ABSTRACT

Background: In the U.S., 25 states have laws that explicitly criminalize the transmission or exposure of HIV. This study, grounded in Nancy Krieger's ecosocial theory, estimated the association between HIV criminalization laws and state- (Aim 1) and county-level (Aim 2) HIV incidence rates, as well as individual HIV testing history (Aim 3), and assessed effect modification by overpolicing, using incarceration rates as a proxy.

Methods: The study uses data from state- and county-level HIV incidence data from AIDSVu (2010-2019), incarceration data from the Vera Institute of Justice (2010-2018), and HIV testing data from BRFSS (2016-2019). For Aim 1, a longitudinal analysis was conducted using multivariate marginal Poisson GEE models to estimate rate ratios. For Aim 2, count-rate hierarchical (multilevel) models were fitted to estimate rate ratios. For Aim 3, logistic regression models were fitted to estimate odds ratios.

Results: The presence of a state HIV testing law was associated with a higher state HIV incidence in the general and Hispanic populations (aRR=1.48 and 1.68, respectively), but higher incarceration at the state level did not significantly modify the relationship between the law and HIV incidence. At the county level, being in a state with an HIV-specific criminalization statute was associated with a higher county-wide HIV incidence rate for all three populations (aRR=1.14, 1.30, and 1.32 for the general, Black, and Hispanic populations, respectively). Unlike the state-level analysis, this association was attenuated by a higher jailed population rate for the general and Black populations. The effect modification was statistically significant for the general population ($p=0.01$) and marginally significant for the Black population ($p=0.06$). Finally, the presence of a state HIV testing law (aOR=1.06) was associated with a greater likelihood of HIV testing history in the general population. However, in HIV criminalization states, heavier policing negatively modified the effect of the law on the likelihood of having ever received an HIV test ($p<0.01$).

Public health implications: This study contributes to a gap in the literature by using recent data to estimate the association of HIV criminalization laws and their enforcement with HIV incidence rates and HIV testing behavior.

THE EFFECTS OF HIV CRIMINALIZATION LAWS (AND THEIR ENFORCEMENT) ON HIV RISK AMONG BLACK AND HISPANIC POPULATIONS

by

Jessica Maciel Keralis

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Advisory Committee:
Associate Professor, Quynh C. Nguyen
Dean's representative, Associate Professor, Michel H. Boudreaux
Professor Scott C. Burris, J.D.
Associate Professor, Typhanye V. Dyer
Associate Professor, Xin He
Assistant Research Professor, Rodman E. Turpin

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I have often stated that, in my extensive literature review on the topic of this dissertation, I have probably read every single peer-reviewed publication on HIV criminalization in the U.S., with the exception of a handful of qualitative analyses. I firmly believe that is true. Accordingly, I humbly acknowledge that I was able to complete this work by standing on the shoulders of scholarly giants. The theoretical framework for this dissertation was built on a foundation laid by the legal scholars, epidemiologists, public health professionals, and human rights advocates who have been doing this work for decades.

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Chapter 1.
Introduction

Chapter 1: Introduction

1.1 Background and rationale

1.1.1 Background

The history of the U.S. HIV epidemic

Human immunodeficiency virus (HIV) is a retrovirus (1) that is transmitted from person to person through contact with or transfer of blood, breast milk, and body fluids emitted during sexual contact (semen, pre-ejaculate, and vaginal and rectal fluids) (2). HIV was first identified, though not recognized, in the literature with a 1981 report in *MMWR* of a cluster of *Pneumocystis carinii* pneumonia (PCP) among a group of homosexual men in Los Angeles (3). The U.S. Centers for Disease Control and Prevention (CDC) designated it as acquired immunodeficiency syndrome (AIDS) in 1982 (4). The emergence of HIV in the U.S. exposed considerable stigma and panic toward those who contracted the virus. As this hysteria and handwringing unfolded in the 1980s, legal scholars and lawmakers began to consider what role the law – specifically, criminal law – should play in controlling the epidemic.

The rise of HIV criminalization laws

Initial legal analysis

Early legal opinions on whether, and how, criminal law should be used to control the spread of HIV varied considerably. Some scholars cautioned against the use of criminalization as a means of deterring behaviors that spread HIV, warning that it would lead to disproportionate prosecution of socially marginalized minorities and could backfire by discouraging individuals at risk from seeking testing and treatment (5-9). Others viewed the use of criminal punishment as entirely appropriate, as an AIDS diagnosis was widely viewed as a "death sentence" due to the high fatality rate, lack of a cure or effective treatment (10). Hamblin argued that the law should be used as a tool to protect the socioeconomically vulnerable who were at risk for HIV (11). Nearly all legal analyses recognized the difficulty of demonstrating both the causation and the intent, negligence, or recklessness required for criminal homicide charges (e.g., murder, manslaughter, or negligent homicide) or assault (5, 7-10, 12-16). As a solution, those in favor of criminalizing HIV recommended the development of targeted criminal statutes specific to HIV that took into account its modes of transmission and the most recent medical science (10-13, 15, 16).

The President's Commission and the Ryan White CARE Act

As legal experts examined and debated the implications of using the law as a tool to reduce HIV transmission, state legislatures forged ahead with crafting and passing criminalization statutes. They were explicitly encouraged to do so by the federal government, via technical guidance from the executive and funding requirements from Congress. In its 1988 report, the Presidential Commission on the Human Immunodeficiency Virus Epidemic explicitly recommended that states adopt criminal statutes specifically punishing "HIV-infected individuals who knowingly conduct themselves in ways that pose a significant risk of transmission to others" (17). The Commission cited the aforementioned difficulties in using traditional criminal laws regarding murder, attempted murder, and assault to punish HIV transmission in support of its recommendation, reasoning that "[a]n HIV-specific statute…would provide clear notice of socially unacceptable standards of behavior specific to the HIV epidemic and tailor punishment to the specific crime of HIV transmission."

Not long after, Congress codified a requirement into the Ryan White CARE Act that states be able to demonstrate the ability to "prosecute any HIV infected individual who knowingly and intentionally exposes a nonconsenting individual to HIV through a donation of blood, semen, or breast milk, through sexual activity, or through sharing of a hypodermic needle" under their criminal codes in order to receive grant money for HIV care and treatment (18). By 2002, 24 states had adopted statutes that specifically criminalized the exposure or transmission of HIV (19). The remaining states without HIV-specific criminalization statutes had to certify that they could prosecute HIV exposure under their general criminal codes (10).

1.1.2 Rationale

In the decades that have passed since the initial push to enact criminal penalties, scholars and public health practitioners have unified in their opposition to the criminalization of HIV as a means of epidemic control. Numerous commentators have pointed out that HIV criminalization laws are vague and outdated, with statutory language not reflective of recent advances in scientific knowledge of transmission and medical advances in treatment and prevention options.

It is widely hypothesized that these problems with the laws may lead to reduced efficacy of proven public health messaging and other HIV prevention strategies. They are now viewed by the public health community as potentially counterproductive, inadvertently driving the U.S. epidemic despite their stated intent to reduce exposure and transmission. Additionally, because transmission behaviors in the general population cannot be effectively policed, they are disproportionately enforced against marginalized groups, particularly Black and Hispanic individuals. This, in turn, may result in the counterproductive effect of these laws being concentrated among these populations. The rationale for this dissertation, therefore, is to test whether HIV criminalization laws and/or legal enforcement is associated with increases in HIV transmission and HIV testing among Black and Hispanic populations.

HIV criminalization laws are poorly worded and reflect outdated science

Despite the Presidential Commission's exhortation that "criminal sanctions for HIV transmission…must be directed only towards behavior which is scientifically established as a mode of transmission," most criminalization statutes passed by states were poorly written and overbroad (13, 14, 19-26). Some statutes have language that does not adequately specify which behaviors are prohibited. For example, the South Dakota and Tennessee statutes prohibit individuals with HIV from engaging in "intimate contact" with another person who does not have HIV (27). Before it was reformed in 2014 (28), the Iowa statute also proscribed "intimate contact," but only defined the term as "intentional exposure of the body of one person to a bodily fluid of another person in a manner that could result in the transmission of HIV." The South Dakota law does not define the term at all. Similarly, Louisiana's law makes it illegal to intentionally expose another to HIV through "sexual contact" but provides no definition of the term. Other laws specifically criminalize behaviors that have no demonstrable risk of HIV transmission. For example, Arkansas and Michigan define fellatio, cunnilingus, and penetration of objects as potential exposures, actions which carry negligible or no demonstrated risk of HIV transmission. Louisiana includes spitting as a potential mechanism of transmission, while six states include saliva in their definitions of potentially infectious body fluids; seven include fecal matter; eight include urine; and five include all three; none of which pose a risk for bloodborne pathogen transmission (29).

With the development of effective antiretroviral therapy (ART), HIV became a manageable chronic disease, and people living with HIV now have nearly the same life expectancy as the general population (30-32). People Living with HIV (PLWH) who take their ART medications as prescribed and maintain viral suppression have effectively no risk of transmitting HIV to their sexual partners (33). This scientific breakthrough is now recognized as "treatment as prevention" (34) or "undetectable=untransmittable" (U=U) (35). HIV-negative persons who are at high risk for acquiring HIV also have access to pre-exposure prophylaxis (PrEP), which is highly effective at preventing HIV transmission (36, 37). However, most HIV criminalization statutes strictly mandate disclosure of HIV status to potential partners (5, 8) and do not recognize condom use (24), viral suppression, ART, nor PrEP use (38) as an affirmative defense. Thus, these laws do not reflect the most up-to-date science for HIV prevention and treatment.

HIV criminalization laws are not uniformly enforced

The deficiencies in the text of many of these laws, along with the epidemic's concentration among Black and Hispanic populations and other marginalized groups, make the laws ripe for abuse by law enforcement (39). While laws that criminalize HIV transmission nominally fall under the umbrella of public health law – which is designed to empower the state to protect the health of the population at large by means of inspections, quarantine, and mandatory vaccinations and treatment – they are impossible to enforce uniformly across the population because the behaviors that spread HIV (i.e., condomless sex and shared injection drug use) are both private and highly gratifying (40). Simply put, it is impossible to enforce such laws uniformly for both practical (i.e., the "not enough policemen" problem) and constitutional (i.e., infringing on citizens' right to privacy without probable cause) reasons (7, 40). Instead, they are disproportionately enforced against groups that are already stigmatized and vulnerable, including Black and Hispanic populations, sex workers, drug users (41). A number of public health law experts have highlighted the potential for HIV criminalization laws to be selectively enforced by prosecutors (5, 8, 19, 26), and there is some evidence that they have been used to specifically target Black and Hispanic individuals (39, 41, 42).

HIV criminalization contradicts effective public health messages

Since the mid-2000s, public health professionals, lawyers, and advocates have been in nearly universal agreement that laws criminalizing HIV are, at best, ineffective, and at worst, counterproductive (43-50). Public health scientists argue that such statues may counteract effective public health messages on HIV prevention and safer sex by conveying a sense of "passive innocence" among the public and diminishing individuals' sense of personal responsibility for protecting themselves and their partner (i.e., not needing to take precautions related to safer sex because the legal system bears the responsibility for preventing transmission) (24, 43, 47). With few exceptions, these laws (1) require that the individual be aware of their HIV status and (2) specify that they are in violation of the law if they expose another person without first disclosing their status. In most states, not only is transmission not required, but neither condom use (24), viral suppression, ART, nor PrEP (38) qualify as an affirmative defense. Thus, these laws may encourage riskier behaviors because most statutes only require disclosure (5, 8), and possibly also to avoid detection (e.g., anonymous sex) (7, 14, 47).

Additionally, HIV criminalization laws may discourage HIV testing (51) by motivating individuals to eliminate their culpability under the law (5-9, 13, 14, 24, 26, 52-56), as individuals must be aware of their HIV status to be criminally liable (50). Because groups at higher risk for acquiring HIV are also at higher risk of being targeted by law enforcement (e.g., Black and Hispanic individuals and persons who inject drugs), they are naturally motivated to reduce the ability of the justice system to charge them with additional offenses. Many researchers hypothesize that this is the primary mechanism by which HIV criminalization laws discourage testing, and therefore indirectly increase HIV transmission (41, 50, 57, 58). They may also reinforce stigma against HIV (14, 26, 42, 43, 56). Reducing HIV testing among high-risk groups in particular risks exacerbating the epidemic because nearly 40% of all cases of HIV transmission are attributable to individuals who are unaware of their status (59).

1.2 Objectives and research questions

1.2.1 Objectives

There are two broad objectives of this dissertation. The first is to empirically test whether laws that explicitly criminalize HIV exposure have an independent effect on HIV incidence rates and HIV testing behavior, both among the general population and specifically among Black and Hispanic populations. The second is to empirically test whether heavier policing affects HIV incidence rates and HIV testing behavior, either as an effect modifier of HIV criminalization laws or as an independent factor, among the same populations.

Both objectives will be addressed at three different population levels in each of the three chapters.

1. Chapter 3 will test whether HIV criminalization laws affect **HIV incidence rates** at the **state population level**, and whether **heavier policing at the state level** modifies this effect or has its own independent effect.

2. Chapter 4 will test whether HIV criminalization laws affect **HIV incidence rates** at the **county population level**, and whether heavier **county-level policing** modifies this effect or has its own independent effect.
3. Chapter 5 will test whether HIV criminalization laws affect **individual (person-level)** likelihood of having received an HIV test, and whether **heavier policing at the state level** modifies this likelihood or has its own independent effect.

1.2.2 Research questions

The research questions are similar between Chapters 3-5, with each set tailored to the population level it addresses.

Chapter 3

1. Do states with HIV-specific criminalization laws have higher state-level HIV incidence rates?
    a. Is the presence of an HIV-specific criminalization law associated with a higher state-level HIV incidence rate?
    b. Does heavier policing modify the effect of HIV-specific criminalization laws on state-level HIV incidence rates?
2. Do states with heavier policing have higher state-level HIV incidence rates? In other words, is heavier policing associated with a higher state-level HIV incidence rate?

Chapter 4

1. Do states with HIV-specific criminalization laws have higher county-level HIV incidence rates?
    a. Is the presence of an HIV-specific criminalization law associated with a higher county-level HIV incidence rate?
    b. Do counties with heavier policing have higher county-level HIV incidence rates? In other words, is heavier policing associated with a higher county-level HIV incidence rate?

2. Is the relationship between the presence of an HIV-specific criminalization law and county-level HIV incidence rates modified by higher county-level policing?

Chapter 5

1. Are individuals living in states with HIV-specific criminalization laws less likely to receive an HIV test?
    a. In other words, is the presence of an HIV-specific criminalization law associated with a lower likelihood of having received an HIV test?
    b. Does heavier policing modify the effect of HIV-specific criminalization laws on the likelihood of receiving an HIV test?
2. Are individuals living in states with states with heavier policing less likely to receive an HIV test? In other words, is heavier policing at the state level associated with a lower likelihood of having received an HIV test?

1.3 Theoretical and conceptual frameworks and hypotheses

1.3.1 Theoretical framework: Ecosocial theory

Developed by Nancy Krieger (60), ecosocial theory is a multi-level framework that is closely linked to social epidemiology as a distinct sub-discipline within the field of epidemiology (61). Ecosocial theory focuses particularly on *social* inequalities in health and provides a framework for questions about who and what drives them. It is characterized by four primary constructs: **embodiment**, or how individuals biologically incorporate their physical and social environments; **pathways of embodiment**, or how social and economic power structures define and constrain individuals' biological and social trajectories; **cumulative interplay between exposure, susceptibility, and resistance** as expressions of the aforementioned pathways of embodiment; and **accountability and agency**, which names the State as a responsible agent in the patterns of disease distribution in a given society. The accountability and agency construct also calls on epidemiologists to acknowledge how the first three constructs drive social inequalities in health and to explicitly identify the strengths and limitations of the scale at which they conduct their research. The variables that will be used in this analysis have been mapped onto the appropriate theoretical construct in the table below.

Table 1.1 Analysis variables mapped onto constructs of ecosocial theory

Level	Variable	Ecosocial construct			
		Embodiment	Pathways of embodiment	Cumulative interplay	Accountability and agency
State and County	Presence of an HIV criminalization law				X
	HIV incidence rate			X	
	HIV prevalence rate			X	
	Demographics	X			
	SES indicators		X		
	Urbanicity		X		
	SGM stigma		X		
	Incarcerated population rate				X
Individual	HIV testing history			X	
	Demographics: age, sex, race	X			
	Demographics: marital status		X		
	SES indicators		X		
	HIV risk behavior			X	
	SGM status	X			

As a multi-level framework, ecosocial theory is well suited to support empirical inquiries into the effects of laws and policy on population health patterns in general. Because it recognizes the interplay between factors on different scales of an individual's environment, the framework can accommodate additional theories to explain phenomena at specific levels within a complex system. Law is a structural determinant of health that can influence individual health behaviors directly through awareness and desire to be compliant, as well as indirectly through enforcement by police and by creating, or perhaps arising from, a social and cultural environment and set of expectations.

In addition, ecosocial theory is well suited to the exploration of law as a deterrent to HIV testing among Black and Hispanic individuals in the U.S. Sewell et al. (62) examine modern overpolicing trends to understand how Black communities interact with law enforcement and modify their own behaviors accordingly. While these frameworks were developed specifically to address issues facing the Black community, they provide a foundation for exploring similar phenomena among Hispanic communities. There is evidence that HIV criminalization laws are disproportionately enforced against Black and Hispanic people (39, 41, 42). Kay and Smith (63) note that states with HIV criminalization laws have relatively larger population proportions of African-Americans. This phenomenon is not unique to HIV, as Black and Hispanic individuals were also more likely to be targeted by COVID-19 emergency laws than white individuals (64). An overwhelming number of commentators on HIV criminalization laws have noted that it is impossible to enforce these statutes uniformly across the entire population (7, 40) and that the potential for abuse is high (39), pointing to the potential for them to be selectively enforced by prosecutors who already enjoy considerable discretion in bringing charges (5, 8, 19, 26). In a descriptive analysis of criminal prosecutions for HIV exposure, Lazzarini, Bray, and Burris (19) found no evidence of systemic enforcement of these laws but noted that "[w]hat seems to determine who gets prosecuted is the accident of being caught."

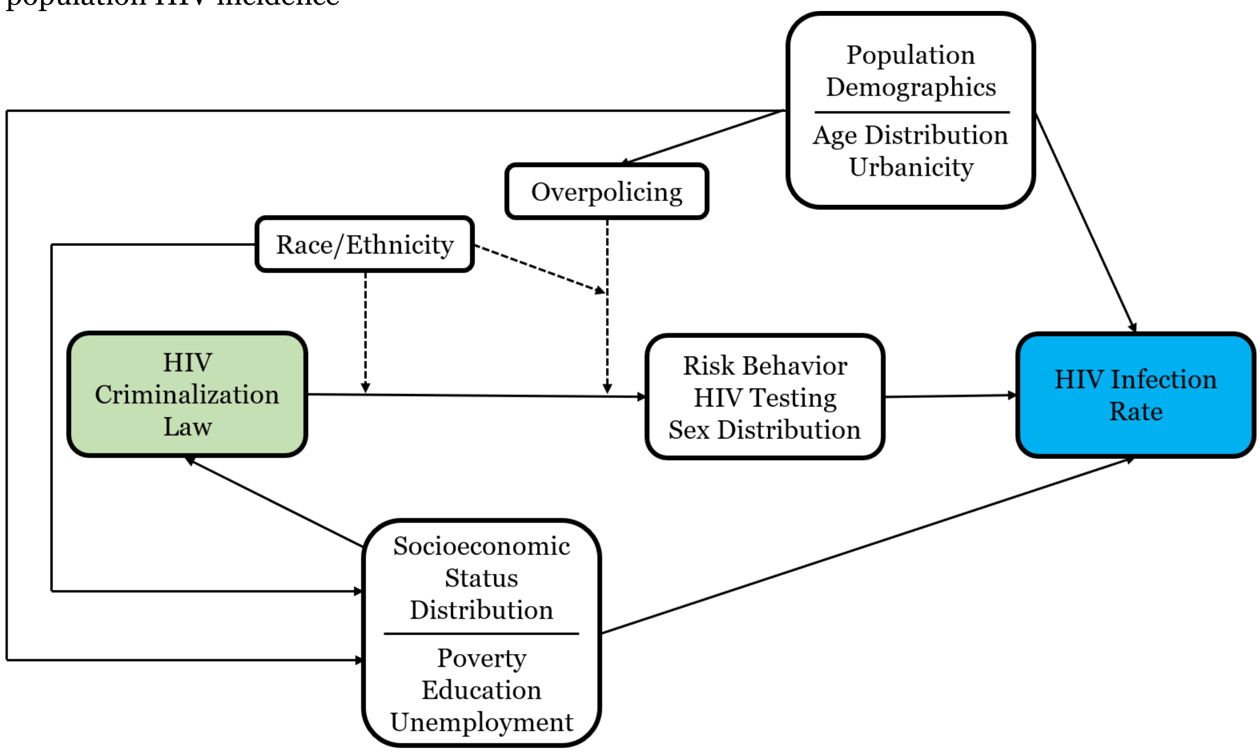
1.3.2 Conceptual framework

Structural factors that increase HIV risk at the population level

The conceptual framework for this manuscript, represented visually in the directed acyclic graphs (DAGs) that follow, applies the theoretical framework developed above to explain how structural factors such as state HIV criminalization laws may affect population-level HIV incidence rates and individual HIV testing behaviors among racial minority populations, though overpolicing as an effect modifier. It also incorporates other structural barriers to health, such as poverty, unemployment and education disparities, that disproportionately increase HIV risk and impact HIV testing behavior among Black and Hispanic populations, potentially resulting in increases in HIV incidence at the population level and lower likelihood of HIV testing at the individual level.

Krieger explicitly framed ecosocial theory as a tool for exploring racial disparities in health and well-being that stem from structural barriers such as poor socioeconomic status and racial discrimination (61, 65). She has also used ecosocial theory to explain the higher rates of HIV incidence among Black and Hispanic women, particularly the poor, observing that HIV is a "biologic expression of inextricably connected social experience" (66). Black and Hispanic individuals in the U.S. are much more likely to be poor, with 18.8% of Black and 15.7% of Hispanic individuals living below the federal poverty line, compared to 7.3% for both white and Asian individuals (67). They are disproportionately more likely to be unemployed and underemployed (68, 69), and Hispanics in particular are more likely to have seasonal or irregular employment (70, 71). These disparities in poverty, education, and unemployment have been linked to increased HIV risk (41, 72, 73).

Figure 1.1. Conceptual framework for the relationship between HIV criminalization laws and population HIV incidence

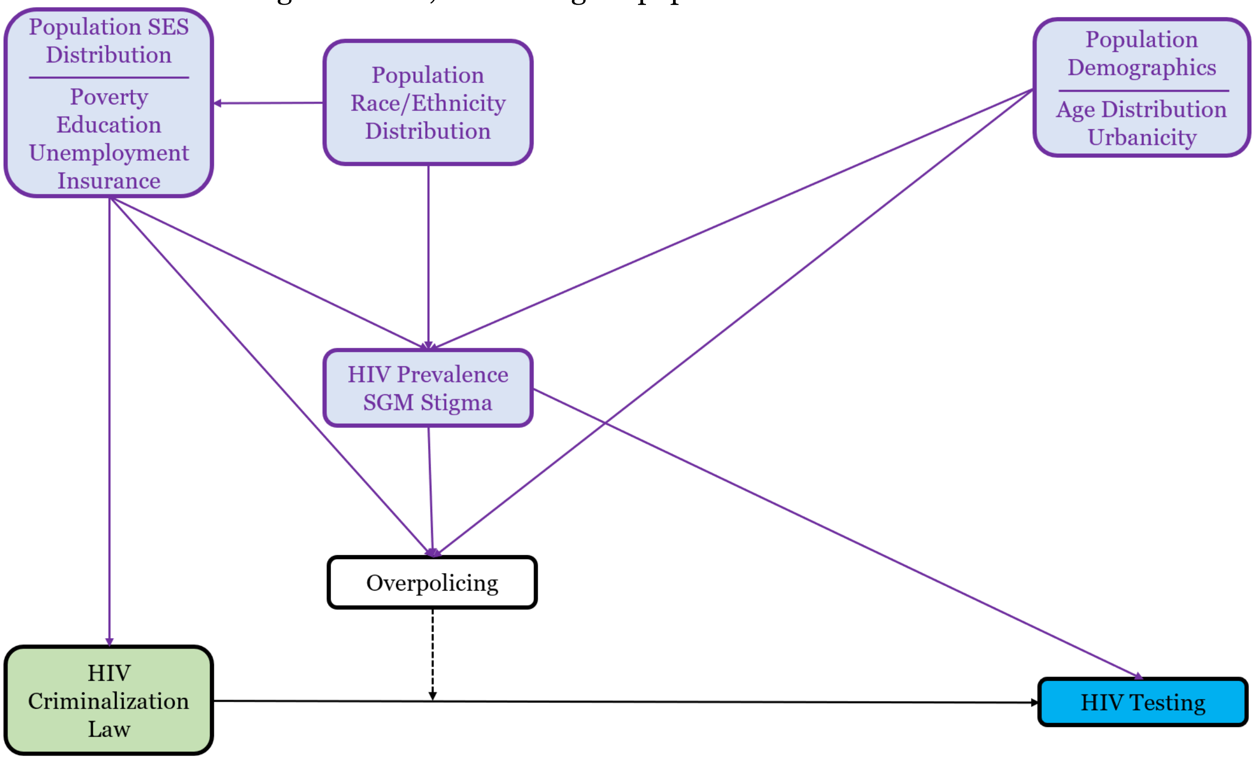


Ecosocial theory also provides a foundation for understanding how structural determinants create excess HIV risk at the neighborhood level among Black and Hispanic communities by worsening income, unemployment, and education disparities. Black and Hispanic individuals are more likely to live in urban areas (74, 75). As a physical and social ecosystem, cities represent a higher-risk environment for HIV transmission due to higher population density, a larger number of social relationships, and a higher concentration of individuals ages 15-44, who are more sexually active. The U.S. HIV epidemic is highly concentrated in urban areas, with 82% of PLWH residing in major urban centers and large disparities in diagnosis rates between Black and Hispanic individuals and white individuals (76). Within cities, Black and Hispanic individuals are in neighborhoods with concentrated poverty and unemployment, regardless of family income (77, 78). Historical discriminatory practices in the 20th century U.S., such as redlining, discouraged economic investment in these communities and widened the long-term wealth gap between Black and Hispanic families vs. white families (79). As a result, these low-income neighborhoods have fewer employment and business development opportunities, and they become targets for overpolicing, which further exacerbates the individual- and community-level risk socioeconomic risk factors for HIV (62, 80). It is critical to note that, while these structural determinants may have measurable impacts on HIV-related risk behaviors by the people who experience them, they also create excess risk at the community beyond what the individual can "control": Kelley et al. (81) estimated that Black MSM have a measurably higher risk of HIV exposure *per person increase* in the number of partners when compared to white MSM.

As detailed previously, HIV criminalization laws can be conceptualized as structural factors that make certain populations more vulnerable to the spread of HIV using ecosocial theory. For my research questions, the ecosocial theoretical framework also accommodates mechanisms to explain why specific racial and ethnic minority groups are subject to heavier policing (increased surveillance by, interaction with, and arrests and incarceration) than the general population. Heavier policing results in increased deaths and incarceration of Black males, resulting in these men being "missing" from their communities. This has been previously shown to affect HIV incidence rates in this group by Johnson and Raphael (82), who demonstrated that the Black male incarceration dynamic is a major driver of HIV among African Americans. The high rate of Black male incarceration creates a gender imbalance in these communities and disrupts the continuity of heterosexual relationships. This, in turn, increases the likelihood of concurrent sexual partnerships among members and decreases the ability of minority women to be selective in partner choice and negotiate safer sex practices. This is supported by cross-sectional studies that have found that recent incarceration is associated with a higher likelihood of concurrent partnerships and unprotected sex (83-87), both of which elevate HIV risk.

Structural barriers to HIV testing at the population level

Figure 1.2a. Conceptual framework for the relationship between HIV criminalization and individual HIV testing likelihood, accounting for population-level factors

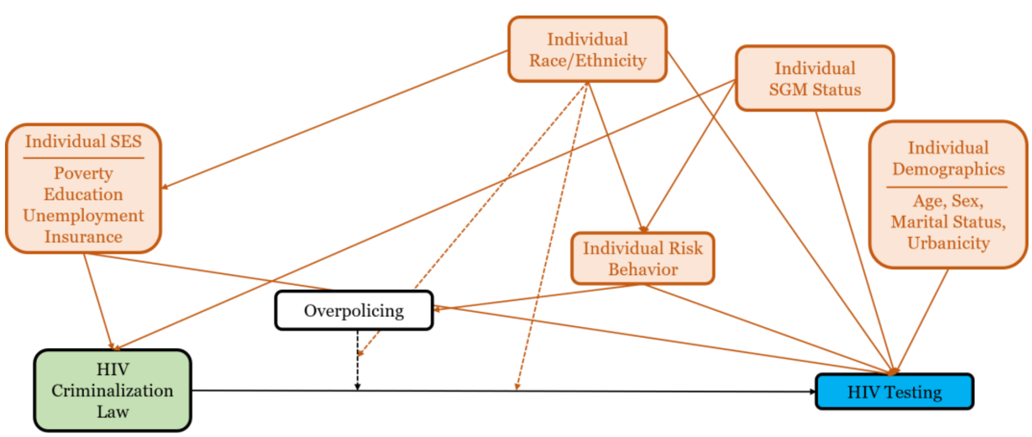


Stigma against sexual and gender minorities (SGM) is a well-documented structural barrier to HIV testing. Gay, bisexual, and other men who have sex with men (MSM) are the group most affected by HIV in the U.S., comprising nearly 70% of new HIV cases in 2018; of these, 37% were among Black MSM and 30% were among Hispanic MSM (88). SGM stigma may be compounded for Black and Hispanic MSM due to the intersection of their racial and sexual minority status. In addition to experiencing homophobia due to their SGM status, Black and Hispanic MSM frequently experience racial and ethnic discrimination in LGBT spaces, attenuating the ability of social support in such spaces to protect against psychological distress (89).Homophobia (both internalized and externally experienced) has been shown to be negatively associated with HIV testing among MSM in general (90, 91), and among Black (92, 93) and Hispanic (94) MSM specifically.

HIV criminalization laws serve as structural factors that create an environment that drives changes in behavior, particularly HIV testing behavior, among individuals belonging to racial and ethnic minority groups. Individuals from minority communities already have more frequent encounters with law enforcement and the justice system, and they are also more likely to have HIV. In states with HIV-specific criminalization laws, when they come into contact with law enforcement, if their HIV status is discovered in the course of the investigation, an HIV criminalization charge could potentially be added to others. While it is possible to prosecute HIV exposure using general criminal statutes, such prosecution is, in theory, more difficult because of requirements to prove intent and direct causation. A number of legal scholars (9, 10, 12, 13, 20, 22), as well as the President's Commission (95), have noted this distinction and its role in the efforts by state legislatures to pass HIV-specific criminalization laws (24, 58, 96). Because HIV exposure is therefore easier to prosecute under laws specifically crafted for this purpose, this may be more likely to happen in states with HIV-specific criminalization laws. This could, in turn, drive individuals from minority communities to avoid HIV testing to minimize their exposure to liability under the law.

Individual-level determinants of HIV testing

Figure 1.2b. Conceptual framework for the relationship between HIV criminalization and individual HIV testing likelihood, accounting for individual-level factors

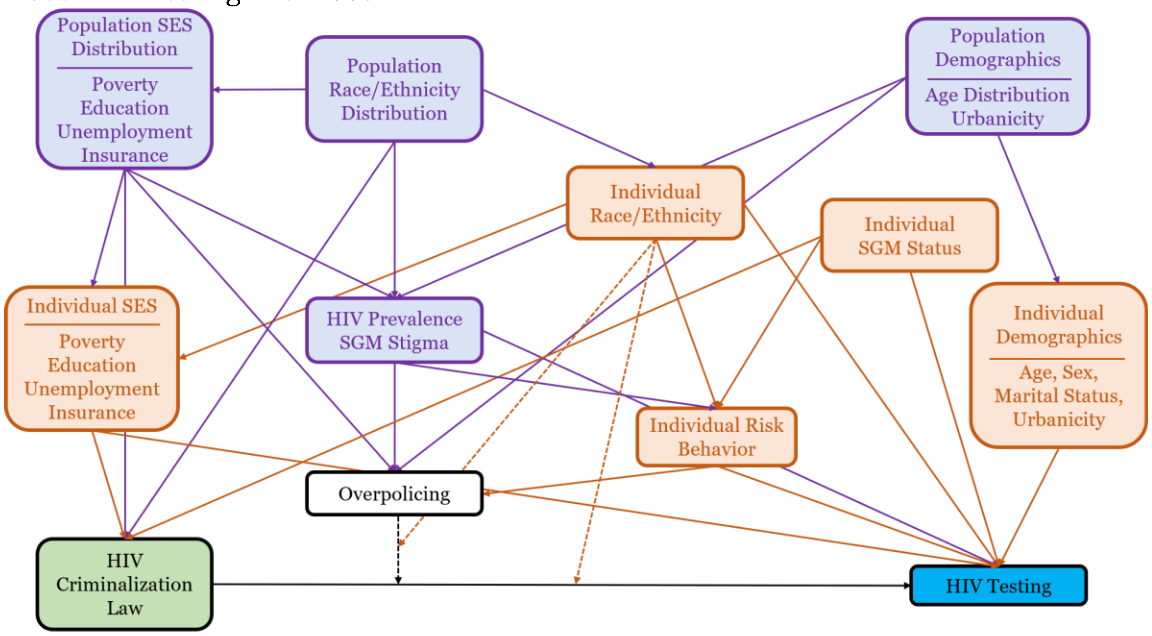


In addition to structural barriers, there are a number of individual demographic, socioeconomic, and behavioral factors that are associated with higher likelihood and frequency of HIV testing. Research on HIV testing patterns consistently shows that males (58, 97-101), those in stable relationships (58, 100, 101), and older individuals (generally 45 years and older) (99-104) are less likely to have ever been tested for HIV, while Black populations (97, 99, 101, 104), Hispanics (97, 99, 101, 105), self-identified sexual and gender minorities (97, 100-102, 104), and those who report recent HIV-related risk behaviors or previous STI (97, 98) are more likely to report previous testing. HIV testing rates are lower among youth (generally less than 25 years) (97, 99). Lower socioeconomic status, including lower educational attainment, unemployment, poverty, are also associated with lower likelihood of HIV testing among adults (58, 100-102). Findings on the association between having health insurance and HIV testing vary, with some studies finding that being insured increases the likelihood of HIV testing (58, 98, 106) while others report an inverse association (101) or no relationship (100, 104). This may be due to some analyses combining public (i.e., Medicaid) and private insurance, as those with Medicaid are also poor, and low income is associated with lower likelihood of HIV testing. Gai and Marthinsen (106) found that states that expanded Medicaid saw increased rates of HIV testing. Frasca et al. (102) separated private and public insurance and found that MSM with private insurance were more likely to get tested for HIV, while those with Medicaid were less likely.

As an independent driver of HIV risk, overpolicing in communities of color drives changes in HIV testing behavior. Heavier policing of black males drives them to "go into hiding," reducing their participation in civic social life to avoid contact with "the system" – that is, law enforcement and the criminal justice system. Sewell et al. similarly posit that racial socialization results in Black populations developing fear and mistrust of law enforcement as they learn about historical discrimination and ongoing racial profiling by police (62). This is true of Hispanics as well, who, along with Black populations, have been shown to be significantly more likely to report having negative interactions with police, to believe that police engage in misconduct, and to live in heavily-policed neighborhoods (107). This may contribute to black and Hispanic men avoiding HIV testing as a means of “system avoidance” (108). Previous analysis has demonstrated that the Tuskegee Syphilis Study, an infamous example of the U.S. government’s indifference to the human rights and well-being of black men and their families, has led directly to decreased medical care-seeking and increased medical mistrust by black men, which produced measurable differences in life expectancy (109). There is also evidence that Hispanic immigrants avoid HIV testing for fear that their test results would be reported to the government (110) and trigger legal consequences (111). While Black populations and Hispanics are more likely than other racial and ethnic groups to get tested for HIV (101, 104, 112), they are also more likely to be tested and diagnosed late in the course of infection, and previous studies using NHBS data (113) and nationally representative survey data (112) have found that around a third of Black populations and Hispanics have never been tested for HIV, despite its increased prevalence among these groups. This “system avoidance” that creates lower rates of HIV testing may be exacerbated in states with HIV-specific criminalization laws.

The DAG below represents the combined conceptual framework of both individual- and population-level confounders of the relationships between HIV criminalization laws, overpolicing, and individual-level likelihood of getting tested for HIV.

Figure 1.2c. Full conceptual framework for the relationship between HIV criminalization and individual HIV testing likelihood



1.3.3 Hypotheses

In accordance with the theoretical and conceptual frameworks outlined above, my hypotheses for the research questions proposed for Chapters 3-5 are as follows.

Chapter 3

1. In states with HIV-specific criminalization statutes, the law will not be independently associated with higher state-level HIV incidence rates. However, in states with HIV-specific criminalization statutes, heavier policing will modify the effect of the law on state-level HIV incidence rates among Black and Hispanic populations, but not among the general population. HIV-specific criminalization laws will be associated with higher state-level HIV incidence rates in states with high overpolicing; in states with low overpolicing, HIV-specific criminalization laws will not be associated with state-level HIV incidence rates.
2. States with heavier policing will have higher state-level HIV incidence rates among Black and Hispanic populations, but not among the general population.

Chapter 4

1. In states with HIV-specific criminalization statutes, the law will not be independently associated with higher county-level HIV incidence rates. However, counties with heavier policing will have higher county-level HIV incidence rates among Black and Hispanic populations, but not among the general population.
2. In counties with heavier policing, the relationship between HIV-specific criminalization statutes and county-level HIV incidence rates will be stronger among Black and Hispanic populations, but not among the general population.

Chapter 5

1. In states with HIV-specific criminalization statutes, the law will not be independently associated with lower likelihood of having received an HIV test. However, in states with HIV-specific criminalization statutes, heavier policing will modify the effect of the law the likelihood of having received an HIV test among Black and Hispanic populations, but not among the general population. In other words, HIV-specific criminalization laws will be associated with lower likelihood of having received an HIV test in states with high overpolicing; in states with low overpolicing, HIV-specific criminalization laws will not be associated with likelihood of having received an HIV test.
2. Black and Hispanic individuals living in states with heavier policing will be less likely to receive an HIV test.

1.4 Innovation and significance

1.4.1 Innovation

To date, there have been few quantitative analyses that measure the effects of HIV criminalization laws on HIV incidence rates, and those that exist use much older data (41, 73, 114). Only two longitudinal studies on the relationship between HIV criminalization laws and HIV incidence rates have previously been published (73, 115). This dissertation will contribute to addressing a gap in knowledge by harnessing the strengths of study designs that have seldom, or never, been used to answer these research questions. Chapter 3 will use a longitudinal study design, the strengths of which include the ability to control for variation within each state (intra-subject variation) as well as secular trends in HIV prevalence. Chapter 4 will make use of multilevel modeling, which has never been used to answer empirical questions about the effects of HIV criminalization. The use of multilevel modeling will account for correlated outcomes among groups (in this case, counties within a state) and allow states with fewer counties to "borrow" statistical strength from the population to aid in estimation.

To date, only one other empirical analysis on the relationship between HIV criminalization laws and HIV testing has been published to date, and it is the only one to use an interaction term in conjunction with the existence of HIV criminalization laws to measure factors related to HIV transmission in populations (58). However, it uses much older data. Thus, this analysis will contribute to addressing a gap in knowledge by using more recent data to contribute to the literature examining the effects of HIV criminalization laws on HIV testing in Chapter 5.

This dissertation is also only the second study (to my knowledge) to estimate the effects of the justice system on race-specific rates (82), as well as only the second one to use an interaction term in conjunction with the existence of HIV criminalization laws to measure factors related to HIV transmission in populations (58).

1.4.2 Significance

Since the first U.S. case of HIV was identified in 1981, the epidemic has resulted in over 700,000 deaths, and there are currently more than 1.1 million people living with HIV in the U.S. (116). Nearly 37,000 people received an HIV diagnosis in 2019, the most recent year for which national data are available (117). Of those, 41.7% were among Black individuals (despite comprising only 13.4% of the population) and 28.5% among Hispanics (despite comprising only 18.5% of the population), compared to 24.5% among non-Hispanic whites (who make up 76.3% of the population) (118). Black and Hispanic individuals are overrepresented in new diagnoses among MSM, transgender individuals, and persons who inject drugs (PWID), and a disproportionately high number of new diagnoses among females occur in Black women (117, 119). Both groups are also disproportionately affected by ecosocial determinants of excess HIV risk, including poverty, unemployment, and education disparities (41, 72, 73), which represent structural barriers to health.

HIV testing is one of the most important strategies for reducing transmission. While individuals with undiagnosed HIV make up 13.3% of PLWH in the U.S. (120), nearly 40% of all cases of HIV transmission are attributable to this group (59). Thus, widespread HIV screening has the potential to reduce HIV transmission by increasing early HIV diagnosis, reducing the number of PLWH who are unaware of their HIV status and facilitating linkage to care (97, 105). With the development of effective antiretroviral therapy (ART), HIV became a manageable chronic disease, and people living with HIV now have nearly the same life expectancy as the general population (30-32). PLWH who take their ART medications as prescribed and maintain viral suppression have effectively no risk of transmitting HIV to their sexual partners (33). This scientific breakthrough is now recognized as "treatment as prevention" (34) or "undetectable=untransmittable" (U=U) (35). For this reason, CDC recommends that everyone between the ages of 13 and 64 get tested for HIV at least once, and that those at higher risk be tested more frequently (99). This is particularly important for Black and Hispanic populations, who, in addition to sharing a disproportionate burden of HIV prevalence, are also more likely to be unaware of their HIV status. Disparities in undiagnosed HIV persist in these groups, with 13.4% of Black PLWH and 16.4% of Hispanic PLWH unaware of their status, compared to 10.8% of White PLWH.

HIV criminalization laws are defined as HIV-specific laws that criminalize or control behaviors that can potentially expose another person to HIV (121). This includes laws that target sexual intercourse and other sexual contact; injection drug use (IDU) or parenteral transfer; exposure via biting, spitting, or scratching; or exposure via organs, blood, or bodily fluids (122).

Much ink has been spilled interrogating both the morality and efficacy of such statutes (123). Public health professionals, lawyers, and advocates are in nearly universal agreement that laws criminalizing HIV are, at best, ineffective, and at worst, counterproductive (43-50). HIV and human rights advocates argue that these laws further criminalize already marginalized groups, including Black and Hispanic individuals, and counteract effective public health messages on HIV prevention and safer sex. They do this by encouraging risky behaviors – because individuals are absolved of liability following disclosure – and discouraging HIV testing. It has been widely hypothesized that HIV criminalization laws may discourage HIV testing (51) by motivating individuals to eliminate their culpability under the law (5-9, 13, 14, 24, 26, 52-56), as individuals must be aware of their HIV status to be criminally liable (50).Reducing HIV testing among those at high risk for HIV in particular risks exacerbating the epidemic because nearly 40% of all cases of HIV transmission are attributable to individuals who are unaware of their status (59). Because groups at higher risk for acquiring HIV are also at higher risk of being targeted by law enforcement (e.g., Black and Hispanic individuals and persons who inject drugs), they are naturally motivated to reduce the ability of the justice system to charge them with additional offenses. Many researchers hypothesize that this is the primary mechanism by which HIV criminalization laws discourage testing, and therefore indirectly increase HIV transmission (41, 50, 57, 58).

Chapter 2.
Methods

Chapter 2: Methods

2.1 Detailed information about study design

Chapter 3 is a longitudinal study that tests the hypotheses that (1) state HIV criminalization laws are associated with higher state-level HIV transmission rates and (2) this association is modified by heavier policing at the state level. The analysis uses state-level demographic, socioeconomic, legal, and HIV incidence and policy data from 2010 to 2019. It is an ecological analysis done on the state level for three different populations: the general population, the Black population, and the Hispanic population. The exposure is the presence of a state-level HIV criminalization law, the outcome is the statewide HIV incidence rate, and the effect modifier is the state-level incarcerated population rate (representing overpolicing at the state level). All fifty states and the District of Columbia (the full sample) were included for the general population (N=51). The Black and Hispanic population models only included states where the HIV incidence rate was considered stable for the majority of the time period (N=40 and 39, respectively). Rates generated from a numerator less than 12 are considered unstable (124).

Chapter 4 is a multilevel (hierarchical) modeling study, with counties nested within U.S. states, that tests the hypotheses that (1) state HIV criminalization laws are associated with higher county-level HIV transmission rates and (2) this association is modified by heavier policing at the county level. The analysis uses county-level demographic, socioeconomic and HIV incidence data, as well as state-level legal and HIV policy data from 2010 to 2019. It is an ecological analysis done on the county level for three different populations: the general population, the Black population, and the Hispanic population. The exposure is the presence of a state-level HIV criminalization law, the outcome is the county-wide HIV incidence rate, and the effect modifier is the county-level jailed population rate (representing overpolicing at the county level). All U.S. counties and county equivalents (other than those in Connecticut, Delaware, and Vermont, which had no jail population data for any year), including the District of Columbia, were eligible for inclusion. Counties were included if they had stable HIV incidence rates for at least six of the ten years of the study period. For the general population, this included 363 counties in 44 states; for the Black population, 187 counties in 33 states were included; and for the Hispanic population, 103 counties in 29 states were included.

Chapter 5 is a serial cross-sectional study that tests the hypotheses that (1) state HIV criminalization laws discourage HIV testing among Black and Hispanic populations and (2) this effect is modified by heavier policing. The analysis uses data individual-level HIV testing history, demographic, socioeconomic, and HIV risk behavior data, as well as state-level demographic, socioeconomic, legal, and HIV policy data from 2016 to 2019. It is a person-level analysis for three different populations: the general population, the Black population, and the Hispanic population. The exposure is the presence of a state-level HIV criminalization law, the outcome is whether or not the individual has even been tested for HIV, and the effect modifier is the state-level incarcerated population rate (representing overpolicing at the state level). The study included participants from the 2016-2019 BRFSS for all fifty states and the District of Columbia with non-missing data (i.e., not missing, "Unknown," or "Refused" for HIV testing history, HIV risk behavior, sex, race, Hispanic ethnicity, marital status, education, or employment status. For the general population, this resulted in a sample size of n=1,488,465; for the Black population, n=123,237; and one for the Hispanic population, n=93,548.

2.2 Assessment of potential biases

2.2.1 Selection bias

Selection bias is defined as distortion of the true measure of association of interest due to systematic error in the way in which subjects are selected into the study population or analysis. For retrospective designs such as those used in this study, selection bias arises when the outcome influences the selection of subjects differentially into exposure groups. However, this is unlikely to be an issue for this study. Chapters 3 and 4 feature ecological analyses, done at the state and county levels, respectively. Inclusion of states or counties is based solely on HIV rate instability, which is determined by population density and is not related to presence of a state-level HIV criminalization law.

In Chapter 5, the unit of analysis is the individual BRFSS survey participant, and the outcome is self-reported HIV testing history. BRFSS is a system of telephone surveys that collects data in all 50 states and the District of Columbia. Potential sources of error in selection for the survey include sampling and non-sampling error. Sampling error for BRFSS is difficult to assess, as sample design varies by state (125). BRFSS data are self-reported, so non-sampling error would arise from limitations inherent in self-reported data, including recall and social desirability biases. It is extremely unlikely for either of these to be influenced by the existence of an HIV criminalization statute. However, HIV testing history was missing for 11.65% (n=208,697) of the study sample. The exclusion of these respondents has the potential to bias results, if nonresponse for HIV testing history is related to living in a state that criminalizes HIV.

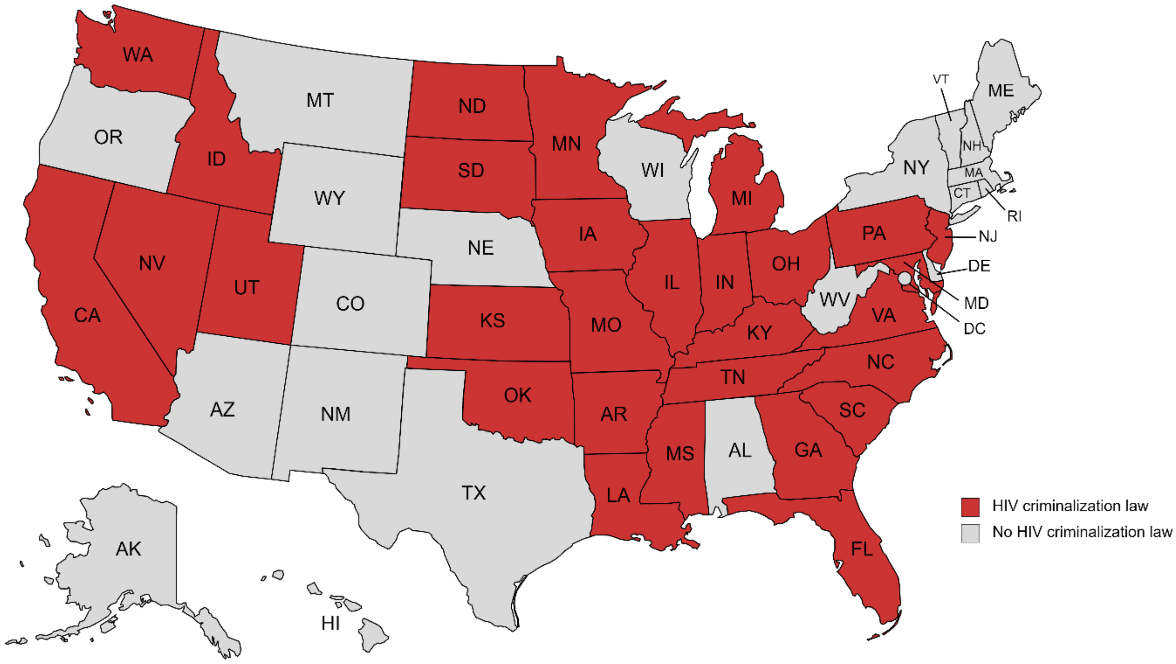
2.2.2 Information bias

Information bias refers to a distortion of the true measure of association of interest due to systematic error in the way in which exposure or outcome data are collected. It can arise from imperfect definitions of study variables or flawed data collection procedures, resulting in differential misclassification of exposure, outcome, or covariates. The potential for misclassification (both differential and non-differential) is detailed for each data source below.

Exposure: Presence of a state-level HIV criminalization law. Potential measurement issues on HIV criminalization laws can arise due to disagreement among legal scholars how to classify statutes for empirical research. Every state in the U.S. has prosecuted HIV exposure in some way, either using HIV-specific criminal laws, STI or communicable disease laws, or general criminal statutes (126, 127). Because every state's law is different, and some are vaguely worded, classifying them according to the chosen definition of "exposure" can be challenging.

Whether or not a state has an HIV-specific criminalization statute was determined by comparing documentation from the U.S. Centers for Disease Control and Prevention (CDC) (121), the Center for HIV Law and Policy (122), Lambda Legal (27), the LawAtlas Policy Surveillance Program (128), and Trevor Hoppe's book *Punishing Disease: HIV and the Criminalization of Sickness* (129). For all three analyses in this study, the independent variable was operationalized as having a criminal statute that either explicitly criminalizes HIV or is clearly written to be applied to HIV exposure based on defined modes of transmission and similarity to HIV-specific criminalization laws in other states. Where all sources agree that a state has or does not have an HIV-specific criminalization statute, the state was coded as "1" or "0," respectively. Where they did not agree, I read the text of the statute(s) in question, reviewed analysis notes from the CDC's 2020 update of their summary of HIV criminalization laws by state (130), conducted additional research where necessary, and made a decision. My final classification for all 50 states and the District of Columbia is visualized below. Potential measurement issues related to my own determination stem from the fact that I am not a lawyer and do not have formal legal training in interpretation of laws. However, I relied on thorough documentation from sources that do have such training. Though there were minor differences due to interpretation and the year of compilation, all sources were relatively consistent. Also, the text of the laws in question is fairly clear. Thus, the potential for misclassification is low. Thus, the overall potential for misclassification based on information from the sources used here is low and is unlikely to be related to the outcomes of any of the analyses in the study (state- and county-level HIV incidence and HIV testing history for Chapters 3, 4, and 5, respectively).

Figure 2.1. HIV criminalization laws by state



Outcome: HIV incidence rate. State- and county-level rates of new HIV diagnoses provided by AIDSVu are calculated using HIV diagnosis counts from the CDC's national HIV surveillance database and population estimates from the U.S. Census Bureau (124). Reporting jurisdictions receive HIV case reports from hospitals, physicians, public and private clinics, medical records systems (e.g., death certificates or tumor registries), and electronic laboratory reporting (131, 132) and report those data to CDC. CDC then provides the aggregate counts to AIDSVu according the data re-release agreements between CDC and each state (124). HIV surveillance data are likely to be very high quality and near complete: as of December 2018, CDC estimated that all but one jurisdiction were reporting 85% or more of their HIV cases (117). While these data are nearly complete, they do not account for all new HIV diagnoses, and completeness may not be uniform across states. This will likely result in underestimation of HIV incidence rates that varies by state. Additionally, the figures may not necessarily reflect *recent* HIV acquisition, as the CDC estimates that the median HIV diagnosis delay in the U.S. is three years (133). It is impossible to verify whether any differential misclassification exists, as figures for HIV case reporting completeness by state are not available. However, it is unlikely that misclassification would be differential based on whether a state has an HIV criminalization law.

Outcome: HIV testing history (and other BRFSS covariates). As detailed above, the outcome of interest in Chapter 5 is HIV testing history of BRFSS survey participants. Because BRFSS data are self-reported, misclassification could arise from limitations inherent in self-reported data, including recall and social desirability biases. This could affect the validity of HIV testing history, as well as other individual-level covariates from the survey such as HIV risk behavior. However, BRFSS respondents are more likely to report having had an HIV test than NHIS respondents, possibly because social desirability bias is stronger during in-person interviews when compared to phone interviews (134). Additionally, the presence of a state HIV criminalization law is unlikely to influence reporting of a past HIV test. Studies in states where HIV criminalization laws exist have found that, while awareness of the law is high among persons living with HIV (PLWH) (135, 136), it is low among high-risk individuals with negative or unknown HIV status (137). Therefore, the potential for differential misclassification based on living in a state with an HIV criminalization law is low.

Effect modifier: Total incarcerated population rate. The Vera Institute's Incarceration Trends project (138) estimates prison population counts using data from the National Corrections Reporting Program (NCRP), as well as data from state correctional departments (139). Jail population counts are determined using data from the Annual Survey of Jails (ASJ) and Census of Jails (COJ). NCRP, ASJ, and COJ are all administered by the Bureau of Justice Statistics at the U.S. Department of Justice. Because NCRP data were reported by all 50 states for all years of the analysis, and are based on individual-level records, data on prison population counts are likely to be high quality. For 2005, 2013, and 2019, jail population counts are taken from the COJ, which is meant to be a complete enumeration. For the remaining years, the counts are derived from ASJ, which is designed to be nationally representative. While the overall response rate is high (typically above 90%), there remains the potential for measurement error in the estimates (140). The Vera research team that compiled the data set aggregated counts at the jurisdiction level for all years in which they were available in the ASJ, combined those counts with COJ figures, and then used linear interpolation to estimate counts for missing years (141). This allowed them to produce estimates for counties in states that do not participate in the survey or report to the census, and to provide more accurate figures for counties with both city and county jails. While this process of data cleaning and interpolation undoubted corrected or minimized some errors, it is important to note that the resulting figures are estimates which are likely subject to measurement error. It is impossible to verify whether any differential misclassification exists, as error rates by reporting jurisdiction are not available. However, the accuracy of jail and prison population counts is unlikely to differ by whether the facility is in a state with an HIV criminalization law, or by state- or county-level HIV incidence rates or testing patterns.

American Community Survey demographic and socioeconomic covariates. Population-level estimates of demographic and socioeconomic covariates were obtained from one-year state estimates and one- and five-year county estimates of the American Community Survey (ACS), a nationally representative survey that is conducted continuously by the Census Bureau each month of every year. The Census Bureau's MAF/TIGER database (MTdb) currently serves as the sampling frame for the ACS. Detailed information about the development and maintenance of MTdb is available from the ACS documentation (142). ACS data on population-level demographic and socioeconomic potential confounders are likely to be high-quality and unbiased. The data used to create the sampling frame integrates multiple sources and reaches a high coverage of each state in the U.S. (143). Potential sources of error include sampling and non-sampling error. Sampling error for the ACS is well-documented and unbiased in this analysis, as it is extremely unlikely to be influenced by the existence of an HIV criminalization statute (the exposure) or HIV incidence rates or testing patterns (the outcomes). Similarly, while non-sampling error (e.g., from data entry errors or use of controls in the weighting) is also possible, it is unlikely to be systematic, as well as unlikely to be related to the exposure or outcome of interest in this analysis. Thus, the potential for differential misclassification of estimates from the ACS is extremely low.

Census data covariate: state urban population percentage. The Census is a full enumeration of the U.S. population (144). As for ACS data on population-level demographic and socioeconomic potential confounders, Census data on urban population percentages by state are likely to be high-quality and unbiased. Because the Census is a full population enumeration, sources of error are from non-sampling error. However, errors in the Census enumeration are minimal due to multiple well-documented quality checks (145). Any misclassification of urban population percentage is likely to be nondifferential, as it is extremely unlikely to be influenced by the existence of an HIV criminalization statute (the exposure) or HIV incidence rates or testing patterns (the outcomes).

NCHS data covariate: county urbanicity level. The urban-rural classification scheme for counties is based on the Office of Management and Budget's (OMB) February 2013 delineation of metropolitan and micropolitan statistical areas and vintage 2012 postcensal estimates of the resident U.S. population (146). The U.S. Census is a full enumeration of the U.S. population (144). As for ACS data on population-level demographic and socioeconomic potential confounders, Census data on urban population percentages by state are likely to be high-quality and unbiased. Because the Census is a full population enumeration, sources of error are from non-sampling error. However, errors in the Census enumeration are minimal due to multiple well-documented quality checks (145). Any misclassification of urban population percentage is likely to be nondifferential, as it is extremely unlikely to be influenced by the existence of an HIV criminalization statute or HIV incidence rates or testing patterns.

State-level covariate: federal HIV spending. Federal HIV spending (dollars per capita) was calculated using data on total federal HIV spending from the Kaiser Family Foundation (147). Few details were provided on how the data were obtained, other than through a special request to the National Association of State and Territorial AIDS Directors in 2017. However, federal funding data is publicly available and easily verifiable. Accuracy of this data is extremely unlikely to be influenced by the existence of an HIV criminalization statute or HIV incidence rates or testing patterns, and thus the potential for differential misclassification is very low.

State-level covariate: Physicians per 1,000 population. Data on the number of physicians per 1,000 population were obtained from the Area Health Resource Files (AHRF) (148). The AHRF state population data, which serve as the denominator for this metric, are obtained from ACS five-year estimates. The numerator, the total number of physicians, is obtained from the American Medical Association Masterfile. Misclassification in either of these data sources is most likely nondifferential, as neither could reasonably be expected to be influenced by the existence of an HIV criminalization statute or HIV incidence rates or testing patterns.

State-level covariate: SGM stigma. A composite variable constructed by Tran, Hatzenbuehler, and Goldstein (149) was used to represent state-level structural stigma against sexual and gender minorities. Each state's integer score was derived from 1) density of same-sex couples per 1,000 households (obtained from the 2010 Census); 2) percentage of public high schools with gay-straight alliances for each state (obtained from the CDC School Health Profiles); 3) an ordinal summary variable of state policies and law related to sexual orientation (excluding HIV laws); and 4) an average value of public opinion toward sexual minorities and policies related to SGM issues. These data sources are all publicly available and verifiable, and any misclassification is unlikely to be differential based on the existence of an HIV criminalization statute or HIV incidence rates or testing patterns. Therefore, the potential for information bias is very low.

2.2.3 Confounding

Potential confounders for all three analyses were chosen a priori, based on an extensive literature review, the theoretical and conceptual frameworks for this dissertation, and previous similar published analyses (73, 82, 115). While the standard data-driven approach for identifying a confounder is a 10% change in effect size resulting from its inclusion, data-driven methods for selecting potential confounders to include as model covariates should only be used when investigators lack prior knowledge to help them identify confounders (150, 151). Because individual- and population-level drivers of HIV risk are well-studied, a data-driven change-in-estimate approach was not considered sufficient grounds for ruling out confounding in this analysis. Additionally, because separate models were fit for the general population and for the Black and Hispanic populations, it was important that any population-level covariates included in one model be included in the others, to ensure comparability of parameter estimates between models.

Model covariates in all three analyses were assessed for confounding using the 10% change-in-estimate approach. If the inclusion of a given covariate did not result in a significant change in effect size in *any* of the models, or was only relevant to one of the models, then it was removed. For the analysis in Chapter 5, this resulted in individual health insurance status (from BRFSS data) and the percentage of the population with some college education (from ACS data) being dropped from all models. Per capita federal expenditure on HIV programs by state was also dropped to reduce multicollinearity, as dropping this did not change the HIV criminalization law parameter by more than 10% in any of the models. For the analyses in Chapter 3, the percentage of the population with health insurance was dropped. For the analyses in Chapter 4, all of the originally selected covariates were retained, as dropping any of them resulted in at least a 10% change in effect estimate for at least one of the models in each analysis.

2.3 Statistical approaches to test hypotheses

2.3.1 How do state HIV criminalization laws and overpolicing at the state level affect state-level HIV incidence rates?

For the state-level analysis in Chapter 3, three multivariate marginal Poisson (log-linear) GEE models were fitted, using extra-Poisson variance to account for overdispersion and an unstructured pairwise correlation matrix. The use of GEE accounted for within-state variation, and the use of the log-link function is appropriate for estimating the outcome, which is state-level HIV incidence rate ratios. Terms for the exposure (the presence of an explicit state HIV criminalization statute) and the effect modifier (the statewide incarceration rate), as well as an interaction between the two, were included in all models.

Terms for population-level confounders at the state level related to demographic and socioeconomic trends specific the population of interest were included in each of the three models. For the general population model, this included the percent female, percent ages 15-44, percent Hispanic, percentage of the population made up of specific racial minority groups, percent below the federal poverty level, unemployment rate, and educational attainment for the entire population. For the Black population model, this included the percent female, percent ages 15-44, percent below the federal poverty level, unemployment rate, and educational attainment for the Black population, as well as the percentage of the state's population that is Black. For the Hispanic population model, this included the percent female, percent ages 15-44, percent below the federal poverty level, unemployment rate, and educational attainment for the Hispanic population, as well as the percentage of the state's population that is Hispanic. Terms for the percent of the population residing in urban areas, dollars of HIV federal spending per capita, and score for stigma against sexual and gender minorities, as well as a term for the year to account for secular trends, were included in all models.

2.3.2 How do state HIV criminalization laws and overpolicing at the county level affect county-level HIV incidence rates?

Three multivariate multilevel (hierarchical) models for count-rate data were fitted, with years nested inside counties, and counties nested within states for the county-level analysis in Chapter 4. For the general population, a quasi-Poisson model was used to account for under-dispersion. For the Black and Hispanic populations, negative binomial models were used to account for overdispersion. The use of the log-link function is appropriate for estimating the outcome, which is county-level HIV incidence rate ratios. A Cholesky variance/covariance matrix was used for all three models (152). Terms for the exposure (the presence of an explicit state HIV criminalization statute) and the effect modifier (the county-level jailed population rate), as well as an interaction between the two, were included in all models.

Terms for population-level confounders at the county level related to demographic and socioeconomic trends specific the population of interest were included in each of the three models. For the general population model, this included the percent female, the age distribution, percent Hispanic, percentage of the population made up of specific racial minority groups, percent below the federal poverty level, unemployment rate, and educational attainment for the entire population. For the Black population model, this included the percent female, age distribution, percent below the federal poverty level, unemployment rate, and educational attainment for the Black population, as well as the percentage of the county's population that is Black. For the Hispanic population model, this included the percent female, age distribution, percent below the federal poverty level, unemployment rate, and educational attainment for the Hispanic population, as well as the percentage of the county's population that is Hispanic. Terms for the county's urbanicity level, dollars of HIV federal spending per capita at the state level, and score for stigma against sexual and gender minorities at the state level, as well as a term for the year to account for secular trends, were included in all models.

2.3.3 How do state HIV criminalization laws and overpolicing at the state level affect individual HIV testing behavior?

In Chapter 5, three multivariate logistic regression models were constructed for the individual-level analysis: one with all BRFSS respondents, one with Black respondents (to represent the Black population), and one with Hispanic respondents (to represent the Hispanic population). The use of the logit link function is appropriate for estimating the outcome, which is odds ratios for individual-level HIV testing history (yes/no). Terms for the exposure (the presence of an explicit state HIV criminalization statute) and the effect modifier (the statewide incarceration rate), as well as an interaction between the two, were included in all models.

Terms for individual- and state-level confounders were included in all models. Individual-level confounders included HIV risk behavior within the last year, demographics (sex at birth, age, race, Hispanic ethnicity, marital status, living in an urban area), and socioeconomic status indicators (education level, employment status, and poverty status). Terms for population-level (ecological) confounders at the state level related to demographic and socioeconomic trends specific the population of interest were included in each of the three models. For the general population model, this included the percent female, percent ages 15-44, percent Hispanic, percentage of the population made up of specific racial minority groups, percent below the federal poverty level, unemployment rate, and educational attainment for the entire population. For the Black population model, this included the percent female, percent ages 15-44, percent below the federal poverty level, unemployment rate, and educational attainment for the Black population, as well as the percentage of the state's population that is Black. For the Hispanic population model, this included the percent female, percent ages 15-44, percent below the federal poverty level, unemployment rate, and educational attainment for the Hispanic population, as well as the percentage of the state's population that is Hispanic. Terms for the percent of the population residing in urban areas, dollars of HIV federal spending per capita, physicians per 1,000 population, and score for stigma against sexual and gender minorities, as well as a term for the year to account for secular trends, were included in all models.

All analyses were conducted using SAS 9.4 (153).

2.4 Assessment of potential interaction effects

The effect modifier – examining whether the relationship between the presence of a state-level HIV-specific criminalization law and the outcome of interest for each is modified by overpolicing (using the incarcerated population rate as a proxy) – is a key component of the hypothesis. As it is required for the hypothesis testing and interpretation, it will be included in all models for all three analyses. Because individuals from minority communities already have more frequent encounters with law enforcement and the justice system, and are also more likely to have HIV, those who are HIV-positive and living in a state with an HIV-specific criminalization law may be subjected to additional charges under the law when they come into contact with law enforcement, if their HIV status is discovered in the course of the investigation. In order to minimize their exposure to liability under the law, individuals from minority communities that experience heavier policing might avoid HIV testing and thus be unaware of their status, passing the virus on to others and driving up the HIV incidence rate in states with these laws.

2.5 Model specification

2.5.1 How do state HIV criminalization laws and overpolicing at the state level affect state-level HIV incidence rates?

Based on the statistical approaches to test the hypotheses specified above, the following model was fit for the general population, where i represents each state and j each year:

$Log[E(Y_{ij})] = \beta_0 + \beta_1$ *HIV criminalization law*$_i$ $+ \beta_2$ *incarceration rate*$_{ij}$ $+ \beta_3$ *HIV criminalization law*$_i$***incarceration rate*$_{ij}$ $+ \beta_4$ *percent female*$_{ij}$ $+ \beta_5$ *percent age 15-44*$_{ij}$ $+ \beta_6$ *percent Black*$_{ij}$ $+ \beta_7$ *percent Asian*$_{ij}$ $+ \beta_8$ *percent Hispanic*$_{ij}$ $+ \beta_9$ *percent urban*$_{ij}$ $+ \beta_{10}$ *percent HS graduate*$_{ij}$ $+ \beta_{11}$ *percent some college*$_{ij}$ $+ \beta_{12}$ *percent living in poverty*$_{ij}$ $+ \beta_{13}$ *unemployment rate*$_{ij}$ $+ \beta_{14}$ *federal HIV spending per capita*$_i$ $+ \beta_{15}$ *SGM stigma*$_i$ $+ \beta_{16}$ *year*$_{ij}$

The following model was fit for the Black population:

$Log[E(Y_{ij})] = \beta_0 + \beta_1$ *HIV criminalization statute*$_i$ $+ \beta_2$ *Black incarceration rate*$_{ij}$ $+ \beta_3$ *HIV criminalization statute*$_i$***Black incarceration rate*$_{ij}$ $+ \beta_4$ *Black percent female*$_{ij}$ $+ \beta_5$ *Black percent age 15-44*$_{ij}$ $+ \beta_6$ *percent Black*$_{ij}$ $+ \beta_7$ *percent urban*$_{ij}$ $+ \beta_8$ *Black percent HS graduate*$_{ij}$ $+ \beta_9$ *Black* *percent some college*$_j$ + β_{10} *Black percent living in poverty*$_{ij}$ + β_{11} *Black unemployment rate*$_{ij}$ + β_{12} *federal HIV spending per capita*$_i$ + β_{13} *SGM stigma*$_i$ + β_{14} *year*$_{ij}$

The following model was fit for the Hispanic population:

Log[E(Y$_{ij}$*)]* = β_0 + β_1 *HIV criminalization statute*$_i$ + β_2 *Hispanic incarceration rate*$_{ij}$ + β_3 *HIV criminalization statute*$_i$** Hispanic incarceration rate*$_{ij}$+ β_4 *Hispanic percent female*$_{ij}$ + β_5 *Hispanic percent age 15-44*$_{ij}$ + β_6 *percent Hispanic* + β_7 *percent urban*$_{ij}$ + β_8 *Hispanic percent HS graduate*$_{ij}$ + β_9 *Hispanic percent some college*$_j$ + β_{10} *Hispanic percent living in poverty*$_{ij}$ + β_{11} *Hispanic unemployment rate*$_{ij}$ + β_{12} *federal HIV spending per capita*$_i$ + β_{13} *SGM stigma*$_i$ + β_{14} *year*$_{ij}$

2.5.2 How do state HIV criminalization laws and overpolicing at the county level affect county-level HIV incidence rates?

Based on the statistical approaches to test the hypotheses specified above, the following model was fit for the general population, where i represents each state, j each county within each state i, and k each year:

Log[E(Y$_{ijk}$*)]* = α_{ijk} + β_1 *HIV criminalization statute*$_i$ + β_2 *jailed population rate*$_{ijk}$ + β_3 *HIV criminalization statute*$_i$** jailed population rate*$_{ijk}$ + β_4 *percent female*$_{ijk}$ + β_5 *percent age 15-24*$_{ijk}$ + β_6 *percent age 25-44*$_{ijk}$ + β_7 *percent age 45-64*$_{ijk}$ + β_8 *percent Black*$_{ijk}$ + β_9 *percent Asian*$_{ijk}$ + β_{10} *percent Native American or Alaska Native*$_{ijk}$ + β_{11} *percent Native Hawaiian/Other Pacific Islander*$_{ijk}$ + β_{12} *percent Hispanic*$_{ijk}$ + β_{13a} *urbanicity level: large central metro*$_{ij}$ + β_{13b} *urbanicity level: large fringe metro*$_{ij}$ + β_{13c} *urbanicity level: medium metro*$_{ij}$ + β_{13d} *urbanicity level: small metro*$_{ij}$ + β_{14} *percent HS graduate*$_{ijk}$ + β_{15} *percent some college*$_{ijk}$ + β_{16} *percent living in poverty*$_{ijk}$ + β_{17} *percent insured*$_{ijk}$ + β_{18} *unemployment rate*$_{ijk}$ + β_{19} *federal HIV spending per capita*$_i$ + β_{20} *SGM stigma*$_i$ + β_{21} *year*$_{ijk}$

The following model was fit for the Black population:

Log[E(Y$_{ijk}$*)]* = α_{ijk} + β_1 *HIV criminalization statute*$_i$ + β_2 *Black jailed population rate*$_{ijk}$ + β_3 *HIV criminalization statute*$_i$** Black jailed population rate*$_{ijk}$ + β_4 *Black percent female*$_{ijk}$ + β_5 *Black* *percent age 15-24*$_{ijk}$ + β_6 *Black percent age 25-44*$_{ijk}$ + β_7 *Black percent age 45-64*$_{ijk}$ + β_8 *percent Black*$_{ijk}$ + β_{9a} *urbanicity level: large central metro*$_{ij}$ + β_{9b} *urbanicity level: large fringe metro*$_{ij}$ + β_{9c} *urbanicity level: medium metro*$_{ij}$ + β_{9d} *urbanicity level: small metro*$_{ij}$ + β_{10} *Black percent HS graduate*$_{ijk}$ + β_{11} *Black percent some college*$_{ijk}$ + β_{12} *Black percent living in poverty*$_{ijk}$ + β_{13} *Black percent insured*$_{ijk}$ + β_{14} *Black unemployment rate*$_{ijk}$ + β_{15} *federal HIV spending per capita*$_i$ + β_{16} *SGM stigma*$_i$ + β_{17} *year*$_{ijk}$

The following model was fit for the Hispanic population:

Log[E(Y$_{ijk}$*)]* = α_{ijk} + β_1 *HIV criminalization statute*$_i$ + β_2 *Hispanic jailed population rate*$_{ijk}$ + β_3 *HIV criminalization statute*$_i$** *Hispanic jailed population rate*$_{ijk}$ + β_4 *Hispanic percent female*$_{ijk}$ + β_5 *Hispanic percent age 15-24*$_{ijk}$ + β_6 *Hispanic percent age 25-44*$_{ijk}$ + β_7 *Hispanic percent age 45-64*$_{ijk}$ + β_8 *percent Hispanic*$_{ijk}$ + β_{9a} *urbanicity level: large central metro*$_{ij}$ + β_{9b} *urbanicity level: large fringe metro*$_{ij}$ + β_{9c} *urbanicity level: medium metro*$_{ij}$ + β_{10} *Hispanic percent HS graduate*$_{ijk}$ + β_{11} *Hispanic percent some college*$_{ijk}$ + β_{12} *Hispanic percent living in poverty*$_{ijk}$ + β_{13} *Hispanic percent insured*$_{ijk}$ + β_{14} *Hispanic unemployment rate*$_{ijk}$ + β_{15} *federal HIV spending per capita*$_i$ + β_{16} *SGM stigma*$_i$ + β_{17} *year*$_{ijk}$

2.5.3 How do state HIV criminalization laws and overpolicing at the state level affect individual HIV testing behavior?

Based on the statistical approaches to test the hypotheses specified above, the following model was fit for all BRFSS participants who met the inclusion criteria, to represent the general population, where i represents each state, j each year, and k each individual:

logit(hπ_{ijk}*)* = α_{ijk} + β_1 *HIV criminalization statute*$_i$ + β_2 *incarceration rate*$_{ik}$ + β_3 *HIV criminalization statute*$_i$** *incarceration rate*$_{ik}$ + β_4 *HIV risk behavior*$_{ijk}$ + β_5 *age*$_{ijk}$ + β_6 *female sex*$_{ijk}$ + β_{7a} *race: Black*$_{ijk}$ + β_{7b} *race: American Indian/Alaska Native*$_{ijk}$ + β_{7c} *race: Asian*$_{ijk}$ + β_{7d} *race: Multiracial or other*$_{ijk}$ + β_8 *Hispanic ethnicity*$_{ijk}$ + β_9 *married*$_{ijk}$ + β_{10} *live in urban area*$_{ijk}$ + β_{11a} *education: did not graduate HS*$_{ijk}$ + β_{11b} *education: graduated HS*$_{ijk}$ + β_{12} *employed*$_{ijk}$ +

β_{13} *below FPL*$_{ijk}$ + β_{14} *percent female*$_{ij}$ + β_{15} *percent age 15-44*$_{ij}$ + β_{16} *percent Black*$_{ij}$ + β_{17} *percent Asian*$_{ij}$ + β_{18} *percent Native American or Alaska Native*$_{ij}$ + β_{19} *percent Native Hawaiian/Other Pacific Islander*$_{ij}$ + β_{20} *percent Hispanic*$_{ij}$ + β_{21} *percent urban*$_{i}$ + β_{22} *percent HS graduate*$_{ij}$ + β_{23} *percent living in poverty*$_{ij}$ + β_{24} *percent insured*$_{ij}$ + β_{25} *unemployment rate*$_{ij}$ + β_{26} *physicians per 1,000 pop*$_{i}$ + β_{27} *SGM stigma*$_{i}$ + β_{28} *year*$_{ijk}$

The following model was fit for Black BRFSS participants who met the inclusion criteria, to represent the Black population:

logit(hπ_{ijk}*)* = α_{ijk} + β_1 *HIV criminalization statute*$_{i}$ + β_2 *Black incarceration rate*$_{ij}$ + β_3 *HIV criminalization statute*$_{i}$** Black incarceration rate*$_{ij}$ + β_4 *HIV risk behavior*$_{ijk}$ + β_5 *age*$_{ijk}$ + β_6 *female sex*$_{ijk}$ + β_7 *Hispanic ethnicity*$_{ijk}$ + β_8 *married*$_{ijk}$ + β_9 *live in urban area*$_{ijk}$ + β_{10a} *education: did not graduate HS*$_{ijk}$ + β_{10b} *education: graduated HS*$_{ijk}$ + β_{11} *employed*$_{ijk}$ + β_{12} *below FPL*$_{ijk}$ + β_{13} *Black percent female*$_{ij}$ + β_{14} *Black percent age 15-44*$_{ij}$ + β_{15} *percent Black*$_{ij}$ + β_{16} *percent urban*$_{ij}$ + β_{17} *Black percent HS graduate*$_{ij}$ + β_{18} *Black percent living in poverty*$_{ij}$ + β_{19} *Black percent insured*$_{ij}$ + β_{20} *Black unemployment rate*$_{ij}$ + β_{21} *physicians per 1,000 pop*$_{i}$ + β_{22} *SGM stigma*$_{i}$ + β_{23} *year*$_{ij}$

The following model was fit for Hispanic BRFSS participants who met the inclusion criteria, to represent the Hispanic population:

logit(hπ_{ijk}*)* = α_{ijk} + β_1 *HIV criminalization statute*$_{i}$ + β_2 *Hispanic incarceration rate*$_{ij}$ + β_3 *HIV criminalization statute*$_{i}$** Hispanic incarceration rate*$_{ij}$ + β_4 *HIV risk behavior*$_{ijk}$ + β_5 *age*$_{ijk}$ + β_6 *female sex*$_{ijk}$ + β_{7a} *race: Black*$_{ijk}$ + β_{7b} *race: American Indian/Alaska Native*$_{ijk}$ + β_{7c} *race: Asian*$_{ijk}$ + β_{7d} *race: Multiracial or other*$_{ijk}$ + β_8 *married*$_{ijk}$ + β_9 *live in urban area*$_{ijk}$ + β_{10a} *education: did not graduate HS*$_{ijk}$ + β_{10b} *education: graduated HS*$_{ijk}$ + β_{11} *employed*$_{ijk}$ + β_{12} *below FPL*$_{ijk}$ + β_{13} *Hispanic percent female*$_{ij}$ + β_{14} *Hispanic percent age 15-44*$_{ij}$ + β_{15} *Hispanic Black*$_{ij}$ + β_{16} *percent urban*$_{ij}$ + β_{17} *Hispanic percent HS graduate*$_{ij}$ + β_{18} *Hispanic percent living in poverty*$_{ij}$ + β_{19} *Hispanic percent insured*$_{ij}$ + β_{20} *Hispanic unemployment rate*$_{ij}$ + β_{21} *physicians per 1,000 pop*$_{i}$ + β_{22} *SGM stigma*$_{i}$ + β_{23} *year*$_{ij}$

2.6 Assessment of model assumptions

2.6.1 Log-linear GEE model with repeated measures

Count or count rate outcome variable. The outcomes of the analyses in Chapter 3 are statewide HIV incidence rates among the general, Black, and Hispanic populations. These rates represent the number of new HIV diagnoses per 100,000 population. The use of the log link function is appropriate for estimating incidence rate ratios.

Subjects are independent. Because the state is the level of analysis, and all 51 states and the District of Columbia are included, the full population (rather than a representative sample) is used to fit the model. Thus, this assumption is not applicable.

Variance equal to the mean. In a traditional Poisson model for count data, the variance should be equal to the mean. When the variance is greater than the mean, the model is over-dispersed; when it is less than the mean, it is under-dispersed.

When using PROC GENMOD to conduct GEE, the dispersion parameter is estimated by maximum likelihood and then held fixed during the GEE estimation. The estimate of the dispersion parameter can be obtained, along with the other maximum likelihood estimates, by including the PRINTMLE option in the REPEATED statement. The maximum likelihood estimates (including the dispersion parameter) for each population model are displayed in the following tables.

Table 2.1a. Analysis of initial parameter estimates, general population model

Parameter	Estimate	SE	95% CI		p-value
Intercept	39.0235	17.82	4.0948	73.952	0.0285
Law	0.1924	0.08	0.035	0.3499	0.0166
incarcrate	0.0002	1E-04	0.0001	0.0004	0.0045
Law*incarcrate	-0.0001	1E-04	-0.0002	0.0001	0.2816
pfemale	0.0778	0.026	0.0277	0.1279	0.0023
p15_44	0.0077	0.009	-0.0108	0.0262	0.4155
ppopblack	0.0408	0.002	0.0364	0.0452	<0.0001
ppopasian	0.0095	0.003	0.0038	0.0152	0.0011
ppophispanic	0.0159	0.002	0.012	0.0197	<0.0001
urbanicity	0.0155	0.002	0.0124	0.0187	<0.0001
phsgrad	0.0248	0.005	0.0159	0.0337	<0.0001
psomecollege	-0.0077	0.002	-0.0111	-0.0044	<0.0001
ppoverty	0.0058	0.007	-0.0081	0.0197	0.4157
unemployment_rate	0.0091	0.01	-0.0108	0.029	0.3702
per_capita	0.0015	0.001	-0.0006	0.0036	0.1568
stigma	-0.0069	0.007	-0.02	0.0062	0.3021
year	-0.0215	0.009	-0.0387	-0.0044	0.0139

Scale	0.6933	0	0.6933	0.6933	

Table 2.1b. Analysis of initial parameter estimates, Black population model

Parameter	Estimate	SE	95% CI		p-value
Intercept	57.47	16.75	24.6414	90.299	0.0006
Law	0.3878	0.099	0.1941	0.5814	<0.0001
incarcrate_black	0.0001	0	0	0.0001	0.023
Law*incarcrate_black	-0.0001	0	-0.0001	0	0.0122
pfemaleblack	0.012	0.007	-0.0014	0.0254	0.0802
p15_44black	0.0354	0.009	0.0172	0.0536	0.0001
ppopblack	0.0114	0.002	0.0068	0.016	<0.0001
urbanicity	0.018	0.002	0.0141	0.0219	<0.0001
phsgradblack	0.0012	0.007	-0.0124	0.0148	0.8649
psomecollegeblack	-0.0115	0.005	-0.0219	-0.0011	0.0308
ppovertyblack	-0.001	0.004	-0.0095	0.0075	0.815
unemployment_ratebla	-0.0052	0.006	-0.0171	0.0066	0.3871
per_capita	0.0045	9E-04	0.0027	0.0064	<0.0001
stigma	0.0203	0.007	0.0071	0.0335	0.0026
year	-0.0283	0.008	-0.0447	-0.0119	0.0007
Scale	1.3835	0	1.3835	1.3835	

Table 2.1c. Analysis of initial parameter estimates, Hispanic population model

Parameter	Estimate	SE	95% CI		p-value
Intercept	28.9939	24.58	-19.1777	77.166	0.2381
Law	0.2838	0.118	0.0521	0.5156	0.0164
incarcrate_hispanic	0.0001	1E-04	-0.0001	0.0003	0.4834
Law*incarcrate_hispa	-0.0001	1E-04	-0.0003	0.0001	0.4262
pfemalehispanic	-0.0587	0.014	-0.0855	-0.0318	<0.0001
p15_44hispanic	0.0141	0.013	-0.0114	0.0396	0.2781
ppophispanic	-0.0035	0.003	-0.0086	0.0015	0.169
urbanicity	0.0127	0.003	0.0066	0.0188	<0.0001
phsgradhispanic	0.0304	0.006	0.0191	0.0418	<0.0001
psomecollegehispanic	0.0097	0.004	0.0017	0.0177	0.0175
ppovertyhispanic	0.0193	0.005	0.0099	0.0287	<0.0001
unemployment_ratehis	-0.0088	0.01	-0.0281	0.0105	0.3723
per_capita	0.0123	0.001	0.0097	0.0148	<0.0001
stigma	-0.0321	0.009	-0.0505	-0.0137	0.0006
year	-0.0133	0.012	-0.0371	0.0105	0.2726
Scale	1.3819	0	1.3819	1.3819	

No severe multicollinearity. Unlike in normal response models, collinearity in the raw predictors does not necessarily cause ill-conditioning in the information matrix for generalized linear models, although it can (154). Very large standard errors for model parameters and large off-diagonal values in either the covariance or correlation matrix suggest an ill-conditioned information matrix, but this can result from reasons other than collinearity among raw predictors. Rather, collinearity among the weighted predictors directly affects the information matrix. This distinction is important, because weights may reduce the effect of collinearity among raw predictors; conversely, they can also cause ill-conditioning in the information matrix even for non-collinear raw predictors. To assess for multicollinearity among the weighted predictors, I examined the standard errors and the correlation and parameter covariance matrices of the fitted models, as these can indicate whether the information matrix is ill-conditioned. Based on the standard errors of the parameter estimates, the estimated covariance matrices, and the working correlation matrices, there does not appear to be any severe multicollinearity. Covariance and working correlation matrices for all three models can be viewed in the appendix for this chapter.

2.6.2 Multilevel (hierarchical) log-linear regression model

Count or count rate outcome variable. The outcomes of the analyses in Chapter 4 are county-wide HIV incidence rates among the general, Black, and Hispanic populations. These rates represent the number of new HIV diagnoses per 100,000 population. The use of the log link function is appropriate for estimating incidence rate ratios.

Variance equal to the mean. In a traditional Poisson model for count data, the variance should be equal to the mean. When the variance is greater than the mean, the model is over-dispersed; when it is less than the mean, it is under-dispersed. Overdispersion can be addressed by incorporating a dispersion parameter into the Poisson model, or by fitting a negative binomial model. Under-dispersion can be addressed by using a quasi-Poisson model (155).

When fitting the general population model, the generalized chi-square/DF ratio indicated under-dispersion when fitted using the Poisson, dispersion-adjusted Poisson, and negative binomial distributions:

Table 2.2a. Dispersion diagnostics for multilevel (hierarchical) general population model

	Distribution		
	Poisson	Dispersion-adjusted Poisson	Negative binomial
-2 Res Log Pseudo-Likelihood	850.48	776.54	844.49
Generalized Chi-Square	2604	2530.33	2486
Gener. Chi-Square / DF	0.81	0.78	0.77

Based on the presence of under-dispersion, I fitted the general population model using the quasi-Poisson distribution. In contrast, both the Black and Hispanic population models were over-dispersed. The negative binomial distribution yielded a generalized chi-square/DF ratio closest to 1, so those models were fit with that distribution.

Table 2.2b. Dispersion diagnostics for multilevel (hierarchical) Black population model

	Distribution		
	Poisson	Dispersion-adjusted Poisson	Negative binomial
-2 Res Log Pseudo-Likelihood	1417	401.83	409.78
Generalized Chi-Square	4102.1	4402.23	1671.9
Gener. Chi-Square / DF	2.48	2.66	1.01

Table 2.2c. Dispersion diagnostics for multilevel (hierarchical) Hispanic population model

	Distribution		
	Poisson	Dispersion-adjusted Poisson	Negative binomial
-2 Res Log Pseudo-Likelihood	549.71	484.25	443
Generalized Chi-Square	1264.5	1312.78	846.84
Gener. Chi-Square / DF	1.4	1.45	0.94

No severe multicollinearity. Unlike in normal response models, collinearity in the raw predictors does not necessarily cause ill-conditioning in the information matrix for generalized linear models, although it can (154). Very large standard errors for model parameters and large off-diagonal values in either the covariance or correlation matrix suggest an ill-conditioned information matrix, but this can result from reasons other than collinearity among raw predictors. Rather, collinearity among the weighted predictors directly affects the information matrix. This distinction is important, because weights may reduce the effect of collinearity among raw predictors; conversely, they can also cause ill-conditioning in the information matrix even for non-collinear raw predictors. To assess for multicollinearity among the weighted predictors, I examined the standard errors and the correlation and parameter covariance matrices of the fitted models, as these can indicate whether the information matrix is ill-conditioned. Based on the standard errors of the parameter estimates and the covariance and the correlation matrices, there does not appear to be any severe multicollinearity. Covariance and correlation matrices for all three models can be viewed in the appendix for this chapter.

2.6.3 Binary logistic regression model

Binary outcome variable. The outcome of the analyses in Chapter 5 is whether the individual BRFSS respondent reported having ever had an HIV test (yes/no). These rates represent the number of new HIV diagnoses per 100,000 population. The use of the logit link function is appropriate for estimating the log likelihood of a binary outcome variable (in this case, whether or not the individual reported a history of HIV testing).

Observations are independent. BRFSS is a system of telephone surveys that collects data in all 50 states and the District of Columbia. Sample design for BRFSS varies by state (125); however, the data are designed to be representative of the U.S. population and include strata, cluster, and weight variables to account for the design in analyses. It is analogous to a simple random sample, in which the individuals selected are independent, but with the decreased cost and increased efficiency that come with complex survey design.

Linearity in the logit of the outcome (logit(π)) for continuous variables. The Box-Tidwell test was used to test the assumption of linearity in the logit of the outcome for continuous variables in logistic regression (156). A statistically significant p-value for the interaction term between a continuous variable and its natural logarithm indicates non-linearity in the logit. All three models had non-linearity for multiple continuous variables. The solution typically recommended to correct for violation of this assumption is to transform the continuous variables in some way, with the goal of improving model fit. However, this could make interpretation of the covariates difficult, particularly in the case of a more complex transformation (e.g., squaring or cubing the independent variables). Results for the Box-Tidwell test for all three models can be found in the appendix of this chapter.

No severe multicollinearity. Multicollinearity was assessed for each model by fitting it as a linear regression model with the final set of covariates and examining the variance inflation factor (VIF) for each covariate (157). All three models had some collinearity, indicated by one or more variables having a VIF value greater than 10. The general population model had the some of the highest VIF values, while the Black population model had the most variables with VIF>10. To attempt to reduce multicollinearity, the variables with the highest VIF values were dropped one at a time, to see if the estimate for the HIV criminalization law term changed by more than 10% (per the criteria for assessment of confounding). The only variable with a high VIF value that could be dropped without causing a change in the law parameter estimate greater than 10% in any of the models was per capita federal expenditure on HIV programs by state. Tables displaying VIF values greater than 10 before and after this change are displayed below.

Table 2.3a. Assessing multicollinearity, general population model

	Original model		**Updated model**	
	Tolerance	**VIF**	**Tolerance**	**VIF**
ppopblack	0.09077	11.017	0.11801	8.47403
ppopasian	0.08391	11.917	0.09254	10.8066
phsgrad	0.0926	10.799	0.09335	10.712
phys_per1000	0.08667	11.538	0.09831	10.172
per_capita	0.03103	32.232	(removed)	
prevalence	0.01952	51.234	0.07369	13.5706

Table 2.3b. Assessing multicollinearity, Black population model

	Original model		**Updated model**	
	Tolerance	**VIF**	**Tolerance**	**VIF**
ppovertyblack	0.07131	14.023	0.07137	14.0106
ppoverty	0.05758	17.369	0.06248	16.0045
pinsured	0.09415	10.622	0.09771	10.2345
unemployment_rate	0.09127	10.956	0.09246	10.8158
urbanicity	0.0986	10.142	0.09861	10.141
stigma	0.0879	11.377	0.0923	10.8343
phys_per1000	0.02708	36.93	0.06302	15.867
per_capita	0.03247	30.795	(removed)	
Black_prevalence	0.06186	16.165	0.06962	14.3639

Table 2.3c. Assessing multicollinearity, Hispanic population model

	Original model		**Updated model**	
	Tolerance	**VIF**	**Tolerance**	**VIF**
ppophispanic	0.07833	12.766	0.07962	12.5603
ppoverty	0.08386	11.924	0.09271	10.7866
phys_per1000	0.05272	18.969	0.12712	7.86659
per_capita	0.10777	9.2793	(removed)	

No strongly influential outliers. In order to identify outliers, I generated residual chi-squared deviance statistics and predicted probabilities for each observation and plotted them against each other for each population sample (158). All three samples had a small number of outliers. However, these outliers are unlikely to be strongly influential, as they made up a small portion of the overall sample size for all three groups (1.3%, 0.8%, and 0.1% of the general, Black, and Hispanic population samples with residual chi-squared deviance values greater than 5, respectively). Plots of the residual chi-squared deviance statistics and predicted probabilities for each sample can be found in the appendix of this chapter.

Sufficiently large sample size. Three multivariate logistic regression model were fitted: one with all BRFSS participants (n=1,488,465), one with Black participants only (n=123,237), and one with Hispanic participants only (n=93,548). All three samples are sufficiently large.

2.A Appendix

2.A.1 Log-linear GEE model with repeated measures

Table 2A.1a. Estimated covariance matrix, general population model

	Prm1	Prm2	Prm3	Prm4	Prm5	Prm6	Prm7	Prm8	Prm9
Prm1	660.77	0.1001	-0.000406	0.0000291	-0.15543	-0.05507	0.02994	-0.008523	0.00761
Prm2	0.1001	0.01343	0.0000112	-0.000012	0.0002764	0.0001396	-0.000088	0.0001077	-0.000142
Prm3	-0.000406	0.0000112	1.53E-08	-1.14E-08	1.11E-06	-1.60E-08	-2.02E-07	1.81E-07	-1.57E-07
Prm4	0.0000291	-0.000012	-1.14E-08	1.27E-08	-1.62E-07	-1.45E-07	7.00E-08	-1.03E-07	1.60E-07
Prm5	-0.15543	0.0002764	1.11E-06	-1.62E-07	0.00136	0.0000385	-0.000081	0.0000753	0.000012
Prm6	-0.05507	0.0001396	-1.60E-08	-1.45E-07	0.0000385	0.000185	3.73E-07	-7.17E-06	-1.36E-06
Prm7	0.02994	-0.000088	-2.02E-07	7.00E-08	-0.000081	3.73E-07	0.0000105	-5.59E-06	2.01E-06
Prm8	-0.008523	0.0001077	1.81E-07	-1.03E-07	0.0000753	-7.17E-06	-5.59E-06	0.0000177	-8.43E-09
Prm9	0.00761	-0.000142	-1.57E-07	1.60E-07	0.000012	-1.36E-06	2.01E-06	-8.43E-09	8.07E-06
Prm10	0.009004	-0.000013	-3.61E-08	-6.16E-09	-0.000015	-4.31E-06	1.07E-06	-2.50E-06	-3.25E-06
Prm11	0.01359	-0.000013	-1.92E-07	1.63E-08	-0.000035	0.0000478	5.14E-06	-3.38E-06	5.38E-06
Prm12	0.02232	0.0000155	4.60E-08	-1.33E-08	8.73E-06	-0.000012	-6.10E-07	7.44E-07	-1.58E-06
Prm13	0.09995	0.0003621	1.15E-08	-3.56E-07	-0.000088	-3.98E-06	5.61E-06	-3.47E-06	-0.000016
Prm14	-0.31409	-0.000346	8.02E-09	2.70E-07	0.00006	1.88E-06	-0.000014	4.28E-06	4.01E-06
Prm15	-0.000314	0.0000309	6.71E-08	-1.91E-08	-2.62E-06	-0.000015	-1.76E-06	1.62E-06	4.21E-07
Prm16	-0.03964	-0.000557	-5.16E-07	4.97E-07	0.0000826	-0.000034	-1.92E-06	5.69E-06	0.0000106
Prm17	-0.32372	-0.000065	1.71E-07	-1.56E-09	0.0000439	0.0000228	-0.000013	2.55E-06	-3.85E-06

	Prm10	Prm11	Prm12	Prm13	Prm14	Prm15	Prm16	Prm17
Prm1	0.009004	0.01359	0.02232	0.09995	-0.31409	-0.000314	-0.03964	-0.32372
Prm2	-0.000013	-0.000013	0.0000155	0.0003621	-0.000346	0.0000309	-0.000557	-0.000065
Prm3	-3.61E-08	-1.92E-07	4.60E-08	1.15E-08	8.02E-09	6.71E-08	-5.16E-07	1.71E-07
Prm4	-6.16E-09	1.63E-08	-1.33E-08	-3.56E-07	2.70E-07	-1.91E-08	4.97E-07	-1.56E-09
Prm5	-0.000015	-0.000035	8.73E-06	-0.000088	0.00006	-2.62E-06	0.0000826	4.39E-05
Prm6	-4.31E-06	0.0000478	-0.000012	-3.98E-06	1.88E-06	-0.000015	-0.000034	2.28E-05
Prm7	1.07E-06	5.14E-06	-6.10E-07	5.61E-06	-0.000014	-1.76E-06	-1.92E-06	-0.000013
Prm8	-2.50E-06	-3.38E-06	7.44E-07	-3.47E-06	4.28E-06	1.62E-06	5.69E-06	2.55E-06
Prm9	-3.25E-06	5.38E-06	-1.58E-06	-0.000016	4.01E-06	4.21E-07	0.0000106	-3.85E-06
Prm10	5.24E-06	-6.11E-07	7.08E-07	0.0000123	-8.54E-06	-9.44E-07	4.20E-06	-4.24E-06
Prm11	-6.11E-07	0.000043	-9.82E-06	-3.71E-06	-8.26E-06	-3.13E-06	-2.01E-06	-6.96E-06
Prm12	7.08E-07	-9.82E-06	6.06E-06	6.31E-06	-7.20E-06	5.84E-07	-1.61E-06	-0.000011
Prm13	0.0000123	-3.71E-06	6.31E-06	0.0001048	-0.000091	-4.09E-06	-0.000038	-0.000048
Prm14	-8.54E-06	-8.26E-06	-7.20E-06	-0.000091	0.0002152	3.49E-06	0.0000468	0.000155
Prm15	-9.44E-07	-3.13E-06	5.84E-07	-4.09E-06	3.49E-06	2.36E-06	1.28E-06	5.49E-07
Prm16	4.20E-06	-2.01E-06	-1.61E-06	-0.000038	0.0000468	1.28E-06	0.0000933	1.85E-05
Prm17	-4.24E-06	-6.96E-06	-0.000011	-0.000048	0.0001549	5.49E-07	0.0000185	0.00016

Table 2A.1b. Estimated covariance matrix, Black population model

	Prm1	Prm2	Prm3	Prm4	Prm5	Prm6	Prm7	Prm8
Prm1	280.55	0.30229	-0.00003	-0.00008	0.006375	-0.03301	-0.003866	0.004951
Prm2	0.30229	0.009758	1.61E-06	-2.89E-06	0.0000249	0.0000402	-0.000067	0.0000101
Prm3	-0.00003	1.61E-06	6.40E-10	-5.20E-10	2.37E-08	1.95E-09	-6.22E-09	-1.10E-08
Prm4	-0.00008	-2.89E-06	-5.20E-10	9.29E-10	-9.01E-09	-9.17E-10	1.78E-08	-4.79E-09
Prm5	0.006375	0.0000249	2.37E-08	-9.01E-09	0.0000468	0.0000177	-4.91E-06	-3.36E-06
Prm6	-0.03301	0.0000402	1.95E-09	-9.17E-10	0.0000177	0.0000862	5.76E-06	-4.58E-07
Prm7	-0.003866	-0.000067	-6.22E-09	1.78E-08	-4.91E-06	5.76E-06	5.47E-06	8.74E-07
Prm8	0.004951	0.0000101	-1.10E-08	-4.79E-09	-3.36E-06	-4.58E-07	8.74E-07	3.95E-06
Prm9	0.03408	3.52E-07	-3.80E-08	-2.27E-09	9.16E-06	0.0000206	4.63E-06	2.25E-06
Prm10	0.02243	-0.000096	-3.08E-08	2.72E-08	0.0000125	0.0000114	4.56E-06	-1.68E-07
Prm11	0.03105	0.0000361	-2.24E-08	-1.43E-08	2.18E-06	-4.24E-06	2.58E-06	4.00E-06
Prm12	-0.08255	-0.000159	-6.62E-09	4.41E-08	-5.16E-06	0.0000111	1.40E-06	-3.14E-06
Prm13	0.0009387	0.0000475	1.20E-08	-1.25E-08	1.29E-06	6.62E-08	-1.57E-06	-8.01E-07
Prm14	-0.005652	-0.000053	-5.32E-08	9.89E-09	-5.24E-06	3.95E-06	-3.31E-06	7.68E-06
Prm15	-0.13987	-0.000151	1.52E-08	4.01E-08	-5.07E-06	0.0000134	1.63E-06	-2.56E-06

	Prm9	Prm10	Prm11	Prm12	Prm13	Prm14	Prm15
Prm1	0.03408	0.02243	0.03105	-0.08255	0.0009387	-0.005652	-0.13987
Prm2	3.52E-07	-0.000096	0.0000361	-0.000159	0.0000475	-0.000053	-0.000151
Prm3	-3.80E-08	-3.08E-08	-2.24E-08	-6.62E-09	1.20E-08	-5.32E-08	1.52E-08
Prm4	-2.27E-09	2.72E-08	-1.43E-08	4.41E-08	-1.25E-08	9.89E-09	4.01E-08
Prm5	9.16E-06	0.0000125	2.18E-06	-5.16E-06	1.29E-06	-5.24E-06	-5.07E-06
Prm6	0.0000206	0.0000114	-4.24E-06	0.0000111	6.62E-08	3.95E-06	0.0000134
Prm7	4.63E-06	4.56E-06	2.58E-06	1.40E-06	-1.57E-06	-3.31E-06	1.63E-06
Prm8	2.25E-06	-1.68E-07	4.00E-06	-3.14E-06	-8.01E-07	7.68E-06	-2.56E-06
Prm9	0.0000483	0.0000311	0.0000161	-9.45E-06	-2.03E-06	-4.45E-06	-0.000019
Prm10	0.0000311	0.0000284	0.000012	-5.21E-06	-1.79E-06	-6.09E-06	-0.000013
Prm11	0.0000161	0.000012	0.0000187	-0.000016	-1.58E-06	-3.39E-06	-0.000016
Prm12	-9.45E-06	-5.21E-06	-0.000016	0.0000365	-4.77E-07	4.24E-06	0.0000413
Prm13	-2.03E-06	-1.79E-06	-1.58E-06	-4.77E-07	8.59E-07	-2.91E-07	-3.80E-07
Prm14	-4.45E-06	-6.09E-06	-3.39E-06	4.24E-06	-2.91E-07	0.0000455	2.91E-06
Prm15	-0.000019	-0.000013	-0.000016	0.0000413	-3.80E-07	2.91E-06	0.0000699

Table 2A.1c. Estimated covariance matrix, Hispanic population model

	Prm1	Prm2	Prm3	Prm4	Prm5	Prm6	Prm7	Prm8
Prm1	316.34	-0.31571	-0.000203	0.0003226	0.01279	-0.04227	-0.003638	-0.005322
Prm2	-0.31571	0.007319	4.86E-06	-6.64E-06	0.0000625	0.0000217	-0.000016	2.39E-06
Prm3	-0.000203	4.86E-06	5.02E-09	-4.74E-09	-8.04E-08	-3.58E-08	-3.33E-08	1.06E-08
Prm4	0.0003226	-6.64E-06	-4.74E-09	7.06E-09	-3.28E-08	-4.90E-09	2.71E-08	-1.45E-08
Prm5	0.01279	0.0000625	-8.04E-08	-3.28E-08	0.0000981	0.0000498	3.98E-06	-9.43E-06
Prm6	-0.04227	0.0000217	-3.58E-08	-4.90E-09	0.0000498	0.0000884	8.66E-06	-3.19E-06
Prm7	-0.003638	-0.000016	-3.33E-08	2.71E-08	3.98E-06	8.66E-06	3.48E-06	-1.66E-06
Prm8	-0.005322	2.39E-06	1.06E-08	-1.45E-08	-9.43E-06	-3.19E-06	-1.66E-06	5.10E-06
Prm9	0.01619	0.0000143	-2.46E-08	-1.65E-08	8.80E-06	6.74E-06	9.37E-07	-2.35E-06
Prm10	0.009553	-0.000039	-3.02E-08	4.63E-08	4.43E-06	0.0000103	1.51E-06	-8.09E-07
Prm11	-0.002881	0.0000817	3.16E-08	-5.97E-08	-7.06E-07	2.43E-06	4.75E-07	2.46E-06
Prm12	-0.0875	0.0000114	-3.63E-08	-4.21E-08	-6.81E-07	1.68E-06	9.69E-07	-1.35E-06
Prm13	0.0000467	0.0000434	3.08E-08	-3.79E-08	-4.61E-07	-3.90E-06	-2.53E-07	-5.63E-07
Prm14	-0.03029	-0.000079	-9.04E-08	-7.50E-09	0.0000151	0.0000139	7.65E-07	6.36E-06
Prm15	-0.156	0.0001513	1.02E-07	-1.56E-07	-9.67E-06	0.0000175	1.51E-06	2.78E-06

	Prm9	Prm10	Prm11	Prm12	Prm13	Prm14	Prm15
Prm1	0.01619	0.009553	-0.002881	-0.0875	0.0000467	-0.03029	-0.156
Prm2	0.0000143	-0.000039	0.0000817	0.0000114	0.0000434	-0.000079	0.0001513
Prm3	-2.46E-08	-3.02E-08	3.16E-08	-3.63E-08	3.08E-08	-9.04E-08	1.02E-07
Prm4	-1.65E-08	4.63E-08	-5.97E-08	-4.21E-08	-3.79E-08	-7.50E-09	-1.56E-07
Prm5	8.80E-06	4.43E-06	-7.06E-07	-6.81E-07	-4.61E-07	0.0000151	-9.67E-06
Prm6	6.74E-06	0.0000103	2.43E-06	1.68E-06	-3.90E-06	0.0000139	0.0000175
Prm7	9.37E-07	1.51E-06	4.75E-07	9.69E-07	-2.53E-07	7.65E-07	1.51E-06
Prm8	-2.35E-06	-8.09E-07	2.46E-06	-1.35E-06	-5.63E-07	6.36E-06	2.78E-06
Prm9	0.0000176	1.53E-06	-1.32E-06	-3.13E-06	1.45E-06	4.78E-07	-8.56E-06
Prm10	1.53E-06	8.69E-06	2.65E-06	-3.91E-06	-1.35E-06	1.69E-07	-5.26E-06
Prm11	-1.32E-06	2.65E-06	0.000012	-9.07E-06	2.46E-08	-2.13E-06	1.12E-06
Prm12	-3.13E-06	-3.91E-06	-9.07E-06	0.0000509	3.86E-07	0.0000171	0.0000435
Prm13	1.45E-06	-1.35E-06	2.46E-08	3.86E-07	8.83E-07	-1.56E-06	8.62E-08
Prm14	4.78E-07	1.69E-07	-2.13E-06	0.0000171	-1.56E-06	0.0000463	0.0000141
Prm15	-8.56E-06	-5.26E-06	1.12E-06	0.0000435	8.62E-08	0.0000141	0.0000771

Table 2A.2a. Working correlation matrix, general population model

	Col1	Col2	Col3	Col4	Col5	Col6	Col7	Col8	Col9
Row1	1	0.8009	0.6415	0.5138	0.4115	0.3296	0.2639	0.2114	0.1693
Row2	0.8009	1	0.8009	0.6415	0.5138	0.4115	0.3296	0.2639	0.2114
Row3	0.6415	0.8009	1	0.8009	0.6415	0.5138	0.4115	0.3296	0.2639
Row4	0.5138	0.6415	0.8009	1	0.8009	0.6415	0.5138	0.4115	0.3296
Row5	0.4115	0.5138	0.6415	0.8009	1	0.8009	0.6415	0.5138	0.4115
Row6	0.3296	0.4115	0.5138	0.6415	0.8009	1	0.8009	0.6415	0.5138
Row7	0.2639	0.3296	0.4115	0.5138	0.6415	0.8009	1	0.8009	0.6415
Row8	0.2114	0.2639	0.3296	0.4115	0.5138	0.6415	0.8009	1	0.8009
Row9	0.1693	0.2114	0.2639	0.3296	0.4115	0.5138	0.6415	0.8009	1

Table 2A.2b. Working correlation matrix, Black population model

	Col1	Col2	Col3	Col4	Col5	Col6	Col7	Col8	Col9
Row1	1	0.7101	0.5042	0.358	0.2542	0.1805	0.1282	0.091	0.0646
Row2	0.7101	1	0.7101	0.5042	0.358	0.2542	0.1805	0.1282	0.091
Row3	0.5042	0.7101	1	0.7101	0.5042	0.358	0.2542	0.1805	0.1282
Row4	0.358	0.5042	0.7101	1	0.7101	0.5042	0.358	0.2542	0.1805
Row5	0.2542	0.358	0.5042	0.7101	1	0.7101	0.5042	0.358	0.2542
Row6	0.1805	0.2542	0.358	0.5042	0.7101	1	0.7101	0.5042	0.358
Row7	0.1282	0.1805	0.2542	0.358	0.5042	0.7101	1	0.7101	0.5042
Row8	0.091	0.1282	0.1805	0.2542	0.358	0.5042	0.7101	1	0.7101
Row9	0.0646	0.091	0.1282	0.1805	0.2542	0.358	0.5042	0.7101	1

Table 2A.2c. Working correlation matrix, Hispanic population model

	Col1	Col2	Col3	Col4	Col5	Col6	Col7	Col8	Col9
Row1	1	0.7442	0.5539	0.4122	0.3068	0.2283	0.1699	0.1265	0.0941
Row2	0.7442	1	0.7442	0.5539	0.4122	0.3068	0.2283	0.1699	0.1265
Row3	0.5539	0.7442	1	0.7442	0.5539	0.4122	0.3068	0.2283	0.1699
Row4	0.4122	0.5539	0.7442	1	0.7442	0.5539	0.4122	0.3068	0.2283
Row5	0.3068	0.4122	0.5539	0.7442	1	0.7442	0.5539	0.4122	0.3068
Row6	0.2283	0.3068	0.4122	0.5539	0.7442	1	0.7442	0.5539	0.4122
Row7	0.1699	0.2283	0.3068	0.4122	0.5539	0.7442	1	0.7442	0.5539
Row8	0.1265	0.1699	0.2283	0.3068	0.4122	0.5539	0.7442	1	0.7442
Row9	0.0941	0.1265	0.1699	0.2283	0.3068	0.4122	0.5539	0.7442	1

2.A.2 Multilevel (hierarchical) log-linear regression model

Table 2A.4a. Covariance matrix, general population model

Effect	Row	Col1	Col2	Col3	Col4	Col5	Col6	Col7	Col8	Col9	Col10	Col11	Col12	Col13
Intercept	1	49.6272	-0.01306	-0.00005	0.000049	-0.0062	-0.01871	-0.01725	-0.0285	0.000733	0.001961	0.002636	0.00129	-0.01017
Law	2	-0.01306	0.005122	3.14E-06	-3.39E-06	4.46E-06	0.000012	0.000021	0.000015	1.42E-06	-0.00001	-5.13E-06	8.02E-06	0.000168
incarcrate	3	-0.00005	3.14E-06	9.12E-09	-9.01E-09	2.48E-08	1.94E-08	3.68E-08	2.95E-08	-2.08E-08	5.25E-09	-4.68E-09	3.83E-09	-8.69E-08
Law*incarcrate	4	0.000049	-3.39E-06	-9.01E-09	9.74E-09	-2.84E-08	-1.13E-08	-3.25E-08	-8.62E-09	1.83E-08	-1.02E-10	4.30E-10	-2.36E-09	5.74E-08
pfemale	5	-0.0062	4.46E-06	2.48E-08	-2.84E-08	0.000029	4.68E-06	6.40E-06	4.04E-06	-2.30E-06	-1.16E-06	-1.15E-06	-3.85E-07	8.17E-06
p15_24	6	-0.01871	0.000012	1.94E-08	-1.13E-08	4.68E-06	0.000031	0.000019	0.000029	1.19E-06	-2.16E-06	-9.60E-07	4.55E-07	0.000011
p25_44	7	-0.01725	0.000021	3.68E-08	-3.25E-08	6.40E-06	0.000019	0.000036	0.00003	3.49E-07	-4.77E-06	-1.02E-06	-1.21E-07	0.000016
p45_64	8	-0.0285	0.000015	2.95E-08	-8.62E-09	4.04E-06	0.000029	0.00003	0.000067	2.43E-06	-3.31E-06	-1.17E-06	2.59E-06	0.000027
ppopaian	9	0.000733	1.42E-06	-2.08E-08	1.83E-08	-2.30E-06	1.19E-06	3.49E-07	2.43E-06	0.000039	2.04E-07	7.13E-07	3.11E-07	-4.53E-07
ppopasian	10	0.001961	-0.00001	5.25E-09	-1.02E-10	-1.16E-06	-2.16E-06	-4.77E-06	-3.31E-06	2.04E-07	0.000014	1.82E-07	3.83E-07	-0.00004
ppopblack	11	0.002636	-5.13E-06	-4.68E-09	4.30E-10	-1.15E-06	-9.60E-07	-1.02E-06	-1.17E-06	7.13E-07	1.82E-07	1.51E-06	5.09E-07	2.37E-07
ppophispanic	12	0.00129	8.02E-06	3.83E-09	-2.36E-09	-3.85E-07	4.55E-07	-1.21E-07	2.59E-06	3.11E-07	3.83E-07	5.09E-07	2.03E-06	1.13E-06
ppopnhopi	13	-0.01017	0.000168	-8.69E-08	5.74E-08	8.17E-06	0.000011	0.000016	0.000027	-4.53E-07	-0.00004	2.37E-07	1.13E-06	0.000794
nchs_urcs: 1	14	-0.02705	-0.00023	-5.36E-07	5.65E-07	-0.00011	0.000039	-0.00006	0.000045	0.000162	-0.00002	-3.84E-06	-0.00001	0.000056
nchs_urcs: 2	15	-0.03703	-0.00024	-3.81E-07	3.95E-07	-0.0001	0.000052	0.000017	0.000051	0.000161	-0.00001	3.85E-06	-0.00001	0.000055
nchs_urcs: 3	16	-0.0362	-0.0002	-5.76E-07	5.74E-07	-0.00009	0.000048	0.000022	0.000085	0.000163	3.01E-06	5.95E-06	-0.00001	-0.00003
nchs_urcs: 4	17	-0.03004	-0.00013	-8.10E-07	7.76E-07	-0.00008	0.000047	0.000048	0.000114	0.000171	-5.82E-09	4.42E-06	-5.33E-06	0.000038
nchs_urcs: 5	18													
phsgrad	19	0.003619	-1.35E-06	-8.36E-09	2.46E-09	-6.65E-07	-2.46E-07	-7.03E-07	-5.37E-07	1.31E-06	1.55E-06	5.10E-07	2.26E-06	-4.61E-06
psomecollege	20	0.004566	6.27E-06	8.68E-10	-2.13E-09	-1.35E-06	-2.24E-06	-2.54E-06	-1.30E-06	1.25E-06	-4.97E-07	7.46E-07	2.09E-06	2.11E-06
ppoverty	21	-0.00077	4.70E-06	7.60E-11	-1.80E-09	-6.73E-07	-1.78E-06	3.83E-07	2.20E-06	-5.77E-07	2.91E-07	-6.15E-07	-1.72E-07	2.27E-06
pinsured	22	0.000061	-9.65E-08	-3.90E-10	4.05E-10	-5.10E-09	-1.69E-08	-2.31E-09	2.91E-08	-1.86E-08	5.15E-09	-1.12E-08	-3.20E-09	-6.80E-08
unemployment_rate	23	-0.01297	-2.46E-06	-9.31E-11	-7.08E-09	7.52E-07	5.05E-07	8.37E-07	1.73E-06	-7.05E-08	2.34E-07	-3.93E-07	1.94E-07	-3.55E-08
per_capita	24	-0.0001	9.60E-06	-1.15E-08	1.19E-08	-6.22E-07	-2.78E-07	-9.39E-07	2.99E-07	2.60E-07	4.21E-07	-4.09E-07	9.47E-08	2.72E-06
stigma	25	-0.00421	-0.00016	-2.79E-08	3.37E-08	-2.27E-06	1.66E-06	-2.51E-06	9.36E-06	-2.01E-07	6.22E-06	-1.56E-06	2.10E-06	-1.12E-06
year	26	-0.02391	3.77E-06	2.04E-08	-2.18E-08	2.32E-06	8.40E-06	7.50E-06	0.000013	-5.02E-07	-8.57E-07	-1.28E-06	-7.75E-07	4.12E-06

Effect	Row	Col14	Col15	Col16	Col17	Col18	Col19	Col20	Col21	Col22	Col23	Col24	Col25	Col26
Intercept	1	-0.02705	-0.03703	-0.0362	-0.03004		0.003619	0.004566	-0.00077	0.000061	-0.01297	-0.0001	-0.00421	-0.02391
Law	2	-0.00023	-0.00024	-0.0002	-0.00013		-1.35E-06	6.27E-06	4.70E-06	-9.65E-08	-2.46E-06	9.60E-06	-0.00016	3.77E-06
incarcrate	3	-5.36E-07	-3.81E-07	-5.76E-07	-8.10E-07		-8.36E-09	8.68E-10	7.60E-11	-3.90E-10	-9.31E-11	-1.15E-08	-2.79E-08	2.04E-08
Law*incarcrate	4	5.65E-07	3.95E-07	5.74E-07	7.76E-07		2.46E-09	-2.13E-09	-1.80E-09	4.05E-10	-7.08E-09	1.19E-08	3.37E-08	-2.18E-08
pfemale	5	-0.00011	-0.0001	-0.00009	-0.00008		-6.65E-07	-1.35E-06	-6.73E-07	-5.10E-09	7.52E-07	-6.22E-07	-2.27E-06	2.32E-06
p15_24	6	0.000039	0.000052	0.000048	0.000047		-2.46E-07	-2.24E-06	-1.78E-06	-1.69E-08	5.05E-07	-2.78E-07	1.66E-06	8.40E-06
p25_44	7	-0.00006	0.000017	0.000022	0.000048		-7.03E-07	-2.54E-06	3.83E-07	-2.31E-09	8.37E-07	-9.39E-07	-2.51E-06	7.50E-06
p45_64	8	0.000045	0.000051	0.000085	0.000114		-5.37E-07	-1.30E-06	2.20E-06	2.91E-08	1.73E-06	2.99E-07	9.36E-06	0.000013
ppopaian	9	0.000162	0.000161	0.000163	0.000171		1.31E-06	1.25E-06	-5.77E-07	-1.86E-08	-7.05E-08	2.60E-07	-2.01E-07	-5.02E-07
ppopasian	10	-0.00002	-0.00001	3.01E-06	-5.82E-09		1.55E-06	-4.97E-07	2.91E-07	5.15E-09	2.34E-07	4.21E-07	6.22E-06	-8.57E-07
ppopblack	11	-3.84E-06	3.85E-06	5.95E-06	4.42E-06		5.10E-07	7.46E-07	-6.15E-07	-1.12E-08	-3.93E-07	-4.09E-07	-1.56E-06	-1.28E-06
ppophispanic	12	-0.00001	-0.00001	-0.00001	-5.33E-06		2.26E-06	2.09E-06	-1.72E-07	-3.20E-09	1.94E-07	9.47E-08	2.10E-06	-7.75E-07
ppopnhopi	13	0.000056	0.000055	-0.00003	0.000038		-4.61E-06	2.11E-06	2.27E-06	-6.80E-08	-3.55E-08	2.72E-06	-1.12E-06	4.12E-06
nchs_urcs: 1	14	0.009156	0.007818	0.007559	0.007215		-2.62E-06	-0.00003	0.000014	2.26E-07	-0.00002	4.47E-06	0.000042	0.000013
nchs_urcs: 2	15	0.007818	0.008402	0.007501	0.007234		-0.00001	-0.00003	0.000031	3.61E-07	-0.00003	2.39E-06	0.000026	0.000017
nchs_urcs: 3	16	0.007559	0.007501	0.007882	0.007215		-8.10E-06	-0.00003	0.000015	1.82E-07	-0.00002	4.16E-06	9.19E-06	0.000016
nchs_urcs: 4	17	0.007215	0.007234	0.007215	0.008414		-5.75E-06	-0.00002	0.000012	1.35E-07	-0.00002	4.64E-06	-8.25E-07	0.000011
nchs_urcs: 5	18													
phsgrad	19	-2.62E-06	-0.00001	-8.10E-06	-5.75E-06		0.000013	8.67E-06	1.21E-06	1.15E-08	8.31E-07	1.82E-07	1.06E-06	-2.23E-06
psomecollege	20	-0.00003	-0.00003	-0.00003	-0.00002		8.67E-06	8.70E-06	1.80E-06	1.85E-08	1.12E-06	3.22E-08	4.81E-07	-2.58E-06
ppoverty	21	0.000014	0.000031	0.000015	0.000012		1.21E-06	1.80E-06	5.62E-06	7.19E-08	-9.35E-07	1.64E-07	-1.11E-08	2.58E-07
pinsured	22	2.26E-07	3.61E-07	1.82E-07	1.35E-07		1.15E-08	1.85E-08	7.19E-08	2.10E-08	-1.49E-08	2.77E-09	8.96E-09	-3.25E-08
unemployment_rate	23	-0.00002	-0.00003	-0.00002	-0.00002		8.31E-07	1.12E-06	-9.35E-07	-1.49E-08	8.44E-06	4.88E-08	2.23E-06	6.33E-06
per_capita	24	4.47E-06	2.39E-06	4.16E-06	4.64E-06		1.82E-07	3.22E-08	1.64E-07	2.77E-09	4.88E-08	3.90E-06	3.94E-06	4.64E-08
stigma	25	0.000042	0.000026	9.19E-06	-8.25E-07		1.06E-06	4.81E-07	-1.11E-08	8.96E-09	2.23E-06	3.94E-06	0.00009	2.02E-06
year	26	0.000013	0.000017	0.000016	0.000011		-2.23E-06	-2.58E-06	2.58E-07	-3.25E-08	6.33E-06	4.64E-08	2.02E-06	0.000012

Table 2A.4b. Correlation matrix, general population model

Effect	Row	Col1	Col2	Col3	Col4	Col5	Col6	Col7	Col8	Col9	Col10	Col11	Col12	Col13
Intercept	1	1	-0.02591	-0.0693	0.0708	-0.1645	-0.4745	-0.4083	-0.4945	0.01661	0.07472	0.3048	0.1284	-0.05121
Law	2	-0.02591	1	0.4587	-0.4803	0.01163	0.03017	0.04947	0.02558	0.00318	-0.05278	-0.05832	0.07859	0.08345
incarcrate	3	-0.0693	0.4587	1	-0.9558	0.04838	0.03636	0.06415	0.03769	-0.03469	0.01476	-0.03992	0.02813	-0.03228
Law*incarcrate	4	0.0708	-0.4803	-0.9558	1	-0.05378	-0.02054	-0.05493	-0.01068	0.02958	-0.00028	0.00355	-0.01681	0.02063
pfemale	5	-0.1645	0.01163	0.04838	-0.05378	1	0.1562	0.1994	0.09215	-0.06863	-0.05831	-0.1756	-0.05043	0.05411
p15_24	6	-0.4745	0.03017	0.03636	-0.02054	0.1562	1	0.5649	0.6245	0.03381	-0.1034	-0.1397	0.05705	0.06757
p25_44	7	-0.4083	0.04947	0.06415	-0.05493	0.1994	0.5649	1	0.6111	0.00927	-0.2134	-0.1388	-0.01414	0.0934
p45_64	8	-0.4945	0.02558	0.03769	-0.01068	0.09215	0.6245	0.6111	1	0.04743	-0.1086	-0.117	0.2219	0.1175
ppopaian	9	0.01661	0.00318	-0.03469	0.02958	-0.06863	0.03381	0.00927	0.04743	1	0.00875	0.09268	0.03482	-0.00256
ppopasian	10	0.07472	-0.05278	0.01476	-0.00028	-0.05831	-0.1034	-0.2134	-0.1086	0.00875	1	0.03975	0.07204	-0.4264
ppopblack	11	0.3048	-0.05832	-0.03992	0.00355	-0.1756	-0.1397	-0.1388	-0.117	0.09268	0.03975	1	0.2905	0.00684
ppophispanic	12	0.1284	0.07859	0.02813	-0.01681	-0.05043	0.05705	-0.01414	0.2219	0.03482	0.07204	0.2905	1	0.02818
ppopnhopi	13	-0.05121	0.08345	-0.03228	0.02063	0.05411	0.06757	0.0934	0.1175	-0.00256	-0.4264	0.00684	0.02818	1
nchs_urcs: 1	14	-0.04013	-0.03312	-0.05859	0.05987	-0.2126	0.07193	-0.1087	0.05732	0.2705	-0.05509	-0.03266	-0.1073	0.02091
nchs_urcs: 2	15	-0.05735	-0.03583	-0.04353	0.04364	-0.1986	0.1018	0.03121	0.06794	0.2797	-0.03236	0.03423	-0.1024	0.02138
nchs_urcs: 3	16	-0.05789	-0.03186	-0.06793	0.06556	-0.1881	0.09718	0.04195	0.1165	0.2935	0.0091	0.05456	-0.08739	-0.01325
nchs_urcs: 4	17	-0.04649	-0.01998	-0.09243	0.08566	-0.1546	0.09244	0.087	0.1514	0.2972	-0.00002	0.03926	-0.04078	0.01481
nchs_urcs: 5	18													
phsgrad	19	0.141	-0.00518	-0.02403	0.00684	-0.03409	-0.01207	-0.03217	-0.01801	0.05755	0.1144	0.1141	0.4352	-0.04489
psomecollege	20	0.2197	0.0297	0.00308	-0.00731	-0.08561	-0.1355	-0.1433	-0.05397	0.06738	-0.04521	0.206	0.4959	0.0254
ppoverty	21	-0.04582	0.02768	0.00034	-0.00768	-0.05305	-0.1344	0.02694	0.1133	-0.03883	0.03289	-0.2113	-0.051	0.03393
pinsured	22	0.0602	-0.00931	-0.02822	0.0283	-0.00658	-0.0209	-0.00266	0.02455	-0.02043	0.00954	-0.06299	-0.01549	-0.01666
unemployment_rate	23	-0.6336	-0.01182	-0.00034	-0.02471	0.04832	0.03107	0.04806	0.07273	-0.00387	0.02162	-0.1103	0.04684	-0.00043
per_capita	24	-0.00689	0.06793	-0.06078	0.06094	-0.05883	-0.02516	-0.07932	0.01852	0.021	0.05723	-0.1687	0.03363	0.04887
stigma	25	-0.06312	-0.2323	-0.03091	0.03603	-0.04482	0.03135	-0.04428	0.1208	-0.00338	0.1764	-0.1338	0.1559	-0.00422
year	26	-0.9971	0.01546	0.06276	-0.06502	0.127	0.4409	0.3674	0.4513	-0.02355	-0.06757	-0.3066	-0.1598	0.043

Effect	Row	Col14	Col15	Col16	Col17	Col18	Col19	Col20	Col21	Col22	Col23	Col24	Col25	Col26
Intercept	**1**	-0.04013	-0.05735	-0.05789	-0.04649		0.141	0.2197	-0.04582	0.0602	-0.6336	-0.00689	-0.06312	-0.9971
Law	**2**	-0.03312	-0.03583	-0.03186	-0.01998		-0.00518	0.0297	0.02768	-0.00931	-0.01182	0.06793	-0.2323	0.01546
incarcrate	**3**	-0.05859	-0.04353	-0.06793	-0.09243		-0.02403	0.00308	0.00034	-0.02822	-0.00034	-0.06078	-0.03091	0.06276
Law*incarcrate	**4**	0.05987	0.04364	0.06556	0.08566		0.00684	-0.00731	-0.00768	0.0283	-0.02471	0.06094	0.03603	-0.06502
pfemale	**5**	-0.2126	-0.1986	-0.1881	-0.1546		-0.03409	-0.08561	-0.05305	-0.00658	0.04832	-0.05883	-0.04482	0.127
p15_24	**6**	0.07193	0.1018	0.09718	0.09244		-0.01207	-0.1355	-0.1344	-0.0209	0.03107	-0.02516	0.03135	0.4409
p25_44	**7**	-0.1087	0.03121	0.04195	0.087		-0.03217	-0.1433	0.02694	-0.00266	0.04806	-0.07932	-0.04428	0.3674
p45_64	**8**	0.05732	0.06794	0.1165	0.1514		-0.01801	-0.05397	0.1133	0.02455	0.07273	0.01852	0.1208	0.4513
ppopaian	**9**	0.2705	0.2797	0.2935	0.2972		0.05755	0.06738	-0.03883	-0.02043	-0.00387	0.021	-0.00338	-0.02355
ppopasian	**10**	-0.05509	-0.03236	0.0091	-0.00002		0.1144	-0.04521	0.03289	0.00954	0.02162	0.05723	0.1764	-0.06757
ppopblack	**11**	-0.03266	0.03423	0.05456	0.03926		0.1141	0.206	-0.2113	-0.06299	-0.1103	-0.1687	-0.1338	-0.3066
ppophispanic	**12**	-0.1073	-0.1024	-0.08739	-0.04078		0.4352	0.4959	-0.051	-0.01549	0.04684	0.03363	0.1559	-0.1598
ppopnhopi	**13**	0.02091	0.02138	-0.01325	0.01481		-0.04489	0.0254	0.03393	-0.01666	-0.00043	0.04887	-0.00422	0.043
nchs_urcs: 1	**14**	1	0.8914	0.8898	0.822		-0.00751	-0.09364	0.06053	0.01632	-0.08213	0.02365	0.04689	0.0407
nchs_urcs: 2	**15**	0.8914	1	0.9217	0.8603		-0.03521	-0.1034	0.1423	0.0272	-0.09447	0.01322	0.0301	0.05356
nchs_urcs: 3	**16**	0.8898	0.9217	1	0.8859		-0.02504	-0.097	0.0716	0.01418	-0.07573	0.02372	0.01093	0.05174
nchs_urcs: 4	**17**	0.822	0.8603	0.8859	1		-0.01721	-0.06897	0.05406	0.01012	-0.0752	0.02562	-0.00095	0.03654
nchs_urcs: 5	**18**					1								
phsgrad	**19**	-0.00751	-0.03521	-0.02504	-0.01721		1	0.8072	0.1406	0.02175	0.07852	0.02531	0.03073	-0.1802
psomecollege	**20**	-0.09364	-0.1034	-0.097	-0.06897		0.8072	1	0.2567	0.04328	0.1308	0.00553	0.01722	-0.2565
ppoverty	**21**	0.06053	0.1423	0.0716	0.05406		0.1406	0.2567	1	0.2094	-0.1357	0.03501	-0.00049	0.03198
pinsured	**22**	0.01632	0.0272	0.01418	0.01012		0.02175	0.04328	0.2094	1	-0.03547	0.0097	0.00653	-0.06595
unemployment_rate	**23**	-0.08213	-0.09447	-0.07573	-0.0752		0.07852	0.1308	-0.1357	-0.03547	1	0.00851	0.08118	0.6399
per_capita	**24**	0.02365	0.01322	0.02372	0.02562		0.02531	0.00553	0.03501	0.0097	0.00851	1	0.2106	0.0069
stigma	**25**	0.04689	0.0301	0.01093	-0.00095		0.03073	0.01722	-0.00049	0.00653	0.08118	0.2106	1	0.06262
year	**26**	0.0407	0.05356	0.05174	0.03654		-0.1802	-0.2565	0.03198	-0.06595	0.6399	0.0069	0.06262	1

Table 2A.5a. Covariance matrix, Black population model

Effect	Row	Col1	Col2	Col3	Col4	Col5	Col6	Col7	Col8	Col9	Col10	Col11
Intercept	1	61.9257	-0.00891	-0.00004	0.000017	-0.01648	-0.00923	-0.00949	-0.00359	0.000939	0.002931	0.003048
Law	2	-0.00891	0.01049	4.36E-06	-4.97E-06	0.000014	0.000027	-7.93E-07	-0.00001	-0.00001	-4.25E-06	2.44E-06
incarcrate_black	3	-0.00004	4.36E-06	4.84E-09	-4.68E-09	1.80E-08	4.08E-08	2.46E-08	-8.12E-10	1.99E-09	1.45E-09	5.39E-09
Law*incarcrate_black	4	1.7E-05	-4.97E-06	-4.68E-09	5.31E-09	-1.00E-08	-3.22E-08	-8.15E-09	5.96E-11	3.83E-11	-1.15E-09	-8.33E-10
p15_24black	5	-0.01648	0.000014	1.80E-08	-1.00E-08	0.00004	0.000024	0.000022	1.48E-06	7.99E-07	1.38E-07	-1.16E-06
p25_44black	6	-0.00923	0.000027	4.08E-08	-3.22E-08	0.000024	0.000043	0.000025	3.47E-06	1.25E-06	-1.16E-06	-3.04E-06
p45_64black	7	-0.00949	-7.93E-07	2.46E-08	-8.15E-09	0.000022	0.000025	0.000052	9.72E-08	-5.46E-07	-1.39E-06	-1.99E-06
pfemaleblack	8	-0.00359	-0.00001	-8.12E-10	5.96E-11	1.48E-06	3.47E-06	9.72E-08	0.000017	-4.50E-07	-9.41E-08	-3.57E-07
ppopblack	9	0.00094	-0.00001	1.99E-09	3.83E-11	7.99E-07	1.25E-06	-5.46E-07	-4.50E-07	2.00E-06	6.03E-08	1.91E-07
phsgradblack	10	0.00293	-4.25E-06	1.45E-09	-1.15E-09	1.38E-07	-1.16E-06	-1.39E-06	-9.41E-08	6.03E-08	6.93E-06	4.28E-06
psomecollegeblack	11	0.00305	2.44E-06	5.39E-09	-8.33E-10	-1.16E-06	-3.04E-06	-1.99E-06	-3.57E-07	1.91E-07	4.28E-06	5.26E-06
ppovertyblack	12	-0.00052	2.91E-07	-2.52E-09	9.30E-10	4.67E-08	1.17E-07	6.01E-07	-5.30E-08	-7.59E-09	-3.33E-08	3.73E-08
pinsured_black	13	0.00312	2.80E-07	1.15E-10	-1.22E-10	-1.17E-07	4.39E-07	-8.61E-08	-3.00E-08	1.64E-08	-7.70E-08	-2.67E-07
unemployment_ratebla	14	-0.00989	-4.03E-06	-1.43E-09	-1.97E-09	-2.72E-07	9.60E-07	4.64E-08	-3.97E-08	-2.68E-07	3.66E-07	4.31E-07
nchs_urcs: 1	15	-0.06286	0.0002	1.94E-08	7.67E-08	0.000068	-0.0001	-0.00004	-0.00002	6.91E-06	-0.00001	-0.00003
nchs_urcs: 2	16	-0.1036	-0.00009	4.17E-08	8.92E-08	0.000075	-0.00008	-0.00006	-0.00002	0.000014	-0.00002	-0.00005
nchs_urcs: 3	17	-0.05216	-0.00008	-1.66E-07	1.78E-07	0.000059	-0.00005	-0.00002	7.84E-07	0.000015	-0.00001	-0.00003
nchs_urcs: 4	18	-0.00867	-8.25E-06	-3.16E-07	2.14E-07	0.000047	-0.00003	5.64E-06	-0.00001	9.37E-06	-5.10E-06	-0.00001
nchs_urcs: 5	19											
per_capita	20	-0.00023	0.000039	-1.71E-12	-1.33E-09	-2.10E-07	-5.14E-07	-4.63E-07	-4.14E-07	-6.36E-07	-6.13E-08	8.54E-08
stigma	21	-0.00344	0.000037	5.80E-08	-5.30E-08	-7.58E-07	-4.31E-06	5.45E-06	-5.72E-06	-4.39E-06	-8.29E-07	-5.56E-07
year	22	-0.03043	-1.02E-07	1.81E-08	-5.88E-09	7.20E-06	3.49E-06	3.65E-06	1.31E-06	-4.97E-07	-1.63E-06	-1.62E-06

Effect	Row	Col12	Col13	Col14	Col15	Col16	Col17	Col18	Col19	Col20	Col21	Col22
Intercept	1	-0.00052	0.003118	-0.00989	-0.06286	-0.1036	-0.05216	-0.00867		-0.00023	-0.00344	-0.03043
Law	2	2.91E-07	2.80E-07	-4.03E-06	0.0002	-0.00009	-0.00008	-8.25E-06		0.000039	0.000037	-1.02E-07
incarcrate_black	3	-2.52E-09	1.15E-10	-1.43E-09	1.94E-08	4.17E-08	-1.66E-07	-3.16E-07		-1.71E-12	5.80E-08	1.81E-08
Law*incarcrate_black	4	9.30E-10	-1.22E-10	-1.97E-09	7.67E-08	8.92E-08	1.78E-07	2.14E-07		-1.33E-09	-5.30E-08	-5.88E-09
p15_24black	5	4.67E-08	-1.17E-07	-2.72E-07	0.000068	0.000075	0.000059	0.000047		-2.10E-07	-7.58E-07	7.20E-06
p25_44black	6	1.17E-07	4.39E-07	9.60E-07	-0.0001	-0.00008	-0.00005	-0.00003		-5.14E-07	-4.31E-06	3.49E-06
p45_64black	7	6.01E-07	-8.61E-08	4.64E-08	-0.00004	-0.00006	-0.00002	5.64E-06		-4.63E-07	5.45E-06	3.65E-06
pfemaleblack	8	-5.30E-08	-3.00E-08	-3.97E-08	-0.00002	-0.00002	7.84E-07	-0.00001		-4.14E-07	-5.72E-06	1.31E-06
ppopblack	9	-7.59E-09	1.64E-08	-2.68E-07	6.91E-06	0.000014	0.000015	9.37E-06		-6.36E-07	-4.39E-06	-4.97E-07
phsgradblack	10	-3.33E-08	-7.70E-08	3.66E-07	-0.00001	-0.00002	-0.00001	-5.10E-06		-6.13E-08	-8.29E-07	-1.63E-06
psomecollegeblack	11	3.73E-08	-2.67E-07	4.31E-07	-0.00003	-0.00005	-0.00003	-0.00001		8.54E-08	-5.56E-07	-1.62E-06
ppovertyblack	12	6.93E-07	2.52E-09	-2.35E-07	2.15E-06	5.39E-06	2.38E-06	1.81E-06		3.13E-08	-1.97E-07	2.42E-07
pinsured_black	13	2.52E-09	2.22E-06	2.02E-07	1.09E-07	-1.49E-06	-2.35E-06	-2.27E-06		-1.19E-07	9.49E-07	-1.64E-06
unemployment_ratebla	14	-2.35E-07	2.02E-07	4.53E-06	-0.00002	-9.11E-06	-0.00001	-0.00001		1.25E-08	1.59E-06	4.86E-06
nchs_urcs: 1	15	2.15E-06	1.09E-07	-0.00002	0.01553	0.01467	0.01371	0.0127		-1.47E-07	0.000127	0.000027
nchs_urcs: 2	16	5.39E-06	-1.49E-06	-9.11E-06	0.01467	0.016	0.01377	0.01272		-1.20E-06	0.000106	0.000047
nchs_urcs: 3	17	2.38E-06	-2.35E-06	-0.00001	0.01371	0.01377	0.01422	0.01254		-2.25E-06	-0.00002	0.000021
nchs_urcs: 4	18	1.81E-06	-2.27E-06	-0.00001	0.0127	0.01272	0.01254	0.01504		-2.24E-06	-0.00003	-1.17E-06
nchs_urcs: 5	19											
per_capita	20	3.13E-08	-1.19E-07	1.25E-08	-1.47E-07	-1.20E-06	-2.25E-06	-2.24E-06		4.09E-06	6.14E-06	1.11E-07
stigma	21	-1.97E-07	9.49E-07	1.59E-06	0.000127	0.000106	-0.00002	-0.00003		6.14E-06	0.000134	1.77E-06
year	22	2.42E-07	-1.64E-06	4.86E-06	0.000027	0.000047	0.000021	-1.17E-06		1.11E-07	1.77E-06	0.000015

Table 2A.5b. Correlation matrix, Black population model

Effect	Row	Col1	Col2	Col3	Col4	Col5	Col6	Col7	Col8	Col9	Col10	Col11
Intercept	1	1	-0.01106	-0.07883	0.03047	-0.3301	-0.1795	-0.1673	-0.1107	0.08449	0.1415	0.1689
Law	2	-0.01106	1	0.6123	-0.6655	0.02199	0.04038	-0.00107	-0.02741	-0.09142	-0.01576	0.0104
incarcrate_black	3	-0.07883	0.6123	1	-0.9231	0.04068	0.08978	0.04905	-0.00283	0.02021	0.0079	0.03379
Law*incarcrate_black	4	0.03047	-0.6655	-0.9231	1	-0.02163	-0.0677	-0.01553	0.0002	0.00037	-0.00601	-0.00499
p15_24black	5	-0.3301	0.02199	0.04068	-0.02163	1	0.588	0.4857	0.05661	0.0891	0.00823	-0.07994
p25_44black	6	-0.1795	0.04038	0.08978	-0.0677	0.588	1	0.5386	0.129	0.1357	-0.06758	-0.2033
p45_64black	7	-0.1673	-0.00107	0.04905	-0.01553	0.4857	0.5386	1	0.00327	-0.0537	-0.07351	-0.1205
pfemaleblack	8	-0.1107	-0.02741	-0.00283	0.0002	0.05661	0.129	0.00327	1	-0.0773	-0.00867	-0.03784
ppopblack	9	0.08449	-0.09142	0.02021	0.00037	0.0891	0.1357	-0.0537	-0.0773	1	0.01622	0.05908
phsgradblack	10	0.1415	-0.01576	0.0079	-0.00601	0.00823	-0.06758	-0.07351	-0.00867	0.01622	1	0.7094
psomecollegeblack	11	0.1689	0.0104	0.03379	-0.00499	-0.07994	-0.2033	-0.1205	-0.03784	0.05908	0.7094	1
ppovertyblack	12	-0.07952	0.00341	-0.04347	0.01534	0.00884	0.02158	0.1002	-0.01545	-0.00645	-0.0152	0.01953
pinsured_black	13	0.2658	0.00184	0.00111	-0.00112	-0.0124	0.04506	-0.00801	-0.00488	0.00778	-0.01963	-0.07803
unemployment_ratebla	14	-0.5906	-0.0185	-0.00964	-0.01273	-0.02015	0.06904	0.00303	-0.00453	-0.08924	0.06523	0.08834
nchs_urcs: 1	15	-0.06411	0.01566	0.00224	0.00844	0.08658	-0.1253	-0.04152	-0.03385	0.03927	-0.03383	-0.1125
nchs_urcs: 2	16	-0.104	-0.00676	0.00474	0.00967	0.09324	-0.09891	-0.06345	-0.03353	0.07943	-0.05994	-0.1704
nchs_urcs: 3	17	-0.05558	-0.00643	-0.01996	0.02051	0.07825	-0.06601	-0.02125	0.0016	0.08873	-0.04115	-0.1098
nchs_urcs: 4	18	-0.00899	-0.00066	-0.03704	0.02397	0.06005	-0.0411	0.00638	-0.02208	0.0541	-0.0158	-0.03595
nchs_urcs: 5	19											
per_capita	20	-0.01433	0.1886	-0.00001	-0.00905	-0.01634	-0.03894	-0.03176	-0.04967	-0.2225	-0.01152	0.01842
stigma	21	-0.03784	0.03114	0.07213	-0.0629	-0.01033	-0.05699	0.06541	-0.12	-0.2685	-0.02721	-0.02098
year	22	-0.998	-0.00026	0.06703	-0.02081	0.293	0.1378	0.1306	0.08224	-0.09081	-0.1602	-0.1821

Effect	Row	Col12	Col13	Col14	Col15	Col16	Col17	Col18	Col19	Col20	Col21	Col22
Intercept	1	-0.07952	0.2658	-0.5906	-0.06411	-0.104	-0.05558	-0.00899		-0.01433	-0.03784	-0.998
Law	2	0.003412	0.00184	-0.0185	0.01566	-0.00676	-0.00643	-0.00066		0.1886	0.03114	-0.00026
incarcrate_black	3	-0.04347	0.00111	-0.00964	0.00224	0.00474	-0.01996	-0.03704		-0.00001	0.07213	0.06703
Law*incarcrate_black	4	0.01534	-0.00112	-0.01273	0.00844	0.00967	0.02051	0.02397		-0.00905	-0.0629	-0.02081
p15_24black	5	0.00884	-0.0124	-0.02015	0.08658	0.09324	0.07825	0.06005		-0.01634	-0.01033	0.293
p25_44black	6	0.02158	0.04506	0.06904	-0.1253	-0.09891	-0.06601	-0.0411		-0.03894	-0.05699	0.1378
p45_64black	7	0.1002	-0.00801	0.00303	-0.04152	-0.06345	-0.02125	0.00638		-0.03176	0.06541	0.1306
pfemaleblack	8	-0.01545	-0.00488	-0.00453	-0.03385	-0.03353	0.0016	-0.02208		-0.04967	-0.12	0.08224
ppopblack	9	-0.00645	0.00778	-0.08924	0.03927	0.07943	0.08873	0.0541		-0.2225	-0.2685	-0.09081
phsgradblack	10	-0.0152	-0.01963	0.06523	-0.03383	-0.05994	-0.04115	-0.0158		-0.01152	-0.02721	-0.1602
psomecollegeblack	11	0.01953	-0.07803	0.08834	-0.1125	-0.1704	-0.1098	-0.03595		0.01842	-0.02098	-0.1821
ppovertyblack	12	1	0.00203	-0.1325	0.02077	0.05118	0.02393	0.01774		0.01858	-0.02048	0.07497
pinsured_black	13	0.002034	1	0.06356	0.00059	-0.00788	-0.01323	-0.01241		-0.03952	0.05502	-0.2837
unemployment_ratebla	14	-0.1325	0.06356	1	-0.05814	-0.03385	-0.05154	-0.05691		0.00291	0.06449	0.5894
nchs_urcs: 1	15	0.02077	0.00059	-0.05814	1	0.9305	0.9224	0.8308		-0.00058	0.08809	0.05533
nchs_urcs: 2	16	0.05118	-0.00788	-0.03385	0.9305	1	0.9129	0.8198		-0.00468	0.07223	0.09679
nchs_urcs: 3	17	0.02393	-0.01323	-0.05154	0.9224	0.9129	1	0.8572		-0.00933	-0.01442	0.04463
nchs_urcs: 4	18	0.01774	-0.01241	-0.05691	0.8308	0.8198	0.8572	1		-0.00902	-0.02245	-0.00246
nchs_urcs: 5	19								1			
per_capita	20	0.01858	-0.03952	0.00291	-0.00058	-0.00468	-0.00933	-0.00902		1	0.2627	0.01411
stigma	21	-0.02048	0.05502	0.06449	0.08809	0.07223	-0.01442	-0.02245		0.2627	1	0.03947
year	22	0.07497	-0.2837	0.5894	0.05533	0.09679	0.04463	-0.00246		0.01411	0.03947	1

Table 2A.6a. Covariance matrix, Hispanic population model

Effect	Row	Col1	Col2	Col3	Col4	Col5	Col6	Col7	Col8	Col9	Col10	Col11
Intercept	1	270.47	-0.1035	-0.00041	0.000365	-0.07327	-0.04427	0.03704	-0.02095	-0.00211	0.008384	0.01003
Law	2	-0.1035	0.02167	6.54E-06	-7.64E-06	0.000248	8.95E-06	-0.00009	0.000105	0.000053	-4.02E-06	0.000012
incarcrate_hispanic	3	-0.00041	6.54E-06	2.16E-08	-2.11E-08	1.53E-07	2.20E-07	6.28E-08	6.06E-08	-4.58E-09	-3.04E-08	-4.61E-09
Law*incarcrate_hispa	4	0.00037	-7.64E-06	-2.11E-08	2.51E-08	-1.65E-07	-1.95E-07	-5.74E-08	-6.52E-08	7.08E-09	2.69E-08	2.97E-08
p15_24hispanic	5	-0.07327	0.000248	1.53E-07	-1.65E-07	0.000192	0.000039	0.000028	0.000027	3.48E-06	-8.05E-06	-1.42E-06
p25_44hispanic	6	-0.04427	8.95E-06	2.20E-07	-1.95E-07	0.000039	0.000135	0.000078	0.000095	-2.45E-07	-7.49E-06	-0.00001
p45_64hispanic	7	0.03704	-0.00009	6.28E-08	-5.74E-08	0.000028	0.000078	0.000171	0.000021	-6.52E-06	-5.13E-06	-0.00001
pfemalehispanic	8	-0.02095	0.000105	6.06E-08	-6.52E-08	0.000027	0.000095	0.000021	0.000182	-9.78E-07	-1.89E-06	-0.00001
ppophispanic	9	-0.00211	0.000053	-4.58E-09	7.08E-09	3.48E-06	-2.45E-07	-6.52E-06	-9.78E-07	5.77E-06	-4.01E-07	6.44E-07
phsgradhispanic	10	0.00838	-4.02E-06	-3.04E-08	2.69E-08	-8.05E-06	-7.49E-06	-5.13E-06	-1.89E-06	-4.01E-07	0.000012	3.90E-06
psomecollegehispanic	11	0.01003	0.000012	-4.61E-09	2.97E-08	-1.42E-06	-0.00001	-0.00001	-0.00001	6.44E-07	3.90E-06	9.06E-06
ppovertyhispanic	12	0.00792	-9.40E-06	-7.51E-09	2.32E-08	-2.86E-06	6.35E-07	1.10E-06	8.08E-07	-6.49E-07	-2.01E-07	3.86E-07
pinsured_hispanic	13	0.0057	-1.70E-06	-5.44E-09	9.06E-09	-8.36E-07	1.20E-06	7.77E-08	7.32E-07	3.97E-08	-2.35E-07	-3.23E-07
unemployment_ratehis	14	-0.04515	-0.00003	-1.03E-09	1.08E-08	-2.54E-06	0.000011	8.46E-06	3.16E-06	-4.84E-07	3.26E-07	-8.24E-07
nchs_urcs: 1	15	-0.173	-0.0009	-8.15E-07	1.35E-06	0.000225	-0.00045	-0.00032	-0.0004	0.000255	-0.00003	0.000047
nchs_urcs: 2	16	-0.2694	-0.00079	-7.95E-07	1.44E-06	0.000263	-0.00037	-0.00036	-0.00028	0.000255	-0.00005	0.000031
nchs_urcs: 3	17	-0.0604	-0.00161	-1.30E-06	1.66E-06	0.000097	-0.00019	-0.00006	-0.00024	0.000151	-0.00003	0.00005
nchs_urcs: 4	18											
per_capita	19	-0.00126	0.00009	9.66E-10	-6.86E-09	2.26E-06	-6.81E-06	-5.45E-06	-2.18E-06	6.72E-07	1.04E-06	-1.92E-08
stigma	20	0.00062	-0.00061	1.84E-09	-1.31E-08	0.000026	0.000038	0.000054	0.000033	1.92E-06	-1.20E-07	-2.67E-06
year	21	-0.133	0.000039	1.93E-07	-1.74E-07	0.000033	0.000017	-0.00002	4.53E-06	9.00E-07	-4.10E-06	-4.68E-06

Effect	Row	Col12	Col13	Col14	Col15	Col16	Col17	Col18	Col19	Col20	Col21
Intercept	1	0.007917	0.005696	-0.04515	-0.173	-0.2694	-0.0604		-0.00126	0.000619	-0.133
Law	2	-9.40E-06	-1.70E-06	-0.00003	-0.0009	-0.00079	-0.00161		0.00009	-0.00061	0.000039
incarcrate_hispanic	3	-7.51E-09	-5.44E-09	-1.03E-09	-8.15E-07	-7.95E-07	-1.30E-06		9.66E-10	1.84E-09	1.93E-07
Law*incarcrate_hispa	4	2.32E-08	9.06E-09	1.08E-08	1.35E-06	1.44E-06	1.66E-06		-6.86E-09	-1.31E-08	-1.74E-07
p15_24hispanic	5	-2.86E-06	-8.36E-07	-2.54E-06	0.000225	0.000263	0.000097		2.26E-06	0.000026	0.000033
p25_44hispanic	6	6.35E-07	1.20E-06	0.000011	-0.00045	-0.00037	-0.00019		-6.81E-06	0.000038	0.000017
p45_64hispanic	7	1.10E-06	7.77E-08	8.46E-06	-0.00032	-0.00036	-0.00006		-5.45E-06	0.000054	-0.00002
pfemalehispanic	8	8.08E-07	7.32E-07	3.16E-06	-0.0004	-0.00028	-0.00024		-2.18E-06	0.000033	4.53E-06
ppophispanic	9	-6.49E-07	3.97E-08	-4.84E-07	0.000255	0.000255	0.000151		6.72E-07	1.92E-06	9.00E-07
phsgradhispanic	10	-2.01E-07	-2.35E-07	3.26E-07	-0.00003	-0.00005	-0.00003		1.04E-06	-1.20E-07	-4.10E-06
psomecollegehispanic	11	3.86E-07	-3.23E-07	-8.24E-07	0.000047	0.000031	0.00005		-1.92E-08	-2.67E-06	-4.68E-06
ppovertyhispanic	12	4.75E-06	2.33E-07	8.37E-07	1.51E-06	0.000025	0.00001		-3.19E-07	-1.92E-06	-4.00E-06
pinsured_hispanic	13	2.33E-07	9.87E-07	-1.99E-07	-3.63E-06	-9.70E-07	-1.40E-06		-1.26E-07	9.19E-07	-2.89E-06
unemployment_ratehis	14	8.37E-07	-1.99E-07	0.000022	0.000057	0.000084	0.000061		-4.87E-07	7.46E-06	0.000022
nchs_urcs: 1	15	1.51E-06	-3.63E-06	0.000057	0.07543	0.0733	0.06602		5.23E-06	-0.00024	0.000064
nchs_urcs: 2	16	0.000025	-9.70E-07	0.000084	0.0733	0.07782	0.06614		7.59E-06	-0.00012	0.000109
nchs_urcs: 3	17	0.00001	-1.40E-06	0.000061	0.06602	0.06614	0.06662		-0.00001	-0.00012	4.39E-06
nchs_urcs: 4	18										
per_capita	19	-3.19E-07	-1.26E-07	-4.87E-07	5.23E-06	7.59E-06	-0.00001		9.68E-06	9.22E-06	7.17E-07
stigma	20	-1.92E-06	9.19E-07	7.46E-06	-0.00024	-0.00012	-0.00012		9.22E-06	0.000529	-1.95E-06
year	21	-4.00E-06	-2.89E-06	0.000022	0.000064	0.000109	4.39E-06		7.17E-07	-1.95E-06	0.000066

Table 2A.6b. Correlation matrix, Hispanic population model

Effect	Row	Col1	Col2	Col3	Col4	Col5	Col6	Col7	Col8	Col9	Col10	Col11
Intercept	**1**	1	-0.04275	-0.1685	0.1401	-0.3212	-0.2319	0.1721	-0.09432	-0.05331	0.1467	0.2028
Law	**2**	-0.04275	1	0.3021	-0.3273	0.1213	0.00523	-0.04751	0.05286	0.15	-0.00787	0.0276
incarcrate_hispanic	**3**	-0.1685	0.3021	1	-0.9039	0.07489	0.129	0.03265	0.03053	-0.01297	-0.05954	-0.01043
Law*incarcrate_hispa	**4**	0.1401	-0.3273	-0.9039	1	-0.07494	-0.106	-0.02766	-0.03047	0.0186	0.0488	0.06231
p15_24hispanic	**5**	-0.3212	0.1213	0.07489	-0.07494	1	0.2449	0.1521	0.1415	0.1043	-0.167	-0.03394
p25_44hispanic	**6**	-0.2319	0.00523	0.129	-0.106	0.2449	1	0.511	0.6086	-0.00877	-0.1857	-0.2991
p45_64hispanic	**7**	0.1721	-0.04751	0.03265	-0.02766	0.1521	0.511	1	0.1188	-0.2074	-0.1127	-0.2781
pfemalehispanic	**8**	-0.09432	0.05286	0.03053	-0.03047	0.1415	0.6086	0.1188	1	-0.03014	-0.04035	-0.2836
ppophispanic	**9**	-0.05331	0.15	-0.01297	0.0186	0.1043	-0.00877	-0.2074	-0.03014	1	-0.04809	0.08912
phsgradhispanic	**10**	0.1467	-0.00787	-0.05954	0.0488	-0.167	-0.1857	-0.1127	-0.04035	-0.04809	1	0.3731
psomecollegehispanic	**11**	0.2028	0.0276	-0.01043	0.06231	-0.03394	-0.2991	-0.2781	-0.2836	0.08912	0.3731	1
ppovertyhispanic	**12**	0.2209	-0.02931	-0.02344	0.06729	-0.09468	0.02509	0.03868	0.02743	-0.1241	-0.02659	0.05878
pinsured_hispanic	**13**	0.3486	-0.01166	-0.03726	0.05753	-0.06067	0.1043	0.00597	0.05455	0.01664	-0.06798	-0.1082
unemployment_ratehis	**14**	-0.5915	-0.04935	-0.00151	0.01465	-0.03947	0.2035	0.1391	0.05047	-0.04345	0.02022	-0.05902
nchs_urcs: 1	**15**	-0.0383	-0.0222	-0.0202	0.03092	0.05901	-0.1415	-0.08769	-0.1071	0.3859	-0.03618	0.05635
nchs_urcs: 2	**16**	-0.05873	-0.01926	-0.01939	0.03265	0.06804	-0.1156	-0.09836	-0.07458	0.3805	-0.05063	0.03699
nchs_urcs: 3	**17**	-0.01423	-0.04225	-0.03431	0.04068	0.02697	-0.06467	-0.01766	-0.06793	0.2442	-0.03245	0.0641
nchs_urcs: 4	**18**											
per_capita	**19**	-0.02467	0.1959	0.00211	-0.01392	0.05244	-0.1886	-0.1339	-0.05178	0.08995	0.09573	-0.00205
stigma	**20**	0.00164	-0.1799	0.00054	-0.0036	0.08034	0.1423	0.1783	0.1056	0.03467	-0.00151	-0.03863
year	**21**	-0.9979	0.03289	0.1624	-0.1353	0.296	0.1807	-0.2009	0.04132	0.04621	-0.1454	-0.192

Effect	Row	Col12	Col13	Col14	Col15	Col16	Col17	Col18	Col19	Col20	Col21
Intercept	**1**	0.2209	0.3486	-0.5915	-0.0383	-0.05873	-0.01423		-0.02467	0.00164	-0.9979
Law	**2**	-0.02931	-0.01166	-0.04935	-0.0222	-0.01926	-0.04225		0.1959	-0.1799	0.03289
incarcrate_hispanic	**3**	-0.02344	-0.03726	-0.00151	-0.0202	-0.01939	-0.03431		0.00211	0.00054	0.1624
Law*incarcrate_hispa	**4**	0.06729	0.05753	0.01465	0.03092	0.03265	0.04068		-0.01392	-0.0036	-0.1353
p15_24hispanic	**5**	-0.09468	-0.06067	-0.03947	0.05901	0.06804	0.02697		0.05244	0.08034	0.296
p25_44hispanic	**6**	0.02509	0.1043	0.2035	-0.1415	-0.1156	-0.06467		-0.1886	0.1423	0.1807
p45_64hispanic	**7**	0.03868	0.00597	0.1391	-0.08769	-0.09836	-0.01766		-0.1339	0.1783	-0.2009
pfemalehispanic	**8**	0.02743	0.05455	0.05047	-0.1071	-0.07458	-0.06793		-0.05178	0.1056	0.04132
ppophispanic	**9**	-0.1241	0.01664	-0.04345	0.3859	0.3805	0.2442		0.08995	0.03467	0.04621
phsgradhispanic	**10**	-0.02659	-0.06798	0.02022	-0.03618	-0.05063	-0.03245		0.09573	-0.00151	-0.1454
psomecollegehispanic	**11**	0.05878	-0.1082	-0.05902	0.05635	0.03699	0.0641		-0.00205	-0.03863	-0.192
ppovertyhispanic	**12**	1	0.1076	0.08269	0.00253	0.04039	0.01808		-0.047	-0.03836	-0.2265
pinsured_hispanic	**13**	0.1076	1	-0.04311	-0.0133	-0.0035	-0.00547		-0.04082	0.04024	-0.3585
unemployment_ratehis	**14**	0.08269	-0.04311	1	0.04472	0.065	0.05089		-0.03375	0.06985	0.5853
nchs_urcs: 1	**15**	0.002528	-0.0133	0.04472	1	0.9568	0.9313		0.00612	-0.03822	0.02897
nchs_urcs: 2	**16**	0.04039	-0.0035	0.065	0.9568	1	0.9186		0.00875	-0.01825	0.04801
nchs_urcs: 3	**17**	0.01808	-0.00547	0.05089	0.9313	0.9186	1		-0.01742	-0.02092	0.0021
nchs_urcs: 4	**18**							1			
per_capita	**19**	-0.047	-0.04082	-0.03375	0.00612	0.00875	-0.01742		1	0.1288	0.02842
stigma	**20**	-0.03836	0.04024	0.06985	-0.03822	-0.01825	-0.02092		0.1288	1	-0.01048
year	**21**	-0.2265	-0.3585	0.5853	0.02897	0.04801	0.0021		0.02842	-0.01048	1

2.A.3 Binary logistic regression model

Table 2A.7a. Box-Tidwell test for the general population model

General population	Estimate	SE	Wald χ²	p-value
Intercept	-87.0913	16.3151	28.4949	<0.0001
incarcrate	0.00985	0.00163	36.6215	<0.0001
_AGE80	0.7685	0.00655	13773.09	<0.0001
p15_44	1.5856	1.3534	1.3727	0.2414
pfemale	0.028	0.0221	1.613	0.2041
ppopblack	0.0669	0.0217	9.4867	0.0021
ppopasian	0.0343	0.0719	0.2277	0.6332
ppopaian	0.3407	0.0227	224.6429	<0.0001
ppopnhopi	0.6588	0.0742	78.7744	<0.0001
ppophispanic	-0.0427	0.02	4.5506	0.0329
phsgrad	0.0483	0.0294	2.7019	0.1002
ppoverty	0.8434	0.2072	16.5701	<0.0001
pinsured	3.3988	0.8769	15.0221	0.0001
unemployment_rate	0.475	0.1658	8.2106	0.0042
urbanicity	0.2611	0.0783	11.1292	0.0008
stigma	0.1674	0.0447	13.9894	0.0002
phys_per1000	-1.4344	0.4217	11.5719	0.0007
prevalence	-0.00679	0.00261	6.7596	0.0093
incarcrat*ln_incarcr	-0.00119	0.0002	35.1107	<0.0001
_AGE80*ln_age80	-0.1658	0.00135	15070.78	<0.0001
p15_44*ln_p15_44	-0.3388	0.2882	1.3816	0.2398
pfemale*ln_pfemale				
ppopblack*ln_ppopbla	-0.0119	0.00547	4.7083	0.03
ppopasian*ln_ppopasi	0.032	0.0295	1.1712	0.2792
ppopaian*ln_ppopaian	-0.1417	0.00956	219.4709	<0.0001
ppopnhopi*ln_ppopnho	1.0232	0.1113	84.5463	<0.0001
ppophispa*ln_ppophis	0.0177	0.00511	11.9982	0.0005
phsgrad*ln_phsgrad	-0.00826	0.00694	1.4176	0.2338
ppoverty*ln_ppoverty	-0.2345	0.0557	17.7079	<0.0001
pinsured*ln_pinsured	-0.61	0.1594	14.6394	0.0001
unemploym*ln_unemplo	-0.1593	0.0609	6.8485	0.0089
urbanicit*ln_urbanic	-0.054	0.015	13.0128	0.0003
stigma*ln_stigma	-0.1278	0.0252	25.6723	<0.0001
phys_per1*ln_phys_pe	0.7109	0.2029	12.2764	0.0005
prevalenc*ln_prevale	0.00104	0.00038	7.4534	0.0063

Table 2A.7b. Box-Tidwell test for the Black population model

Black population	Estimate	SE	Wald χ^2	p-value
Intercept	125.5	46.5054	7.2778	0.007
incarcrate_black	0.00708	0.00398	3.1685	0.0751
_AGE80	0.8371	0.0195	1843.12	<0.0001
p15_44black	-5.0857	2.4715	4.2341	0.0396
pfemaleblack	0.3899	1.4605	0.0713	0.7895
ppopblack	-0.019	0.0787	0.0581	0.8095
phsgradblack	0.6224	0.6163	1.0198	0.3126
ppovertyblack	-1.1383	0.2857	15.8689	<0.0001
pinsured_black	1.3568	0.6989	3.7691	0.0522
unemployment_ratebla	1.3611	0.4756	8.1891	0.0042
ppoverty	1.6079	0.638	6.3508	0.0117
pinsured	-6.558	2.6464	6.1408	0.0132
unemployment_rate	-2.2724	0.9316	5.9502	0.0147
urbanicity	-0.5198	0.441	1.3888	0.2386
stigma	-0.5286	0.1674	9.9724	0.0016
phys_per1000	3.5142	3.1561	1.2398	0.2655
per_capita	0.0695	0.0348	3.9952	0.0456
Black_prevalence	-0.0187	0.0104	3.2199	0.0728
incarcrat*ln_incarcr	-0.00078	0.00044	3.204	0.0735
_AGE80*ln_age80	-0.1812	0.00403	2024.99	<0.0001
p15_44bla*ln_p15_44b	1.0213	0.5074	4.0512	0.0441
pfemalebl*ln_pfemale	-0.0812	0.3025	0.0721	0.7883
ppopblack*ln_ppopbla	-0.00175	0.0184	0.0091	0.9241
phsgradbl*ln_phsgrad	-0.1478	0.1373	1.1586	0.2818
ppovertyb*ln_ppovert	0.2623	0.0662	15.6828	<0.0001
pinsured_*ln_pinsure	-0.2562	0.1287	3.9617	0.0465
unemploym*ln_unemplo	-0.4015	0.1402	8.2047	0.0042
ppoverty*ln_ppoverty	-0.4241	0.1727	6.0264	0.0141
pinsured*ln_pinsured	1.2106	0.4828	6.2878	0.0122
unemploym*ln_unemplo	0.8404	0.3467	5.8763	0.0153
urbanicit*ln_urbanic	0.099	0.0841	1.3875	0.2388
stigma*ln_stigma	0.2716	0.0928	8.5577	0.0034
phys_per1*ln_phys_pe	-1.9822	1.6089	1.5178	0.218
Black_pre*ln_black_p	0.00245	0.00133	3.3863	0.0657

Table 2A.7c. Box-Tidwell test for the Hispanic population model

Hispanic population	Estimate	SE	Wald χ^2	p-value
Intercept	-131.5	69.0034	3.6311	0.0567
incarcrate_hispanic	-0.00702	0.00625	1.262	0.2613
_AGE80	0.7782	0.0297	687.17	<0.0001
p15_44hispanic	-2.1443	2.5009	0.7352	0.3912
pfemalehispanic	2.7055	2.1152	1.6361	0.2009
ppophispanic	-0.0697	0.0971	0.5155	0.4728
phsgradhispanic	-0.1321	0.5672	0.0542	0.8159
ppovertyhispanic	-0.4212	0.2458	2.9368	0.0866
pinsured_hispanic	-0.0676	0.4636	0.0213	0.8841
unemployment_ratehis	0.1016	0.2652	0.1467	0.7017
ppoverty	0.4804	0.9043	0.2822	0.5953
pinsured	7.7318	3.1577	5.9953	0.0143
unemployment_rate	0.8168	1.2204	0.4479	0.5033
urbanicity	0.034	0.3357	0.0102	0.9194
stigma	-0.1873	0.1865	1.0089	0.3152
phys_per1000	-1.1973	2.718	0.194	0.6596
per_capita	0.0136	0.0186	0.5386	0.463
Hispanic_prevalence	-0.0198	0.0107	3.4475	0.0633
incarcrat*ln_incarcr	0.00084	0.00081	1.0743	0.3
_AGE80*ln_age80	-0.1675	0.00624	719.59	<.0001
p15_44his*ln_p15_44h	0.4412	0.5143	0.7359	0.391
pfemalehi*ln_pfemale	-0.5637	0.4393	1.6465	0.1994
ppophispa*ln_ppophis	0.0233	0.0241	0.9342	0.3338
phsgradhi*ln_phsgrad	0.0288	0.1292	0.0498	0.8234
ppovertyh*ln_ppovert	0.1035	0.0604	2.938	0.0865
pinsured_*ln_pinsure	0.0138	0.0856	0.026	0.8719
unemploym*ln_unemplo	-0.0261	0.0944	0.0765	0.7821
ppoverty*ln_ppoverty	-0.13	0.2482	0.2745	0.6003
pinsured*ln_pinsured	-1.4088	0.5762	5.9783	0.0145
unemploym*ln_unemplo	-0.3408	0.4581	0.5533	0.457
urbanicit*ln_urbanic	-0.00882	0.0631	0.0196	0.8888
stigma*ln_stigma	0.0596	0.1042	0.3275	0.5671
phys_per1*ln_phys_pe	0.6735	1.4013	0.231	0.6308
Hispanic_*ln_hispani	0.00288	0.0015	3.6968	0.0545

Figure 2A.1a. Identifying outliers, all BRFSS participants

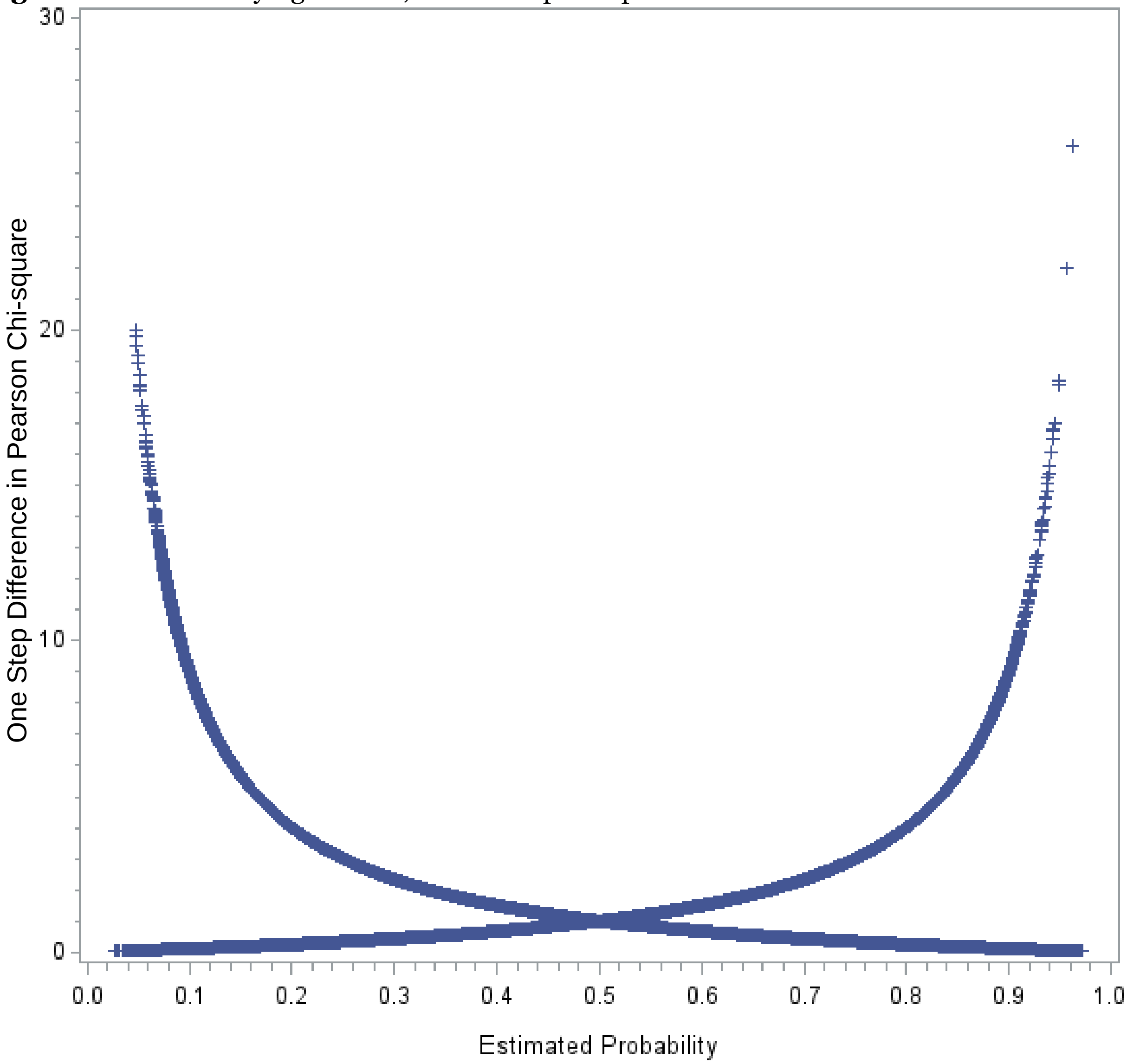


Figure 2A.1b. Identifying outliers, Black BRFSS participants

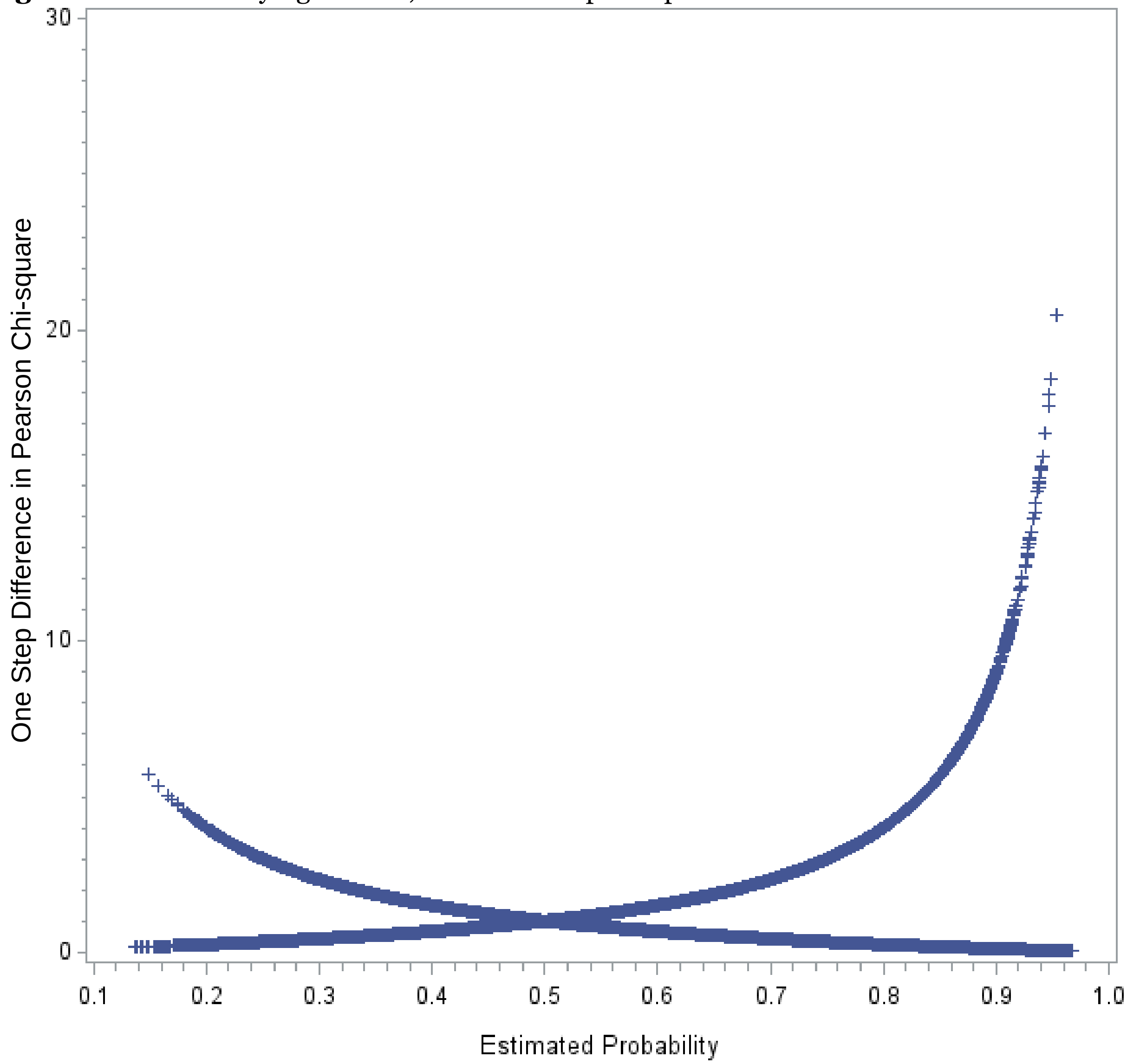
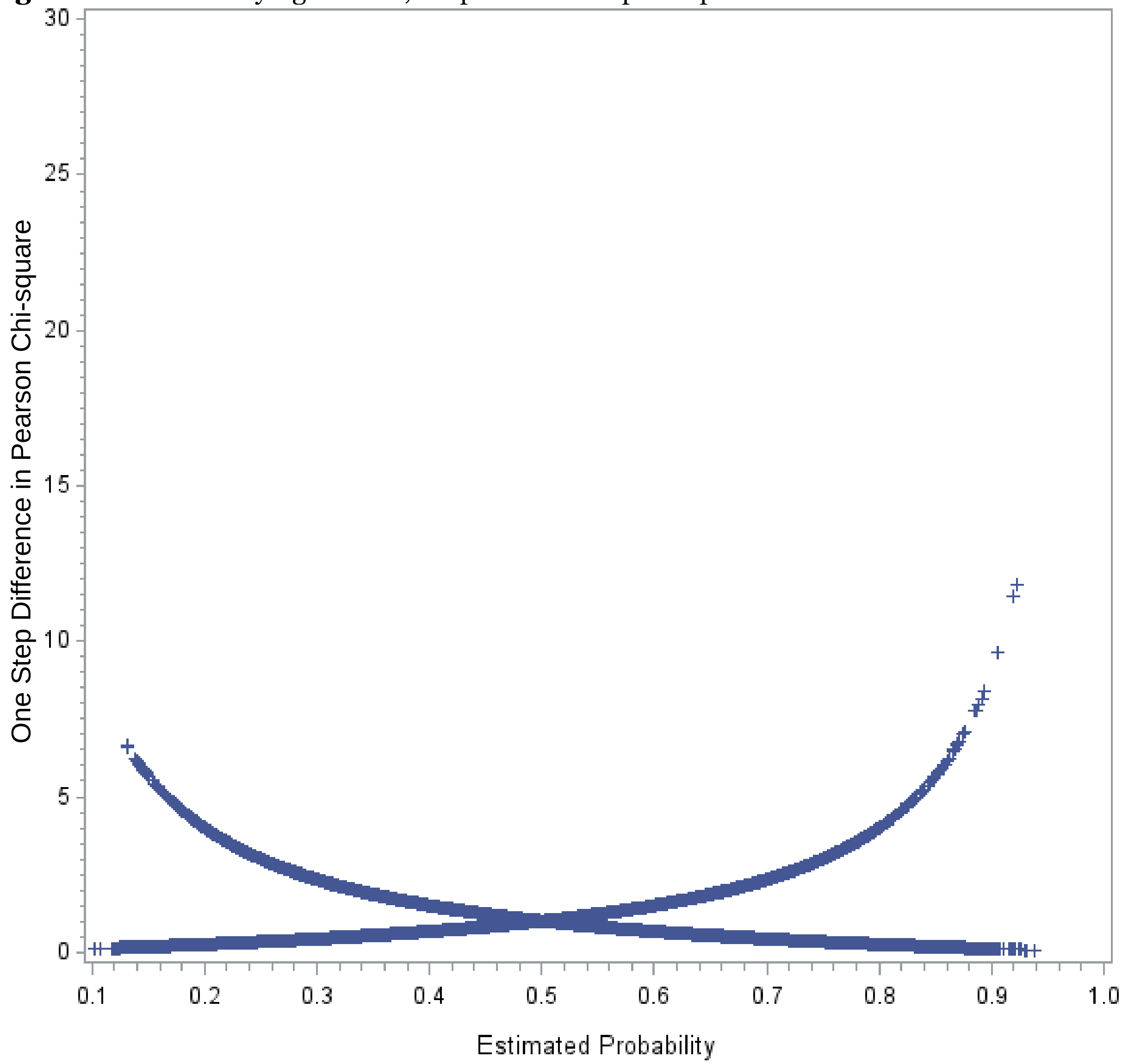


Figure 2A.1c. Identifying outliers, Hispanic BRFSS participants



Chapter 3.
How do state HIV criminalization laws and over-policing at the state level affect state-level HIV incidence rates?

Chapter 3: How do state HIV criminalization laws and over-policing at the state level affect state-level HIV incidence rates?

3.0 Abstract

Introduction: HIV criminalization laws are defined as HIV-specific laws that criminalize or control behaviors that can potentially expose another person to HIV. Public health law experts and advocates have long argued that such laws are counterproductive because they counteract effective public health messages on HIV prevention and safer sex and deter HIV testing. This study used a longitudinal design with state-level data from 2010-2019 to test the hypothesis that HIV criminalization laws are associated with higher HIV incidence among Black and Hispanic populations, and that this effect is modified by heavier policing (using incarceration rates as a proxy).

Methods: State-level HIV incidence data from 2010-2019 were merged with state-level demographic, socioeconomic, incarceration rate, and HIV-related sociologic and economic data. For the general population HIV incidence rate, all 50 states and the District of Columbia were included (N=51); for the Black and Hispanic populations, states with stable HIV incidence rates for >5 years were included (N=40 and N=39, respectively). HIV incidence rates over time and incarcerated population rates by state were visualized. Three multivariate marginal Poisson (log-linear) GEE models were fitted for each population of interest. Terms for the presence of an explicit HIV criminalization statute and the statewide incarceration rate, as well as an interaction between the two, were included in all models.

Results: For the general and Hispanic populations, an HIV criminalization law was associated with higher statewide HIV incidence rate (aRR=1.48 and 1.68, respectively), and the association was marginally significant for both models (p=0.0554 and 0.0873, respectively). A higher statewide incarceration rate was also significantly associated with a higher HIV incidence rate for the general population (aRR=1.0005). No significant effect modification between

incarceration and HIV criminalization was observed. Among the Black population, neither HIV criminalization nor the state incarceration rate was significantly associated with HIV incidence. **Conclusion**: HIV incidence at the state level may be increased by HIV criminalization laws and higher state-level incarceration rates. State policy makers in states with HIV criminalization laws should consider how these laws, as well as heavier policing, may inadvertently increase HIV transmission.

3.1 Introduction

Since the first U.S. case of HIV was identified in 1981, the epidemic has resulted in over 700,000 deaths, and there are currently more than 1.1 million people living with HIV in the U.S. (116). Nearly 37,000 people received an HIV diagnosis in 2019, the most recent year for which national data are available (117). Of those, 41.7% were among Black individuals (despite comprising only 13.4% of the population) and 28.5% among Hispanic individuals (despite comprising only 18.5% of the population), compared to 24.5% among non-Hispanic white individuals (who make up 76.3% of the population) (118). Black and Hispanic individuals are overrepresented in new diagnoses among men who have sex with men (MSM), transgender individuals, and persons who inject drugs (PWID), and a disproportionately high number of new diagnoses among females occur in Black women (117, 119). Both groups are also disproportionately affected by ecosocial determinants of excess HIV risk, including poverty, unemployment, and education disparities (41, 72, 73), which represent structural barriers to health.

HIV criminalization laws are defined as HIV-specific laws that criminalize or control behaviors that can potentially expose another person to HIV (121). This includes laws that target sexual intercourse and other sexual contact; injection drug use (IDU) or parenteral transfer; exposure via biting, spitting, or scratching; or exposure via organs, blood, or bodily fluids (122). Much ink has been spilled interrogating both the morality and efficacy of such statutes (123). Public health professionals, lawyers, and advocates are in nearly universal agreement that laws criminalizing HIV are counterproductive (43-50), with high potential to further criminalize groups already at higher risk for HIV, including Black and Hispanic individuals, and counteract effective public health messages on HIV prevention and safer sex. Many researchers hypothesize that HIV criminalization laws discourage testing, and therefore indirectly increase HIV transmission, because individuals must be aware of their HIV status to be criminally liable (41, 50, 57, 58).

Overpolicing in Black and Hispanic communities of color may serve as an independent structural determinant of HIV transmission by inducing changes in behavior that increase HIV risk. Both Black and Hispanic individuals have been shown to be significantly more likely to report having negative interactions with police, to believe that police engage in misconduct, and to live in heavily-policed neighborhoods (107). Heavier policing of Black and Hispanic males drives them to "go into hiding," reducing their participation in civic social life to avoid contact with law enforcement and the criminal justice system (62). This may contribute to Black and Hispanic men avoiding HIV testing as a means of "system avoidance" (108). While Black and Hispanic individuals are more likely than other racial and ethnic groups to get tested for HIV (101, 104, 112), they are also more likely to be tested and diagnosed late in the course of infection. Previous studies using NHBS data (113) and nationally representative survey data (112) have found that around a third of Black and Hispanic participants have never been tested for HIV, despite its increased prevalence among these groups. Because Black and Hispanic individuals are also at higher risk of being targeted by law enforcement, they are naturally motivated to reduce the ability of the justice system to charge them with additional offenses. In order to test the hypotheses that (1) state HIV criminalization laws are associated with higher state-level HIV transmission rates and (2) this association is modified by heavier policing (using incarceration rates as a proxy) at the state level, I conducted a longitudinal study using annual state HIV incidence data from 2010-2019, with U.S. states as the level of analysis.

3.2 Methods

3.2.1 Data sources

Statewide HIV incidence rates for the general population and for the Black and Hispanic populations from 2010-2019 were be obtained from AIDSVu (124). Data on HIV criminalization laws by state were obtained from the U.S. Centers for Disease Control and Prevention (121), the Center for HIV Law and Policy (122), Lambda Legal (27), the LawAtlas Policy Surveillance Program (128), and Trevor Hoppe's book *Punishing Disease: HIV and the Criminalization of Sickness* (129). Each state was coded as either having an HIV-specific criminalization law or not (1 or 0). State population demographic (percent ages 15-44, percent Hispanic, percentage of the population made up of racial minorities) and socioeconomic (overall and race-specific percent below the federal poverty level, unemployment rate, educational attainment) covariates were derived from the American Community Survey one-year state estimates. The percentage of the population residing in urban areas for each state was taken from the 2010 decennial Census. Percentages were coded as integers in the data (0-100). Federal HIV spending (dollars per capita) was calculated using data on total federal HIV spending from the Kaiser Family Foundation (147). A composite variable representing state-level structural stigma against sexual and gender minorities was obtained from a previous analysis by Tran, Hatzenbuehler, and Goldstein (149). Finally, total incarcerated population (jails and prisons combined) rates (incarcerated persons per 100,000 adults) were used as a proxy measure for state-level policing. Incarceration rates were calculated using data from the Bureau of Justice Statistics (159-161) and the Vera Institute of Justice Incarceration Trends project (138). Incarceration data were available through 2018; available rates were used to extrapolate incarceration rates for 2019.

3.2.2 Study population and descriptive analysis

This was an ecological analysis on the state level. All fifty states and the District of Columbia (the full population of state-level jurisdictions) were included in the analysis (N=51). Descriptive statistics were generated to characterize HIV incidence rates and incarceration rates for the general population and for the Black and Hispanic populations. Whether or not each state has a law criminalizing HIV exposure is displayed in Figure 3.1. Median HIV incidence rates for each population group, as well as state-specific HIV incidence rates, over the ten-year time period are displayed in Figure 3.2. State-level incarceration rates for the general, Black, and Hispanic populations are shown in Figure 3.3.

Figure 3.1. HIV criminalization laws by state

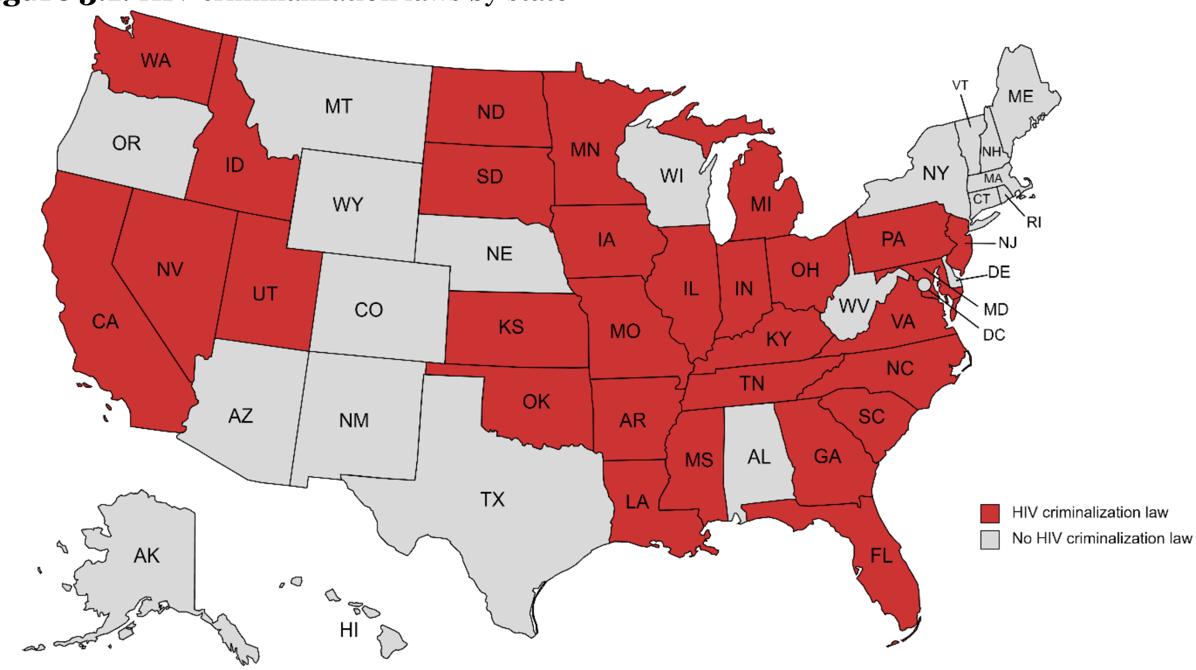
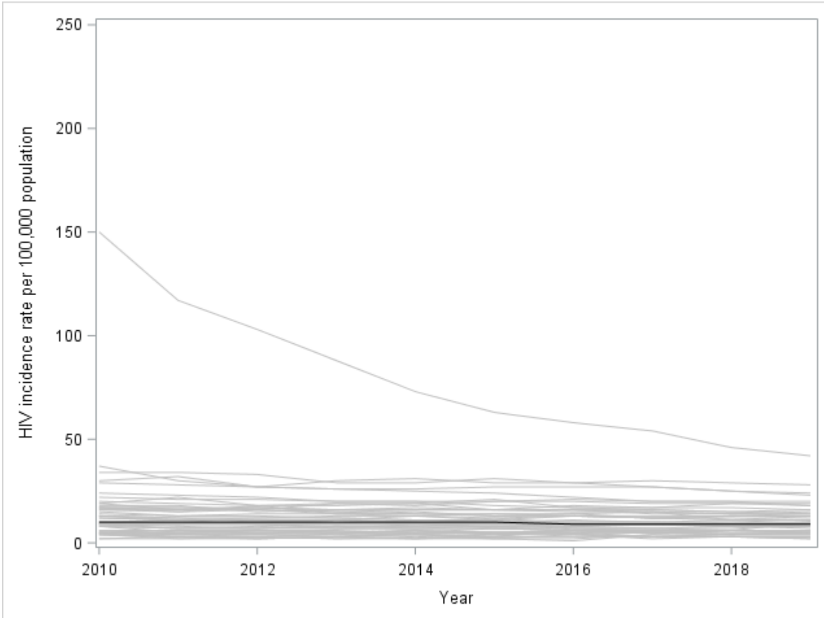
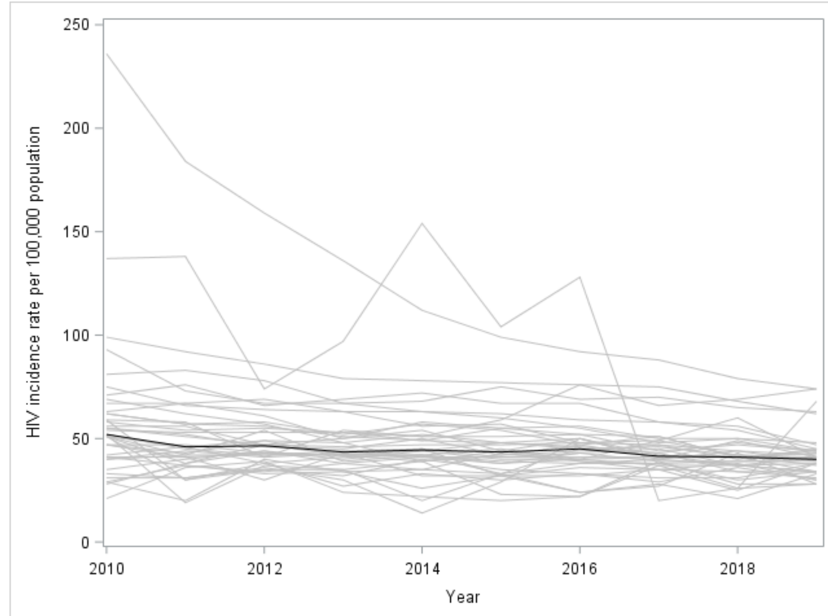


Figure 3.2. HIV incidence rates for the general (a), Black (b), and Hispanic (c) populations, 2010-2019

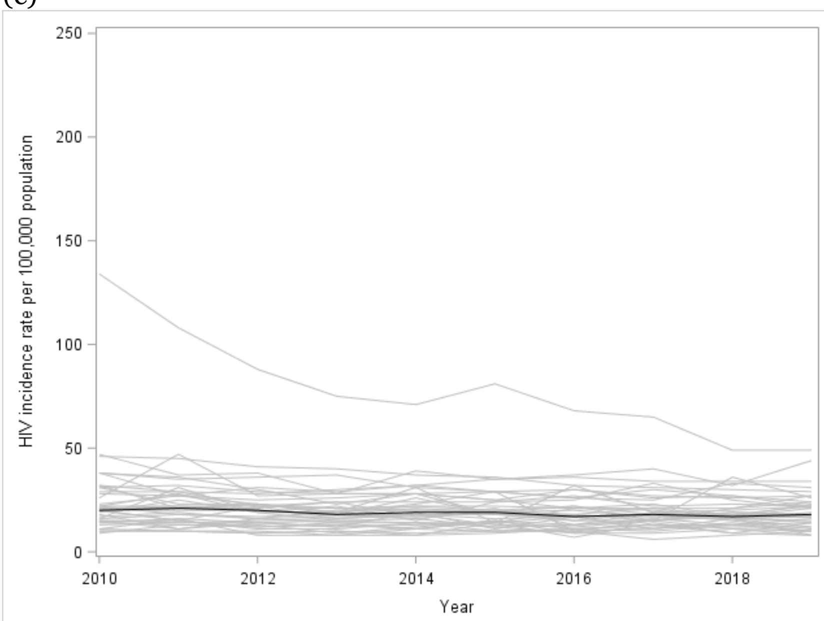
(a)



(b)



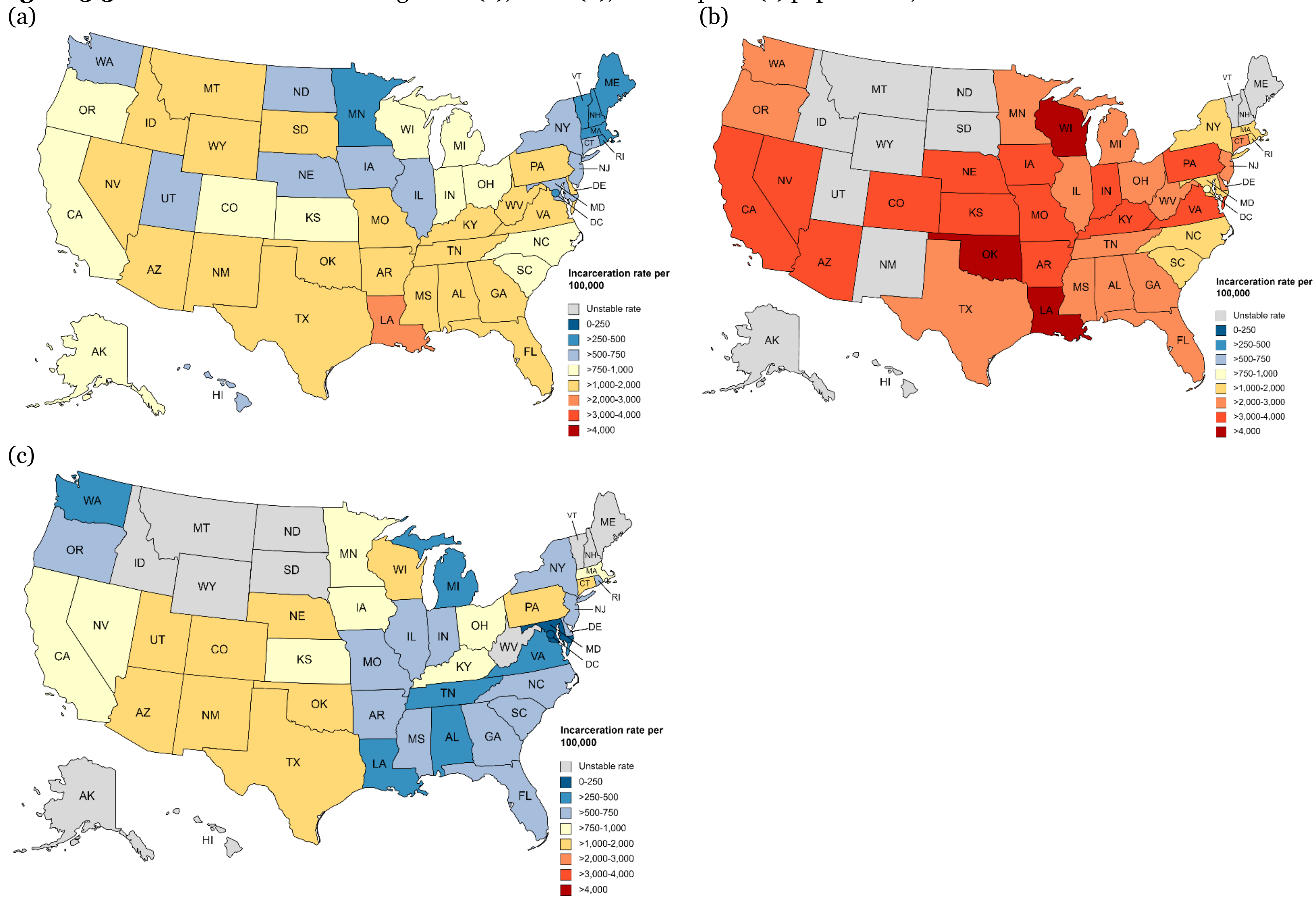
(c)



Notes: Individual state incidence rates are in gray. The median rate for all states is in black.

Figures 3.2(b) and 3.2(c) exclude Alaska, Hawaii, Idaho, Montana, New Hampshire, North Dakota, South Dakota, Vermont, and Wyoming due to unstable HIV incidence rates for over half of the analysis time period. Figure 3.2(b) also excludes New Mexico and Utah. Figure 3.2(c) also excludes Delaware, Maine, and West Virginia.

Figure 3.3. Incarceration rates for the general (a), Black (b), and Hispanic (c) populations, 2018



3.2.3 Poisson GEE regression models

Three multivariate marginal Poisson (log-linear) GEE models were fitted, using extra-Poisson variance to account for overdispersion and the autoregression covariance matrix structure to account for serial correlation within each state (162). Terms for the exposure of interest (the presence of an explicit HIV criminalization statute) and the effect modifier (the statewide incarceration rate), as well as an interaction between the two, were included in all models. The year was also included to account for secular trends. Demographic and socioeconomic covariates on the state level were included in all models. For the general population model, these covariates corresponded to the general population for each state; for the Black and Hispanic population-specific models, covariates specific to those populations were used. Additionally, the Black and Hispanic population models only included states where the HIV incidence rate was considered stable for the majority of the time period (N=40 and 39, respectively). The analyses were conducted using SAS 9.4 (153). This study was determined to not be human subjects research and is therefore exempt from review by the University of Maryland College Park Institutional Review Board (reference #1811297-1).

3.3 Results

3.3.1 Descriptive analysis

Figures 3.2(a)-3.2(c) show HIV incidence rates per 100,000 population by state for the general population and for the Black and Hispanic populations, respectively. Rates ranged from a low of 2 per 100,000 for the general population in Idaho, Montana, New Hampshire, North Dakota, and Vermont to a high of 236 per 100,000 in Washington, D.C. HIV incidence either held constant or decreased over the analysis time period in all states.

Figures 3.3(a)-3.3(c) show incarceration rates per 100,000 adult population by state for the general population and for the Black and Hispanic populations, respectively. Rates ranged from a low of 165.40 per 100,000 for the Hispanic population in Washington, D.C. to a high of

5,061.74 per 100,00 for the Black population in Wisconsin. Statewide incarceration rates were lowest for the Hispanic population in 30 states and highest for the Black population in all states.

3.3.2 Model results

Parameter estimates and rate ratios for the model fitted for the general population are shown in Table 3.1. Having an HIV criminalization law was associated with a higher HIV incidence rate (aRR=1.48, 95% CL 0.99-2.22), and the association was marginally significant (p=0.0554). A higher statewide HIV incarceration rate was also significantly associated with a higher incidence rate (aRR=1.0005, 95% CL 1.0001-1.0009). However, a higher statewide incarceration rate did not modify the effect of the law in states that criminalize HIV transmission.

State-level demographic patterns that were significantly associated with higher HIV incidence at the state level included the percentage of the population that is Black (aRR=1.04, 95% CL 1.03-1.05), the percentage of the population with Hispanic ethnicity (aRR=1.01, 95% CL 1.00-1.02), and the percent living in an urban area (aRR=1.01, 95% CL 1.00-1.02). Female (aRR=1.08, 95% CL=0.99-1.17) and Asian (aRR=1.01, 95% CL 0.99-1.02) population percentages were also marginally significant. Socioeconomic status indicators with a significant association with the HIV incidence rate were the percentage of the population with a high school diploma, which was associated with higher HIV incidence (aRR=1.02, 95% CL 1.00-1.03), and the percent with some college education, which was associated with lower HIV incidence (aRR=0.99, 95% CL 0.99-1.00). The statewide age distribution, federal HIV expenditure, and state-level SGM stigma were not significantly associated with new HIV diagnoses.

Table 3.2 displays model parameter estimates and rate ratios for the Black population model. Unlike the model for the general population, the presence of a statewide HIV criminalization law was not significantly associated with a higher HIV incidence rate among the Black population at the state level (aRR=1.32, 95% CL 0.81-2.15). The statewide Black

Table 3.1. Parameter estimates for general population model for predicting statewide HIV incidence rate, 2010-2019 (N=51)

Parameter	aRR	95% CL		p-value
Exposures				
HIV criminalization law (yes/no)	1.4848	0.9909	2.2249	0.0554
Incarceration rate	1.0005	1.0001	1.0009	0.0086
Law*Incarceration interaction term¤	0.9997	0.9993	1.0001	0.1681
Demographics				
% Female	1.0785	0.9937	1.1706	0.0705
% Age 15-44	1.0101	0.9593	1.0634	0.7046
% Black or African American	1.0408	1.0321	1.0496	<0.0001
% Asian	1.0079	0.9997	1.0162	0.0581
% Hispanic (any race)	1.0146	1.0054	1.0239	0.0017
% Living in urban area	1.0126	1.0052	1.0199	0.0007
Socioeconomic status indicators				
% Graduated high school	1.0176	1.0071	1.0281	0.0009
% Some college	0.9936	0.9913	0.9959	<0.0001
% Living in poverty	0.9977	0.9866	1.0088	0.6815
State unemployment rate	1.0053	0.9874	1.0235	0.5639
HIV-relevant indicators				
HIV federal spending per capita	1.0030	0.9975	1.0086	0.2867
SGM stigma	0.9785	0.9502	1.0077	0.1477
Year	**0.9741**	**0.9544**	**0.9944**	**0.0126**

¤ *The interaction term effect represents a ratio of risk ratios*

incarceration rate showed no association with the statewide Black HIV incidence rate, nor did it modify the effect of the law. Demographic factors that showed a significant association with a higher HIV diagnosis rate included the percentage of the population that is female (aRR=1.02, 95% CL 1.00-1.05). Socioeconomic factors associated with a lower rate of new HIV diagnoses included the statewide Black unemployment rate (aRR=0.99, 95% CL 0.98-1.00). The percentage of the Black population living in poverty (aRR=1.02, 95% CI 1.01-1.04) and federal spending on HIV programs per capita (aRR=1.01, 95% CL 1.00-1.01) were both significantly associated with higher HIV incidence among the Black population. Age distribution, educational attainment, the percentage of the state population that is Black, and the percentage living in urban areas showed no association with the statewide Black HIV incidence rate.

Parameter estimates and rate ratios for the Hispanic population model are displayed in Table 3.3. The presence of a state HIV criminalization law was positively associated with the

Table 3.2. Parameter estimates for Black population model for predicting statewide Black HIV incidence rate, 2010-2019 (N=40)

Parameter	aRR	95% CL		p-value
Exposures				
HIV criminalization law (yes/no)	1.3175	0.8064	2.1522	0.2710
Incarceration rate	1.0000	0.9999	1.0002	0.6782
Law*Incarceration interaction term¤	0.9999	0.9998	1.0001	0.4750
Demographics				
% Female (Black pop.)	1.0236	1.0010	1.0466	0.0402
% Age 15-44 (Black pop.)	1.0074	0.9805	1.0351	0.5917
% Black or African American	1.0097	0.9959	1.0239	0.1691
% Living in urban area	0.9918	0.9788	1.0050	0.2230
Socioeconomic status indicators				
% Graduated high school (Black pop.)	1.0112	0.9884	1.0344	0.3408
% Some college (Black pop.)	0.9994	0.9783	1.0209	0.9581
% Living in poverty (Black pop.)	1.0226	1.0058	1.0397	0.0082
State unemployment rate (Black pop.)	0.9852	0.9769	0.9936	0.0006
HIV-relevant indicators				
HIV federal spending per capita	1.0067	1.0024	1.0110	0.0022
SGM stigma	0.9214	0.8693	0.9766	0.0058
Year	**0.9636**	**0.9417**	**0.9859**	**0.0015**

¤ *The interaction term effect represents a ratio of risk ratios*

statewide Hispanic HIV incidence rate (aRR=1.68, 95% CL 0.93-3.03), and the association was marginally significant (p=0.0873). The state Hispanic incarceration rate showed no significant association with HIV diagnoses in the Hispanic population, nor did it significantly modify the association between the HIV criminalization law and new diagnoses. Per capita federal spending on HIV programs was significantly associated with new HIV diagnoses in the Hispanic population (aRR=1.01, 95% CL 1.01-1.02). The Hispanic unemployment rate (aRR=0.98, 95% CL 0.97-1.00) was marginally associated with a lower HIV incidence rate among the Hispanic population. The age and sex distributions, Hispanic population percentage, urbanicity, educational attainment, poverty, and state-level SGM stigma showed no significant association with the Hispanic HIV incidence rate.

3.4 Discussion

In this analysis, I tested whether state HIV criminalization laws are positively associated with the statewide HIV incidence rate, and whether this relationship is modified by higher statewide incarceration rates (to represent heavier policing at the state level). In both the general population and the Hispanic population, the presence of a state HIV testing law was associated with a higher rate of new HIV diagnoses; heavier policing (as represented by the state incarceration rate) was also significantly associated with an increased HIV incidence rate for the general population only. However, higher incarceration at the state level did not significantly modify the relationship between the law and HIV incidence. Neither of these factors significantly impacted HIV incidence among the Black population.

Only three quantitative analyses using existing data have examined whether HIV criminalization laws are associated with higher HIV rates, and they have used varying methods and found conflicting results. Using cross-sectional data from 2010, Forsyth and Valdiserri (41) found no significant association between state-level HIV-specific criminalization laws and AIDS diagnosis rates among MSM. Only two longitudinal studies on the relationship between HIV criminalization laws and HIV incidence rates have been published to date, and they reached opposite conclusions. Using generalized estimating equations, Sweeney et al. (73) found no significant association between AIDS diagnoses from 1994 to 2010 and HIV criminalization laws by state. Using the same data, covariates, and analytic approach, however, Sah et al. (115) examined the laws' association with the proportion of PLWH diagnosed and the annual percentage change in HIV prevalence. They drew very different inferences as a result, concluding that HIV criminalization laws are associated with a lower proportion of HIV diagnosis and increased HIV prevalence. The results of this analysis, which use HIV incidence (rather than AIDS diagnoses) and more recent data, support the findings of Sah and colleagues.

The association between the state incarcerated population rate and HIV incidence in the general population may be explained the higher overall risk of HIV acquisition among individuals involved with the criminal justice system. Despite declining steadily over the last 20

Table 3.3. Parameter estimates for the Hispanic population model for predicting statewide HIV incidence rate, 2010-2019 (N=39)

Parameter	aRR	95% CL		p-value
Exposures				
HIV criminalization law (yes/no)	1.6770	0.9271	3.0331	0.0873
Incarceration rate	1.0003	0.9999	1.0007	0.1693
Law*Incarceration interaction term¤	0.9997	0.9991	1.0003	0.3134
Demographics				
% Female (Hispanic pop.)	0.9722	0.9339	1.0122	0.1700
% Age 15-44 (Hispanic pop.)	1.0261	0.9913	1.0620	0.1430
% Hispanic	0.9942	0.9828	1.0057	0.3210
% Living in urban area	1.0115	0.9957	1.0274	0.1548
Socioeconomic status indicators				
% Graduated high school (Hispanic pop.)	0.9993	0.9817	1.0172	0.9392
% Some college (Hispanic pop.)	0.9956	0.9847	1.0065	0.4279
% Living in poverty (Hispanic pop.)	1.0086	0.9926	1.0248	0.2937
State unemployment rate (Hispanic pop.)	0.9840	0.9664	1.0020	0.0821
HIV-relevant indicators				
HIV federal spending per capita	1.0113	1.0066	1.0158	<0.0001
SGM stigma	0.9688	0.9165	1.0241	0.2630
Year	**0.9894**	**0.9603**	**1.0193**	**0.4816**

¤ *The interaction term effect represents a ratio of risk ratios*

years, HIV prevalence in U.S. prisons is still approximately five times that of the U.S. general population, and incarceration is considered an independent risk factor for HIV (163, 164). This phenomenon may not have been seen in the Hispanic population model due to lower overall incarceration rates for the Hispanic population. This may reflect a truly lower incarceration rate than other demographic groups, or it may be due to the fact that data collection on ethnicity in state criminal justice departments is of inconsistent quality and is often poor (141).

3.4.1 Limitations

One limitation of this study is its small population size. Because this is a state-level analysis, the total population is N=51, which is fairly small by epidemiologic standards. The number of states was even smaller for the models fitted with data from the Black and Hispanic populations. HIV incidence rates for the Black and Hispanic populations were unstable for all or most years for N=10 and N=11 states, respectively. This may have resulted in low statistical power and lack of precision in parameter estimates.

The results of the marginal Poisson models using GEE should be interpreted with caution, particularly when considering the estimated independent effect of the law itself. Every state in the U.S. has prosecuted HIV exposure in some way, such as through the use of general criminal statutes in states that do not have HIV-specific criminal laws (126, 127). Thus, HIV criminalization occurs in some form in every state. That being said, the overwhelming majority of the literature on this topic has specifically argued the shortcomings and potential for harm of criminal laws that explicitly target HIV and has called for empirical research that investigates the effects of these HIV-specific criminalization laws (19, 39, 42, 43, 47, 137, 165, 166).

Finally, the imprisonment rate may be an imperfect proxy for overpolicing. While Black and Hispanic individuals are disproportionately represented in jails and prisons, overpolicing does not always lead to arrest, and so the imprisonment rate in a state may not fully capture the extent to which these individuals perceive overpolicing, which can also include harassment by police officers or arrests that do not lead to imprisonment.

3.4.2 Strengths

Despite the limitations in the available data, this study has several notable strengths. To date, there have been few quantitative analyses that measure the effects of HIV criminalization laws on HIV incidence rates, and those that exist use much older data (41, 73, 114). Thus, this analysis will contribute to addressing a gap in knowledge by harnessing the strengths of the longitudinal study design, which include the ability to control for variation within each state (intra-subject variation) as well as secular trends in HIV prevalence. This is also only the second study to estimate the effects of the justice system on race-specific rates (82), as well as only the second one to use an interaction term in conjunction with the existence of HIV criminalization laws to measure factors related to HIV transmission in populations (58).

3.5 Conclusion

HIV criminalization laws have long been contested as a tool for HIV prevention, with public health and human rights advocates arguing that they are ineffective and may have a counteractive effect. However, few studies have attempted to measure the effect of these laws on HIV transmission, and those that have arrived at conflicting results. This study contributes to the legal and policy epidemiology literature by using recent data to estimate the association of HIV criminalization laws, as well as the potential for their enforcement, with HIV incidence rates at the state level. The body of commentary on HIV criminalization laws has noted repeatedly that it is impossible to enforce HIV criminalization laws uniformly across the entire population (7, 40); indeed, a previous descriptive analysis of criminal prosecutions for HIV exposure (19) found no evidence of systemic enforcement of these laws but noted that "[w]hat seems to determine who gets prosecuted is the accident of being caught." State policy makers in states with HIV criminalization laws should consider how these laws, as well as heavier policing, may affect population-level HIV transmission dynamics and inadvertently drive HIV transmission. Policy makers should work toward eliminating HIV criminalization laws or reforming them so that (1) they require criminal intent for prosecution and (2) they take into consideration behaviors that eliminate to substantially reduce risk (e.g., condom usage and viral suppression through medication adherence) (22). This could go a long way toward minimizing the potential for heavy policing and selective enforcement to have a detrimental effect of HIV prevention

Chapter 4.
How do state HIV criminalization laws and over-policing at the county level affect county-level HIV incidence rates?

Chapter 4: How do state HIV criminalization laws and over-policing at the county level affect county-level HIV incidence rates?

4.0 Abstract

Introduction: The U.S. HIV epidemic is concentrated in a small number of jurisdictions, primarily urban areas and the South. It also disproportionately affects Black and Hispanic communities, which are more likely to be located in the aforementioned areas. Individuals in these communities are disproportionately affected by ecosocial determinants of excess HIV risk, including poverty, unemployment, and education disparities, as well as overpolicing, which further exacerbates the individual- and community-level risk socioeconomic risk factors for HIV. HIV criminalization laws, defined as HIV-specific laws that criminalize or control behaviors that can potentially expose another person to HIV, also represent a structural barrier to health. This study used multilevel modeling with state- and county-level data from 2010-2018 to test the hypothesis that HIV criminalization laws are associated with higher county HIV incidence, and that this effect is modified by heavier county-level policing (using jailed population rates as a proxy), with U.S. counties nested within states.

Methods: County-level HIV incidence data from 2010-2019 were merged with county-level demographic, socioeconomic, and jailed population rate data for counties with stable HIV incidence rates for >5 years. State-level data included HIV criminalization law data and HIV-related sociologic and economic data. For the general population, 355 counties were included; for the Black population, 179 counties were included; and for the Hispanic population, 102 counties were included. HIV incidence rates over time and incarcerated population rates by county were visualized. Three multivariate multilevel (hierarchical) models for count-rate data were fitted, with years nested inside counties, and counties nested within states. Terms for the presence of an explicit HIV criminalization statute and the county jailed population rate, as well as an interaction between the two, were included in all models.

Results: An HIV criminalization law was associated with higher countywide HIV incidence rate for all three populations (aRR=1.14, 1.30, and 1.32 for the general, Black, and Hispanic populations, respectively). The association was marginally significant for the general and Hispanic population models (p=0.07) and significant for the Black population model (p=0.02). This association was modified by an increased county jailed population rate for the general and Black populations; this effect modification was significant for the general population (p=0.01) and marginally significant for the Black population (p=0.06).

Conclusion: Heavier policing at the county level may affect the timeliness of HIV diagnosis among the general and Black populations. County-level officials and policy makers in states with HIV criminalization laws should consider how community policing dynamics may discourage HIV testing, which is one of the most important strategies for ending the HIV epidemic.

4.1 Introduction

The U.S. HIV epidemic is not geographically uniform. Just as the country's population is concentrated in cities and certain geographic regions, the burden of HIV in the U.S. is concentrated in cities and, by region, the South (167). The burden of HIV is high in urban areas, with 82% of PLWH residing in major urban centers (76). Out of 3,143 counties and county equivalents in the U.S., the U.S. Department of Health and Human Services focused its efforts on just 49 of those jurisdictions (48 counties and Washington, D.C.) in its "Ending the HIV Epidemic" initiative because they accounted for over half of HIV diagnoses in the U.S. (168) An additional seven states, nearly all in the South, were selected because at least 10% of new HIV diagnoses were in rural areas (169).

HIV also disproportionately impacts Black and Hispanic populations in the U.S. Of the nearly 37,000 people received an HIV diagnosis in 2019 (117), 41.7% were among Black individuals and 28.5% among Hispanic individuals, compared to 24.5% among non-Hispanic white individuals; these groups make up 13.4%, 18.5%, and 76.3% of the population, respectively (118). These groups are disproportionately affected by ecosocial determinants of excess HIV risk, including poverty, unemployment, and education disparities (41, 72, 73). Structural determinants create excess HIV risk at the neighborhood level among Black and Hispanic communities by worsening income, unemployment, and education disparities. For example, Black and Hispanic individuals are more likely to live in urban areas (74, 75) and in neighborhoods with concentrated poverty and unemployment (77, 78). These low-income neighborhoods become targets for overpolicing, which further exacerbates the individual- and community-level risk socioeconomic risk factors for HIV (62, 80). It is critical to note that, while these structural determinants may have measurable impacts on HIV-related risk behaviors by the people who experience them, they also create excess risk at the community beyond what the individual can "control." For example, Kelley et al. (81) estimated that Black MSM have a measurably higher risk of HIV exposure *per person increase* in the number of partners when compared to white MSM.

An important, but less studied, HIV-related structural barrier to health faced by Black and Hispanic populations in the U.S. are HIV criminalization laws. HIV criminalization laws exist at the state level and are defined as HIV-specific laws that criminalize or control behaviors that can potentially expose another person to HIV (121). This includes laws that target sexual intercourse and other sexual contact; injection drug use (IDU) or parenteral transfer; exposure via biting, spitting, or scratching; or exposure via organs, blood, or bodily fluids (122). These laws are directly related to overpolicing because HIV transmission-related behaviors cannot be uniformly policed in the general population, so they are disproportionately enforced against marginalized groups. Individuals from Black and Hispanic communities already have more frequent encounters with law enforcement and the justice system, and they are also more likely to have HIV. In states with HIV-specific criminalization laws, when they come into contact with law enforcement, if their HIV status is discovered in the course of the investigation, an HIV criminalization charge could potentially be added to others. This may drive individuals from Black and Hispanic communities to avoid HIV testing to minimize their exposure to liability under the law, which could, in turn, exacerbate HIV transmission, as nearly 40% of all cases of HIV transmission are attributable to individuals who do not know their status (59).

In order to test the hypotheses that (1) state HIV criminalization laws are associated with higher county-level HIV transmission rates and (2) this association is modified by heavier policing (using jailed population rates as a proxy) at the county level, I conducted a multilevel modeling study using annual county HIV incidence data from 2010-2019, with U.S. counties nested within states. Despite the fact that HIV criminalization laws exist at the state level, counties were chosen as the level analysis because of the localized nature of both HIV transmission networks and policing patterns, as noted above.

4.2 Methods

4.2.1 Data sources

County-level HIV incidence rates and rate stability information (rates generated from a numerator less than 12 are considered unstable) for the general population and for the Black and Hispanic populations from 2010-2019 were be obtained from AIDSVu (124). Data on HIV criminalization laws by state were obtained from the U.S. Centers for Disease Control and Prevention (121), the Center for HIV Law and Policy (122), Lambda Legal (27), the LawAtlas Policy Surveillance Program (128), and Trevor Hoppe's book *Punishing Disease: HIV and the Criminalization of Sickness* (129). Each state was coded as either having an HIV-specific criminalization law or not (1 or 0). County population demographic (percent ages 15-24, 25-44, and 45-64; percent Hispanic; percentage of the population made up of racial minorities) and socioeconomic (overall and race-specific percent below the federal poverty level, unemployment rate, educational attainment) covariates were derived from the American Community Survey one-year and five-year (if one-year estimates were not available) county estimates. The urbanization level for each county (on an ordinal scale of 1-6) was taken from the NCHS Urban-Rural Classification Scheme for Counties (146). State-level federal HIV spending (dollars per capita) was calculated using data on total federal HIV spending for each state from the Kaiser

Family Foundation (147). A composite variable representing state-level structural stigma against sexual and gender minorities was obtained from a previous analysis by Tran, Hatzenbuehler, and Goldstein (149). Finally, total jailed population rates (persons in jail per 100,000 adults) were used as a proxy measure for county-level policing. Jail rates were calculated using data from the Vera Institute of Justice Incarceration Trends project (138). Jailed population data were available through 2018; available rates were used to extrapolate jailed population rates for 2019.

4.2.2 Study population and descriptive analysis

This was an ecological analysis on the county level. Connecticut, Delaware, and Vermont had no jail population data for any year, so counties from those states were excluded. All other U.S. counties and county equivalents, including the District of Columbia (hereafter referred to as "counties"), were eligible for inclusion. Counties were included if they had stable HIV incidence rates for the population of interest for at least six of the ten years of the study period. For the general population, this included 355 counties in 43 states. For the Black population, 179 counties in 33 states had stable HIV incidence rates for at least six years over the study period, so those were included in the analysis for that population. For the Hispanic population, 102 counties in 29 states met the Hispanic HIV rate stability criteria and so were included in that analysis. These counties account for 64.0%, 58.4%, and 64.6% of the total, Black, and Hispanic population in the U.S., respectively.

Descriptive statistics showing how counties and their populations were distributed, according to whether or not they are subject to a state-level HIV criminalization law and by urbanicity level, are shown in Table 4.1. Whether or not each state has a law criminalizing HIV exposure is displayed in Figure 4.1. Median HIV incidence rates for each population group, as well as county-specific HIV incidence rates, over the nine-year time period are displayed in Figure 4.2. County-level jailed population rates for the general, Black, and Hispanic populations are shown in Figure 4.3.

Table 4.1. Descriptive statistics for counties included in the analyses for the general, Black, and Hispanic populations, 2019

	General population				Black population				Hispanic population			
	Counties		Population (2019)		Counties		Population (2019)		Counties		Population (2019)	
	N	%	N	%	N	%	N	%	N	%	N	%
Counties	355	100	210,165,450	100	179	100	27,340,891	100	102	100	38,964,302	100
HIV criminalization law												
No	84	23.7	58,629,973	27.9	32	17.9	5,557,038	20.3	32	31.4	13,141,042	34.0
Yes	271	76.3	151,535,477	72.1	147	82.1	21,783,853	79.7	70	68.6	25,554,120	66.0
NCHS urban-rural classification scheme												
Large central metro	63	17.7	93,405,238	44.4	56	31.3	15,073,011	54.9	48	47.1	25,208,118	64.7
Large fringe metro	116	32.7	61,562,321	29.3	51	28.5	6,732,129	24.5	30	29.4	6,503,490	16.7
Medium metro	123	34.6	47,619,648	22.7	53	29.6	4,430,816	16.2	22	21.6	6,629,616	17.0
Small metro	44	12.4	6,827,465	3.2	17	9.5	838,454	3.1	2	2.0	302,919	0.8
Micropolitan	9	2.5	750,778	0.4	2	1.1	86,663	0.3	-	-	-	-

Figure 4.1. HIV criminalization laws by state

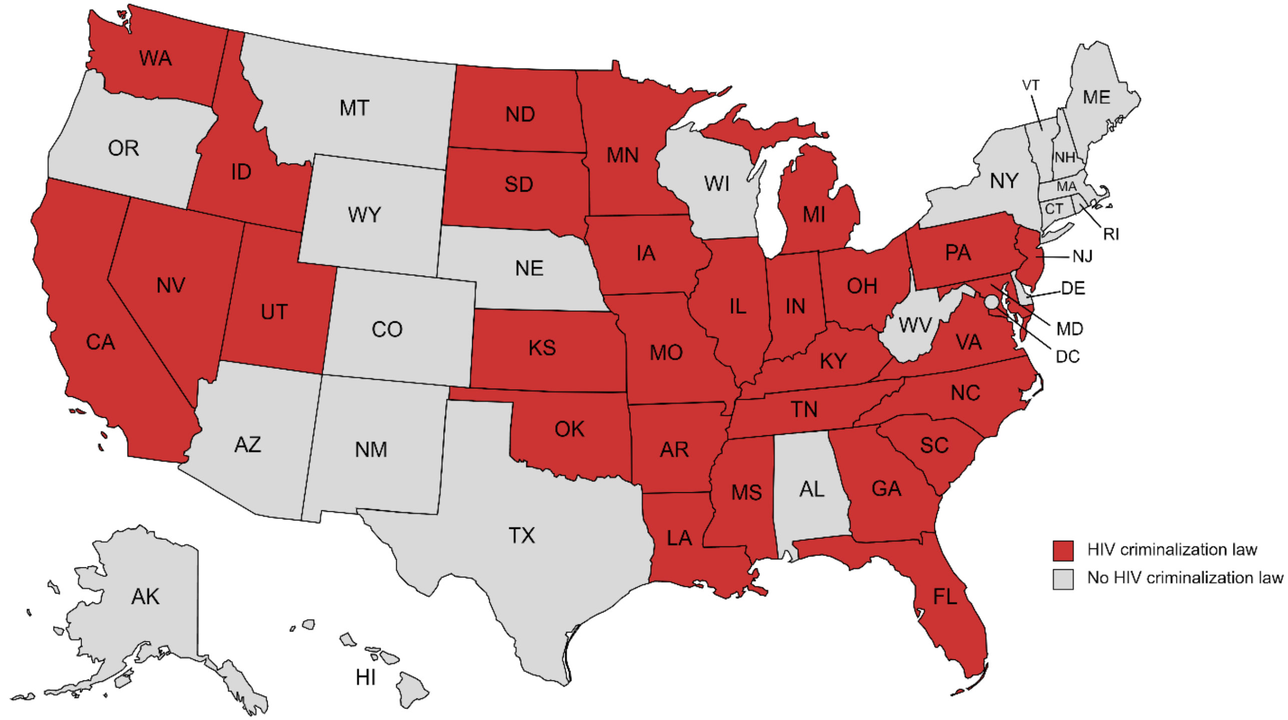
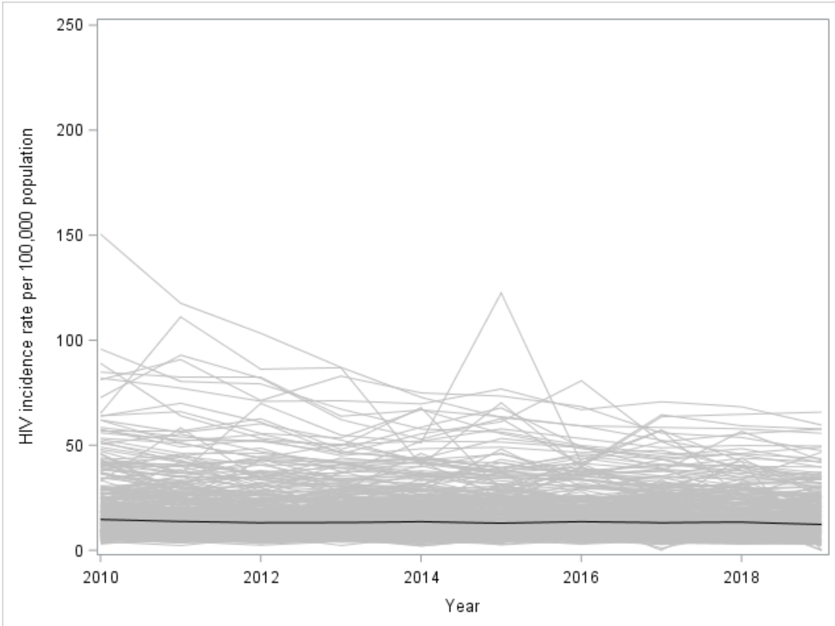
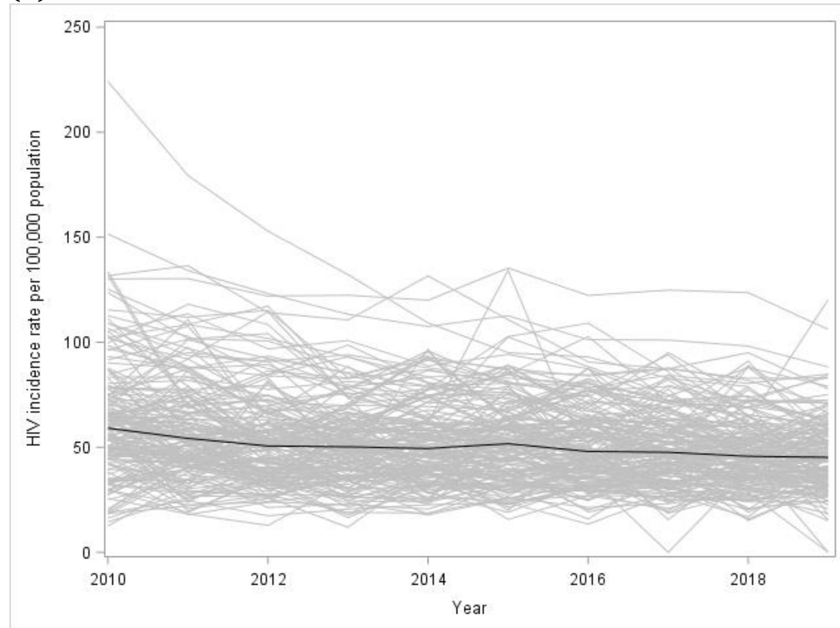


Figure 4.2: HIV incidence rates for the general (a), Black (b), and Hispanic (c) populations, 2010-2019

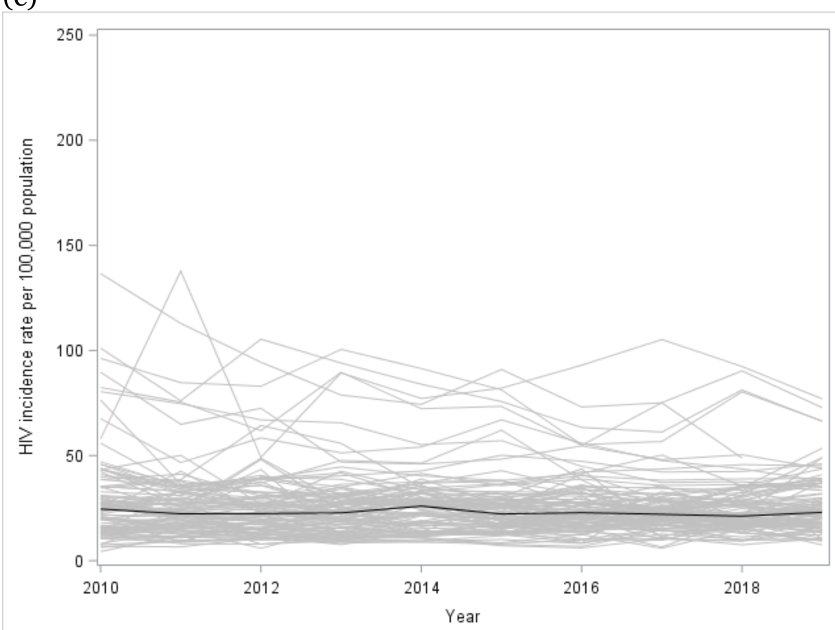
(a)



(b)



(c)

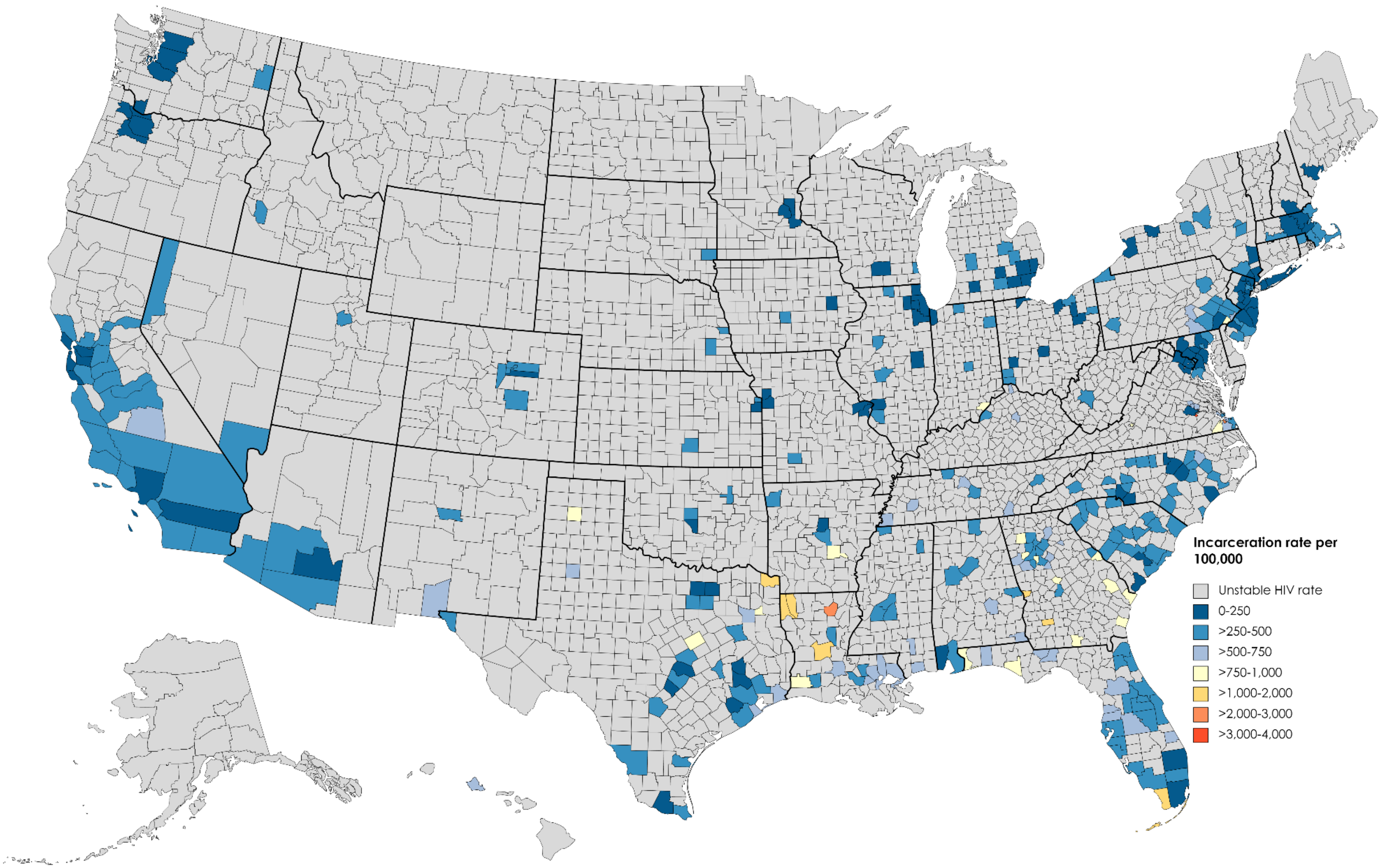


Notes: Individual county incidence rates are in gray. The median rate for all counties is in black.

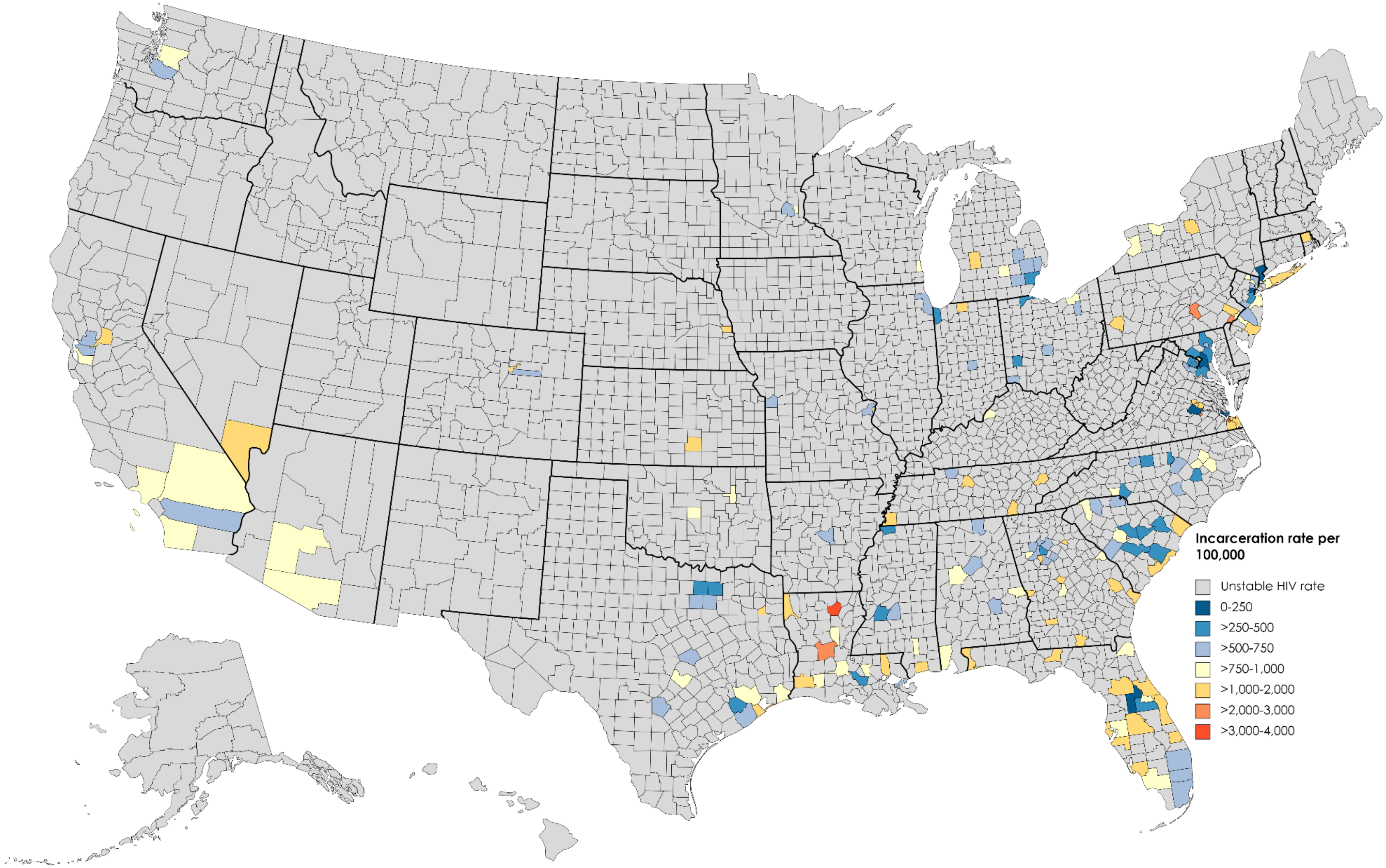
Figure 4.2(a) includes 355 counties from 43 states. Figure 4.2(b) includes 179 counties from 33 states. Figure 4.2(c) includes 102 counties in 29 states.

Figure 4.3: Jailed population rates for the general (a), Black (b), and Hispanic (c) populations, 2018

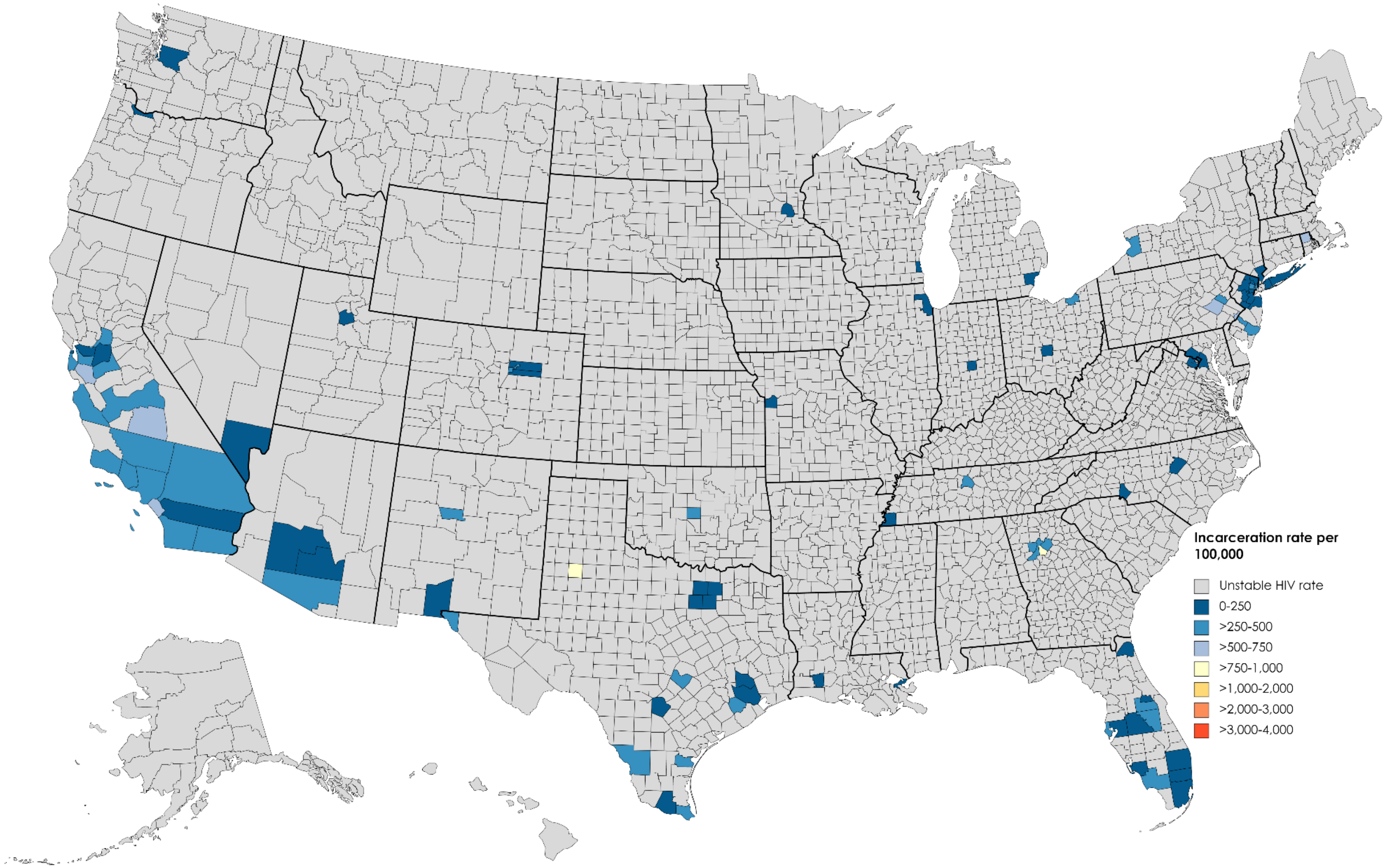
(a)



(b)


Incarceration rate per 100,000
Unstable HIV rate
0-250
>250-500
>500-750
>750-1,000
>1,000-2,000
>2,000-3,000
>3,000-4,000

(c)


Incarceration rate per 100,000
Unstable HIV rate
0-250
>250-500
>500-750
>750-1,000
>1,000-2,000
>2,000-3,000
>3,000-4,000

4.2.3 Multilevel (hierarchical) models

Three multivariate multilevel (hierarchical) models for count-rate data were fitted, with years nested inside counties, and counties nested within states. For the general population, a quasi-Poisson model was used to account for under-dispersion. For the Black and Hispanic populations, negative binomial models were used to account for overdispersion. A Cholesky variance/covariance matrix was used for all three models (152). Terms for the exposure of interest (the presence of an explicit HIV criminalization statute) and the effect modifier (the statewide incarceration rate), as well as an interaction between the two, were included in all models. Demographic and socioeconomic covariates on the county levels were included in all models. For the general population model, these covariates corresponded to the general population for each county; for the Black and Hispanic population-specific models, covariates specific to those populations were used. The analyses were conducted using SAS 9.4 (153). This study was determined to not be human subjects research and is therefore exempt from review by the University of Maryland College Park Institutional Review Board (reference #1811297-1).

4.3 Results

4.3.1 Descriptive analysis

Table 4.1 shows descriptive statistics for the U.S. counties, as well as their resident populations, included in the analyses for each of the three populations. For all three groups, the majority of counties were in states with an HIV-specific criminalization law (76.3% of counties for the general population, 82.1% for the Black population, and 68.6% for the Hispanic population). This meant that the majorities of the populations included in the counties were also living in HIV criminalization states (72.1%, 79.7%, and 66% of the general, Black, and Hispanic populations, respectively). By urbanicity, the largest categories for the general population were medium metro (34.6% of counties) and large fringe metro (32.7% of counties), though nearly half of the population living in this group of counties are in the large central metro urbanicity category (44.4%). In contrast, the largest urbanicity categories for counties included for the

Black population were large central metro and medium metro (31.3% and 29.6% of counties, respectively). For counties included for the Hispanic population, the largest urbanicity category was large central metro (47.1% of counties). For both the Black and Hispanic populations, over half of the populations residing in the included counties lived in large central metro counties (54.9% and 64.7%, respectively). No micropolitan counties were included for the Hispanic population, and none of the three groups included counties in the non-core category.

Figures 4.2(a)-4.2(c) show HIV incidence rates per 100,000 population by county for the general population and for the Black and Hispanic populations, respectively. For the general population, rates ranged from a low of 3 per 100,000 in Chester County, Pennsylvania to a high of 150.5 per 100,000 in Washington, D.C. For the Black population, the lowest county rate was 13.4 per 100,000 in Suffolk County, New York, while the highest was 224.1 per 100,000 in Washington, D.C. Among the Hispanic population, the county rates ranged from 5.9 per 100,00 in San Joaquin and Tulare counties in California to 137.8 per 100,000 in Orleans Parish, Louisiana.

Figures 4.3(a)-4.3(c) show jailed population rates per 100,000 adult population by state for the general population and for the Black and Hispanic populations, respectively. For the general population, rates ranged from a low of 18.8 per 100,000 in Cameron County, Texas to a high of 3,445.6 per 100,00 in Petersburg City, Virginia. Rates for the Black population ranged from 4.6 per 100,000 in Edgecombe County, North Carolina to 3,767.4 per 100,000 in Ouachita Parish, Louisiana. For the Hispanic population, jailed population rates ranged from less than 1 per 100,00 in Fairfax County, Virginia to 2,664.5 per 100,000 in Franklin County, Ohio.

4.3.2 Model results

Effect estimates and rate ratios for the general population model are shown in Table 4.2. Being in a state with an HIV criminalization law was associated with an increase in HIV incidence rate (aRR=1.14, 95% CL=0.99-1.31), and the association was marginally significant (p=0.07). In states without an HIV criminalization law, a higher county jailed population rate was also associated with a higher county HIV incidence rate (aRR=1.0004, 95% CL=1.0002-1.0005). However, in counties within HIV criminalization states, a higher jailed population rate had a counteractive effect, as the interaction term was significantly associated with a decrease in HIV rate ratio between criminalization and non-criminalization states (p=0.01).

County-level demographic factors significantly associated with an increased HIV incidence rate included higher percentages of young people aged 15-24 (aRR=1.03, 95% CL 1.02-1.04), higher percentages of people aged 25-44 (aRR=1.04, 95% CL 1.03-1.05) and 45-64 (aRR=1.04, 95% CL 1.02-1.05), a higher percentage of the population that is Black (aRR=1.03, 95% CL 1.027-1.033) and Asian (aRR=1.01, 95% CL 1.00-1.02), and a higher percentage of Hispanic ethnicity (aRR=1.008, 95% CL 1.005-1.011). Classification as a "large central metro" county was also significantly associated with a higher HIV incidence rate.

Socioeconomic status indicators on the county level associated with higher HIV incidence included a higher percentage of the population living in poverty (aRR=1.006, 95% CL 1.001-1.010) and a higher insured percentage (aRR=1.0004, 95% CL 1.0001-1.0006). Conversely, a higher percentage of the population with a high school diploma or equivalent (aRR=0.9925, 95% CL 0.9856-0.9995) and with some college education (aRR=0.99, 95% CL 0.984-0.996), as well as a higher unemployment rate (aRR=0.993, 95% CL 0.987-0.998), were associated with a lower rate of new HIV diagnoses. Increased state-level HIV spending per capita was also associated with a higher county-level HIV diagnosis rate (aRR=1.005, 95% CL 1.001-1.009).

Table 4.3 shows parameter estimates for the model predicting HIV incidence rate in the Black population. Similar to the general population model, both a state-level HIV criminalization law (aRR=1.30, 95% CL 1.05-1.59) and a higher jailed population rate (for non-criminalization states; aRR=1.0002, 95% CL 1.0001-1.0004) were significantly associated with higher HIV incidence among the county Black population. A higher jailed population rate also modified the effect of the presence of a state HIV criminalization law on the Black HIV incidence rate, as it was associated with a decrease in HIV rate ratio between criminalization and non-criminalization states. This effect modification was marginally significant (p=0.06).

The percentage of the Black population aged 15-24 (aRR=1.01, 95% CL 1.00-1.03) and aged 25-44 (aRR=1.02, 95% CL 1.01-1.03), as well as the percentage of the county population that is Black (aRR=1.009, 95% CL 1.006-1.012) and the percentage of the Black population living in poverty (aRR=1.002, 95% CL 1.000-1.004), were significantly associated with a higher Black HIV incidence rate. Similar to the general population model, classification as a "large central metro" county (aRR=1.43, 95% CL 1.04-1.98) and increased state-level HIV federal spending per capita (aRR=1.006, 95% CL 1.0002-1.010) were also significantly associated with an increase in HIV diagnoses. Conversely, a higher percentage of the Black population with some college education was associated with a decrease in HIV incidence in the county Black population (aRR=0.994, 95% CL 0.990-0.998). Gender balance, the percentage of the population aged 45-64, insurance, and unemployment at the county level were not associated with HIV incidence, nor was stigma against sexual and gender minorities at the state level.

Model estimates and rate ratios for the Hispanic population are shown in Table 4.4. Similar to the general and Black population models, being in an HIV criminalization state was associated with a higher Hispanic HIV incidence rate at the county level (aRR=1.32, 95% CL 0.99-1.81), and the association was marginally significant (p=0.07). However, the Hispanic jailed population rate was not associated with new HIV diagnoses (in non-criminalization states), nor did it modify the association between HIV criminalization and HIV incidence.

Demographic factors associated with an increase in county HIV incidence included the percentage of the population aged 15-24 (aRR=1.05, 95% CL 1.03-1.08), 25-44 (aRR=1.02, 95% CL 1.00-1.05), and 45-64 (aRR=1.03, 95% CL 1.00-1.05). Federal HIV spending per capita at the state level also showed a significant association with increased HIV incidence (aRR=1.01, 95% CL 1.00-1.02), while the percentage of the Hispanic population living in poverty was significantly associated with a decrease in HIV incidence (aRR=0.995, 95% CL 0.991-0.999).

The percentage of the county population that was female, the overall Hispanic population percentage, county urban-rural classification, education, insurance, and unemployment all showed no significant association with new HIV diagnoses, nor did state-level stigma against sexual and gender minorities.

Table 4.2. Parameter estimates for general population model for predicting county-level HIV incidence rate, 2010-2019 (N=355)

Parameter	aRR	95% CL		p-value
Exposures				
HIV criminalization law (yes/no)	1.1385	0.9899	1.3093	0.0692
Jailed population rate	1.0003	1.0002	1.0005	0.0002
Law*Jailed pop. interaction term¤	0.9998	0.9996	0.9999	0.0101
Demographics				
% Female	0.9807	0.9707	0.9908	0.0002
% Age 15-24	1.0260	1.0151	1.0369	<0.0001
% Age 25-44	1.0381	1.0264	1.0500	<0.0001
% Age 45-64	1.0388	1.0231	1.0547	<0.0001
% Black or African American	1.0300	1.0274	1.0325	<0.0001
% Asian	1.0078	1.0006	1.0150	0.0332
% American Indian or Alaska Native	1.0027	0.9907	1.0148	0.6579
% Native Hawaiian/Other Pacific Islander	0.9920	0.9401	1.0467	0.7679
% Hispanic (any race)	1.0082	1.0054	1.0110	<0.0001
NCHS urban-rural classification scheme for counties				
Large central metro	1.3749	1.1427	1.6544	0.0008
Large fringe metro	0.9543	0.7991	1.1397	0.6056
Medium metro	0.9885	0.8329	1.1731	0.8948
Small metro	0.9918	0.8304	1.1846	0.9279
Micropolitan		(Ref.)		
Socioeconomic status indicators				
% Graduated high school	0.9925	0.9856	0.9995	0.0364
% Some college	0.9900	0.9843	0.9957	0.0006
% Living in poverty	1.0056	1.0012	1.0100	0.0133
% Insured	1.0004	1.0001	1.0006	0.0125
County unemployment rate	0.9925	0.9870	0.9980	0.0076
HIV-relevant indicators				
HIV federal spending per capita	1.0053	1.0014	1.0092	0.0077
SGM stigma	1.0164	0.9974	1.0357	0.0916
Year	**0.9821**	**0.9760**	**0.9883**	**<0.0001**

¤ *The interaction term effect represents a ratio of risk ratios*

Table 4.3. Parameter estimates for Black population model for predicting county-level HIV incidence rate, 2010-2019 (N=179)

Parameter	aRR	95% CL		p-value
Exposures				
HIV criminalization law (yes/no)	1.2955	1.0541	1.5922	0.0200
Jailed population rate	1.0002	1.0001	1.0004	0.0080
Law*Jailed pop. interaction term¤	0.9999	0.9997	1.0000	0.0647
Demographics				
% Female (Black pop.)	1.0062	0.9982	1.0142	0.1287
% Age 15-24 (Black pop.)	1.0127	1.0001	1.0254	0.0477
% Age 25-44 (Black pop.)	1.0215	1.0089	1.0342	0.0008
% Age 45-64 (Black pop.)	1.0019	0.9884	1.0156	0.7826
% Black or African American	1.0090	1.0062	1.0117	<0.0001
NCHS urban-rural classification scheme for counties				
Large central metro	1.4332	1.0351	1.9843	0.0365
Large fringe metro	1.0782	0.7757	1.4986	0.6566
Medium metro	1.1610	0.8443	1.5965	0.3642
Small metro	1.1230	0.8114	1.5542	0.4886
Micropolitan		(Ref.)		
Socioeconomic status indicators				
% Graduated high school (Black pop.)	0.9962	0.9912	1.0013	0.1467
% Some college (Black pop.)	0.9939	0.9895	0.9983	0.0068
% Living in poverty (Black pop.)	1.0019	1.0002	1.0035	0.0271
% Insured (Black pop.)	0.9988	0.9962	1.0015	0.3927
County unemployment rate (Black pop.)	0.9979	0.9937	1.0020	0.3083
HIV-relevant indicators				
HIV federal spending per capita	1.0060	1.0021	1.0100	0.0053
SGM stigma	1.0070	0.9847	1.0298	0.5465
Year	**0.9813**	**0.9744**	**0.9883**	**<0.0001**

¤ *The interaction term effect represents a ratio of risk ratios*

Table 4.4. Parameter estimates for Hispanic population model for predicting county-level HIV incidence rate, 2010-2019 (N=102)

Parameter	aRR	95% CL		p-value
Exposures				
HIV criminalization law (yes/no)	1.3182	0.9869	1.7608	0.0731
Jailed population rate	1.0000	0.9997	1.0003	0.8877
Law*Jailed pop. interaction term¤	1.0000	0.9997	1.0003	0.9942
Demographics				
% Female (Hispanic pop.)	1.0047	0.9795	1.0306	0.7168
% Age 15-24 (Hispanic pop.)	1.0525	1.0270	1.0787	<0.0001
% Age 25-44 (Hispanic pop.)	1.0247	1.0035	1.0464	0.0225
% Age 45-64 (Hispanic pop.)	1.0264	1.0022	1.0511	0.0324
% Hispanic	1.0013	0.9965	1.0061	0.5946
NCHS urban-rural classification scheme for counties				
Large central metro	1.5331	0.8818	2.6656	0.1522
Large fringe metro	1.0240	0.5834	1.7972	0.9353
Medium metro	0.9219	0.5485	1.5494	0.7633
Small metro		(Ref.)		
Socioeconomic status indicators				
% Graduated high school (Hispanic pop.)	1.0060	0.9995	1.0126	0.0696
% Some college (Hispanic pop.)	1.0043	0.9987	1.0099	0.1348
% Living in poverty (Hispanic pop.)	0.9952	0.9912	0.9993	0.0214
% Insured (Hispanic pop.)	1.0001	0.9981	1.0020	0.9507
County unemployment rate (Hispanic pop.)	0.9975	0.9888	1.0063	0.5757
HIV-relevant indicators				
HIV federal spending per capita	1.0112	1.0050	1.0175	0.0016
SGM stigma	1.0269	0.9814	1.0746	0.2620
Year	**0.9934**	**0.9795**	**1.0075**	**0.3561**

¤ *The interaction term effect represents a ratio of risk ratios*

4.4 Discussion

This multilevel modeling study assessed whether state HIV criminalization laws were associated with higher county HIV incidence rates, and whether that association was modified by overpolicing at the county level (as represented by jailed population rates), for the general, Black, and Hispanic populations. For all three populations, being in a state with an HIV-specific criminalization statute was associated with a higher county-wide HIV diagnosis rate, though this association was attenuated by a higher jailed population rate for the general and Black populations. The effect modification was statistically significant for the general population (p=0.02) and marginally significant for the Black populations (p=0.07). A higher jailed population rate was also significantly associated with a higher county-level HIV incidence rate in counties in non-criminalization states for the general and Black populations.

To my knowledge, this is the first study that has assessed the association between HIV criminalization at the state level and HIV incidence rates at the county level. The statistically significant effect modification of the higher jailed population rate on the association between HIV criminalization and new diagnoses is interesting and may represent fewer cases of HIV cases being diagnosed in counties that are policed more heavily. It has been widely hypothesized in public health research on HIV criminalization laws that these statutes may discourage HIV testing (51) by motivating individuals to eliminate their culpability under the law (5-9, 13, 14, 24, 26, 52-56), as individuals must be aware of their HIV status to be criminally liable (50). Many researchers theorize that this is the primary mechanism by which HIV criminalization laws discourage testing, and therefore indirectly increase HIV transmission (41, 50, 57, 58). They may be more motivated to do this in areas where encounters with law enforcement are more likely. In a descriptive analysis of criminal prosecutions for HIV exposure, Lazzarini, Bray, and Burris (19) found no evidence of systemic enforcement of these laws but noted that "[w]hat seems to determine who gets prosecuted is the accident of being caught." This is supported by findings from an analysis on HIV criminalization laws by Sah et al. (115), which examined the laws' association with the proportion of PLWH diagnosed and the annual percentage change in HIV prevalence. They concluded that HIV criminalization laws are associated with a lower proportion of HIV diagnosis and increased (undiagnosed) HIV prevalence.

4.4.1 Limitations

The results of this study and their interpretation are subject to several limitations. The results of the multilevel models should be interpreted with caution, particularly when considering the estimated independent effect of the law itself. HIV criminalization occurs in some form in every state, as every state in the U.S. has prosecuted HIV exposure in some way (e.g., through the use of general criminal statutes (126, 127)). This can present a challenge to empirical research that aims to measure the effect of HIV criminalization on HIV incidence rates or related behaviors. However, previous empirical analysis on this topic have demonstrated a statistically detectable effect (115), as have studies on other criminal laws, such as gun control (170-173) and texting-while-driving bans (174). The overwhelming majority of the literature on this topic has specifically argued the shortcomings and potential for harm of criminal laws that explicitly target HIV and has called for empirical research that investigates the effects of these HIV-specific criminalization laws (19, 39, 42, 43, 47, 137, 165, 166).

Stable HIV incidence rates were not available for all counties for all years. As detailed in the Methods section, counties were only included if they had a stable HIV rate for at least six years of the ten-year analysis period. Additionally, no jail population data were available for any years from Connecticut or Delaware. This resulted in only 11.3% of counties being included for the general population, 5.7% of counties for the Black population, and 3.2% of counties for the Hispanic population. While the included counties accounted for nearly two thirds of each of the three populations, this may indicate that the results are not generalizable to more sparsely populated counties, or counties with low HIV incidence.

The jailed population rate may be an imperfect proxy for overpolicing. Overpolicing, can include harassment by police officers and other contact with law enforcement that does not lead to arrest, and so the county jailed population rate may not fully capture the extent to which these individuals perceive overpolicing. Hispanic jail population data in particular may not be accurate for all jurisdictions due to the fact that data collection on ethnicity in state criminal justice departments is of inconsistent quality and is often poor (141).

4.4.2 Strengths

This study has several notable strengths. To date, there have been few quantitative analyses that measure the effects of HIV criminalization laws on HIV incidence rates, and those that exist use much older data (41, 73, 114). Only two longitudinal studies on the relationship between HIV criminalization laws and HIV incidence rates have been published to date (73, 115), and none to my knowledge have ever used a multilevel modeling approach. Thus, this analysis will contribute to addressing a gap in knowledge by harnessing the strengths of the multilevel modeling, which include accounting for correlated outcomes among groups (in this case, counties within a state) and allowing states with fewer counties to "borrow" statistical strength from the population to aid in estimation. This is also only the second study (to my knowledge) to estimate the effects of the justice system on race-specific HIV rates (82), as well as only the second one to use an interaction term in conjunction with the existence of HIV criminalization laws to measure factors related to HIV transmission in populations (58).

4.5 Conclusion

A small number of jurisdictions in the U.S. bear a disproportionate burden of the country's HIV epidemic. Most of these counties, which account for over half of the U.S. population, are subject to state-level HIV criminalization laws. However, the enforcement of these laws may depend on policing behavior and patterns, which in turn vary by jurisdiction according to local elections and resources. County-level officials and policy makers in states with HIV criminalization laws should consider how these laws, as well as heavier policing, may affect population-level HIV transmission dynamics and the ability of public health systems to diagnose individuals with HIV and link them to care in a timely manner. In particular, those charged with forming and executing criminal justice policy should consider how community policing dynamics may discourage HIV testing, which is one of the most important strategies for ending the HIV epidemic.

Chapter 5.
How do state HIV criminalization laws and overpolicing at the state level affect individual HIV testing behavior?

Chapter 5: How do state HIV criminalization laws and overpolicing at the state level affect individual HIV testing behavior?

5.0 Abstract

Introduction: HIV testing is an important strategy for reducing HIV transmission. However, HIV testing may be discouraged by HIV criminalization laws. Furthermore, these laws may be unevenly enforced against individuals more likely to encounter the justice system, particularly Black and Hispanic individuals. This study used a serial cross-sectional design with individual- and state-level data from 2016-2019 to test the hypothesis that HIV criminalization laws are associated with lower HIV testing likelihood among Black and Hispanic individuals, and that this effect is modified by heavier policing (using incarceration rates as a proxy).

Methods: Individual-level HIV testing, demographic, and socioeconomic data from BRFSS were merged with state-level demographic, socioeconomic, incarceration rate, and HIV-related sociologic and economic data from 2016-2019. Incarcerated population rates by state were visualized. Three multivariate logistic regression models were fitted for each population of interest. Terms for the presence of an explicit HIV criminalization statute and the statewide incarceration rate, as well as an interaction between the two, were included in all models. All analyses accounted for the complex survey design of BRFSS.

Results: For the general population, both an HIV criminalization law and an increased incarceration rate were associated with higher likelihood of HIV testing history. However, a higher incarceration rate had a counteractive effect in HIV criminalization states, as the interaction term was significantly associated with a decrease in likelihood of having ever received an HIV test ($p=0.0004$). For the Black population, living in a state with an HIV criminalization statute was not significantly associated with a history of HIV testing. However, higher Black incarceration rates were significantly associated with an increased likelihood of having ever received an HIV test ($p=0.0398$). Among the Hispanic population, neither HIV

criminalization nor the state incarceration rate was significantly associated with HIV testing history.

Conclusion: HIV testing may be discouraged by heavier policing in states with HIV criminalization laws. State policy makers in states with HIV criminalization laws should consider how heavier policing may deter HIV testing in the general population, which may inadvertently increase HIV transmission.

5.1 Introduction

In the U.S., nearly 37,000 people received an HIV diagnosis in 2019, the most recent year for which national figures are available (117). HIV testing is one of the most important strategies for reducing HIV acquisition. While individuals with undiagnosed HIV make up 13.3% of persons living with HIV in the U.S. (120), nearly 40% of all cases of HIV transmission are attributable to this group (59). Thus, widespread HIV screening has the potential to reduce HIV transmission by increasing early HIV diagnosis, reducing the number of persons living with HIV who are unaware of their HIV status and facilitating linkage to care (97, 105). With the development of effective antiretroviral therapy, HIV became a manageable chronic disease, and people living with HIV now have nearly the same life expectancy as the general population (30-32). Persons living with HIV who take their medications as prescribed and maintain viral suppression have effectively no risk of transmitting HIV to their sexual partners (33). This scientific breakthrough is now recognized as “treatment as prevention” (34) or “undetectable=untransmittable” (U=U) (35). For this reason, CDC recommends that everyone between the ages of 13 and 64 get tested for HIV at least once, and that those at higher risk for HIV be tested more frequently (99).

Among new HIV diagnoses in the U.S., 41.7% were among Black populations and 28.5% among Hispanic populations (despite comprising only 13.4 and 18.5% of the population, respectively) (118). Black and Hispanic populations, in addition to sharing a disproportionate burden of HIV prevalence, are also more likely to be unaware of their HIV status. Racial and ethnic disparities in undiagnosed HIV persist, with 14% of Black persons living with HIV and 16.7% of Hispanic persons living with HIV unaware of their HIV positivity, compared to 11.3% of White persons living with HIV.

HIV criminalization laws are defined as HIV-specific laws that criminalize or control behaviors that can potentially expose another person to HIV (121). Public health professionals, lawyers, and advocates are in nearly universal agreement that laws criminalizing HIV are, at best, ineffective, and at worst, counterproductive (43-50). HIV and human rights advocates argue that these laws further criminalize already marginalized groups, including Black and Hispanic individuals, and counteract effective public health messages on HIV prevention and safer sex. In particular, it has been widely hypothesized that HIV criminalization laws may discourage HIV testing (51) by motivating individuals to eliminate their culpability under the law (5-9, 13, 14, 24, 26, 52-56), as individuals must be aware of their HIV status to be criminally liable (50). Many researchers hypothesize that this is the primary mechanism by which HIV criminalization laws discourage testing, and therefore indirectly increase HIV transmission (41, 50, 57, 58).

As an independent driver of HIV risk, overpolicing in communities of color may drive changes in behavior and reinforces additional structural determinants that contribute to racial disparities in HIV incidence rates. Heavier policing of Black males drives them to "go into hiding," reducing their participation in civic social life to avoid contact with "the system" – that is, law enforcement and the criminal justice system (62). This is true of Hispanic individuals as well, who have also been shown to be significantly more likely to report having negative interactions with police, to believe that police engage in misconduct, and to live in heavily-policed neighborhoods (107). This may contribute to Black and Hispanic men avoiding HIV testing as a means of "system avoidance" (108). There is also evidence that Hispanic immigrants avoid HIV testing for fear that their test results would be reported to the government (110) and trigger legal consequences (111). While Black and Hispanic individuals are more likely than other racial and ethnic groups to get tested for HIV (101, 104, 112), they are also more likely to be tested and diagnosed late in the course of infection. Previous studies using NHBS data (113) and nationally representative survey data (112) have found that around a third of Black and Hispanic participants have never been tested for HIV, despite its increased prevalence among these groups. This "system avoidance" that creates lower rates of HIV testing may be exacerbated in states with HIV-specific criminalization laws.

To date there has only been one empirical study on the state-level effects of HIV criminalization laws on HIV testing (58). There has also been little work to date examining the relationship between *effect modifiers* of HIV criminalization and factors related to HIV risk. In order to test the hypotheses that (1) state HIV criminalization laws discourage HIV testing among Black and Hispanic populations and (2) this effect is modified by heavier policing (using incarceration rates as a proxy), I conducted a set of serial cross-sectional analyses, using annual survey data on individual HIV testing history from 2016 to 2019.

5.2 Methods

5.2.1 Data sources

HIV testing history and individual-level demographic and socioeconomic covariates (age, sex, race, ethnicity, marital status, urbanicity, poverty, education, employment, and HIV risk behavior) were obtained from the CDC's Behavioral Risk Factor Surveillance System (BRFSS), a system of telephone surveys that collects data in all 50 states and the District of Columbia. Data on HIV criminalization laws by state were obtained from the U.S. Centers for Disease Control and Prevention (121), the Center for HIV Law and Policy (122), Lambda Legal (27), the LawAtlas Policy Surveillance Program (128), and Trevor Hoppe's book *Punishing Disease: HIV and the Criminalization of Sickness* (129). Each state was coded as either having an HIV-specific criminalization law or not (1 or 0). State demographic (percent ages 15-44, percent Hispanic, percentage of the population made up of racial minorities) and socioeconomic (overall and race-specific percent below the federal poverty level, unemployment rate, percent with health insurance, educational attainment) covariates were derived from the American Community Survey one-year state estimates. The percentage of the population residing in urban areas for each state was taken from the 2010 decennial Census. Percentages were coded as integers in the data (0-100). Statewide HIV prevalence rates were be obtained from AIDSVu (124). Data on the number of physicians per 1,000 population were obtained from the Area Health Resource Files (148). A composite variable representing state-level structural stigma against sexual and gender minorities was obtained from a previous analysis by Tran, Hatzenbuehler, and Goldstein (149). Finally, total incarcerated population (jails and prisons combined) rates (incarcerated persons per 100,000 adults) were used as a proxy measure for state-level policing. Incarceration rates were calculated using data from the Bureau of Justice Statistics (159-161) and the Vera Institute of Justice Incarceration Trends project (138). Incarceration data were available through 2018; available rates were used to extrapolate incarceration rates for 2019.

5.2.2 Study sample and descriptive analysis

This analysis included participants from the 2016-2019 BRFSS for all fifty states and the District of Columbia. Participants with non-missing data (a response of "Yes" or "No") for HIV testing history ("Including fluid testing from your mouth, but not including tests you may have had for blood donation, have you ever been tested for H.I.V?") and HIV risk behavior ("Do Any [HIV-related] High Risk Situations Apply") were included. Little's MCAR test (175) was conducted jointly for observations with missing values for sex, race, Hispanic ethnicity, marital status, education, and employment status; the result was non-significant ($\chi^2<0.0000001$, $p\approx1$), so those records (n=303,865) were excluded from the fitted models using domain estimation. The final analytic sample included 1,488,465 participants.

Descriptive statistics were generated to characterize the population represented by the survey sample, grouped by states with and without HIV criminalization laws. Statistics include the number of sample respondents in each category, survey-weighted percentage estimates, and p-values for significant differences between the two groups using the Rao-Scott chi-square test.

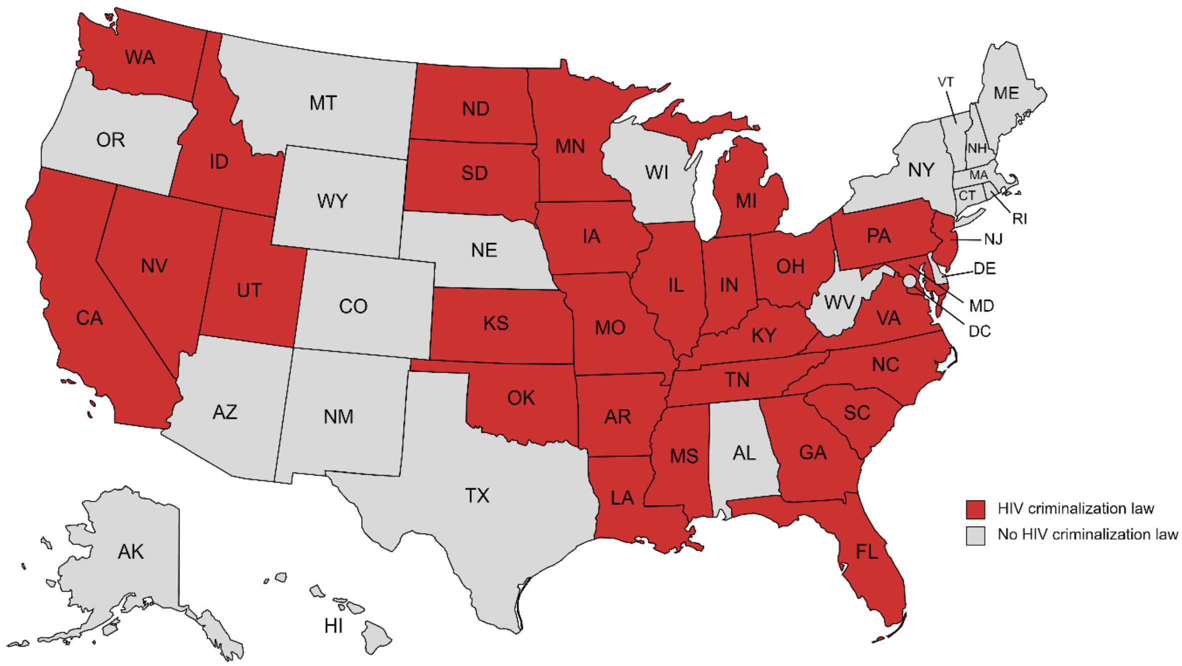
Variables included respondent sex at birth, age group, race, Hispanic ethnicity, marital status, whether they live in an urban area, education level, poverty status, employment status, and history of HIV testing and HIV-related risk behavior. Whether or not each state has a law criminalizing HIV exposure is displayed in Figure 4.1.

5.2.3 Multiple imputation for missing data

As stated previously, respondents with missing values for sex, race, Hispanic ethnicity, marital status, education, and employment status were excluded from the study population. Missingness for these variables was low, ranging from 0.1% for sex to 2.4% for race. All variables except race were missing for less than 2% of respondents from 2016-2019. However, poverty status and urbanicity were missing for a large percentage of survey respondents (16.5% and 26%, respectively). These variables were not missing completely at random (χ^2=43000.12, $p<0.000001$ for Little's MCAR test), so these values were imputed using multiple imputation.

BRFSS respondent poverty status was coded based on reported income, household size (combining adults and children in the household), and poverty guidelines published by the U.S. Department of Health and Human Services (176). Whether the respondent lived in an urban area was determined by the respondent's metropolitan status code (MSCODE for landline respondents) or county of residence (_METSTAT for cell phone respondents). Missing values were imputed using approximate Bayesian bootstrap imputation, a cell-based donor selection method for hot deck imputation which is recommended for use with multiple imputation (177). Cells were defined using respondent state, sex, race, Hispanic ethnicity, 10-year age group, employment status, and education status. The imputation was repeated 20 times.

Figure 5.1. HIV criminalization laws by state



5.2.4 Logistic regression models

Three multivariate logistic regression model were fitted: one with all BRFSS participants (n=1,488,465), one with Black participants only (n=123,237), and one with Hispanic participants only (n=93,548). Terms for the exposure of interest (the presence of an explicit HIV criminalization statute) and the effect modifier (the statewide incarceration rate), as well as an interaction between the two, were included in all models. Survey year was also included to account for secular trends. Demographic and socioeconomic covariates on both the population and the individual levels were included in all models. For the model with all respondents, these covariates corresponded to the general population for each state; for the Black and Hispanic population-specific models, covariates specific to those populations were used.

Additionally, in order to try to estimate a causal effect, a difference-in-difference analysis was conducted, comparing changes in HIV testing history between California and Nevada. California significantly modified its HIV testing statute in 2017 (going into effect on January 1, 2018), transitioning the crime of HIV exposure from a felony to a misdemeanor and reducing the maximum possible sentence to six months (178, 179). The “treatment” was coded as a repeal of the original law, with 2016-2017 being the pre-period and 2018-2019 being the post-period. Nevada, which has an HIV criminalization statute that remained unchanged, was chosen as the control state because of its geographic proximity and similar demographic makeup. State-level ecological variables were dropped from these models to achieve convergence. Results are displayed in the appendix.

All analyses were adjusted for the BRFSS complex survey design and accounted for the pooling of multiple survey cycles and sampling design effects using the SURVEY family of SAS procedures. The analyses were conducted using SAS 9.4 (153). This study was determined to not be human subjects research and is therefore exempt from review by the University of Maryland College Park Institutional Review Board (reference #1811297-1).

5.3 Results

5.3.1 Descriptive analysis

Table 5.1 displays the demographic and socioeconomic characteristics of the BRFSS respondents included in the analysis, including sample size and unweighted and weighted percentages, grouped by whether respondents lived in states with and without HIV criminalization laws. Approximately 40% of the study sample lived in non-criminalization states. The population represented by the study sample was slightly more than 50% female (51.4% in both non-criminalization and criminalization states), mostly white (76.7% and 74.5% in non-criminalization and criminalization states, respectively) and non-Hispanic (82.9% and 87.4%). The smallest population age group represented by the sample was 18-24 years old, while the largest was aged 65 years or older, with the remaining population distributed roughly evenly among the other age categories. Slightly more than half were married or had a live-in partner (55.8% and 55.4% in non-criminalization and criminalization states, respectively), and a majority were employed (58.1% and 57.2%). The population represented in criminalization states had slightly lower levels of education, with a larger percentage not having a high school diploma (12.1% vs. 11.7%) and a smaller percentage having some college (59.8% vs. 61.7%).

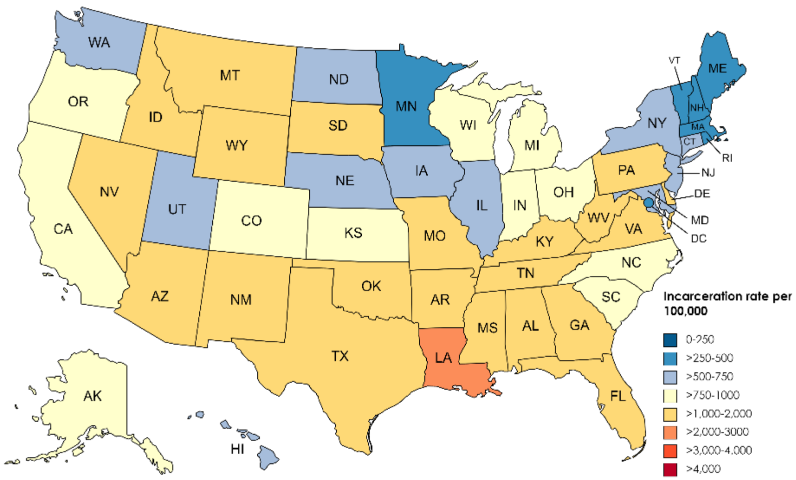
Table 5.1. Demographic and socioeconomic characteristics of the study sample (n=1,488,465)

	HIV Criminalization Law?				
	No		Yes		
	n^	Weighted %	n^	Weighted %	p-value§
Sex at birth					
Female	333,013	51.4%	496,879	51.4%	0.9090
Male	264,868	48.6%	393,705	48.6%	
Race					
White	500,894	76.7%	736,162	74.5%	<0.0001
Black or African American	34,261	10.4%	88,976	13.4%	
American Indian or Alaska Native	14,200	2.1%	15,270	1.4%	
Asian	16,649	5.1%	14,939	5.4%	
Multiracial or other	31,877	5.7%	35,237	5.4%	
Hispanic ethnicity					
No	553,229	82.9%	841,688	87.4%	<0.0001
Yes	44,652	17.1%	48,896	12.6%	
Age group					
18-24 years	31,346	12.7%	53,385	12.5%	<0.0001
25-34 years	58,683	17.6%	92,504	16.9%	
35-44 years	66,887	16.1%	103,944	16.0%	
45-54 years	90,840	16.3%	135,391	16.4%	
55-64 years	131,594	16.8%	187,708	17.0%	
65+ years	218,531	20.6%	317,652	21.2%	
Married					
No	266,294	44.2%	395,767	44.6%	0.0647
Yes	331,587	55.8%	494,817	55.4%	
Employed					
No	294,845	41.9%	446,752	42.8%	<0.0001
Yes	303,036	58.1%	443,832	57.2%	
Education					
Did not graduate high school	37,005	11.7%	61,447	12.1%	<0.0001
Graduated high school	157,348	26.6%	244,443	28.1%	
Some college	403,528	61.7%	584,694	59.8%	
Live in urban area					
No	151,625	10.2%	196,566	10.8%	<0.0001
Yes	305,002	55.9%	448,458	54.6%	
Unknown	141,254	33.9%	245,560	34.6%	
Below FPL					
No	461,127	73.4%	659,859	70.9%	<0.0001
Yes	49,512	11.3%	72,994	11.3%	
Unknown	87,242	15.3%	157,731	17.7%	

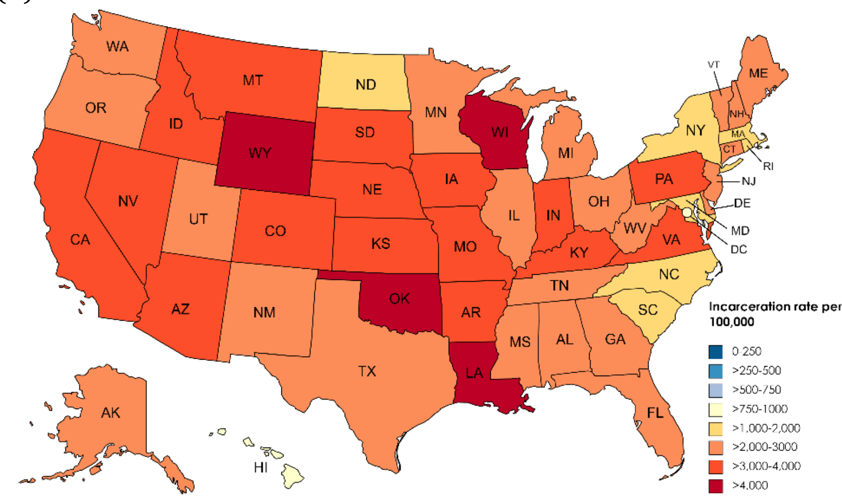
^*Weighted percentages may differ slightly from unweighted n's*
§*P-values are for Rao-Scott chi-square test*

Figure 5.2: Incarceration rates for the general (a), Black (b), and Hispanic (c) populations, 2018

(a)



(b)



(c)

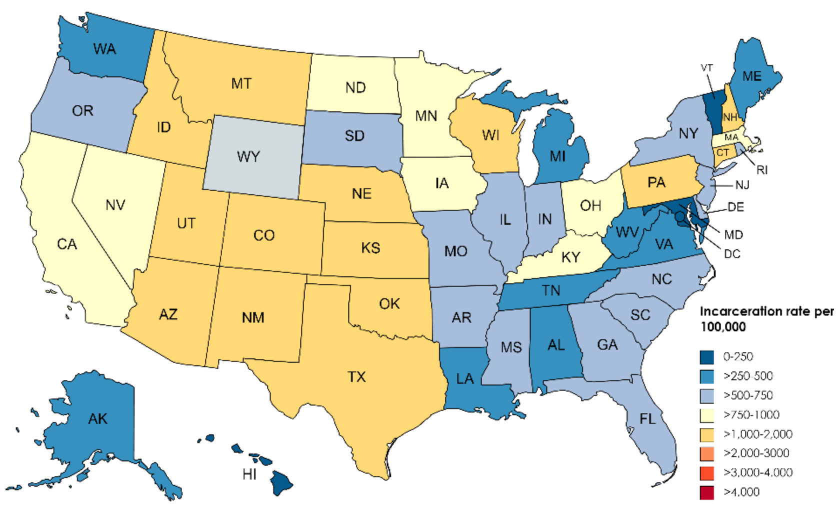


Table 5.2. HIV testing history and risk behavior by residence in criminalization vs. non-criminalization state

	HIV Criminalization Law?				
	No		Yes		
	n^	Weighted %	n^	Weighted %	p-value§
HIV test					
No	399,647	59.3%	605,250	60.4%	<0.0001
Yes	198,234	40.7%	285,334	39.6%	
HIV risk behavior					
No	574,108	93.4%	854,675	93.6%	0.2984
Yes	23,773	6.6%	35,909	6.4%	

^Weighted percentages may differ slightly from unweighted n's
§P-values are for Rao-Scott chi-square test

Approximately a third of the population represented by both groups had unknown urbanicity status (33.9% and 34.6%). In criminalization states, the population represented by the sample was more likely to be above the federal poverty level (70.9% vs. 73.4%) and more likely to have unknown poverty status (17.7% vs. 15.3%) due to missing information on household size, income, or both.

Table 5.2 shows the percentages of the study population who have ever received an HIV test and who reported at least one HIV-related risk behavior in the past year. In non-criminalization states, a slightly higher percentage of the population reported having ever received an HIV test (40.7% vs. 39.6%). The percentage reporting at least one HIV-related risk behavior in the previous year was similar between the two groups (6.6% and 6.4% in non-criminalization and criminalization states, respectively).

5.3.2 Model results

The parameter estimates for the general population model (all races and Hispanic and non-Hispanic survey respondents) are shown in Table 5.3. Before accounting for incarceration rate (i.e., at an incarceration rate of 0 per 100,000), living in a state with an HIV criminalization law was associated with higher likelihood of having ever received an HIV test (aOR=1.063), and the result was marginally significant (p=0.069). In states without an HIV criminalization law, a higher incarceration rate was also associated with increased likelihood of HIV testing history (p<0.0001). However, a higher incarceration rate had a counteractive effect in HIV criminalization states, as the interaction term was significantly associated with a *decrease* in likelihood of having ever received an HIV test (p=0.002).

Among individual-level factors, reporting an HIV-related risk behavior in the past year and Black race were associated with more than double the odds of having ever gotten an HIV test (aOR=2.42, 95% CL 2.32-2.52 and aOR=2.32, 95% CL 2.25-2.39, respectively). Being employed (aOR=1.22, 95% CL 1.21-1.24) and having an income below the federal poverty level (aOR=1.27, 95% CL 1.23-1.32) were also associated with moderate increases in the likelihood of having any testing history. Additionally, American Indian/Alaska Native and multiracial or other race, Hispanic ethnicity, being married or having a live-in partner, and living in an urban area were associated with small increases in the likelihood of having been tested for HIV. Male sex at birth, increased age, Asian race, and having no college education were all significantly associated with decreased likelihood of a history of HIV testing.

Ecological factors on the state level associated with increased odds of having received an HIV test included a higher percentage of Asian individuals, a higher percentage of individuals living in poverty, higher unemployment, a higher number of physicians per 1,000 population, and a higher statewide HIV prevalence rate. Model results for the ecological variables can be viewed in Table 5A.1 in the appendix.

Table 5.4 displays the model results for the Black population represented by the study sample. For this population, living in a state with an HIV criminalization statute was not significantly associated with a history of HIV testing. However, higher Black incarceration rates were significantly associated with an increased likelihood of having ever received an HIV test (p=0.0127). Black incarceration rate did not modify the effect of HIV criminalization.

Individual-level factors significantly associated with increased likelihood of HIV testing history include reporting an HIV risk behavior in the last year (aOR=2.05, 95% CL 1.83-2.31), being employed (aOR=1.35, 95% CL 1.31-1.40), living below the federal poverty level (aOR=1.28, 95% CL 1.19-1.39), and living in an urban area (aOR=1.20, 95% CL 1.10-1.31). Similar to the general population, male sex at birth, increased age, and having less than a college education all had a significantly lower association with HIV testing history. Additionally, Hispanic ethnicity was associated with a decreased likelihood of having received an HIV test (aOR=0.85, 95% CL 0.79-0.91).

At the ecological level, a higher percentage of Black women and a higher Black HIV prevalence rate were significantly associated with increased odds of having ever received an HIV test. A higher number of physicians per 1,000 was also marginally associated with increased odds of the outcome in this population (p=0.08). A higher percentage of the Black population living in poverty was associated with decreased likelihood of having been tested for HIV. Model results for the ecological variables can be viewed in Table 5A.2 in the appendix.

Finally, the results of the model fitted for the Hispanic population are shown in Table 5.5. Similar to the Black population model, living in a state with an HIV criminalization statute was not significantly associated with a history of HIV testing, though a higher Hispanic incarceration rate was significantly associated with an increased likelihood of having ever received an HIV test (p=0.03). Hispanic incarceration rate did not modify the effect of HIV criminalization. Individual factors significantly associated with increased likelihood of having received an HIV test included reporting an HIV risk behavior in the past year (aOR=2.34, 95% CL 2.09-2.62), Black race (aOR=1.50, 95% CL 1.31-1.70), living in an urban area (aOR=1.20, 95% CI=1.07-1.34), being employed (aOR=1.17, 95% CL 1.13-1.20), and being married (aOR=1.08, 95% CL 1.04-1.11). Similar to the other two population groups, male sex, increased age, and having less than a college education were significantly associated with decreased odds of having received an HIV test.

Ecological factors associated with increased likelihood of having been tested for HIV included a higher percentage of the Hispanic population having some college education, a higher percentage living in poverty and a higher statewide Hispanic HIV prevalence. Higher Hispanic and overall unemployment rates and higher HIV spending per capita were also

Table 5.3. Parameter estimates for general population model for predicting likelihood of HIV testing history (n=1,488,465)

Parameter	aOR	95% CL		p-value
Exposures				
HIV criminalization law (yes/no)	1.0628	0.9950	1.1354	0.0688
Incarceration rate	1.0003	1.0002	1.0003	<0.0001
Law*Incarceration interaction term¤	0.9999	0.9998	1.0000	0.0020
Individual-level factors				
HIV risk behavior	2.4185	2.3233	2.5168	<0.0001
Sex at birth				
Male	0.8942	0.8860	0.9021	<0.0001
Female		(Ref.)		
Age	0.9814	0.9812	0.9822	<0.0001
Race				
Black or African American	2.3217	2.2524	2.3917	<0.0001
American Indian or Alaskan Native	1.2129	1.1468	1.2827	<0.0001
Asian	0.4260	0.4054	0.4480	<0.0001
Multiracial or other	1.0358	0.9960	1.0768	0.0771
White		(Ref.)		
Hispanic ethnicity				
Yes	1.0427	1.0243	1.0618	<0.0001
No		(Ref.)		
Married				
Yes	1.0260	1.0171	1.0356	<0.0001
No		(Ref.)		
Live in urban area				
Yes	1.1062	1.0790	1.1343	<0.0001
No		(Ref.)		
Education				
Did not graduate high school	0.9549	0.9324	0.9773	0.0001
Graduated high school	0.8774	0.8633	0.8914	<0.0001
Some college		(Ref.)		
*Employed**				
Yes	1.2235	1.2117	1.2361	<0.0001
No		(Ref.)		
*Below FPL**				
Yes	1.2732	1.2312	1.3165	<0.0001
No		(Ref.)		

** Model estimates obtained using multiply imputed values*
¤ The interaction term effect represents a ratio of odds ratios

Table 5.4. Parameter estimates for Black population model for predicting likelihood of HIV testing history (n=123,237)

Parameter	aOR	95% CL		p-value
Exposures				
HIV criminalization law (yes/no)	1.0194	0.7718	1.3458	0.8921
Incarceration rate	1.0001	1.0000	1.0002	0.0127
Law*Incarceration interaction term¤	1.0000	0.9999	1.0001	0.5052
Individual-level factors				
HIV risk behavior	2.0543	1.8258	2.3117	<0.0001
Sex at birth				
Male	0.9338	0.9094	0.9589	<0.0001
Female		(Ref.)		
Age	0.9837	0.9822	0.9851	<0.0001
Hispanic ethnicity				
Yes	0.8525	0.7945	0.9148	<0.0001
No		(Ref.)		
Married				
Yes	1.0199	0.9920	1.0481	0.1580
No		(Ref.)		
Live in urban area				
Yes	1.2021	1.1008	1.3126	<0.0001
No		(Ref.)		
Education				
Did not graduate high school	0.9144	0.8616	0.9704	0.0032
Graduated high school	0.8807	0.8445	0.9185	<0.0001
Some college		(Ref.)		
*Employed**				
Yes	1.3547	1.3139	1.3965	<0.0001
No		(Ref.)		
*Below FPL**				
Yes	1.2825	1.1853	1.3882	<0.0001
No		(Ref.)		

** Model estimates obtained using multiply imputed values*

¤ The interaction term effect represents a ratio of odds ratios

Table 5.5. Parameter estimates for Hispanic population model for predicting likelihood of HIV testing history (n=93,458)

Parameter	aOR	95% CL		p-value
Exposures				
HIV criminalization law (yes/no)	0.9344	0.7641	1.1434	0.5086
Incarceration rate	0.9998	0.9996	1.0000	0.0335
Law*Incarceration interaction term¤	1.0000	0.9998	1.0002	0.7772
Individual-level factors				
HIV risk behavior	2.3405	2.0917	2.6195	<0.0001
Sex at birth				
Male	0.7829	0.7596	0.8065	<0.0001
Female		(Ref.)		
Age	0.9917	0.9900	0.9940	<0.0001
Race				
Black or African American	1.4955	1.3139	1.7023	<0.0001
American Indian or Alaskan Native	1.0126	0.8940	1.1468	0.8432
Asian	0.7028	0.5305	0.9315	0.0142
Multiracial or other	0.9835	0.8976	1.0779	0.7229
White		(Ref.)		
Married				
Yes	1.0752	1.0429	1.1085	<0.0001
No		(Ref.)		
Live in urban area				
Yes	1.2005	1.0725	1.3431	0.0016
No		(Ref.)		
Education				
Did not graduate high school	0.8197	0.7811	0.8598	<0.0001
Graduated high school	0.9444	0.9039	0.9871	0.0108
Some college		(Ref.)		
*Employed**				
Yes	1.1666	1.1298	1.2044	<0.0001
No		(Ref.)		
*Below FPL**				
Yes	1.0173	0.9418	1.0986	0.6611
No		(Ref.)		

** Model estimates obtained using multiply imputed values*

¤ The interaction term effect represents a ratio of odds ratios

significantly associated with increased odds. A higher percentage of the Hispanic population with a high school education, a higher percentage with health insurance, a higher overall poverty rate, and an increased number of physicians per 1,000 population were all associated with decreased likelihood of HIV testing history. Model results for the ecological variables can be viewed in Table 5A.3 in the appendix.

5.4 Discussion

The goal of this study was to test whether state HIV criminalization laws are negatively associated with HIV testing history, and whether this relationship is modified by heavier policing. In the general population, both the presence of a state HIV testing law and heavier policing (as represented by the state incarceration rate) were associated with a greater likelihood of HIV testing history. However, in HIV criminalization states, heavier policing *negatively* modified the effect of the law on the likelihood of having ever received an HIV test. This result means that heavier policing at the state level attenuates the positive association between living in a state with an HIV-specific criminalization statute and HIV testing history, or that the increase in likelihood of having received an HIV test is smaller in HIV criminalization states with higher incarceration rates. Many states with HIV criminalization laws also have a higher overall burden of HIV, which may result in a higher overall likelihood of getting tested for HIV among residents. However, the negative interaction with heavier policing, as represented by the statewide incarceration rate, supports the hypothesis that individuals living in states with heavier policing may avoid HIV testing to reduce their exposure to HIV criminalization laws in the event that they become involved in the justice system.

Lee (58) found no association between HIV testing and the existence of an HIV criminalization statute. However, similar to the results of this analysis, the author found that an interaction term between the existence of an HIV criminalization statute and increased media coverage of individuals who had been charged under the statute was related to a decrease in HIV testing among at-risk individuals. Tran, Hatzenbuehler, and Goldstein (149) also found no association between structural stigma related to sexual orientation and the presence of an HIV criminalization law, nor between stigma and felony status of the law. However, there was a significant association between structural stigma and proportion of arrests for HIV exposure per 100,000 persons living with HIV by state. These studies suggest that it is not merely the existence of laws criminalizing HIV, but also the enforcement via prosecutions for other crimes, that have the potential to impact HIV transmission and related factors, including HIV testing.

While this dynamic may be present in the population as a whole, it may be that different factors serve as primary drivers of HIV testing behavior in Black and Hispanic populations. Only the incarceration rate was significantly positively associated with HIV testing history among the Black population. This may be due to the high rates of incarceration among these populations – HIV testing is a routine part of intake in many prisons. Black individuals have a lifetime probability of 16.2% of being incarcerated, compared to a lifetime probability of 2.5% for White individuals (180). Additionally, because HIV exposure can (and has) been prosecuted in some way in every state – using STI or communicable disease laws or general criminal statutes in states that do not have HIV-specific criminal laws (126, 127) – individuals from heavily-policed communities may assume they will be targeted regardless of the laws in their state, and thus their HIV testing behavior will not be impacted by HIV-specific criminalization statutes.

In both the general population and Black population models, individual-level demographic or socioeconomic factors showed the opposite association with HIV testing history compared to their ecological counterparts. For example, among the general population, while Asian race was associated with lower odds of having ever been tested for HIV, a higher statewide percentage of Asians in the population was associated with an increase in that individual's likelihood of previous HIV testing. Similarly, in the Black population model, poverty status was associated with higher odds of HIV testing history, while a higher percentage of the state's Black population living in poverty was associated with decreased odds. These contradictory results showcase the ecological fallacy, which consists in thinking that relationships observed for groups necessarily hold for individuals (181). For example, Asian race might make an individual less likely to have received an HIV test, because members of that population are more likely to consider themselves low risk, and there are also cultural taboos within certain Asian ethnic groups. However, a state with a higher proportion of Asians is likely to be more urbanized, more educated, and more liberal, and may have more governmental resources dedicated to HIV prevention, thus resulting in a higher overall likelihood of getting tested for residents in the general population. Similarly, individuals living in poverty are more likely to be targeted for intervention by HIV prevention programs, at the same time that states with higher levels of poverty might have fewer healthcare and HIV testing resources. It is also worth noting that the effect size of most of the statistically significant ecological factors is much smaller than the individual-level factors.

5.4.1 Limitations

HIV testing history was missing for 11.65% (n=208,697) of the study sample. The exclusion of these respondents has the potential to bias results, if nonresponse for HIV testing history is related to living in a state that criminalizes HIV. The results should be interpreted with caution, particularly when considering the estimated independent effect of the law itself. In the difference-in-differences analysis, which compared HIV testing history between California (the "treatment" state) and Nevada (the "control" state) residents and designated 2018-2019 as the "post-treatment period," the effect of California's revision of its HIV criminalization statute (which went into effect in 2018) was not statistically significant (p=0.19 for the general population; p=0.27 for the Black and Hispanic populations; results displayed in tables 5A.4-5A.6 in the appendix), making it difficult to draw any convincing causal inferences. However, it is worth noting that this may be due to the relatively short time frame of the analysis (two years pre-revision and two years post-revision).

As noted previously, every state in the U.S. has prosecuted HIV exposure in some way, such as through the use of general criminal statutes in states that do not have HIV-specific criminal laws (126, 127). Thus, HIV criminalization occurs in some form in every state. That being said, the overwhelming majority of the literature on this topic has specifically argued the shortcomings and potential for harm of criminal laws that explicitly target HIV and has called for empirical research that investigates the effects of these HIV-specific criminalization laws (19, 39, 42, 43, 47, 137, 165, 166).

Finally, the imprisonment rate may be an imperfect proxy for over-policing, which is an effect modifier in the conceptual model. While Black and Hispanic people are disproportionately represented in jails and prisons, overpolicing does not always lead to arrest, and so the imprisonment rate in a state may not fully capture the extent to which these individuals perceive overpolicing, which can also include harassment by police officers or arrests that do not lead to imprisonment.

5.4.2 Strengths

Despite the limitations in the available data, this study has several notable strengths, including its large sample size and use of recent data. To date, only one other empirical analysis on the relationship between HIV criminalization laws and HIV testing has been published to date. It is the only one to use an interaction term in conjunction with the existence of HIV criminalization laws to measure factors related to HIV transmission in populations (58), and it uses much older data. Thus, this analysis will contribute to addressing a gap in knowledge by using more recent data to contribute to the literature examining the effects of HIV criminalization laws on HIV testing.

5.5 Conclusion

An overwhelming number of commentators on HIV criminalization laws have noted that it is impossible to enforce HIV criminalization laws uniformly across the entire population (7, 40), and that there is evidence that HIV criminalization laws are disproportionately enforced against Black and Hispanic people (39, 41, 42). The potential for this abuse is high (39), as the law can be selectively enforced by prosecutors who already enjoy considerable discretion in bringing charges (5, 8, 19, 26). This phenomenon is not unique to HIV, as Black and Hispanic individuals were also more likely to be targeted by COVID-19 emergency laws than white individuals (64). In a descriptive analysis of criminal prosecutions for HIV exposure, Lazzarini, Bray, and Burris (19) found no evidence of systemic enforcement of these laws but noted that "[w]hat seems to determine who gets prosecuted is the accident of being caught." Rather than depending on individuals working within the system to treat justice-involved individuals equitably, policy makers should work toward eliminating HIV criminalization laws or reforming them so that (1) they require criminal intent for prosecution and (2) they take into consideration behaviors that eliminate to substantially reduce risk (e.g., condom usage and viral suppression through medication adherence) (22). This could go a long way toward minimizing the potential for heavy policing and selective enforcement to have a detrimental effect of HIV prevention efforts, including HIV testing.

HIV testing is one of the most important public health tools to prevent new HIV cases and connect people living with HIV to medical care, particularly individuals who are at higher risk. However, the effect of state HIV criminalization laws on HIV testing behavior may be negatively impacted by heavier policing at the state level. This study contributes to the legal and policy epidemiology literature by using recent data to quantify the association of HIV criminalization laws, as well as the potential for their enforcement, with HIV testing behavior at the population level. State policy makers in states with HIV criminalization laws should consider how heavier policing may deter HIV testing in the general population, which may inadvertently increase HIV transmission.

5.A Appendix

Table 5A.1. Parameter estimates for general population model for predicting likelihood of HIV testing history V, including ecological variables (n=1,488,465)

Parameter	aOR	95% CL		p-value
Exposures				
HIV criminalization law (yes/no)	1.0628	0.9950	1.1354	0.0688
Incarceration rate	1.0003	1.0002	1.0003	<0.0001
Law*Incarceration interaction term¤	0.9999	0.9998	1.0000	0.0020
Individual-level factors				
HIV risk behavior	2.4185	2.3233	2.5168	<0.0001
Sex at birth				
Male	0.8942	0.8860	0.9021	<0.0001
Female		(Ref.)		
Age	0.9814	0.9812	0.9822	<0.0001
Race				
Black or African American	2.3217	2.2524	2.3917	<0.0001
American Indian or Alaskan Native	1.2129	1.1468	1.2827	<0.0001
Asian	0.4260	0.4054	0.4480	<0.0001
Multiracial or other	1.0358	0.9960	1.0768	0.0771
White		(Ref.)		
Hispanic ethnicity				
Yes	1.0427	1.0243	1.0618	<0.0001
No		(Ref.)		
Married				
Yes	1.0260	1.0171	1.0356	<0.0001
No		(Ref.)		
Live in urban area				
Yes	1.1062	1.0790	1.1343	<0.0001
No		(Ref.)		
Education				
Did not graduate high school	0.9549	0.9324	0.9773	0.0001
Graduated high school	0.8774	0.8633	0.8914	<0.0001
Some college		(Ref.)		
*Employed**				
Yes	1.2235	1.2117	1.2361	<0.0001
No		(Ref.)		
*Below FPL**				
Yes	1.2732	1.2312	1.3165	<0.0001
No		(Ref.)		
Ecological (state-level) factors				
% Age 15-44	0.9534	0.9465	0.9598	<0.0001
% Female	0.9295	0.9085	0.9503	<0.0001
% Black or African American	0.9946	0.9920	0.9970	<0.0001
% Asian	1.0180	1.0131	1.0222	<0.0001
% American Indian or Alaska Native	0.9824	0.9773	0.9871	<0.0001
% Native Hawaiian/Other Pacific Islander	0.9473	0.9315	0.9627	<0.0001
% Hispanic (any race)	0.9916	0.9891	0.9940	<0.0001
% At least a high school education	0.9761	0.9724	0.9792	<0.0001
% Some college (Black pop.)	0.9996	0.9980	1.0010	0.6555
% Living in poverty	1.0103	1.0030	1.0182	0.0085
% Insured	0.9681	0.9627	0.9734	<0.0001
State unemployment rate	1.0520	1.0356	1.0682	<0.0001
% Living in urban area	0.9959	0.9950	0.9970	<0.0001
SGM stigma	0.9617	0.9550	0.9685	<0.0001
Physicians per 1,000 population	1.0370	1.0080	1.0672	0.0125
State HIV prevalence per 100,000	1.0009	1.0010	1.0010	<0.0001

** Model estimates obtained using multiply imputed values*

¤ The interaction term effect represents a ratio of odds ratios

Table 5A.2. Parameter estimates for Black population model for predicting likelihood of HIV testing history, including ecological variables (n=123,237)

Parameter	aOR	95% CL		p-value
Exposures				
HIV criminalization law (yes/no)	1.0194	0.7718	1.3458	0.8921
Incarceration rate	1.0001	1.0000	1.0002	0.0127
Law*Incarceration interaction term¤	1.0000	0.9999	1.0001	0.5052
Individual-level factors				
HIV risk behavior	2.0543	1.8258	2.3117	<0.0001
Sex at birth				
Male	0.9338	0.9094	0.9589	<0.0001
Female		(Ref.)		
Age	0.9837	0.9822	0.9851	<0.0001
Hispanic ethnicity				
Yes	0.8525	0.7945	0.9148	<0.0001
No		(Ref.)		
Married				
Yes	1.0199	0.9920	1.0481	0.1580
No		(Ref.)		
Live in urban area				
Yes	1.2021	1.1008	1.3126	<0.0001
No		(Ref.)		
Education				
Did not graduate high school	0.9144	0.8616	0.9704	0.0032
Graduated high school	0.8807	0.8445	0.9185	<0.0001
Some college		(Ref.)		
*Employed**				
Yes	1.3547	1.3139	1.3965	<0.0001
No		(Ref.)		
*Below FPL**				
Yes	1.2825	1.1853	1.3882	<0.0001
No		(Ref.)		
Ecological (state-level) factors				
% Age 15-44 (Black pop.)	0.9945	0.9734	1.0161	0.6211
% Female (Black pop.)	1.0378	1.0151	1.0608	0.0008
% Black or African American	0.9974	0.9920	1.0030	0.3796
% At least a high school education (Black pop.)	0.9981	0.9802	1.0161	0.8409
% Some college (Black pop.)	1.0054	0.9900	1.0212	0.5002
% Living in poverty (Black pop.)	0.9847	0.9666	1.0030	0.0962
% Insured (Black pop.)	1.0011	0.9940	1.0080	0.7570
Black unemployment rate	1.0052	0.9773	1.0336	0.7198
% Living in poverty	1.0194	0.9851	1.0544	0.2637
% Insured	1.0043	0.9822	1.0274	0.7117
State unemployment rate	1.0087	0.9277	1.0964	0.8399
% Living in urban area	0.9950	0.9891	1.0010	0.0815
SGM stigma	1.0063	0.9831	1.0305	0.6007
Physicians per 1,000 population	1.0843	0.9900	1.1877	0.0803
State HIV prevalence per 100,000 (Black pop.)	1.0005	1.0003	1.0006	<0.0001

** Model estimates obtained using multiply imputed values*
¤ The interaction term effect represents a ratio of odds ratios

Table 5A.3. Parameter estimates for Hispanic population model for predicting likelihood of HIV testing history, including ecological variables (n=93,548)

Parameter	aOR	95% CL		p-value
Exposures				
HIV criminalization law (yes/no)	0.9344	0.7641	1.1434	0.5086
Incarceration rate	0.9998	0.9996	1.0000	0.0335
Law*Incarceration interaction term¤	1.0000	0.9998	1.0002	0.7772
Individual-level factors				
HIV risk behavior	2.3405	2.0917	2.6195	<0.0001
Sex at birth				
Male	0.7829	0.7596	0.8065	<.0001
Female		(Ref.)		
Age	0.9917	0.9900	0.9940	<0.0001
Race				
Black or African American	1.4955	1.3139	1.7023	<0.0001
American Indian or Alaskan Native	1.0126	0.8940	1.1468	0.8432
Asian	0.7028	0.5305	0.9315	0.0142
Multiracial or other	0.9835	0.8976	1.0779	0.7229
White		(Ref.)		
Married				
Yes	1.0752	1.0429	1.1085	<0.0001
No		(Ref.)		
Live in urban area				
Yes	1.2005	1.0725	1.3431	0.0016
No		(Ref.)		
Education				
Did not graduate high school	0.8197	0.7811	0.8598	<0.0001
Graduated high school	0.9444	0.9039	0.9871	0.0108
Some college		(Ref.)		
*Employed**				
Yes	1.1666	1.1298	1.2044	<0.0001
No		(Ref.)		
*Below FPL**	1.0000			
Yes		0.9418	1.0986	0.6611
No		(Ref.)		
Ecological (state-level) factors				
% Age 15-44 (Hispanic pop.)	0.9709	0.9484	0.9940	0.0143
% Female (Hispanic pop.)	1.0120	0.9782	1.0471	0.4853
% Hispanic	0.9987	0.9910	1.0060	0.7332
% At least a high school education (Hispanic pop.)	0.9715	0.9608	0.9822	<0.0001
% Some college (Hispanic pop.)	1.0195	1.0131	1.0263	<0.0001
% Living in poverty (Hispanic pop.)	1.0262	1.0111	1.0419	0.0008
% Insured (Hispanic pop.)	0.9843	0.9734	0.9950	0.0044
Hispanic unemployment rate	1.0418	0.9990	1.0865	0.0581
% Living in poverty	0.9375	0.9048	0.9714	0.0004
% Insured	0.9940	0.9743	1.0141	0.5543
State unemployment rate	1.1067	1.0243	1.1948	0.0100
% Living in urban area	0.9971	0.9910	1.0030	0.3335
SGM stigma	0.9843	0.9618	1.0070	0.1792
Physicians per 1,000 population	0.8768	0.8033	0.9570	0.0034
State HIV prevalence per 100,000 (Hispanic pop.)	1.0010	1.0010	1.0010	<0.0001

* *Model estimates obtained using multiply imputed values*

¤ *The interaction term effect represents a ratio of odds ratios*

Table 5A.4. Parameter estimates for general population difference-in-differences model for the treatment effect of California's HIV criminalization law reform on likelihood of HIV testing history (n=37,610)

Parameter	aOR	95% CL		p-value
Exposures				
Treat*post	1.1500	0.9339	1.4162	0.1878
Incarceration rate	0.9988	0.9939	1.0036	0.6176
Individual-level factors				
HIV risk behavior	2.7798	2.4671	3.1322	<0.0001
Sex at birth				
Male	0.8775	0.8531	0.9027	<0.0001
Female		(Ref.)		
Age	0.9849	0.9831	0.9866	<0.0001
Race				
Black or African American	2.0119	1.8237	2.2195	<0.0001
American Indian or Alaskan Native	1.2407	1.0843	1.4197	0.0017
Asian	0.4372	0.3972	0.4813	<0.0001
Multiracial or other	0.9837	0.9080	1.0657	0.6870
White		(Ref.)		
Hispanic ethnicity				
Yes	0.9633	0.9280	0.9999	0.0495
No		(Ref.)		
Married				
Yes	1.0718	1.0413	1.1031	<0.0001
No		(Ref.)		
Live in urban area				
Yes	1.0190	0.8808	1.1789	0.7991
No		(Ref.)		
Education				
Did not graduate high school	0.9072	0.8501	0.9681	0.0034
Graduated high school	0.8986	0.8548	0.9447	<0.0001
Some college		(Ref.)		
*Employed**				
Yes	1.2638	1.2251	1.3037	<0.0001
No		(Ref.)		
*Below FPL**				
Yes	1.0315	0.9473	1.1232	0.4743
No		(Ref.)		
Dummies				
Year				
2016		(Ref.)		
2017	1.0182	0.8632	1.2011	0.8302
2018	1.0114	0.9322	1.0974	0.785
2019	1.0236	0.8298	1.2627	0.8272
State				
California	0.8476	0.3925	1.8302	0.6734
Nevada		(Ref.)		

** Model estimates obtained using multiply imputed values*

Table 5A.5. Parameter estimates for Black population difference-in-differences model for the treatment effect of California's HIV criminalization law reform on likelihood of HIV testing history (n=2,726)

Parameter	aOR	95% CL		p-value
Exposures				
Treat*post	1.3724	0.7805	2.4133	0.2713
Incarceration rate	1.0015	0.9983	1.0046	0.3623
Individual-level factors				
HIV risk behavior	2.1052	1.3491	3.2850	0.0011
Sex at birth				
Male	0.8950	0.7993	1.0021	0.0544
Female		(Ref.)		
Age	0.9864	0.9791	0.9938	0.0003
Hispanic ethnicity				
Yes	0.6793	0.5681	0.8124	<0.0001
No		(Ref.)		
Married				
Yes	1.0956	0.9754	1.2306	0.1236
No		(Ref.)		
Live in urban area				
Yes	0.8101	0.2089	3.1410	0.7588
No		(Ref.)		
Education				
Did not graduate high school	0.7843	0.5890	1.0444	0.0963
Graduated high school	1.0768	0.8784	1.3199	0.4759
Some college		(Ref.)		
*Employed**				
Yes	1.4108	1.2466	1.5966	<0.0001
No		(Ref.)		
*Below FPL**				
Yes	1.0567	0.7874	1.4182	0.7128
No		(Ref.)		
Dummies				
Year				
2016		(Ref.)		
2017	0.9742	0.6314	1.5030	0.9058
2018	1.0253	0.7895	1.3315	0.8514
2019	1.1517	0.6785	1.9549	0.6004
State				
California	0.9914	0.6865	1.4317	0.9632
Nevada		(Ref.)		

** Model estimates obtained using multiply imputed values*

Table 5A.6. Parameter estimates for Hispanic population difference-in-differences model for the treatment effect of California's HIV criminalization law reform on likelihood of HIV testing history (n=12,341)

Parameter	aOR	95% CL		p-value
Exposures				
Treat*post	1.3932	0.7768	2.4988	0.2656
Incarceration rate	0.9979	0.9922	1.0035	0.4592
Individual-level factors				
HIV risk behavior	2.6345	2.2030	3.1505	<0.0001
Sex at birth				
Male	0.8110	0.7720	0.8520	<0.0001
Female		(Ref.)		
Age	0.9925	0.9895	0.9956	<0.0001
Race				
Black or African American	1.1199	0.8944	1.4021	0.3233
American Indian or Alaskan Native	1.0821	0.8959	1.3070	0.4123
Asian	0.9508	0.6388	1.4152	0.8035
Multiracial or other	0.9479	0.8213	1.0939	0.4637
White		(Ref.)		
Married				
Yes	1.0646	1.0141	1.1176	0.0116
No		(Ref.)		
Live in urban area				
Yes	1.0722	0.7320	1.5704	0.7187
No		(Ref.)		
Education				
Did not graduate high school	0.8252	0.7686	0.8860	<0.0001
Graduated high school	0.9083	0.8457	0.9755	0.0083
Some college		(Ref.)		
*Employed**				
Yes	1.1685	1.1098	1.2304	<0.0001
No		(Ref.)		
*Below FPL**				
Yes	0.9297	0.8317	1.0393	0.1993
No		(Ref.)		
Dummies				
Year				
2016		(Ref.)		
2017	1.1366	0.7709	1.6758	0.5176
2018	0.9556	0.7583	1.2042	0.6999
2019	0.9323	0.6066	1.4328	0.7489
State				
California	1.2544	0.9126	1.7242	0.1625
Nevada		(Ref.)		

** Model estimates obtained using multiply imputed values*

Chapter 6.
Conclusions

Chapter 6: Conclusions

6.1 Overall conclusions of the findings

In Chapter 3, I tested whether state HIV criminalization laws are positively associated with the statewide HIV incidence rate, and whether this relationship is modified by higher statewide incarceration rates (to represent heavier policing at the state level). In both the general population and the Hispanic population, the presence of a state HIV testing law was associated with a higher rate of new HIV diagnoses. Heavier policing (as represented by the state incarceration rate) was also significantly associated with an increased HIV incidence rate for the general population only. However, higher incarceration at the state level did not significantly modify the relationship between the law and HIV incidence. Neither of these factors significantly impacted statewide HIV incidence among the Black population.

Similarly, the multilevel modeling study in Chapter 4 found that, for all three populations, being in a state with an HIV-specific criminalization statute was associated with a higher county-wide HIV diagnosis rate. A higher jailed population rate was also significantly associated with a higher county-level HIV incidence rate in counties in non-criminalization states for the general and Black populations. However, unlike the state-level analysis, this association was attenuated by a higher jailed population rate for the general and Black populations. The effect modification was statistically significant for the general population (p=0.01) and marginally significant for the Black population (p=0.06).

In Chapter 5, both the presence of a state HIV testing law and heavier policing (as represented by the state incarceration rate) were associated with a greater likelihood of HIV testing history in the general population. However, in HIV criminalization states, heavier policing *negatively* modified the effect of the law on the likelihood of having ever received an HIV test. Only the incarceration rate was significantly positively associated with HIV testing history among the Black and Hispanic populations.

The results of these analyses supported some, but not all, of my hypotheses in Chapter 1. Heavier policing did not modify the effect of HIV criminalization laws on statewide HIV incidence rates in any of the three populations in Chapter 3. My hypothesis for Chapter 4 was partially correct: heavier policing at the county level modified the effect of statewide HIV criminalization laws on county HIV incidence in the Black population, but not the Hispanic population. This effect modification was also statistically significant for the general population. Additionally, the direction of the effect modification was unexpected: for both the general and Black populations, a higher jailed population rate led to a *negative* effect modification. Finally, my hypotheses for Chapter 5 were incorrect as well. I predicted that a heavier policing would negatively modify the association between the presence of an HIV criminalization law and HIV testing likelihood in the Black and Hispanic populations. However, this effect modification was only seen for the general population.

Incarcerated population rates were associated with higher statewide HIV incidence for the general population, higher county HIV incidence for the general and Black populations, and a higher individual likelihood of HIV testing for the general and Black populations. The association between incarcerated population rates and HIV incidence may be explained the higher overall risk of HIV acquisition among individuals involved with the criminal justice system. Despite declining steadily over the last 20 years, HIV prevalence in U.S. prisons is still approximately five times that of the U.S. general population, and incarceration is considered an independent risk factor for HIV (163, 164). Additionally, HIV testing is a routine part of intake in many prisons, which may explain the association between incarceration and HIV testing likelihood. These trends may not have been seen in the Hispanic population model due to lower overall incarceration rates for the Hispanic population. This may reflect a truly lower incarceration rate than other demographic groups, or it may be due to the fact that data collection on ethnicity in state criminal justice departments is of inconsistent quality and is often poor (141).

6.2 Limitations of the study

As noted previously, every state in the U.S. has prosecuted HIV exposure in some way, such as through the use of general criminal statutes in states that do not have HIV-specific criminal laws (126, 127). Thus, HIV criminalization occurs in some form in every state. This can present a challenge to empirical research that aims to measure the effect of HIV criminalization on HIV incidence rates or related behaviors. However, the overwhelming majority of the literature on this topic has specifically argued the shortcomings and potential for harm of criminal laws that explicitly target HIV and has called for empirical research that investigates the effects of these HIV-specific criminalization laws (19, 39, 42, 43, 47, 137, 165, 166).

Imprisoned population rates may be an imperfect proxy for overpolicing, which is an effect modifier in the conceptual model. While Black and Hispanic individuals are disproportionately represented in jails and prisons, overpolicing does not always lead to arrest. Overpolicing can also include harassment by police officers and other contact with law enforcement that does not lead to arrest, and so the imprisoned population rate may not fully capture the extent to which these individuals experience overpolicing. Additionally, Hispanic jail population data may not be accurate for all jurisdictions due to the fact that data collection on ethnicity in state criminal justice departments is of inconsistent quality and is often poor (141).

There were some limitations specific to the data used in the analyses. Stable HIV incidence rates were not available for all jurisdictions for all years. In Chapter 3, HIV incidence rates for the Black and Hispanic populations were unstable for all or most years for N=10 and N=11 states, respectively. This may have resulted in low statistical power and lack of precision in parameter estimates. An additional limitation of the analysis in Chapter 3 is its small population size. Because it is a state-level analysis, the total population is N=51, which is fairly small by epidemiologic standards. In Chapter 4, counties were only included if they had a stable HIV rate for at least six years of the ten-year analysis period. Additionally, no jail population data were available for any years from Connecticut, Delaware, or Vermont. This resulted in only 11.3% of counties being included for the general population, 5.7% of counties for the Black population, and 3.2% of counties for the Hispanic population. While the included counties accounted for nearly two thirds of each of the three populations, this may indicate that the results are not generalizable to more sparsely populated counties, or counties with low HIV incidence. In Chapter 5, HIV testing history was missing for 11.65% (n=208,697) of the study sample. The exclusion of these respondents has the potential to bias results, if nonresponse for HIV testing history is related to living in a state that criminalizes HIV.

Finally, the model results should be interpreted with caution, particularly when considering the estimated independent effect of the law itself. In the difference-in-differences analysis conducted in Chapter 5, which compared HIV testing history between California (the "treatment" state) and Nevada (the "control" state) residents and designated 2018-2019 as the "post-treatment period," the effect of California's revision of its HIV criminalization statute (which went into effect in 2018) was not statistically significant (p=0.19 for the general population; p=0.27 for the Black and Hispanic populations), making it difficult to draw any convincing causal inferences. However, it is worth noting that this may be due to the relatively short time frame of the analysis (two years pre-revision and two years post-revision).

6.3 Public health implications

The statistically significant effect modification of the higher jailed population rate on the association between HIV criminalization and new diagnoses in Chapter 4 is interesting and may represent fewer cases of HIV cases being diagnosed in counties that are policed more heavily. It has been widely hypothesized in public health research on HIV criminalization laws that these statutes may discourage HIV testing (51) by motivating individuals to eliminate their culpability under the law (5-9, 13, 14, 24, 26, 52-56), as individuals must be aware of their HIV status to be criminally liable (50). Many researchers theorize that this is the primary mechanism by which HIV criminalization laws discourage testing, and therefore indirectly increase HIV transmission (41, 50, 57, 58). They may be more motivated to do this in areas where encounters with law enforcement are more likely. In a descriptive analysis of criminal prosecutions for HIV exposure, Lazzarini, Bray, and Burris (19) found no evidence of systemic enforcement of these laws but noted that "[w]hat seems to determine who gets prosecuted is the accident of being caught." This is supported by findings from an analysis on HIV criminalization laws by Sah et al. (115), which examined the laws' association with the proportion of PLWH diagnosed and the annual percentage change in HIV prevalence. They concluded that HIV criminalization laws are associated with a lower proportion of HIV diagnosis and increased (undiagnosed) HIV prevalence.

Similar to the results of the analysis in Chapter 5, the author Lee (58) found that an interaction term between the existence of an HIV criminalization statute and increased media coverage of individuals who had been charged under the statute was related to a decrease in HIV testing among at-risk individuals. Tran, Hatzenbuehler, and Goldstein (149) also found a significant association between structural stigma and proportion of arrests for HIV exposure per 100,000 persons living with HIV by state. These studies suggest that enforcement of laws criminalizing HIV via prosecutions for other crimes have the potential to impact HIV transmission and related factors, including HIV testing, in the general population. However, it may be that different factors serve as primary drivers of HIV testing behavior in Black and Hispanic populations. Because HIV exposure can (and has) been prosecuted in some way in every state – using STI or communicable disease laws or general criminal statutes in states that do not have HIV-specific criminal laws (126, 127) – individuals from heavily-policed communities may assume they will be targeted regardless of the laws in their state, and thus their HIV testing behavior will not be impacted by HIV-specific criminalization statutes.

6.4 Future directions

The literature on HIV criminalization has repeatedly noted a lack of quantitative research on the effects of laws that criminalize the exposure and transmission of HIV and has explicitly called for empirical investigations into the effects of these laws (19, 39, 42, 43, 47, 137, 165, 166). Public health and human rights advocates have been making claims about potential negative effects of these laws for decades, while advocacy groups have been using these claims to support ongoing work to get states to reform their HIV criminalization laws. If the scientific community cannot support these claims with empirical evidence, that risks compromising the advocacy work. Thus, it is in the interest of public health practitioners, human rights advocates, researchers, policy makers, and people living with HIV to ensure that these hypotheses are rigorously tested and held up to scrutiny.

The future of HIV criminalization law reform is always uncertain, as it depends on political will and overall sociopolitical trends more generally. Once laws have been passed, they are often more challenging to repeal or reform, though some progress has been made recently in Iowa (28, 182) and California (179). Normally, these would present excellent opportunities to conduct difference-in-differences analyses to test whether the repeal of the law had a measurable effect on HIV testing behaviors or incidence rates. However, the emergence of the COVID-19 pandemic complicates this. It will be many years before the full impact of COVID-19 on HIV in the U.S. is known, but the little peer-reviewed research that is available shows that groups at risk for HIV acquisition significantly modified their sexual behaviors, both in response to risk of COVID-19 transmission and to stay-at-home orders (183, 184). Additionally, the impact of the pandemic on the U.S. public health system led to disruption of HIV-related services, including testing and treatment, both of which would impact HIV transmission. Untangling the impacts of COVID-19 on all of the structural factors that influence HIV risk will be a monumental challenge.

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