence interval - lower	0.027	
90% confidence interval - upper	0.078	
P-value H_0: RMSEA <= 0.05	0.402	
P-value H_0: RMSEA >=0.08	0.035	
Standardized Root Mean Square Residual		
(SRMR)	0.039	*Good fit*
Parameter Estimates		
Standard errors: Standard		
Information: Expected		
Information saturated (h1) model: Structured		

	Estimate	**Std.Err**	**z-value**	**Std.lv**	**Std.all**	**P(>|z|)**	
Factor Loadings for Syndemic factors =~							
Homelessness	1.000	0.308	0.664				*fixed for scale definition*
Mental health problems	0.521	0.069	7.594	0.161	0.513	0.000	*large association with factor*
DCFS referrals	0.594	0.083	7.127	0.183	0.472	0.000	*modest association with factor*
Incarceration	0.793	0.106	7.477	0.244	0.503	0.000	*large association with factor*
Structural path							
Meth use -> Syndemic	0.412	0.040	10.180	1.336	**0.666*** **	**0.000**	*large association with factor*
Meth use -> No PNC	0.263	0.077	3.404	0.263	**0.262*** **	**0.001**	*small-medium*
Syndemic -> No PNC	0.093	0.147	0.631	0.029	0.057	0.528	*not significant*
Marital status	0.018	0.009	1.908	0.018	0.091	0.056	*not significant*
Age group	0.023	0.013	1.815	0.023	0.087	0.070	*not significant*
Residual variances (unexplained proportion)							
Homelessness	0.121	0.013	9.468	0.121	0.560	0.000	
Mental health problems	0.072	0.006	11.979	0.072	0.736	0.000	
DCFS referrals	0.117	0.009	12.386	0.117	0.777	0.000	
Incarceration	0.177	0.015	12.092	0.177	0.747	0.000	
No PNC	0.221	0.016	13.953	0.221	0.888	0.000	
Syndemic	0.053	0.010	5.035	0.557	0.557	0.000	

Note. Estimator = Maximum Likelihood (ML); optimization via NLMINB. Configural model fit: $\chi^2(16) = 33.19$, p = .007; CFI = .950; TLI = .922; RMSEA = .052 (90% CI = .027–.078); SRMR = .039; AIC = 1881.67; BIC = 1937.23. Model diagnostics: χ^2 test: $p < .05$ indicates modest misfit. CFI/TLI: ≥ .90 = good fit. RMSEA: ≤ .06 = close fit; .06–.08 = reasonable; > .10 = poor. SRMR: ≤ .08 = acceptable.
Parameter estimates are fully standardized (Std.all) and the significance marked **p* < .05, ***p* < .01, ****p* < .001.; positive vs. negative denotes direction. Benchmarks (Cohen, 1988): small ≈ .10; medium ≈ .30; large ≥ .50.

Appendix 2E. Structural Equation Model (SEM) by Birthing Persons' Race. Model 3

Estimator: Maximum Likelihood			
Optimization method: NLMINB			
Number of model parameters		57	
Observations per group			
White		52	
Black		110	
Latinx		211	
Test statistic		110.505	
DF		48	
P-value (Chi-square)		0.000	*Poor fit*
Test statistic for each group			
	Black	23.709	
	Latinx	29.254	
	White	57.542	
Model Test Baseline Model			
Test statistic		414.88	
DF		75	
P-value		0.000	*Poor fit*
User Model versus Baseline Model			
Comparative Fit Undex (CFI)		0.816	*Marginal fit*
Tucker-Lewis Index (TLI)		0.713	*Poor fit*
Loglikelihood and Information Criteria			
Loglikelihood user model (H0)		-850.801	
Loglikelihood unrestricted model (H1)		-795.549	
Akaike (AIC)		1815.602	
Bayesian (BIC)		2035.991	
Sample-size adjusted Bayesian (SABIC)		1855.164	
Root Mean Square Error of Approximation:			
RMSEA		0.105	*Poor fit*
90% confidence interval - lower		0.079	
90% confidence interval - upper		0.131	
P-value H_0: RMSEA <= 0.05		0.001	
P-value H_0: RMSEA >=0.08		0.947	
Standardized Root Mean Square Residual:			
SRMR		0.067	*Acceptable*
Parameter Estimates			
Standard errors: Standard			
Information: Expected			
Information saturated (h1) model: Structured			

Model 3 Model Specifications

X_{1i} = Homelessness, X_{2i} = DCFS referrals, X_{3i} = Current or History of incarceration, X_{4i} = Mental health problems
Z_{1i} = marital status, Z_{2j} = age group
η_i = Syndemic, M_i = Meth use, Y_i = No Prenatal Care
Residuals = $\delta_1 \ldots \delta_4$ & ζ_i, ε_i

Structural model

Black birthing persons: $\eta_i = 0.572^{***} M_i + \zeta_i$; $Y_i = 0.501^{***} M_i - 0.211\ \eta_i + 0.088\ Z_{1i} + 0.030\ Z_{2j} + \varepsilon_i$
Latinx birthing persons: $\eta_i = 0.688^{***} M_i + \zeta_i$; $Y_i = 0.059\ M_i + 0.336^{*}\ \eta_i + 0.018\ Z_{1i} + 0.070\ Z_{2j} + \varepsilon_i$
White birthing persons: $\eta_i = 0.620\ M_i + \zeta_i$; $Y_i = 0.597\ M_i^{*} - 0.493\ \eta_i - 0.043\ Z_{1i} + 0.157\ Z_{2j} + \varepsilon_i$

Black Birthing Persons (n=110)

	Estimate	Std.Err	z-value	Std.lv	Std.all	P(>|z|)
Factor Loadings for Syndemic factors =~						
Homelessness	1.000	0.372	0.781			
DCFS	0.446	0.132	3.384	0.166	0.423	0.001
Incarceration	0.449	0.162	2.768	0.167	0.336	0.006
Mental health problems	0.485	0.117	4.150	0.180	0.555	0.000
Structural path						
Meth use -> Syndemic	0.429	0.084	5.104	1.151	**0.572*** **	**0.000**
Meth use -> No PNC	0.500	0.124	4.047	0.500	**0.501*** **	**0.000**
Syndemic -> No PNC	-0.281	0.196	-1.433	-0.105	-0.211	0.152
Marital status	0.015	0.016	0.966	0.015	0.088	0.334
Age group	0.007	0.022	0.331	0.007	0.030	0.740
Intercepts:						
Homelessness	0.161	0.056	2.858	0.161	0.338	0.004
DCFS	0.106	0.046	2.289	0.106	0.270	0.022
Incarceration	0.365	0.058	6.264	0.365	0.734	0.000
Mental health problems	0.029	0.039	0.735	0.029	0.088	0.462
No PNC	0.205	0.117	1.744	0.205	0.414	0.081
Residual variances (unexplained proportion)						
Homelessness	0.089	0.029	3.048	0.089	0.391	0.002
DCFS	0.126	0.019	6.508	0.126	0.821	0.000
Incarceration	0.220	0.033	6.750	0.220	0.887	0.000
Mental health problems	0.073	0.013	5.842	0.073	0.692	0.000
No PNC	0.198	0.029	6.905	0.198	0.808	0.000
Syndemic	0.093	0.031	3.003	0.673	0.673	0.003

Latinx Birthing Persons (n=211)

	Estimate	Std.Err	z-value	Std.lv	P(>|z|)
Factor Loadings for Syndemic factors =~					
Homelessness	1.000	0.320	0.697		
DCFS	0.515	0.105	4.918	0.165	0.427
Incarceration	0.824	0.138	5.987	0.263	0.541
Mental health problems	0.420	0.081	5.157	0.134	0.451
Structural path					
Meth use -> Syndemic factors	0.440	0.055	8.048	**0.688*** **	0.000
Meth use -> No PNC	0.059	0.115	0.515	0.059	0.606
Syndemic factors -> No PNC	0.524	0.218	2.407	**0.336***	0.016
Marital status	0.018	0.014	1.331	0.088	0.183
Age group	0.021	0.019	1.066	0.070	0.286
Intercepts:					
Homelessness	0.086	0.039	2.218	0.086	0.188
DCFS	0.072	0.034	2.115	0.072	0.186
Incarceration	0.208	0.042	4.895	0.208	0.427
Mental health problems	0.008	0.026	0.322	0.008	0.028
No PNC	0.210	0.097	2.159	0.210	0.422
Residual variances (unexplained proportion)					
Homelessness	0.108	0.017	6.476	0.108	0.514
DCFS	0.122	0.013	9.279	0.122	0.818
Incarceration	0.167	0.020	8.565	0.167	0.707
Mental health problems	0.071	0.008	9.160	0.071	0.797
No PNC	0.209	0.022	9.373	0.209	0.842
Syndemic factors	0.054	0.014	3.717	0.527	0.527

White Birthing Persons (n=52)

	Estimate	Std.Err	z-value	Std.lv	Std.all	P(>|z|)
Factor Loadings for Syndemic factors =~						
Homelessness	1.000	0.149	0.300			
DCFS	1.058	0.744	1.421	0.158	0.360	0.155
Incarceration	1.276	0.869	1.469	0.190	0.389	0.142
Mental health problems	1.729	1.026	1.685	0.258	0.703	0.092
Structural path						
Meth use -> Syndemic	0.185	0.111	1.675	1.241	0.620	0.094
Meth use -> No PNC	0.589	0.235	2.513	0.589	**0.597***	**0.012**
Syndemic -> No PNC	-1.628	1.270	-1.282	-0.243	-0.493	0.200
Marital status	-0.007	0.023	-0.318	-0.007	-0.043	0.751
Age group	0.037	0.030	1.212	0.037	0.157	0.225
Intercepts:						
Homelessness	0.344	0.090	3.828	0.344	0.692	0.000
DCFS	0.158	0.080	1.982	0.158	0.361	0.047
Incarceration	0.277	0.089	3.101	0.277	0.566	0.002
Mental health problems	-0.006	0.066	-0.097	-0.006	-0.018	0.922
No PNC	0.245	0.180	1.360	0.245	0.497	0.174
Residual variances (unexplained proportion)						
Homelessness	0.224	0.047	4.786	0.224	0.910	0.000
DCFS	0.168	0.036	4.677	0.168	0.871	0.000
Incarceration	0.204	0.044	4.612	0.204	0.849	0.000
Mental health problems	0.068	0.027	2.556	0.068	0.505	0.011
No PNC	0.182	0.046	3.934	0.182	0.748	0.000
Syndemic	0.014	0.016	0.879	0.615	0.615	0.379

Note. Estimator = Maximum Likelihood (ML); optimization via NLMINB.
Fit indices for the configural model: $\chi^2(48) = 110.51$, $p < .001$ (poor fit); CFI = 0.816 (marginal) ; TLI = 0.713 (poor) ; RMSEA = 0.105 (90% CI = 0.079–0.131; poor); SRMR = 0.067 (acceptable); AIC = 1815.60; BIC = 2035.99; SABIC = 1855.164.
Model diagnostics interpretation: χ^2 test: a non-significant p-value indicates good fit; here $p < .001$ suggests misfit: CFI/TLI: ≥ 0.90 = good fit, 0.80–0.90 = marginal; RMSEA: ≤ 0.06 = close fit; 0.06–0.08 = reasonable; > 0.10 = poor; SRMR: ≤ 0.08 = acceptable. Parameter estimates are fully standardized (Std.all) and the significance marked *$p < .05$, **$p < .01$, ***$p < .001$. positive vs. negative denotes direction. Benchmarks (Cohen, 1988): small ≈ .10; medium ≈ .30; large ≥ .50

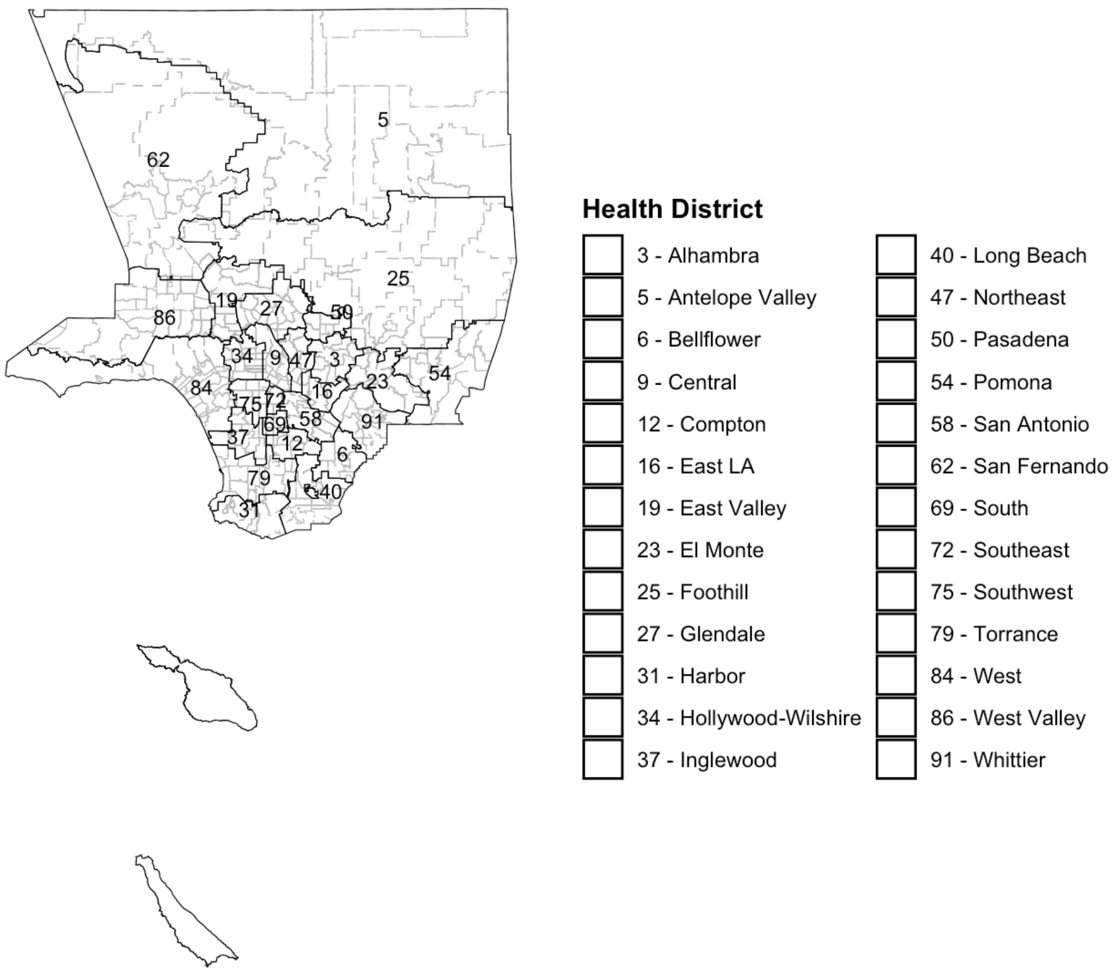
Chapter 3 Appendices

Appendix 3A. Los Angeles County Health Districts (HD) and Service Planning Area (SPA)

HD	HD Name	SPA	SPA Name	Shape Area	Shape Length
3	Alhambra	3	San Gabriel	1,070,967,299.56	201,373.76
5	Antelope Valley	1	Antelope Valley	37,876,895,312.21	1,441,313.54
6	Bellflower	7	East	1,095,871,705.17	263,384.16
9	Central	4	Metro	904,129,659.35	181,211.40
12	Compton	6	South	702,475,630.44	164,867.89
16	East LA	7	East	650,849,715.61	147,906.39
19	East Valley	2	San Fernando	2,055,955,665.78	321,251.97
23	El Monte	3	San Gabriel	1,732,917,894.71	297,306.49
25	Foothill	3	San Gabriel	18,562,895,797.50	1,067,696.15
27	Glendale	2	San Fernando	1,673,981,615.76	249,003.85
31	Harbor	8	South Bay	5,007,847,168.13	982,172.23
34	Hollywood-Wilshire	4	Metro	886,629,665.91	176,409.89
37	Inglewood	8	South Bay	1,052,705,799.80	214,499.83
40	Long Beach	8	South Bay	1,820,826,309.58	311,984.41
47	Northeast	4	Metro	763,688,291.95	170,828.71
50	Pasadena	3	San Gabriel	680,712,048.35	252,694.67
54	Pomona	3	San Gabriel	3,757,618,817.48	395,972.44
58	San Antonio	7	East	1,000,850,547.57	185,700.99
62	San Fernando	2	San Fernando	17,368,963,599.19	818,462.33
69	South	6	South	302,152,591.98	79,863.24
72	Southeast	6	South	228,466,043.06	67,938.88
75	Southwest	6	South	707,878,657.81	148,054.00
79	Torrance	8	South Bay	1,894,206,130.51	335,374.68
84	West	5	West	5,305,298,582.01	645,825.82
86	West Valley	2	San Fernando	5,602,983,275.17	505,328.28
91	Whittier	7	East	1,696,229,513.94	242,733.49

Note. Los Angeles County Health Districts (HDs), updated in 2022, boundaries are used in the study. Los Angeles County is divided into 26 HDs, which are subdivisions of 8 Service Planning areas (SPAs). HDs are used for planning and managing health service delivery across Los Angeles County. Long Beach (HD=40) and Pasadena (HD 50) are excluded from this study. Updating HD and SPA boundaries to align with new U.S. Census Bureau census tract boundaries is performed after every Decennial Census. Data Available from https://egis-lacounty.hub.arcgis.com/datasets/lacounty::health-districts-2022-view/about Access on April 3, 2025.

Appendix 3B. Health District (Solid Black Line) and ZIP Code Tabulation Areas (ZCTAs) Boundaries (Dotted Gray Line)



Appendix 3C. CDC Social Vulnerability Index (SVI) 2018

The CDC Social Vulnerability Index (SVI), developed by the Agency for Toxic Substances and Disease Registry (ATSDR)'s Geospatial Research, Analysis & Services Program, serves as a tool for emergency planners and public health officials to identify communities likely needing additional support during disasters or hazardous events. The SVI evaluates vulnerability across all U.S. using social factors that are organized into four thematic categories: 1. Socioeconomic status; 2. Household Composition & Disability; 3. Minority Status & Language; 4. Housing Type & Transportation. Each tract and zip code receives percentile index (0.00 – 1.00) for individual variables, the four themes, and an overall SVI score, with higher values indicating greater vulnerability.

Socioeconomic Vulnerability Variables
Persons below poverty estimate, 2014-2018 ACS
Persons below poverty estimate MOE, 2014-2018 ACS
Civilian (age 16+) unemployed estimate, 2014-2018 ACS
Civilian (age 16+) unemployed estimate MOE, 2014-2018 ACS
Per capita income estimate, 2014-2018 ACS
Per capita income estimate, MOE, 2014-2018 ACS
Persons (age 25+) with no high school diploma estimate, 2014-2018 ACS
Persons (age 25+) with no high school diploma estimate MOE, 2014-2018 ACS
Household Composition/Disability Vulnerability Variables
Persons aged 65 and older estimate, 2014-2018 ACS
Persons aged 65 and older estimate MOE, 2014-2018 ACS
Persons aged 17 and younger estimate, 2014-2018 ACS
Persons aged 17 and younger estimate MOE, 2014-2018 ACS
Civilian noninstitutionalized population with a disability estimate, 2014-2018 ACS
Civilian noninstitutionalized population with a disability estimate MOE, 2014-2018 ACS
Single parent household with children under 18 estimate, 2014- 2018 ACS
Single parent household with children under 18 estimate MOE, 2014-2018 ACS
Minority Status/Language Vulnerability Variables
Minority (all persons except white, non- Hispanic) estimate, 2014-2018 ACS
Minority (all persons except white, non- Hispanic) estimate MOE, 2014-2018 ACS
Persons (age 5+) who speak English "less than well" estimate, 2014-2018 ACS
Housing Type/Transportation Vulnerability Variables
Housing in structures with 10 or more units estimate, 2014-2018 ACS
Housing in structures with 10 or more units estimate MOE, 2014-2018 ACS
Mobile homes estimate, 2014-2018 ACS
Mobile homes estimate MOE, 2014-2018 ACS
At household level, more people than rooms estimate, 2014-2018 ACS
At household level, more people than rooms estimate MOE, 2014-2018 ACS
Households with no vehicle available estimate, 2014-2018 ACS
Households with no vehicle available estimate MOE, 2014-2018 ACS
Persons in institutionalized group quarters estimate, 2014-2018 ACS
Persons in institutionalized group quarters estimate MOE, 2014-2018 ACS

Note. ACS: American Community Survey, MOE: Margin of Error. Source. CDC Agency for Toxic Substances and Disease Registry, Geospatial Research, Analysis, and Services Program. "CDC Social Vulnerability Index." 2020 https://www.atsdr.cdc.gov/place-health/php/svi/index.html Access on April 10

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