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Hiv In The United States: A Spatial Examination Of Testing And Outcomes

Sazid Shameem Khan

University of South Carolina - Columbia

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by

Sazid Shameem Khan

Bachelor of Arts
University of Florida, 2012

Master of Public Health
University of Florida, 2014

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Accepted by:

Jan Eberth, Major Professor

Myriam Torres, Committee Member

Alexander McLain, Committee Member

Bankole Olatosi, Committee Member

Cheryl L. Addy, Vice Provost and Dean of the Graduate School

DEDICATION

This dissertation is dedicated to my parents, friends, Ph.D. cohort and colleagues that I have worked with up to this point. I surely would not have reached this point without your love, support and guidance along the way.

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ABSTRACT

The main objectives of this dissertation were to provide a complete depiction of the prevalence of HIV across the United States and to assess HIV testing trends among various subpopulations. Additionally, we focused on measuring spatial access to HIV-testing resources across the U.S. South, where HIV is rapidly becoming more burdensome and resources have historically been allocated disproportionately. We sought to identify disparate populations and locations that require further focus moving forward to stem the HIV epidemic.

We utilized a variety of data sources such as the Behavioral Risk Factor Surveillance System (BRFSS) which was used to assess national temporal trends of reported HIV testing among different subpopulations. We used geocoded HIV facility locations, obtained from the Centers for Disease Control and Prevention (CDC), to examine spatial accessibility to HIV testing facilities with a focus on rurality, across the U.S. south. We applied small area estimation (SAE) techniques to model HIV prevalence at the county-level, using auxiliary covariate data and HIV data released by the CDC, to assess the burden of HIV at the local level.

Our study found that as rurality increased, as did suboptimal access to HIV testing facilities across the U.S. south, particularly in more socioeconomically deprived areas. Populations farther than 30 minutes from a testing facility, had lower average median household incomes, higher poverty rates and higher rates of being uninsured. We also found nationwide that females, individuals with health insurance, those who identify as lesbian/gay and partake in high risk behaviors were more likely to report being tested for HIV compared to males, individuals without insurance, those who identify as straight and those who do not partake in high risk behaviors. Our findings also confirmed previous research showing the highest prevalence of HIV along the coastlines and consistently across the U.S. south.

Overall, the work from this dissertation indicates the continued need for targeted interventions, outreach efforts and policies to address disparities regarding the utilization of HIV testing across the country, particularly along the coasts and in the rural south where there is a disproportionate level of access to HIV testing services.

Keywords: HIV, HIV testing, HIV prevalence, small area estimation, geographic information systems, spatial analysis, health disparities

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CHAPTER 1

INTRODUCTION

Human immunodeficiency virus (HIV) has been in the global spotlight for the better part of the past three decades with the first cases being diagnosed in the early 1980s to an estimated 36.7 million people living with HIV worldwide as of 2015 (“Global AIDS Update” 1). HIV rates have steadily declined in the U.S. over the past decade, with new HIV diagnoses dropping by almost 20% from 2005 to 2014 (“Global AIDS Update”). While a concerted effort to lower the rate of HIV burden in urban areas has resulted in an 18% decline in new HIV infections as per the CDC, HIV incidence and prevalence rates have increased in rural areas over the past two decades (Pellowski et al.). Still over 90% of HIV cases in the U.S. occur in major urban areas but due to the sparsity of people in many rural areas, the proportion of the population affected by HIV can be as high if not higher in rural areas compared to their urban counterparts (“HIV/AIDS in Rural America” 1).

In 2008, the Centers for Disease Control and Prevention (“HIV in the United States”) estimated that 49,645 adults and adolescents were living with HIV in rural areas of the U.S. (“HIV in the United States”) and that HIV is having an increasing impact on these communities. As recently as 2015, Indiana experienced the largest outbreak of HIV in its state history and a small, rural community was the epicenter (Ungar).

Indiana is an alarming example of a rural community that was primed for an HIV epidemic given its HIV risk indicators- high prescription painkiller and injection drug use, high unemployment rates, high poverty rates, low levels of education, poor access to healthcare and the low rates of life expectancy in the state (Vyavaharkar).

The uptick in HIV rates coupled with other poor health indicators in rural areas particularly in the south (e.g. high rates of death, diabetes and heart disease) (Reif) did not however lead to an increased focus of research or community outreach in those areas until recently. Rather, the focus on HIV has been missing from many rural communities and has led to the current state of rural health. Furthermore, studies done examining spatial accessibility to HIV related services are either out of date or too small in scope (Dasgupta) to be of much use nationally. There are major concerns regarding incomplete information available on HIV prevalence, access and utilization of HIV resources across the country. Partial data on HIV prevalence rates at the county level up to 2014 is publicly available although rates for large segments of the Midwest and fragments across the rest of the country are missing due to small HIV counts (< 5) in those sparsely populated areas or due to agreements with the state health department to not release such information (such as in South Dakota).

1.1 Statement of the Problem

There is a major gap in the literature examining spatial accessibility and proximity to HIV testing. Current research on the subject is either urban setting specific (Dasgupta; Ganapati) or done outside of the United States (Fulcher). We planned to utilize and expand upon the measures and research done by previous studies but on a nationally representative scale. In addition, there is a lack of publicly available data when it comes to HIV prevalence across the country. Federal agencies like the CDC have released incomplete surveillance reports, suppressing data on HIV prevalence at the county level in various parts of the nation particularly in the Midwest. This is due to one or a combination of the following factors: low HIV count in a small population, missing/unreported data or per the request of the state. Regardless of the rationale, incomplete publicly available data is a problem as it can mask areas with potential HIV problems that can then spread to other communities. There is also very little research on HIV testing rates across areas or population subgroups using data from population-based health surveys such as the Behavioral Risk Factor Surveillance System (BRFSS). There have been studies done using BRFSS data within the past five years, but most have only focused on specific geographic regions or specific subpopulations (Ansa and Ford) but have not utilized the most current data available on a larger scale.

While it is true that nearly half of all people living with acquired immunodeficiency syndrome (AIDS) reside in ten metropolitan areas across the country (Pellowski et al. 3) there are increasingly substantial pockets of HIV occurring in rural America, especially in the south, where there is a lack of focus on HIV surveillance and interventions. The spread of HIV is based on local prevalence, individual behaviors, biological factors and social conditions (Pellowski et al. 2). There have been interventions and policies targeting these factors to some extent since HIV came into the public light (Donley). However, interventions and policies are normally directed at areas where an issue has been assessed, researched and needs correction. However, rural areas can be easily overlooked due to funding restrictions, lack of planning and surveillance activities, and misconceptions about population risk factors. Incomplete, missing, or old data in rural areas hamper efforts to combat rising HIV transmission and can lead to dangerous mismanagement or misidentification of potential HIV hot spots in the future.

1.2 Aims and Hypotheses

The goal of this project is to provide valuable and updated information on different aspects of HIV surveillance in the U.S. This dissertation covered a spectrum of topics ranging from examining spatial accessibility to HIV-testing related resources in the U.S. South (Paper 1), providing more complete and updated estimates of HIV prevalence across all U.S. counties (Paper 2), and assessing HIV testing trends to identify subpopulations in need of support (Paper 3). The specific aims are as follows:

Aim 1: To examine spatial accessibility to HIV testing facilities across the U.S. South, along with measures of area socioeconomic deprivation and other HIV risk indicators which can increase the probability of an HIV epidemic.

Hypothesis 1: As rurality increases, we hypothesized that residents will experience suboptimal access to HIV testing-related resources, particularly in more socioeconomic deprived areas. We also hypothesized that areas with higher proportions of minorities, regardless of the level of rurality of the area, will exhibit lower levels of spatial accessibility to HIV testing facilities.

Rationale: Research shows that factors such as lack of qualified providers with HIV expertise, transportation issues, and stigma can lead to social isolation and play a role in the transmission of HIV (Pellowski 6). These issues are particularly relevant in rural areas where there are fewer options for public transportation and medical providers. In addition, a more tight-knit community leads to a higher likelihood of people finding out if someone has HIV ("HIV/AIDS in Rural America"). Late diagnosis and linkage to HIV care of HIV was also found to be associated with rurality in previous studies (Trepka; Holtgrave). Hence the focus of this aim was to identify if and where there was a disparity of access to HIV testing across the U.S. South. As well as to determine disparities coupled with other HIV risk factors (e.g., insurance coverage, employment status, education status) which can be used to identify potential HIV hotspots/outbreaks.

Aim 2: To estimate HIV prevalence at the county level and to compare prevalence across the country to identify areas with high HIV burden.

Hypothesis 2: We hypothesized that the HIV prevalent case counts predicted by our SAE model will be considered valid and reliable after statistical validation techniques.

Rationale: There are many counties across the United States without publicly available data on HIV prevalence due to being either missing or suppressed. These areas are majority located in rural areas where while the population sizes may be small and spread out, the proportional burden of HIV may be just as great as in more populated areas ("HIV/AIDS in Rural America" 1). Hence the need to estimate rates in those missing areas to better understand the epidemic and find potential hot-spots based on HIV-risk indictors. Risk indicators like high rates of poverty, unemployment and poor education levels, all of which disproportionately plague minority groups. In turn, minority groups are disproportionality burdened with HIV such as African Americans who made up 44% of all new HIV diagnoses in 2009 but only make up 14% of the general population ("HIV in the United States). Areas with high levels of economic deprivation also have the lowest levels of social capital, or the value of one's social network, which has been documented to be associated with higher rates of HIV infection (Cao). We believe that the inclusion of all of these factors into our model will provide strength for our model to accurately predict the prevalence of HIV across the country.

Aim 3: To explore HIV testing rates and individual-level determinants among different population subgroups over time using BRFSS data from 2011-2017.

Hypothesis 3: We hypothesized that utilization of HIV testing will be lower among minority groups, individuals without access to insurance and among males in general.

Rationale: Being tested for HIV is important in stemming the spread of HIV however as mentioned, HIV affects minorities disproportionately (Pellowski et al.). While there have been major strides made in increasing access to HIV testing to stem transmission, through interventions and advancement in technology ("HIV Surveillance Report"), the progress is not equal across all segments of the U.S. population. Even among minority groups, the greatest burden of disease generally follows socioeconomic lines, with the greatest burden observed among the poorest (Pellowski et al. 3).

The overall focus of these aims was to provide a clearer picture of the spatial access to HIV-testing related resources across the U.S. South, utilization of testing resources and assessing the progress made. We also provided insight into HIV prevalence in areas where there was no public data previously available, across the nation to identify disparate populations and locations that require further focus moving forward.

1.3 Importance of Research

This dissertation updated and filled in gaps in the literature regarding the current state of access to HIV-related resources to all regions and population subgroups in the south where HIV is a growing problem. It used the largest publicly available national health-related survey (e.g., BRFSS) to assess trends in HIV testing over time and identify subpopulations that have particularly low (or declining) rates of HIV testing. We also provided a clearer picture of HIV prevalence across the U.S. by estimating prevalence rates for areas that have no publicly available data to identify hot spots. This work is significant in providing much needed attention to HIV in underserved and disenfranchised communities nationwide, both in terms of access to HIV related resources and epidemiologic measures (i.e. prevalence rates). With the shifting demographics of the disease in recent years (P.B. Williams) as well as parallel trends in drug abuse, poverty and healthcare facility closures in rural America (Helseth), a renewed focus on the entire country, especially rural areas, was warranted.

It has been assumed for many years that HIV is solely an urban, big city problem, including people in rural areas who believe it can never happen in their close-knit integrated communities ("Pellowksi"). While new AIDS diagnoses have been declining in urban settings over the past 30 years, they have slowly been increasing in rural settings particularly in the south where 8.6% of new AIDS diagnoses in 2011 were from nonmetropolitan areas ("HIV Surveillance Report").

A major obstacle in determining the burden of HIV in rural settings is the small population sizes which as mentioned leads to a tight-knit community where keeping a diagnosis private can be problematic and hence people are less likely to volunteer to be tested and hence underreported rates (Oppong). This dissertation was innovative in how it tackled the issue of inexact reporting in rural settings through area-level small area estimation modeling technique which will borrow strength from available HIV rates in neighboring counties and utilize data on HIV risk factors in the community to approximate the HIV burden in the area. The results from this dissertation will help identify disenfranchised groups and weaknesses across the country where HIV-related disparities are present and need to be addressed.

CHAPTER 2

BRIEF LITERATURE REVIEW OF THE HIV EPIDEMIC SINCE THE 1980s

2.1 History and Risk Factors

To better understand a disease and how to combat its spread, it is important to understand the history and timeline of important events and policies that have led to the current disease landscape. There have been major historical changes since HIV was first thrust into the public spotlight in 1981; these changes have helped contain the spread of HIV in many but not settings.

The Human Immunodeficiency Virus is thought to have originated back in the 1920s when the Simian immunodeficiency virus (SIV) that infected chimpanzees crossed over to infect humans in the Democratic Republic of the Congo (DRC). Scientists believe the earliest case positively identified as Acquired Immunodeficiency Syndrome (AIDS) was a man in the DRC in 1959 although it has been disputed by some researchers as truly being AIDS as defined later (Worobey). While HIV was not publicly introduced to the American public until the early 1980s, Scientists believe the “patient zero” (“A Timeline of HIV and AIDS”) for HIV in the U.S., traveled to New York from Haiti, a full decade earlier and the disease had been misclassified for years.

The first public introduction to what would later be deemed as AIDS came in 1981 when five young gay men in the Los Angeles Area were diagnosed with a rare form of pneumonia. Along with the pneumonia, the men had other infections resulting from weakened immune systems. These were the first of many reported cases of the rare form of pneumonia among gay men as well as Kaposi's Sarcoma (KS) - a rare form of cancer, reported among a group of gay men in New York and California. Early in the HIV/AIDS epidemic, the disease was coined a "gay cancer" and many in the public as well as some in the medical community shared the sentiment that this was an exclusively homosexual disease. Some in the medical community termed the disease "Gay-Related Immune Deficiency or "GRID" ("A Cluster of Kaposi's Sarcoma"). At this point the case total had risen to over 250 with a fatality rate nearing 50% among immunocompromised gay men ("A Timeline of HIV and AIDS"). The CDC in 1982 coined the term "Acquired Immune Deficiency Syndrome" or 'AIDS" and an official case-definition for the disease ("A Timeline of HIV and AIDS"). It was soon after this in 1983 that AIDS cases were found among female partners of men with AIDS ("Epidemiological Notes") as well as children who had received blood transfusions from a male later to have been diagnosed with AIDS ("A Timeline of HIV and AIDS").

In 1983, the CDC published the first recommended precautions for healthcare workers and allied health professionals to prevent "AIDS transmission" and Congress passed its first bill funding AIDS research and treatment- allocating approximately $12 million for such efforts ("Current Trends Update"). The CDC would provide further clarification on AIDS transmission, notably dismissing the thought of AIDS being transmitted through "food, water, air, or environmental surfaces" ("A Timeline of HIV and AIDS"). Later that year, two laboratories- one led by Dr. Luc Montagnier of the Pasteur Institute in France and another led by Dr. Robert Gallo of the National Cancer Institute, separately isolated strains that they each believe are related to AIDS, labeled the lymphadenopathy-associated virus (LAV) by Montagnier, and HTLV-III by Gallo ("A Timeline of HIV and AIDS"). They would hold a joint press conference classifying their discoveries as a retrovirus claimed to be the cause of AIDS. In 1986, these viruses, after being deemed the same, would be given the official name of the Human Immunodeficiency Virus (HIV) by the International Committee on the Taxonomy of Viruses ("A Timeline of HIV and AIDS").

In 1985 Ryan White, a teenager from Indiana, who had acquired AIDS through contaminated blood products to treat his hemophilia, was barred from his school due to his condition. This led to national media attention after the White family procured legal services to battle for Ryan's rights ("Who is Ryan White?"). Ryan White would live for another 5 years before his death in 1990, several months before the passing of the Ryan White CARE Act 27-which helped to establish a comprehensive system of care that includes primary medical care and essential support services for PLWHV who are uninsured or underinsured. It was soon after this initial media attention that AIDS was officially mentioned for the first time on a public scale by President Ronald Regan. That same year, the National AIDS Network (NAN) was founded as was American Foundation for AIDS Research (amfAR).

Replicating efforts initiated in Europe, the first needle exchange program (NEP) started in Connecticut to stem transmission of HIV in 1986. Now there are over 200 NEPs across 36 states as per CDC ("Needle Exchange"). There was an added focus on needle exchanges in general after the CDC added intravenous drug use (IDU) to the growing list of risk factors for AIDS (i.e., men who have sex with men, Haitian origin, hemophilia A, female sexual partners of men with AIDS). Reducing needle sharing and IDU would help stem the transmission of HIV as the sharing of dirty needles is considered a risk factor for HIV ("Needle Exchange").

A breakthrough in HIV treatment occurred in 1987 with the FDA approval of the first antiretroviral drug zidovudine (AZT), followed by the U.S. Congress backing of $30 million for production and distribution of AZT ("A Timeline of HIV and AIDS"). Later that year, President Reagan would establish the Presidential Commission on HIV, also known as the Watkins Commission, after his first public speech on AIDS. That same year (1987), the U.S. government made two marquee policies regarding HIV/AIDS. The first was a ban of all HIV-positive individuals from immigrating to the U.S. by adding HIV to the "dangerous contagious disease" immigration exclusion list ("A Timeline of HIV and AIDS"). The second was a congressional vote in favor of federally financing educational material on AIDS to promote sexual abstinence and forbid the use of federal funds in the production of any material promoting homosexuality and IDU use, officially termed the "Helms Amendment" ("A Timeline of HIV and AIDS").

As of 1989, the count of reported AIDS cases in the U.S. had grown to 100,000 amid growing interest and funding of HIV research. HRSA provided $20 million to establish HIV care and treatment in the home and community at the state level across the nation, many of which were receiving funding for HIV care for the first time. The Health Resources and Services Administration (HRSA) and the CDC also partnered to provide funding for seven community health centers to provide HIV counseling and testing (would later become a piece of the Ryan White CARE Act of 1990).

In 1990, the U.S. Congress added PLWH to the Americans with Disabilities Act to prohibit discrimination against people with disabilities including HIV ("Global HIV/AIDS Timeline"). This bill came one month prior to the Ryan White CARE Act passage, providing over $220 million annually in federal funding for HIV care and treatment at the community level. The end of 1990 brought about the enactment of the AIDS Housing Opportunity Act, as well as the formation of the Latino Commission on AIDS to identify the needs of the underserved Latino population regarding HIV prevention and care ("A Timeline of HIV and AIDS").

The rapid spread of HIV/AIDS would continue to take its toll on the country as it was deemed in 1992 to be the number one cause of death among men, ages 25-44 (Stolberg). Later in the year, the FDA licensed a 10-minute testing kit which could be used by healthcare professionals to detect HIV-1. At this point, federal funding for HIV/AIDS research and care had reached $4.5 billion (more than double the amount given just 3 years prior in 1989). The HIV Epidemiology Study (HERS) and the Women's Interagency HIV Study (WHIS) both started after congress enacted the National Institutes of Health (NIH) revitalization act which mandated increased involvement of women and minorities in all facets of research. On the other spectrum, the 8th annual International AIDS conference was moved from Boston to Amsterdam due to the travel ban on HIV-positive individuals to the U.S.; a ban that the USA Congress voted overwhelmingly to retain in 1993 and was included as part of the same NIH revitalization act (2.5 million AIDS cases worldwide by this time).

The spread of AIDS in the U.S. would grow to such an extent that from 1994-1995, it was deemed the number one cause of death among all Americans ages 25-44 ("A Timeline of HIV and AIDS"). It would be later in 1994 that the U.S. Food and Drug Administration (FDA) would approve use of an oral HIV test which was the first non-blood antibody test of its kind ("A Timeline of HIV and AIDS"). It was during this time that the CDC would issue a report on the Syringe Exchange Programs (SEPs) deeming it an effective HIV prevention strategy, a time that also saw the total cases of AIDS diagnoses hit half a million in the U.S. ("A Timeline of HIV and AIDS").

1996 was a turning point year in the fight against HIV/AIDS in that it was the first year since the epidemic officially began, that saw a decline in the number of new AIDS cases in the U.S. and HIV was no longer the leading cause of death among Americans aged 25-44 in general; still the leading cause among African Americans that age ("Update Mortality"). It was also the year the FDA made three major announcements regarding HIV: 1) an HIV home testing and collection kit 2) a viral load test to measure the amount of HIV in the blood and 3) the approval of nevirapine- a reverse transcriptase inhibitor drug ("A Timeline of HIV and AIDS"). The following year saw the official shift in standard treatment to highly active antiretroviral therapy (HAART) ("A Timeline of HIV and AIDS"). A shift that saw the advent of *Combivir*, a 2 in 1 ART drug tablet made that would cut down on the number of medication that patients would be required to take.

A final major development before the end of the 90s was the CDC expanding the case definition of HIV for better surveillance and tracking of the epidemic ("A Timeline of HIV and AIDS"). There was also a greater focus on the epidemic and its effect on the Latino community through congressional hearings and attention from the U.S.

Congressional Hispanic Caucus. At this point globally, HIV/AIDS had become the 4th largest cause of death and was the leading cause of death in Africa. The World Health Organization (WHO) noted that there were an estimated 33 million PLWH globally and 14 million had died from AIDS to that point.

While the U.S. had been concentrating on combating HIV/AIDS domestically, the 2000s saw a major shift internationally as the epidemic became more global. Major political moves signifying this shift included the U.S. declaring HIV/AIDS a threat to national security and the signing of an executive order providing assistance to developing countries regarding the production and dissemination of HIV treatments. The U.S. Congress enacted the Global AIDS and Tuberculosis Relief Act of 2000 to help in the global fight against AIDS. Domestically, Congress reauthorized the Ryan White CARE Act for the second time ("A Timeline of HIV and AIDS").

In 2002, HIV would become the number one leading cause of death among ages 15-59 worldwide ("Global HIV/AIDS Timeline"), as the U.S. continued its support of fighting the epidemic globally, particularly in developing countries. This focus in large part was due to the alarming rates of HIV incidence in sub-Saharan Africa and the inability of poor countries to develop the necessary pharmaceuticals for treatment. The Global Fund to Fight AIDS, Tuberculosis and Malaria was created to combat the epidemic by combining government and private efforts ("A Timeline of HIV and AIDS"). The FDA also approved an innovative HIV test called the OraQuick Rapid HIV-1 Antibody Test which rapidly tests for HIV with a finger prick and can be done in non-clinical settings ("A Timeline of HIV and AIDS"). This test would receive an update in 2004 with saliva added as a testing sample option.

A couple of major biological discoveries occurred from 2005 to 2006. It was discovered that approximately $1/10^{th}$ of Europeans were immune to HIV due to genetic adaptions during the plagues of the middle ages. Secondly, an HIV-like virus was found in chimpanzees in south Cameroon, adding further evidence to the theory that HIV was first contracted through human-chimpanzee contact. Researchers also found that male circumcision was found to reduce the risk of female-to-male HIV transmission by up to 60% ("A Timeline of HIV and AIDS").

In 2006, the CDC recommended a shift to the "opt-out" approach to HIV testing for all adult and adolescent patients in health-care settings, including pregnant women where HIV testing would be done unless the individual decides against it ("A Timeline of HIV and AIDS"). Additional recommendations released by the CDC included yearly testing for all individuals of age and the changing of HIV testing consent from separately written to general medical care consent ("New Progress and Guidance"). Meanwhile the WHO released its revised guidelines on HIV treatment, recommending that ART be started for all patients with advanced clinical disease or a CD4 count of 200 cells/mm3 or less ("WHO and UNAIDS") due to increasing data showing the merits of starting treatment earlier in the infection progression.

On a global scale, in 2007 the WHO and the Joint United Nations Programme on HIV/AIDS ("Global AIDS Update") issued guidelines focusing on provider-initiated HIV testing and counseling to increase testing rates particularly in developing nations ("Global AIDS Update"). During this time, the WHO and UNAIDS also announced updated surveillance data indicating a leveling-off of HIV prevalence, a decline in new infections and AIDS-related deaths. Domestically, AIDS-related deaths had surpassed the half-million mark since 1981 with an uptick in HIV incidence particularly among gay men ("A Timeline of HIV/AIDS").

In 2009, President Barack Obama called for the first National HIV/AIDS strategy, launched the Global Health Initiative (GHI) and a major shift in international policy occurred as the travel ban preventing HIV-positive people from entering the USA was lifted (22 years after it was first enacted) ("What is the National HIV/AIDS Strategy?"). Also, during this time, Congress altered the ban on using federal funds towards needle exchange programs although the ban would be reinstated exactly one year later ("A Timeline of HIV and AIDS").

The following year saw the landmark passage of the Patient Protection and Affordable Care Act (ACA) into law ("A Timeline of HIV and AIDS"), which provided special protection for those with pre-existing conditions such as HIV when it comes to purchasing healthcare insurance. Later in 2010, the White House released the inaugural National HIV/AIDS Strategy for the United States. It is a 5-year plan that details the U.S. plan to combat the HIV epidemic (includes priorities and strategic action steps with measurable outcomes laid out) ("A Timeline of HIV and AIDS"). The strategic goals outlined in the plan included: reduce infections, increase access to care and improve health outcomes for PLWH, reduce HIV-related health disparities and health inequalities and to achieve a more coordinated response to the epidemic. The strategy is scheduled to be revisited and updated every 5 years with 2015 being the year of the next update ("What is the National HIV/AIDS Strategy?") (the 2015 update is discussed later in chapter). During this time, the WHO released an updated version of its HIV treatment guidelines, advocating for earlier treatment by raising the CD4+ count indicator to 350 cells/mm^3 from the previous 200 cells/mm^3 ("New Progress and Guidance").

In 2012, the U.S. Department of Health and Human Services (DHHS) revised its treatment guidelines to now make ART recommended for all HIV-infected adults and adolescents regardless of the CD4+ count or viral load measures ("Panel on Antiretroviral Guidelines"). This in part due to research finding that early treatment of HIV positive individuals had major benefits for them and for their HIV-negative partners. Later that year, the FDA approved of an over the counter at-home HIV test with immediate results and also approved the use of the drug *Truvada* as a pre-exposure prophylaxis (PrEP) to reduce risk of HIV infection. UNAIDS estimated that at the end of 2012, that there were over 1.2 million PLWH in the U.S. and 35.3 million PLWH worldwide ("A Timeline of HIV and AIDS"). A study on 25 low and middle-income countries by UNAIDS shows the rate of new HIV infections were cut in half and ART usage had increased by 63% in those countries that were studied.

In 2013, UNAIDS called for a new set of targets for HIV treatment past 2015 and created the 90-90-90 concept. By 2020, 90% of all PLWH will know their HIV status, 90% of all with a positive HIV diagnosis will have received ART and 90% of all people receiving treatment will have successful viral load suppression which is when a person's viral load has reached a level low enough where the person can be deemed healthy and their risk of transmission has been reduced ("90-90-90"). UNAIDS has estimated that with the achievement of these goals by 2020, that we will be on the way to ending the AIDS epidemic by 2030 which would have major health implications worldwide. They believe that these goals are obtainable but only through strong principles grounded in "human rights, mutual respect and inclusion" ("90-90-90"). The concept will take a more comprehensive approach to combating the epidemic, as in aside from the direct measures (increasing access and use of ART), a concerted effort will be made to increase condom programming, ending transmission via mother to child and increase PrEP usage. Also, there will be an increase in harm reduction efforts for people who inject drugs and voluntary male circumcision in high risk areas ("90-90-90"). The UN believes that for these goals to be met that there much be a political will, utilization of advancing technologies in testing and treatment, and system preparedness.

Also, in 2013, the WHO revised its guidelines for HIV treatment to now start once the CD4+ count falls below 500 cell/mm^3 from the previous 350 cells/mm^{3,} ("A Timeline of HIV and AIDS"). These new recommendations were in response to the growing research showing the benefits of initiating treatment earlier in the infection process. This is in accordance with the DHHS recommendations a few years earlier which called for an even more aggressive treatment timeline, initiating it regardless of CD4+ count ("A Timeline of HIV and AIDS").

In 2014, the CDC reported that 1/3rd of PLWH were still receiving care as of 2011 and that the majority were no longer linked to care ("A Timeline of HIV and AIDS"). The CDC also released a report documenting the gaps in HIV care and treatment among Latino populations in the U.S. where less than half (44%) of Latinos diagnosed for HIV had received ART and only 37% has achieved successful viral load suppression ("Gaps in Care"). The following year, the CDC would release a report signifying that all racial/ethnic minority groups experienced a disproportionate burden of HIV. The report also named men who have sex with men (MSM), young adults and people who live in the southern region of the U.S. as particularly vulnerable populations.

In 2015, Indiana state health officials announced an outbreak of HIV in the southeastern, mainly rural portion of the state (“A Timeline of HIV and AIDS”). The outbreak brought to light two major underlying public health issues in rural settings, the spread of HIV and an increase in IDU (“A Timeline of HIV and AIDS”). During this time, the White House released the National HIV/AIDS Strategy: Updated to 2020 (“What is the National HIV/AIDS Strategy?”) which reflected on the accomplishments (and lessons learned) from the 2010 version and provided updated strategies/scientific advancements in combating HIV. Among the changes in the new version, there are 10 new quantitative indicators to better monitor progress and 4 new goals including universal viral suppression and full access to PrEP (“New Guidance and Progress”). The CDC reported that annual HIV diagnoses in the U.S. had dropped 19% from 2005-2014. Although the rates did increase among Latino gay/bisexual men (+24%) and black gay/bisexual men (+22%), it was also reported that only 1 out of 5 sexually active high schoolers were tested for HIV and half of young Americans who have HIV are aware of their status (“Panel on Antiretroviral Guidelines”).

In 2016, the DHHS released new guidelines for state, local, tribal, and territorial health departments so that they can request permission to use federal funds towards syringe service programs (“A Timeline of HIV and AIDS”). The United Nations (UN) held a general assembly meeting in New York that same year where all the member states adopted a new political pledge to end the AIDS epidemic. Medically, the first organ donation from an HIV-positive donor to an HIV-positive recipient occurred in the U.S.

Also, in the past few years the federal ban against men donating blood who had sex with other men had been altered to allow men who had not had sex with men within the past 12 months. Pharmacy researchers also noted that the FDA-approved antiretroviral drug Truvada was effective in reducing the risk of HIV infection but only if women took it daily and twice a week for men (“A Timeline of HIV and AIDS”).

According to WHO (“A Timeline of HIV and AIDS”) PLWH are living longer and healthier lives than ever before with the advancement in ART and major progress has been made in eliminating mother to child transmission. Eight out of every 10 pregnant women living with HIV were on ART. A major development in the global HIV strategy was the midpoint assessment of the UNAIDS 90-90-90 targets. The UNAIDS report on the work done since 2015 to achieve the goals noted the progress made and the work still needed to be done (“A Timeline of HIV and AIDS”). As of 2017, an estimated 70% globally knew their HIV status and among those who knew their status 77% were on treatment. Of those who were on treatment, approximately 82% had successful viral load suppression (“Ending AIDS”).

Treatment coverage increased from 17.8 million in 2015 to 19.5 million in 2016 and the increased rate of additional people on ART annually puts coverage on pace to meet the UN General Assembly’s target of 30 million PLWH on treatment by 2020 (“Press Release”). Seven countries had already achieved 90% of PLWH knowing their status and an additional 16 countries are near the target (between 85%-89% achieved) (“Press Release”). UNAIDS noted in its report that recent data indicated knowledge of HIV status had improved greatly over the past decade and will need to continue to improve as does linkage to care after diagnosis if the targets are to be reached by 2020 as the world tries to end the HIV epidemic soon ("Press Release").

The historical timeline of HIV has shown that domestically and internationally, the strategy to combat this epidemic has changed greatly over the years but has become more collaborative and global in the process. The global collaboration will need to continue in the present and future if the goal is to further contain and eventually, eliminate the spread of HIV particularly in high-risk areas. History has shown that the epidemic can be halted through collective prevention strategies and technological/pharmaceutical advancements in the public health and medical fields on a more global scale.

2.2 Epidemiology of HIV Nationally and Globally

The state of HIV domestically and internationally has been shaped by many different policies and events over the years. HIV/AIDS while initially a domestic issue has since expanded to become a worldwide pandemic, currently affecting nearly 40 million people- although these numbers would be higher if not for global preventative measures ("Ending AIDS") The skyrocketing number of PLWH since the 1980s is attributed in large part to the vast improvement and expanding distribution of ART (Fettig et al.). There are over 17 million PLWH on ART across the globe as of 2015, more than double the number just 5 years prior in 2010 ("Ending AIDS").

2.2.1 National Statistics

As of 2014, there were over 1 million PLWH in the United States with most of them concentrated in distinct geographical regions. There were an estimated 37,600 new infections in the U.S. at the end of 2014, with half of them occurring in the South where the epidemic has shifted towards in recent years ("HIV in the United States"). There was a drop in new infections by 18% from 2008 to 2016 (45,700), with the sharpest decline coming among IDU at 56% The most recent count of new HIV infections was in 2016 (n=39,782, which is a slight uptick from 2014). Among new infections, gay/bisexual men made up 67% of incident cases, specifically African American gay/bisexual men. IDU accounted for 9% of the new HIV diagnoses in 2016 and accounted for 12% of diagnoses among women ("A timeline of HIV and AIDS").

In 2014, the CDC reported that 49% of adults and adolescents being treated for HIV had successful viral load suppression ("HIV Surveillance Report 2016"). All age groups saw a decrease in rate of HIV diagnoses except for the 25-29 age group which saw an increase as did rates for Asians and American Indians/Alaskan Natives while rates from African Americans and Whites decreased and rates remained stable for Latinos (HIV Surveillance Report). New HIV infections by modes of transmission decreased between 2011-2015 including IDU and MSM. In addition to IDU, non-intravenous drug use is also associated with spread of HIV as it promotes sexual transmission.

The U.S. has seen a recent steady increase in HIV among rural communities across the country especially in the epicenter of the Deep South where HIV rates in smaller metropolitan and rural areas were the highest ("HIV/AIDS in Rural America"). The prevalence rate of PLWH in non-metropolitan areas is 99.5 per 100,000 people in the South, with African Americans accounting for 50% of these prevalent cases. As the rate of HIV increases in rural America, as does the burden associated with HIV treatment for rural residents and the healthcare system that serves them. Individuals in rural areas are less likely to have healthcare insurance to cover potential costs of HIV treatment compared to those in urban areas. This is a major issue in rural areas, as people with HIV there are less likely to get tested due to cost or lack of access to testing facilities compared to those in urban areas and once they are diagnosed, they tend to be at a more advanced stage ("HIV/AIDS in Rural America").

A study done on drive-time to HIV care facilities in 3 states in the Midwest (Kansas, Missouri and Nebraska) found that people with HIV in rural areas had to drive an additional 45 minutes to their nearest HIV facility compared to PLWH in urban areas (Oppong). Due to the small population size and interconnectedness of rural communities, there may be issues of confidentiality which may "keep PLWH from seeking medical, support or social services" in their local community for fear of stigma (Oppong). These barriers are major concerns in the changing landscape of HIV nationally.

Overall, while the U.S. has lower rates of HIV prevalence compared to other nations, the areas that do have a high prevalence are typically in areas saddled with poverty (Pellowski). The CDC has reported that HIV prevalence rates tend to be highest among those who are either at or below the poverty level ("Characteristics Associated with HIV"). This is most relevant in the south where poverty, income inequality, residential racial segregation, and poorer health outcomes are all major concerns.

2.2.2 Southern U.S. Statistics

Eight of the top 10 states for annual HIV incidence rates are located in the south and over 40% of PLWH reside in a southern state, the highest rate among any region in the U.S. Even more alarming is that almost half of the deaths among PLWH in the U.S. come from the South. As of 2015, the rate per 100,000 of HIV diagnoses was16.8 in the

South, the highest of any U.S. Census region (Williams). The states with the highest rate of HIV diagnoses per 100,000 were Louisiana (29.2) followed closely by Georgia (28.3) and Florida (27.9). These troubling rates are due in large part to previously mentioned factors (high poverty and poorer health outcomes) along with higher than average rates of people without health insurance, lower levels of education, and poorer social capital (lack of trust, higher rates of racism and stigma still associated with STIs) (P.B. Williams). Another major barrier in stemming the HIV epidemic in the South is that there are fewer people living in the South that are aware of their HIV status compared to the other regions across the U.S. (Williams).

Although most new HIV diagnoses are in urban areas, the south has the highest rates of new HIV diagnoses in suburban and rural areas (Reif). A study done by Weisman (2015) found that those in rural areas of the south were more likely to have a positive AIDS diagnosis within 1 year of HIV infection compared to those in urban areas in the region. This is likely due in large part to the lower retention of HIV treatment associated with rurality along with worse spatial access to HIV care (both in volume of facilities and drive-time to facilities) - factors that can lead to worse rates of viral suppression (Reif). The findings in this study were supported by a CDC report; approximately 75% of people diagnosed were linked to HIV care within 1 month but half of the states across the South fell below that rate ("HIV in the United States"). This evidence coupled with the CDC placing 10 of the 16 states in the South in the top quartile for lifetime risk of being diagnosed for HIV shows the complexities of the epidemic in the South (Williams).

Like many other diseases, there are significant racial/ethnic disparities in HIV diagnoses. In the south, 55% of HIV diagnoses are among African Americans, the single highest proportion for any race in the region (“HIV in the United States”). This disparity may reflect a lack of access to primary healthcare among African Americans, high rates of uninsurance, a disproportionate burden of IDU and other HIV-related risk factors, and a lack of trust in healthcare due to previous acts of injustice (Pellowski). Stigma towards HIV is also particularly high within African American communities, even among adolescents. An even more stigmatized group in the South is the MSM/bisexual African American community, where 60% of all black MSM diagnosed with HIV across the United States in 2014 resided (P.B. Williams).

2.2.3 Northeastern U.S. Statistics

Although the South may be home to the highest percentage of new HIV diagnoses, the Northeast still has the highest prevalence rate of people living with diagnosed HIV infection at 419.5 per 100,000 (“HIV in the United States”) followed by the South at a rate of 352.5 per 100,000.

In terms of HIV infection progressing to AIDS, the Northeast has the second highest rate of annual AIDS diagnoses (accounts for 18% of U.S. total in 2015) and HIV-related deaths (19% of U.S. total) (“HIV in the United States”), although both are far below the rates in the South (53% for both, respectively).

Rates of new diagnoses among African Americans in the Northeast are similar to those in the South (“U.S. Statistics”). In 2015, the Northeast also had the second highest rate of new HIV diagnoses among Hispanics/Latinos (28%), behind only the Western region of the United States.

2.2.4 Midwestern U.S. Statistics

The rate of HIV diagnoses per 100,000 was lowest in the Midwest among the four Census regions at 7.6 per 100,000, with African Americans accounting for 47% of those diagnoses ("HIV in the United States"). In terms of HIV progressing to AIDS, the Midwest has the lowest rates of any region for annual AIDS diagnoses (accounts for 12% of the U.S. total) and among AIDS-related deaths (11% of the U.S. total) (CDC, "HIV in the United States").

Even though the rates in the Midwest are lowest overall (only one state in the region has a cumulative rate greater than 10 cases per 100,000), one area of major concern is the high rates of new HIV diagnoses in rural areas in the Midwest (20%, which is the second highest among the four regions). These troubling numbers are compounded by the farther distances to healthcare facilities that provide HIV care services in rural areas compared to urban areas and the increased stigma associated with HIV among rural communities (Oppong).

2.2.5 Western U.S. Statistics

While the Western region has a higher rate per 100,000 of HIV diagnoses (9.8) and prevalence (244.2) than the Midwest, it has the lowest rate of African Americans diagnosed with HIV at just 18%. As of 2015, the predominant race diagnosed with HIV in the west is Hispanic/Latino (38%) followed by white (34%). Along with the higher prevalence of HIV in the West, there is a higher AIDS-related mortality rate (17%) compared to the Midwest. The West has the second highest rate of new AIDS diagnoses, behind only the Southern region of the United States.

California and Arizona both have higher rates of HIV diagnosis than the rest of the region although the highest rate belongs to Nevada (21.4 per 100,000). This may be due to the high rates of co-morbidities (3rd highest rate in the country for syphilis) and high rates of HIV transmission through MSM ("Nevada"). It is of interest to note when looking at HIV transmission by gender, rates of HIV transmission by intravenous drug use were consistently nearing 25% among females (while intravenous drug use among males were consistently <10%).

2.2.6 Africa

Globally, the highest proportion of PLWH as well as new HIV diagnoses reside in the continent of Africa. The largest gain of ART coverage also came from Africa, mainly in the south and eastern regions. There has been much investment internationally in combating HIV in Africa with mixed but encouraging results.

HIV surveillance across the continent, while improving, is still quite poor, so most current HIV figures come from statistical (vs. direct) estimates. The epidemiological trends of HIV differ based on the region of focus. Sub-Saharan Africa is showing sustained trends of lowering estimated rates of HIV infection and decreased AIDS-related mortality rates along with a higher prevalence of PLWH (estimated 20.8 million in 2000 to an estimated 25 million as of 2012) ("Global Report 2013"). North Africa on the other hand has increasing rates of HIV infection and AIDS-related mortality rates along with higher rates of PLWH (estimated 260,000 as of 2012) ("Progress Report 2011"). However, even with the opposite trends of HIV, the incidence and prevalence of HIV is still much higher in Sub-Saharan Africa compared to the rest of the continent. The higher rates of PLWH is in large part due to the increased access and use of ART across the continent. Also contributing to the lower rates of HIV incidence and prevalence in North Africa is high rates of male circumcision, which has been found to decrease risk of HIV (Abu-Raddad 54). There have been concerted efforts to promote voluntary male circumcision in Sub-Saharan Africa to stem HIV incidence in the region. However, even with the focus on HIV preventative measures, when looking at the top 25 nations in terms of adult population living with HIV, Africa includes 23 of the top 25 nations as of 2017, as per UNAIDS. Further complicating the issue is that as of 2017, approximately 76% of PLWH knew their status in western and northern Africa whereas only 42% of PLWH knew their status in central and eastern Africa ("Ending AIDS").

The common mode of HIV transmission across Africa is unprotected intercourse, both heterosexual and MSM. Intravenous drug use (IDU) is also a key mode of transmission in Northern Africa but not the Sub-Saharan regions. Opium and heroin usage rates are higher in Northern Africa than anywhere in the world aside from the Middle East, such as in Libya where an estimated 90% of HIV cases can be attributed to IDU. Another troubling mode of transmission found more in Sub-Saharan Africa than other areas is mother-to-child transmission. Although using ART treatment limits this type of transmission to only 1% probability, getting access to ART and HIV testing is still not up to par in this region ("Global Report 2013"). There is progress being made however from 1995-2010, over 86% of children susceptible to HIV infection through their mother who did not develop the disease thanks to ART. Still, 88% of all children under the age of 15 with HIV still come from this region due to poor access to HIV care and other risk factors (Fettig et al.).

There has been an overall concerted effort in increasing access to ART in Sub-Saharan Africa and as a result, the AIDS-related mortality has decreased annually since the early 2000s. This is not the case in North Africa where AIDS-related mortality rates have increased during the same time in part due to poor access and use of ART. As of 2012, only 11% of those who needed ART treatment, actually received it in North Africa ("Ending AIDS").

An area where HIV surveillance is lacking due to social norms and stigmas deals with diagnosing HIV via MSM transmission. What little data there is, shows higher rates of HIV among MSM compared to the rest of the general population across the continent of Africa (Abu-Raddad).

2.2.7 Asia

After Africa, the continent of Asia has the second largest burden of HIV globally. Over 5.2 million PLWH as of 2016 and rising due to longer life spans from ART although HIV transmission rates have seen a decline in recent years (Fettig et al. 1). India and China have the largest burden of HIV in Asia with 2.1 million and 780,000 PLWH as of 2012, respectively. Adding the PLWH from Indonesia and that constitutes three-quarters of the total number of PLWH in Asia. Taking into account population size however, India only has a prevalence rate of 0.3%, lower than many other countries in Asia such as Cambodia (0.85) ("Ending AIDS"). The country with the highest HIV prevalence is Thailand at 1.1%. Unlike other countries in Asia where the epidemic is mostly concentrated in specific key populations, the epidemic in Thailand is more generalized among the population.

Overall, approximately 71% of PLWH in Asia know their status as of 2017 and of those who do, two-thirds are on HIV treatment. Domestic efforts in HIV/AIDS response throughout Asia has increased greatly over the past decade to the point where of those who are in treatment, over 80% have successful viral load suppression ("Ending AIDS").

In terms of transmission, MSM accounts for 18% of new HIV infections particularly in urban cities such as Bangkok and Yangon (Fettig et al.). It is reported that this demographic tends to skew younger due to lower rates of HIV testing and condom use among MSM under the age of 25. Injection drug use is another key mode of transmission across the continent. Stringent policing and incarceration of intravenous drug use along with poor drug treatment programs in prisons are all major factors in the high rate of HIV in this category.

A highly susceptible population that is underserved and under researched is the transgender population of Asia. HIV prevalence among transgender populations is higher than rates among MSM in many areas across Asia ("Asia and the Pacific") such as in the urban centers of India (Delhi, Mumbai) and Cambodia. The transgender population is as stigmatized and discriminated against as any high-risk HIV group in Asia. These barriers are key factors in rampant HIV rates among this population and makes testing and treatment more difficult. The current level of AIDS healthcare-related resources throughout the continent are estimated by UNAIDS to be 37% below the needed levels for Asia to reach the 90-90-90 fast track goals by 2020 ("Global Report 2013"), in large part to the decrease in international investment in the cause as funds are being focused on other regions of the world. So more global investment and time is needed to better combat the epidemic in Asia.

2.2.8 Latin America and the Caribbean

As of 2017, 81% of PLWH in Latin America and 64% of PLWH in the Caribbean knew their HIV status. Of those, 72% in Latin America and 81% in the Caribbean were on treatment and among those in treatment, 79% and 67% had achieved viral load suppression in those two regions (“Ending AIDS”).

However, the efforts to treat HIV in Latin America continue to be hampered due to high rates in late diagnosis as 1/3rd of people diagnosed are done so at advanced stages. The number of new infections in Latin America and the Caribbean remained stable this past year at around 100,000 and 17,000, respectively (“Ending AIDS”).

In terms of transmission, the highest prevalence of HIV in Latin America is among MSM with 9 of the 14 countries in the region having rates over 10% (Fettig et al.). Treatment adherence in the region was also worse among female sex workers, IDU and MSM compared to the general population. The Caribbean has an even larger HIV issue among MSM, as over 25% of them are infected with HIV, the highest prevalence in the world for this demographic. Positive developments in the Caribbean stem from increasing rates of pregnant women with HIV receiving treatment (79%) the decline of AIDS-related deaths in both regions. More investment in HIV care is needed in key subpopulations throughout the region if the HIV epidemic is to be controlled, especially among vulnerable populations such as women who make up a larger proportion of PLWH in these two regions than anywhere else in the world at 60% (Fettig et al.).

2.2.9 Europe

Eastern and Western Europe have vastly different outlooks when it comes to the HIV epidemic. While Western Europe has seen decreased rates of AIDS-related mortality over the past decade (due in large part to better access to ART), Eastern Europe has seen increased rates in AIDS-related mortality ("Ending AIDS"). Russia has seen an increase in HIV infection due largely to the major IDU problems in the region. Approximately 80% of HIV infections in Russia are among persons with IDU (Fettig et al.). The epidemiology of HIV in Western Europe mirrors that of other higher-income regions such as North America where with the advent of ART, rates of PLWH has increased in Western Europe to over 800,000 as of 2012 and HIV prevalence is stagnant at 0.2% ("Ending AIDS"). As with North America and other regions with a large immigrant population, Western Europe has a high proportion of its HIV cases coming from ethnic minority populations, specifically Sub-Saharan Africa which accounts for a large portion of AIDS cases (Fettig et al.).

Eastern Europe accounts for approximately 80% of the annual new HIV diagnoses and less than 1/3rd of PLWH were currently on ART ("Progress Report 2011"). Europe has struggled with raising the rates of early diagnosis, as approximately 50% are diagnosed at late (CD4+ count below 350 cells/mm^3) and or advanced stage (CD4+ count below 200 cells/mm^3) ("Progress Report 2011"). Coupled with the fact that a quarter of PLWH in the region are unaware of their status, Europe still has challenges in combating the HIV epidemic, moving forward.

2.2.10 Canada

Canada has seen fluctuating rates of HIV prevalence rates over the past 30 years with rates increasing in the 1980s, followed by a dip in the 1990s and then a gradual increase since then. From 2011-2014, the rates of PLWH in Canada have increased by 10% ("The Epidemiology of HIV"). The estimated prevalence rate in Canada at the end of 2014 was 212 per 100,000. Among PLWH, the majority of them are men (78%), specifically MSM (53%). The remaining proportion of PLWH contracted the disease either through IDU or heterosexual contact and the main mode of transmission differs by region. Health officials in Canada believe that 1 out of every 5 with HIV are undiagnosed in general that 17% of intravenous drug users have HIV ("The Epidemiology of HIV").

While the rate of new infections remains stable, a positive note is that the rate of AIDS-related deaths has decreased in the past decade due to new antiretroviral therapy HIV treatment ("The Epidemiology of HIV").

2.3 Biology of HIV

A major component in understanding the plight of HIV globally is to understand the biological mechanisms of the retrovirus, its origins, how it spreads and the mechanisms behind its treatment. By better understanding the retrovirus itself, researchers have been able to build prevention and containment strategies which have had success but due to the complexity of the disease. There is still have much more to learn and research as HIV continues to spread despite major advancements in medicine and technology regarding disease research.

The HIV retrovirus originally started as a zoonotic virus called simian immunodeficiency virus (SIV) (Maartens 258) and was transmitted by primates in Africa to humans over 100 years ago (Sharp 3). HIV-1 and HIV-2 are the two main types of HIV. HIV-1 is transmitted from apes and is the more transmittable, pandemic form of HIV (Sharp). HIV-2 infections are found almost exclusively in West Africa through sooty mangabey monkey transmission (Maartens 258). HIV-2 infected individuals tend to have lower viral loads which would explain the lower transmission rates when compared to HIV-1 (HIV-2 prevalence rates in general are on the decline (Maartens). HIV-1 has four different group lines- M, N, O and P. Groups M, N and O all come from chimpanzees while group P comes from gorillas (Maartens). Group O was found in 1990 is confined to central-west Africa and accounts for approximately 1% of HIV-1 infections, Group N was found in 1998 is even more isolated, having only been positively diagnosed in 13 patients, all living in Cameroon (Vallari). As of 2011, Group P was found in 2009 and has only been positive transmitted to two patients, both also from Cameroon although one lived in France at the time of diagnosis (Sharp). Group M is the first group to have been discovered and is by far the most impactful as it is the HIV-1 group identified as causing the HIV pandemic that has infected millions of people and still plagues the world today (Maartens).

There are nine group M subtypes- A-D, F-H, J and K (Maartens). A cross-sectional study done looking at worldwide HIV infection data from 2004-2007 found that of the different subtypes, C is the most transmittable. Subtype C accounted for 48% of infections, mostly in Africa and India (“Ending AIDS”). Subtype A which, is found in Europe and East Africa along with subtype B which is found in the Americas, Australia and Europe, accounted for 12% and 11% of global infections, respectively ("Ending AIDS"). HIV-2 has eight different group lines, A-H. However only two groups, A and B, have been positively diagnosed in more than one individual (Sharp 11).

2.3.1 Transmission

Over the past 30 years, while there have been many false claims of how HIV spread (insect bites, touching, sharing household objects with someone infected), there have been multiple methods of HIV transmission have been confirmed: sexual intercourse (heterosexual or men having sex with men-MSM), HIV-tainted blood transfusions, shared intravenous drug equipment, materno-fetal-child paths (in utero, breast milk feeding), and through organ transplantation. It has been noted that male circumcision status (Hemelaar) can either increase or reduce the risk of HIV transmission via sexual intercourse.

The different methods of transmission come with unique secondary complications/illnesses such as co-infections like hepatitis B and C (Lucas). The chief factor in determining the likelihood of HIV transmission is the viral load of HIV blood in the infected individual (Quinn) with the viral load being highest immediately following infection (Lucas). This is particularly an issue when dealing with acute (primary stage) HIV infection where the virus is replicating rapidly while the individual is asymptomatic. Sexual intercourse/contact during this time frame has been central in spreading the HIV infection (Cohen). Since the viral load levels are of such importance, researchers have shaped treatment around the individual achieving successful viral load suppression which is where the levels are at such a low level that the person is deemed healthy and their risk of HVI transmission has been reduced.

2.3.2 Pathogenesis

Once HIV has infected the human host (stage 1), its main target are white blood cells, specifically a cluster of differentiation 4 (CD4) +T lymphocytes, which are important in fighting off infection. The higher the CD4 count in the body, the better it can defend against infection so as the HIV retrovirus targets, infects, replicates within and destroys CD4+T cells, it weakens the body's ability to fight of infection. Specifically, the cell-mediated immunity would be severely weakened as the HIV retrovirus spreads throughout the body. The virus will also target non-CD4+ cells such as endothelial cells, enterocytes, kidney tubules, cardiac muscles but to a much lesser extent (Lucas). This is also the phase of the HIV process where transmission to others is at its highest risk levels. Eventually the HIV retrovirus will slow down its replication and CD4+ destruction process (stage 2) but is still active within the body and transmission of HIV to others is still possible. Normal CD4 counts range between 500-1500 cells per cubic millimeter and if the count drops to below 200 cells due to HIV infection, the most advanced form of HIV infection-acquired immunodeficiency syndrome (AIDS), is diagnosed (stage 3).

Aside from CD4+ count depletion, another critical effect the HIV infection has on the body is the role it plays in increased innate and adaptive immune activation. Regardless of the patient undergoing ART or going untreated, body organ functions will be affected in some capacity due to raised levels of inflammatory markers in the body fluids (Lucas). The longer the HIV infection goes untreated, the higher the likelihood of chronic immune activation. This can have serious implications in cell replication and communication. Dendritic cells infected with HIV, will continue to secrete interferon-alpha cells which leads to low levels of HIV replication (this is even possible during ART treatment). The gut mucosa becomes weakened against gut bacteria due to depleted helper T-cell levels which triggers further acute and chronic inflammation throughout the rest of the body (Lucas).

2.3.3 Antiretroviral therapy

Prior to antiretroviral therapy (ART), the weakened cell-mediated immunity would cause major problems for those infected with HIV, especially in those whose HIV advanced to AIDS (Lucas). Now, those infected with HIV have much long-life expectancies and better quality of living. The CD4 count threshold that has been recommended as a guideline before starting a patient on ART has shifted over the years. The WHO has updated its recommendations several times for when to start ART treatment based on CD4+ counts from an original recommendation of $\leq$200 cells/mm^3 to $\leq$350cells/mm^3 in 2006 (“Antiretroviral Therapy”). In 2013, there was another recommendation added regarding key high-risk populations. People infected with both HIV and either Tuberculosis or Hepatitis B were recommended to undergo ART once their CD4+ count $\leq$500 cells/mm^3. This was also recommended for pregnant and breastfeeding women infected with HIV as well as children under the age of 5 (“Consolidated Guidelines 40”).

It is now recommended for all people infected with HIV to begin ART regardless of CD4+ count (Hofman). This is due to research showing the benefit of starting ART earlier on in the HIV infection process as opposed to waiting until the CD4 count dipped below a specific threshold. This recommendation also takes into account the safer and less risk adverse class of drugs being used in treatment. A drawback of ART until now was pathological toxicity especially in the liver that came with prolonged use ("Panel on Antiretroviral Guidelines") but with the new class of drugs in place, scientists feel comfortable to recommend earlier ART treatment.

2.3.4 Prevention

Since the HIV/AIDS epidemic came into the global spotlight, there has been a major urgency to understand the disease, from its origins to how it is contracted and transmitted, how to treat it and methods of prevention against initial contraction/transmission. In terms of preventative measures, a collection of interventions and measures are needed to stem an HIV epidemic. Prevention measures range from using protection (e.g., condoms) during intercourse, not partaking in IDU or not sharing needles if you do, getting tested before intercourse (both you and your partner), as well as more voluntary male circumcision and even taking pre-exposure prophylaxis (PrEP) if you are considered a high risk for HIV (" Consolidated Guidelines" 64). A relatively recent development in stemming the HIV epidemic (and the IDU epidemic as well) are the community-based needle exchange programs (NEPs). NEPs are set up to provide access to sterile needles and syringes at no cost, as well as to provide a safe drop off spot for already used needles. Studies done have shown the effectiveness of these types of programs in reducing the spread of Hepatitis C infection. Some of these programs also provide access to supplementary services such as STD screening, education on safe needle practices, and prevention materials (e.g., alcohol swabs, condoms) (Castaneda).

In terms of preventing HIV transmission, many of the same measures are recommended including frequent HIV testing, not using and/or sharing dirty needles, and adherence to ART, which has been a major development in the treatment and increased quality of life for PLWH. Adherence to ART treatment after has shown major developments in reducing HIV transmission (Vallari) among all groups of PLWH. Particularly, ART has been seen as a major preventive measure in reducing risk of transmission from mother-to-child. Without any intervention, there is roughly a 25% risk of HIV transmission to the child at birth, but the risk is greatly mitigated if the mother undergoes ART treatment, most preferably, after the first trimester (Sharp).

2.4. Expanding Upon Importance of Research

HIV rates have continued to decrease overall in the U.S., as measures have been taken to stem HIV transmission (safe sex practices, needle exchange programs, increased testing efforts) and raise HIV treatment coverage (advancement in ART and related access to treatment). Many of the aforementioned programs apply explicitly to HIV prevention in urban areas. However, HIV in rural settings (where surveillance data is not always available) has increased over the past decade due to major barriers related to drug use, healthcare accessibility, and socioeconomic deprivation, and has become a major public health concern (Pellowski).

The U.S. is largest funder of HIV programs in the world ("Global Report 2013"), leading to many HIV-related programs and research studies, most exclusively limited to urban areas. There are far fewer studies done in rural areas. Until recently, HIV had been deemed a predominantly urban issue due to its infectious nature, and higher prevalence in urban areas (“HIV in the United States”). HIV in urban settings have decreased while HIV in previously considered low prevalence areas have silently gone up in recent years. The lack of readily available surveillance data in rural settings coupled with high rates of drug use, high rates of poverty and lower education levels have led to HIV in rural settings becoming a public health crisis in this country.

Research on HIV prevention, treatment and survivorship has been focused on PLWH in predominantly urban areas. The major disconnect is that the research has led to policies and interventions that are not encompassing to all PLWH, as persons living in urban areas have vastly different experiences than those living in rural area (Oppong). PLWH in rural areas have major barriers such as access to transportation, availability of HIV related services and healthcare costs due to lower rates of insurance coverage compared to their urban counterparts.

Also, while both populations face stigma and judgment issues, those in urban settings tend to have greater access to additional HIV related resources such as support groups and tend to face a less intense stigma about their condition compared to those in rural settings (P.B. Williams). Rural settings are more likely to hold stereotypical views about HIV (Pellowski). People in those areas also tend to have less knowledge about HIV/AIDS such as how HIV it is contracted and spread (P.B. Williams) which is not faced as often by PLWHA in urban communities.

The textbook example of the culmination of all these factors is in the HIV epidemic observed in rural Indiana in 2015. There were 190 cases of HIV in Scott County, Indiana a largely rural community, in 2015 (Ungar). The outbreak was sparked by an opioid epidemic that has been quietly plaguing the area (like other rural communities) for years. In addition, the county had high rates of poverty and dirty needle sharing was prevalent. The clean needle exchange program (NEPs) used by many states to stem needle sharing, was banned in Indiana at the time. Scott County had only 1 HIV testing site prior to the outbreak- A Planned Parenthood Clinic was defunded and closed in 2013, leaving the area with no free source of testing. This setting had many critical features needed for an outbreak- low SES (poverty), no access to testing and high IDU use (risky behavior). This outbreak served as a warning that the epidemic was no longer an urban problem but a national one (Ungar). As the current mindset starts to shift, new studies need to be done taking into account all factors that affect HIV including social and structural factors in play.

These events have put an even greater emphasis on the need for studies showing the full picture of HIV in America from identifying areas with poor access to care, updating HIV prevalence in un-reported areas to get a better idea of the HIV burden and a closer look at the usage of HIV testing among all population groups.

2.5 Previous Studies and Rationale for Research

The importance of this project comes into perspective when reviewing the previous literature or lack thereof, particularly in recent history (past 5 to 10 years). More research is needed to examine access to HIV-related resources in rural areas, estimate HIV prevalence statistics in rural areas (and other geographic regions with sparse/suppressed HIV data), and explore different disparities in HIV testing rates among various vulnerable subpopulations.

2.5.1 Spatial Access to HIV-Related Resources

There are only a handful of studies that discuss access to HIV-related resources as a factor in the HIV epidemic. Pellowski et. al. discusses many different general barriers to care for PLWH in rural areas, a key factor being suboptimal access to HIV care. It goes into more detail than most on discussing the pitfalls involved in having access to quality HIV care based on "psychological, social, and economic factors". A major topic brought up in previous literature deals with how soon after being infected with HIV, does the person both get tested for and received HIV treatment (Pellowski).

A study done by Weissman et. al., discussed how rurality was identified as a risk factor for late HIV diagnosis in South Carolina. Rural areas in the South, and to an extent, rural areas across the nation, face limited access to HIV care based on density and location of services, as well as stigma that may prevent people from using the resources available to them. Among over 4,000 new diagnoses of HIV between 2001 and 2005 in South Carolina, a quarter resided in rural areas. Among those individuals, it was found that almost half of them were diagnosed late, which greatly impacts their prognosis. A late diagnosis was determined after assessing the CD4+T-cell count at time of diagnosis. It was found that people from rural SC had on average a lower CD4+T cell count than those from urban areas.

There have been no publications within the past five years examining spatial access to HIV-related resources nationally, nor have there been any updates to previous studies looking at spatial access to care focusing on specific regions or subpopulations. Focusing on spatial access to HIV-service providers in Atlanta, GA, Dasgupta et.al.

developed a tool to measure proximity to services and provider related traits in a single measure. In their study, also used road distance measures between a provider and a population cluster (in this case, a census tract centroid) in assessing spatial accessibility. We will be using similar methods in assessing accessibility of HIV-testing resources for Aim 1. A second study by Ganapati et.al, in Miami, FL. delved into a zip-code level investigation of spatial access to HIV service providers. While both of these studies have merit, and provide groundwork to build upon, they focus solely on a single urban setting and are not representative of rural communities. A more comprehensive research is needed to understand the present state of HIV testing accessibility for PLWHA in order to identify areas for future interventions and strategies/policies to

2.5.2 Small Area Estimation

There are numerous studies done on small area estimation (SAE) methodology and the application of SAE to real world outcomes ranging from tobacco use to obesity prevalence, among others. Barker et.al, estimates diabetes incidence and is of particular interest given it utilizes individual-level BRFSS data, which is the primary data set for the 3rd aim of this project. It takes work done from a previous study done by Cadwell, 2005 where they looked at diabetes prevalence and alters it to estimate county-level diabetes incidence in the U.S. Barker et. al. takes a different approach than ours in that it is a unit-level model-based approach, whereas our project utilizes an area-level model-based approach. It does take a similar spatial approach, however (i.e., accounts for region in the SAE model). However, most studies utilize a unit-level approach and very few take a strictly area-level model-based approach. The previously mentioned Cadwell, 2005 article on diabetes prevalence does use the same Poisson distribution for modeling as ours while the Barker study used a binomial distribution. Both articles provided good insight into general differences between small area estimation models and background information on the topic.

Among the scarce number of recent papers that utilize an area-level model-based approach, an article done by Esteban, 2012 looked into different variations of area-level models and examined which was most accurate at estimating poverty in Spain. The paper made a strong argument for why unit-level based model approaches were less feasible to do for this scenario and that area-level models were much easier to apply given the nature of the data available for use. The article also introduced a time component to borrow further strength for the model. We lean on this rationale as well, as only area-level information is publicly available to estimate HIV outcomes at the county level for our study. An article by Trevisani, 2017 also discusses the merits of different model specifications for estimating small area counts (including Poisson modeling, which is utilized in our project) and provided useful comparisons between the different variations of SAE methodologies. Using solely area-level covariates and an innovative spatial modeling approach, we can estimate HIV burden for those areas previously unaccounted for in publicly available statistics, particularly the Western region of the U.S.

2.5.3 HIV Testing rates using BRFSS

There have been quite a few studies done on HIV testing in the past X years, but only a few studies have utilized the Behavioral Risk Factor Surveillance System (BRFSS) as a primary data source. These studies vary in terms of scope, ranging from temporal trends in a single state (Ansa) to nationwide testing rates for a limited age bracket (Ford) to HIV testing pre-and post a particularly policy change, (Gaines) but none have looked at HIV testing rates across the country for all eligible age groups over a length of time.

Still, there is valuable information and methodologies to be taken away from these differing studies. The Ansa, 2016 study focuses on exploring trends among HIV testing rates in adults from 2011-2015 in Georgia. This study provided descriptive statistics concerning overall HIV rates across the state and its subgroups. It also looked at time trends for HIV testing and provided suggestions on how to stem transmission in Georgia based on the results. Our study will incorporate much of what was done in this study on a national scale, over a similar time frame.

The Ford, 2015 study also focuses on temporal trends in HIV testing but focused only among U.S. older adults (50–64 years of age) before and after the release of CDC's routine HIV testing recommendations in 2006. It was a much larger sample size than the study done in Georgia over a longer period (7 years compared to 4). However, unlike our project, this paper broke up the years into two pooled categories (pre-policy change and post updated recommendations in 2006) for comparison as opposed to a continuous trends study as ours will be (2011-2016). The categorical trends analyses did result in interesting findings showing that there was an increase (albeit temporary) in HIV testing rates after the new recommendations came out compared to immediately prior the updates, although they were still lagging behind pre-recommendation highs.

Gaines, 2016 focused on the relationship between the CDC expanded testing initiative (ETI) funding and past-year HIV testing using the 2012 BRFSS. This study looked at the odds of being tested for HIV based on if the state they resided in had ETI funding or not. The major caveat in this study was that it focused on testing for HIV within the past year (based on responses given in the BFRSS). The sample size was the largest of any of the previously mentioned studies as it was a national study but only included one year of data collection. Our study will differ from the Gaines, 2016 paper in that it will look at HIV testing within the past year as well as having ever been tested for HIV among different subpopulations over a five-year period as opposed to just one year.

As mentioned, the above studies have differing yet important objectives regarding exploring HIV testing using BRFSS data. A major void remains in the literature regarding examining HIV testing rates (ever and in past 12 months) overall and among subpopulations across time. Moreover, we have shaped our 3rd aim objectives to directly address this gap.

CHAPTER 3

METHODS

3.1 Overview

To fill in the gaps in the literature and answer these important questions, we used a variety of datasets such as BRFSS to examine HIV testing rates overall and among different subpopulations. We also used spatial data obtained from the CDC (via Freedom of Information Act Request on September 30th, 2017) to examine spatial accessibility to HIV testing facilities. To determine coverage and supply sufficiency, the total population of each county will be utilized to calculate a facility density (per 100,000). We will be classifying rurality at the census tract with the Rural-Urban Commuting Area Codes (RUCA) obtained from the USDA Economic Research Service (ERS) website. For counties that either have missing or suppressed HIV prevalent case counts as reported by Emory University's AIDSVu website, we will utilize innovative area-level small area estimation (SAE) techniques to model prevalence rates for all U.S. counties.

These datasets were supplemented by covariate data from sources such as the Robert Wood Johnson Foundation County Health Rankings which provides county level demographic data (e.g., race, gender), socioeconomic data (e.g., health care costs, insurance status, median household income), data on health behaviors (e.g., excessive drinking and adult smoking), access to medical care (Primary Care Physician ratio and Mental Health provider ratio) and other health outcomes (e.g., diabetes incidence rates). County level age data will come from the U.S. Census Bureau American Community Survey and education status compiled by the Economic Research Service branch of the United States Department of Agriculture. Further explanation on the methods and analysis of the data for each paper is below.

3.2 Paper 1 Methods

3.2.1 Data Sources

We included data from secondary data sources such as the U.S. Department of Health and Human Services' HIV.gov, Emory University's AIDSVu.org, the USDA Economic Research Service (ERS) and the Health Innovation Program at the University of Wisconsin-Madison School of Medicine & Public Health.

The latitude and longitude coordinates for HIV rapid and conventional testing centers were obtained from the CDC through a Freedom of Information Act Request on September 30th, 2017, along with facility physical addresses and are current as of September 2017. This database will be used to map facilities across the South for the purpose of measuring spatial accessibility to HIV resources. We will utilize U.S. census block group boundaries, obtained from the U.S. Census Bureau, in determining facility coverage of the affected population. Rurality at the census tract level will be classified as either: Metropolitan, Micropolitan, Small Town, or Rural through use of the Rural-Urban Commuting Area Codes (RUCA) obtained from the ERS. Populations affected by HIV (i.e., prevalence data) in 2014 will be obtained at the county level from Emory University's AIDSVu.org website.

Area deprivation data, specifically the area deprivation index (ADI), was obtained from the HIP at the University of Wisconsin-Madison. The ADI® is used "as a proxy measure for socioeconomic status to capture patient-level social risk factors not currently available in clinical information systems". The ADI score takes into account 17 different markers of socioeconomic status such as income disparity, percent of families below poverty level, education level among others. The full list of variables used to formulate the ADI score will be provided in Appendix A. The collected data is then standardized and analyzed via factor analysis to condense variables into categorized components. The direction of the components (positive or negative) are then validated and combined to determine that area's index score. The median score for the ADI is 100 and the higher the score, the more deprived the area is deemed to be. More information on the index can be found on the Health Innovation Program's website. It is believed that the more deprived an area is, the more susceptible it is to health disparities and poor health outcomes.

3.2.2 Data Analysis

Basic choropleth maps were used to display the county level ADI scores and HIV testing facility density data. After geocoding and mapping the facility locations, we conducted accessibility analyses via road distance measures at the census tract level. We created a 30-minute drive time buffer around each HIV testing facility and assessed the proportion of population-weighted census tract centroids that fell outside of each of the "coverage zones". The characteristics of the populations in the census tracts that fell in vs. out of the coverage zones were subsequently examined to identify differences between areas we classified as having reasonable access to one or more HIV testing facilities and those who have a farther, less convenient drive to a testing facility.

We then calculated a new variable for facility density, adjusting by total population, at the county level and displayed those values via a choropleth quintile map. This takes into account supply of HIV testing compared to a potential demand, as opposed to a raw density map which does not take into account the population size of the area. We created a bivariate map of the facility count per 100,000 overlaid with area deprivation scores to examine the relationship between supply of testing and available economic resources.

Lastly, to assess the significance of the differences between populations who live in census tracts within 30 minutes of a HIV testing facility and those who live in CTs outside of the coverage zone, we conducted a multivariate regression analysis to assess relationships. We first ran univariate regression analyses followed by a backwards model selection (cutoff: $p<0.2$) to determine which variables to include in the final multivariate logistic regression model. Odds ratios and 95% confidence intervals were obtained from the regression analyses to assess the odds of being located within 30 minutes of a HIV testing facility, given the demographic characteristics of the area.

3.3 Paper 2 Methods

3.3.1 Data

The primary data source of HIV prevalence rates in this study is the AIDSVu 2014 HIV prevalence data set. The data comes from the CDC national HIV surveillance database and encompasses all U.S. states, counties in 48 of the states, and ZIP Codes in 41 major cities.

All HIV diagnoses reported in the dataset are based on an established case definition by the CDC. Medical providers, laboratories, and other organizations providing HIV testing services report HIV cases to the state or local health department, who then report it (deidentified) to the CDC for national monitoring.

To obtain estimates of HIV prevalence in counties that either having missing or masked rates, the AIDSVu dataset is used in conjunction with county and state level covariate data obtained from the following secondary data sources: The Robert Wood Johnson Foundation County Health Ranking System, the U.S. Census American Community Survey, and the U.S. Department of Agriculture.

3.3.2 Small Area Estimation Methodology

The purpose of small area estimation (SAE) is to estimate parameters corresponding with small geographic areas or subpopulations by utilizing the data available from surrounding areas (Dey). Our model will be borrowing strength from available HIV rates in neighboring counties and covariate data to estimates the missing HIV rates. The overall modeling procedure that will be used to run the small area estimation technique will be a Poisson model with standard Proc GLIMMIX procedure. This model is good to use if we anticipate some counties to have very small HIV rates/counts which we do particularly in the Midwest region of the country where the general population is sparse and spread out. In terms of the variable selection process, we will be conducting a backwards model selection where we will be more inclusive than exclusive in selection taking into account statistical and practical (literature review) evidence so we will be using a conservative cutoff of $p \leq 0.1$ for covariate inclusion in the final model. Poisson regression models such as the one that will be used are better suited for using area-specific auxiliary data as opposed to unit-specific data [91] which is appropriate for our study as all the auxiliary data is at the area level.

The following covariates were tested for model selection, all at the county level unless otherwise noted: median age, race (%African American, %Asian, %Hispanic, %White), gender (% female), insurance status (%Uninsured), median household income (in dollars), education level (% with bachelor's degree and % with high school degree) , excessive alcohol consumption (% of adults reporting binge or heavy drinking), chlamydia incidence rate, syphilis incidence rate, poverty level (% poverty), primary care physician to population ratio (PCP ratio), policy regarding HIV education (discussing condom use in schools or not-yes/no) regionality (breakdown discussed below) and state.

After conducting the small area estimation, we calculated the prevalence rate (per 100,000) of HIV in each county and assessed the validity of the model (validation techniques mentioned below).

3.3.3 Formulas and Notation

The preliminary general modeling formula used as the structure to set up the SAE is as follows:

$$\log(\lambda_{ij}) = \log(n_{ij}) + X_{ij}\beta + b_j$$

where for county i in state j, n_{ij} is the population, X_{ij} are the covariate data, β are the regression coefficients and $b_j \sim N(0, \sigma_b^2)$ is a random effect. The above model uses covariates and a random effect at the state level. It is to be noted that the assumption for this SAE is $Y_{ij} \sim Poisson(\lambda_{ij})$ were λ_{ij} = expected (predicted) number of counts (HIV prevalent case counts).

3.3.4 Spatial Modeling Component

HIV in the U.S. has distinct characteristics based on geographic location as different subgroups are more or less affected regionally by HIV; therefore, spatial modeling will be included using regional indicators at state level (South, Northeast, Midwest and West). More granular types of spatial modeling, such as the ICAR approach on the county level, would be difficult due to so the predominance of missing county level data in very rural states (e.g., Montana and the Dakotas). In this case, counties may have no neighboring counties with data and a county level ICAR model would not help with predictions of HIV rates.

3.3.5 Validation Analysis

As small area estimation is in fact an estimation analysis, the results will need to be assessed and validated. There are various validation techniques that would be suitable and used for this dataset. There are a few techniques which use already available rates to validate the estimated values such as the 10-fold cross validation technique (Kohavi), where we would assign each county randomly a number from 1-10 with 10% of the counties per partition and then we would run 10 models where you take a different partition out of the model (called the validation or testing set), and run the model with the remaining partitions (called the training set). We will be able to properly validate and estimate the out-of-sample error for each county in the dataset between observed and predicted rates. Another strategy would be to remove a small subset of counties with already available HIV rates, run the SAE model and compare the percent agreement between the estimated HIV prevalence rates and the direct rates.

A few other cross-validation techniques will utilize statistical mapping such as a calibration curve or the receiver operating characteristic (ROC) curve, which is used to evaluate and compare the performance of a diagnostic test and is useful for assessing the accuracy of predictions (Gonen). We would use the ROC curve to compare the direct estimate (y-axis on the curve) and model-based estimate (x-axis on the curve). In other words, a ROC curve is focused on the sensitivity and (1-minus) the specificity. We can also assess the proportion of HIV found in the county that is observed and predicted by the SAE model and find the difference in proportions. Validating the data predicted will be key in the credibility of this project so we will be utilizing more than one of the validation techniques listed above.

3.4 Paper 3 Methods

3.4.1 Study Design

This was a cross-sectional study done by analyzing self-reported HIV testing data from the 2011-2017 *Behavioral Risk Factor Surveillance System* (*BRFSS*) which is a nationally representative survey. It is the largest continually conducted health survey in the world and collects data from over 400,000 adults annually.

3.4.2 Sample and Data Source

BRFSS is a nationally representative phone-based survey for all 50 states and the District of Columbia and comprehensively explores health behaviors, chronic health conditions and healthcare use. Since 2011, the sampling methodology for the BRFSS has been altered, including an update to its data weighting methodology and incorporating cellular phone-based surveying. From 2011-2017, the BRFSS has surveyed over 3 million adults across the nation. Of those, our study included all who answered the question “Have you ever been tested for HIV, excluding tests as part of a blood donation?” and excluded those who refused or did not answer the HIV-related questions.

3.4.3 Measures

The main dependent variable looked at was overall self-reported HIV testing percentages which was assessed via the set of questions asked in the 2011-2017 BRFSS about if the participant had ever been tested for HIV, excluding tests as part of a blood donation. If the participant answered ‘yes’, further questioning assessed the date and location of the last HIV test. Secondarily, we are interested in assessing past-year HIV testing percentages. We will create a binary variable (yes vs no) identifying if they had been tested within 12 months prior to the interview to assess this objective based on date of last reported HIV test.

The independent variables include demographic data and health behavior indicators which were collected at the individual level. Data on variables associated with HIV testing were collected across the targeted 7-year range of surveys and included: age in years (18–24, 25–34, 35–44, 45–54, 55–64, or 65+), sex (male or female), race/ethnicity (non-Hispanic (NH) white, NH black, NH Asian, NH Native American/Alaskan, NH Native Hawaiian/Pacific Islander or Hispanic), educational attainment (<high school, high school graduate, some college and college graduate), current employment status (employed, self-employed, out of work <1 year, out of work> 1 year, homemaker, student, retired or unable to work) annual household income in United States Dollar (USD (<$25,000, $25,000-$50,000, $50,000-$75,000 and $75,000+)), marital status (married, divorced, widowed, separated, or never married,); healthcare coverage (yes/no).

Risky health behavior measures were also included such as being classified as a binge drinker (yes/no), current smoking status (everyday, some days or not at all) and engaging in any of the following HIV risk behaviors in the past year (HIV high-risk situations (yes/no)) - use of intravenous drugs, treatment for sexually transmitted disease, giving or receiving money or drugs for sex, or having anal sex without a condom.

3.4.4 Analysis

We obtained the weighted percentages of respondents who had ever been tested for HIV stratified by the socio-demographic and health behavior indicators listed above. Additionally, we will calculate the average weighted percentage and average annual percent change over the 7-year period to assess reporting trends during that time. We will run regression analyses to assess the association between ever being tested for HIV and the socio-demographic variables listed above, using data pooled from 2011-2017. We will run a second regression model to assess the association between being tested for HIV within the past 12 months and socio-demographic variables. The estimates in both regression models will be adjusted for by the demographic variables and selected health behavior indicators (age, gender, race/ethnicity, educational attainment, current employment status, annual household income, healthcare insurance coverage, marital status, binge drinker status and smoking status). To account for differences in data collection (nonresponse, respondent selection, and telephone non-coverage), the data was weighted using built-in calculated weights from the BRFSS dataset. Odds ratios, 95% confidence intervals and p-values will be obtained from the regression analyses. Regression analyses were run using survey logistic modeling as opposed to standard logistic regression due to the complex sampling design of the survey (Berglund). All analyses were performed using SAS version 9.4 software.

CHAPTER 4

SPATIAL ACCESS TO HIV TESTING ACROSS THE U.S. SOUTH[1]

[1]Khan S, Olatosi B. Torres M, McLain A, Eberth J. Submitted to *Aids and Behavior*, 11/1/18

4.1 Abstract

Disparities in access to HIV testing facilities affects early diagnosis, linkage into, and retention in HIV care across the U.S. South. We obtained the geocoded addresses of HIV testing facilities across the U.S. South, provided by the CDC, to examine the associations between access to HIV testing facilities, rurality and socioeconomic area deprivation in the U.S. South. Results showed rural areas were more likely to be outside of a 30-minute drive time of a HIV testing facility, particularly in more socioeconomically deprived areas. Populations in areas outside of the coverage zone, had a lower average median household income, higher poverty rates and higher rates of being uninsured compared to populations within the coverage zone. These results can be of value to public health professionals and policy makers identify areas across the region that require further attention planning HIV interventions and policies targeting barriers to HIV care.

Keywords: HIV testing; HIV; Access to Care; Rurality; Geographic Information Systems

4.2. Introduction

Since the 1980's, a major focus has been placed on combating the spread of the Human Immunodeficiency Virus (HIV) in the United States. While progress has been made, especially in reducing HIV transmission rates [89% decline since mid-1980's ("HIV Prevention")], HIV remains a major problem. The South continues to experience disproportionately high HIV incidence, reporting over half of all new HIV diagnoses nationally in 2015 ("HIV in the United States"). Federal efforts to reduce the HIV burden have included investment in HIV testing, prevention and treatment, including reducing HIV risk factors like intravenous drug use (IDU) and unprotected sex in men who have sex with men (MSM) ("HIV Prevention"). These initiatives have resulted in the reduction of new infections over the past 30-years from 130,000 annually in the mid-1980s to 50,000 in 2010 ("HIV Prevention").

From 2005 to 2014 alone, there has been an 18% decline in new HIV infections, primarily in urban areas ("Pellowski"). However, rates of HIV incidence and prevalence have either remained stable or increased in rural areas, with recently recorded infection rates at 6% ("HIV in the United States"). Additionally, HIV incidence in the rural south is higher than in any other rural areas (Pellowski; "HIV in the Southern United States"). The higher rates are due in part to factors such as lack of access to HIV services, transportation issues and social stigma (Pellowski 6). Transportation in particular has been noted as a major barrier to HIV care as it is linked to higher levels of socioeconomic deprivation (lower levels of income, higher rates of unemployment and higher dependence on public transit) (Pellowski 4). These issues are magnified in rural areas due to fewer options for public transportation (or worse efficiency), fewer medical specialists, and tight-knit communities leading to a higher likelihood of people finding out if someone has HIV (Donley). Previous studies found late diagnosis and delayed linkage to HIV care as also associated with rurality (Oppong; Trepka). HIV incidence and prevalence also affect races differently as minority populations are disproportionately affected by HIV. Black Americans accounted for 54% of all new HIV diagnoses and black women accounted for 69% of all new diagnoses among women in the south in 2014 ("HIV in the Southern United States"). The HIV outbreak in rural Indiana from 2015 highlights the dangerous intersection of HIV risk indicators in rural areas such as a HIV-related risky health behavior (intravenous drug use), poverty and a lack of proper HIV-related resources in the area (Ungar).

A major gap exists in the literature regarding spatial accessibility and proximity to HIV testing and treatment facilities, as relevant studies have been conducted mostly in urban settings (Dasgupta et al.; Ganapati) or abroad (Fulcher). While studies focused on metropolitan areas do provide valuable information and groundwork for future studies, there are still major gaps in understanding the rural population living with HIV particularly in the understudied rural south. Access to HIV testing-related resources is important for controlling the HIV epidemic and reducing time to diagnosis and treatment (Pellowski). However, few studies have identified specific areas with poor spatial accessibility to HIV testing facilities, particularly in rural communities, or detailed the environmental context of such areas (Dasgupta et al.; Ganapati). A recent publication by Kimmel et.al, assessed spatial accessibility across the south at the county level which has provided an important foundation for research on this topic. However, as levels of rurality can vary across a county, a more granular examination of local-area resources (e.g., census tract level) is warranted.

The purpose of this study is to examine spatial accessibility to HIV testing facilities across the southern U.S., along with measures of area socioeconomic deprivation and other HIV risk indicators. As rurality increases, we hypothesize that residents will experience suboptimal access to HIV testing-related resources, particularly in more socioeconomic deprived areas. We also hypothesize that areas with higher proportions of minorities, regardless of rurality, will exhibit lower levels of spatial accessibility to HIV testing facilities.

4.3 Methods

4.3.1 Data Sources

We included data from secondary data sources such as the U.S. Department of Health and Human Services' HIV.gov, Emory University's AIDSVu.org website, the USDA Economic Research Service (ERS), the U.S. Census Bureau and the Health Innovation Program (HIP) at the University of Wisconsin-Madison School of Medicine & Public Health (UW).

The HIV rapid and conventional testing centers were geocoded through data obtained from the Centers for Disease Control and Prevention (CDC) through a Freedom of Information Act (FOIA) request and are accurate as of September 2017. The geocoded facilities were mapped using ArcGIS Version 10.2.2 across the South to measure spatial accessibility to HIV testing resources. We utilized U.S. census tract (CT) boundaries, obtained from the U.S. Census, in determining facility coverage of the affected population. Rurality at the census tract level was classified as either: Metropolitan, Micropolitan, Small Town, or Rural through use of the Rural-Urban Commuting Area Codes (RUCA) obtained from the ERS. Each category is defined based on “measures of population density, urbanization, and daily commuting” (“Rural-Urban Commuting Area Codes”). Data used for the codes were extracted from the 2010 Decennial Census and the 2006-2010 American Community Survey. Separately, population estimates provided by the U.S. Census Bureau was coupled with the count of HIV testing facilities obtained from the CDC to create a county-level facility density variable (per 100,000).

The 2016 American Community Survey from the U.S. Census was then used to gather demographic data: race (Non-Hispanic American Indian, Non-Hispanic Asian, Non-Hispanic Black, Non-Hispanic Hawaiian/Pacific Islander, Non-Hispanic White), ethnicity (Hispanic or Non-Hispanic), educational attainment (% with bachelor’s degree by race/ethnicity), insurance status (% Uninsured overall, %uninsured under 18 years old, %uninsured 18-64 year olds, %uninsured 65+, %uninsured among females %uninsured among males) , median household income ($), poverty rates (%overall, %under 18 years old, % 18-64 year olds, % 65+, % among females % among males) at the census tract level for areas with and without access to one of the geocoded HIV testing facilities (see Data Analysis section for details on measuring access).

Area deprivation data, specifically the Area Deprivation Index (ADI®), was obtained from the HIP at the University of Wisconsin-Madison. The ADI® is used “as a proxy measure for socioeconomic status to capture patient-level social risk factors not currently available in clinical information systems” (Singh). The ADI® score takes into account 17 different markers of socioeconomic status such as income disparity, percent of families below poverty level, education level among others. The collected data is then standardized and analyzed via factor analysis to condense variables into categorized components. The direction of the components (positive or negative) are then validated and combined to determine that area's score (Knighton et al.). The score for the ADI® comes in two forms, one assessing the deprivation of an area relative to the rest of its state (score 0-10) and one assessing the deprivation relative to the entire country (percentile score out of 100). The higher the score or percentile, the more deprived the area is deemed to be (Pampel et al.). More information on the index can be found on the Health Innovation Program's website.

4.3.2 Data Analysis

Basic choropleth maps were used to display the county level ADI scores and HIV testing facility density data. After geocoding and mapping the facility locations, we conducted accessibility analyses via road distance measures at the census tract level. We created a 30-minute drive time buffer around each HIV testing facility and assessed the proportion of population-weighted census tract centroids that fell outside of each of the "coverage zones". A 30-minute travel time to care is considered an accessibility threshold for travel for primary care (Kimmel and Masain). The characteristics of the populations in the census tracts that fell in vs. out of the coverage zones were subsequently examined to identify differences between areas we classified as having reasonable access to one or more HIV testing facilities and those who have a farther, less convenient drive to a HIV testing facility (farther than 30-minutes).

We then calculated a new variable for facility density, adjusting by total population, at the county level and displayed those values via a choropleth quintile map. This takes into account supply of HIV testing compared to a potential demand, as opposed to a raw density map which does not take into account the population size of the area. We created a bivariate map of the facility count per 100,000 overlaid with area deprivation scores to examine the relationship between supply of testing and available economic resources in the area.

Lastly, to assess the significance of the differences between populations who live in census tracts within 30 minutes of a HIV testing facility and those who live in CTs outside of the coverage zone, we conducted a multivariate regression analysis to assess relationships. We first ran univariate regression analyses followed by a backwards model selection (cutoff: $p<0.2$) to determine which variables to include in the final multivariate logistic regression model. Odds ratios and 95% confidence intervals were obtained from the regression analyses to assess the odds of being located within 30 minutes of a HIV testing facility, given the demographic characteristics of the area.

4.4 Results

The main objective of our study was to examine spatial accessibility to HIV Testing Facilities across the U.S. South and identify areas where there are greater disparities. Table 4.1 displays the average proportion of census tracts that fall out of the pre-defined 30-minute drive time coverage zone from a HIV testing facility, categorized by RUCA location type. 14.70% of census tracts classified as "rural" in the U.S. south were identified as falling out of the 30-minute coverage zone while 1.34% of census tracts classified as "metropolitan" were out of range.

Table 4.2 further shows facility coverage in the U.S. South within each of the 16 states and the District of Columbia. Among the southern states, Texas had the largest proportion of micropolitan (9.39%), small town (17.75%) and rural (42.54%) census tracts that fall outside of the 30-minute drive time coverage zone. Alabama had the second largest percentage of its census tracts classified as rural to be outside of a 30-minute drive time of any HIV testing facility (25.34%) while Louisiana had the second most among small town classified census tracts (14.1%). West Virginia had the greatest proportion of metropolitan (4.88%) census tracts that fell out of the 30-minute drive time of any of the geocoded HIV facilities followed by Louisiana (3.25%). Washington D.C. and Delaware did not have any census tracts that were not covered by a HIV testing facility within a 30-minute drive-time.

In terms of populations that fell out of the coverage zone, Florida had the largest proportion of its rural population (34.19%) to be farther than 30-minutes from any of the geocoded facilities followed by Texas (19.73%) and Alabama (19.14%). Texas had the largest proportion of its micropolitan (10.43%) and small town (20.70%) populations along with the populations in West Virginia metropolitan census tracts (4.92%) to be outside of a 30-minute drive time from any of the facilities.

Table 4.3 displays descriptive statistics comparing the census tract populations within the 30-minute coverage zone of HIV testing facilities and populations outside of the coverage zone. Univariate logistic regression yielded significant differences for the unstratified covariates ($P<0.05$) between coverage zone inclusion and exclusion). The census tracts with access to a geocoded HIV testing facility within 30 minutes had a higher percentage of Asians (2.9%), Black (20.1%) and mixed raced populations (2.6%).

These populations also had higher median household incomes ($71,265 compared to $63,398), lower average overall rates of uninsured (14.8% compared to 18.7%), slightly higher rates of unemployment (8.0%), higher rates of educational attainment for all racial categories and slightly lower overall poverty rates (17.6%). Standard errors (SE) for each of the characteristics from table III can be found in appendix B.

Table 4.1 Average Percentage of Census Tracts and Population outside of HIV Testing Coverage Zone

Location	Average % of CTS	Average % of Population
Metropolitan	1.34	1.24
Micropolitan	2.78	2.29
Small Town	4.75	4.13
Rural	14.17	10.66

Table 4.2 Percentage of Census Tracts (and Population) Outside 30-Minute Drive Time of a HIV testing Facility

Location	Metropolitan	Micropolitan	Small Town	Rural
AL	3.07 (2.07)	6.9 (6.58)	7.78 (6.73)	25.37 (19.14)
AR	2.53 (2.82)	5.6 (5.37)	8.41 (9.05)	20.69 (17.91)
DC	0 (0)	0 (0)	0 (0)	0 (0)
DE	0 (0)	0 (0)	0 (0)	0 (0)
FL	0.74 (0.61)	1.23 (0.66)	2.13 (2.14)	25.24 (34.19)
GA	0.38 (0.23)	0.46 (0.24)	2.33 (1.38)	1.37 (0.80)
KY	0.51 (0.58)	1.08 (0.31)	3.65 (2.25)	9.35 (7.97)
LA	3.25 (3.46)	6 (5.14)	14.1 (10.47)	10.64 (15.09)
MD	0.37 (0.32)	0 (0)	0 (0)	7.14 (9.17)
MS	0.68 (1.21)	0.89 (0.67)	2.04 (1.86)	2.08 (3.86)
NC	1.16 (0.48)	3.39 (2.00)	1.96 (0.46)	24.76 (16.67)
OK	0.77 (0.49)	1.42 (1.76)	3.03 (1.02)	20.69 (12.35)
SC	2.16 (1.25)	4.58 (2.04)	2.44 (0.92)	9.68 (3.74)
TN	1.19 (1.47)	3.51 (1.46)	4.2 (5.44)	13.79 (2.44)
TX	0.84 (0.93)	9.39 (10.43)	17.75 (20.70)	42.54 (19.73)
VA	0.25 (0.25)	0 (0)	7.29 (4.86)	6.38 (4.12)
WV	4.88 (4.92)	2.9 (2.25)	3.7 (2.96)	21.21 (13.97)

Table 4.3 Average Demographics of Residents in Census Tracts in or Outside of 30 Minutes of HIV Testing Facilities

Variable	No Access (N=598)	Access (N=24,063)
Race (%; p<0.0001)		
American Indian	0.8	0.7
Asian	0.8	2.9
Black	6.7	20.1
Hawaiian/Pacific Islander	0.1	0.1
Non-Hispanic White	86.2	70.7
Ethnicity (%; p<0.0001)		
Hispanic	19.2	16.2
Not Hispanic	80.8	83.8
Education (% with bachelor's degree; p<0.0001)		
Overall	18.4	27.6
American Indian	20.8	20.8
Asian	39.0	48.0
Black	10.3	22.5
Hispanic/Latino	10.8	21.5
Hawaiian/Pacific Islander	18.8	23.4
Non-Hispanic White	21.4	31.4
Income (average $; p<0.0001)	63,398.24	71,265.65
Unemployment Rate (%, ages 16+; p<0.0001)	6.9	8.0
Uninsured (%; p<0.0001)		
Overall	18.7	14.8
Under 18	12.3	7.3
18-64	27.2	21
65+	0.6	1.3
Female	17.7	13.6
Male	19.2	16.0
Rurality (%; p<0.0001)		
Metropolitan	1.3	98.7
Micropolitan	2.8	97.2
Small Town	4.8	95.3
Rural	14.2	85.8
Poverty Rate (%; p<0.0001)		
Overall	18.0	17.6
Under 18	25.8	24.0
18-64	17.1	16.4
65+	11.2	11.3
Female	19.4	18.9
Male	16.1	16.1

Census tracts located outside of a HIV testing facility coverage zone had an average higher percentage of non-Hispanic whites (86.7%), higher rates of uninsured among the 18-64 age category (27.2%) and both genders (17.7% for females and 19.2% for males), higher poverty rates among the under 18 (25.8%) and 18-64 (17.1%) age categories and both genders (19.4% for females and 16.1% for males).

Tables 4.4 and 4.5 display the results of a univariate and multivariable logistic regression to examine associations between access to an HIV testing facility (within 30-minute drive time) and selected sociodemographic covariates. All characteristics except percent female (p=0.37) and percent Hispanic (p=0.5671) were significantly associated with access to HIV testing. Controlling for the other covariates in the model % uninsured was significantly associated with being in a HIV testing facility zone (OR=0.93; 95%CI= 0.91, 0.95; p<0.0001).

Table 4.4 Univariate Regression: Odds of Being Located in a HIV Testing Facility Coverage Zone Across Census Tract Sociodemographic Characteristics

Variable	**Crude OR**	**95% CI**		**P-Value**
% Black	0.989	0.988	0.990	<0.0001
% Hispanic	1.001	0.999	1.002	0.5671
% White	1.010	1.009	1.011	<0.0001
% Female	0.997	0.989	1.004	0.3771
% with bachelor’s Degree	1.019	1.017	1.022	<0.0001
% Uninsured	0.974	0.970	0.978	<0.0001
% below poverty	0.961	0.959	0.964	<0.0001
Rural (Vs Urban)	0.47	0.401	0.552	<0.0001
Unemployment Rate	0.944	0.938	0.950	<0.0001

Table 4.5 Multivariate Logistic Regression: Odds of Being Located in a HIV Testing Facility Coverage Zone Across Census Tract Sociodemographic Characteristics

Variable	Adjusted OR	95% CI		P-Value
% Black	1.04	1.01	1.07	0.006
% Hispanic	1.00	0.99	1.01	0.785
% White	1.00	0.97	1.02	0.717
% Female	1.03	1.00	1.06	0.021
% with bachelor's Degree	1.01	1.00	1.03	0.070
% Uninsured	0.93	0.91	0.95	<.0001
% below poverty	1.03	1.01	1.05	0.012
Rural (Vs Urban)	0.06	0.04	0.09	<.0001
Unemployment Rate	1.05	1.01	1.09	0.009

Also, adjusting for the other covariates in the model, living in a rural setting was significantly associated with lower odds of being in a HIV testing facility coverage zone compared to urban settings (OR=0.06; 95%CI= 0.04, 0.09; p<0.0001) in the South. The magnitude for the association between rurality and access to HIV testing was further strengthened when included in the multivariate model compared to the univariate analysis between rurality and access.

Table 4.6 Multivariate Logistic Regression: Odds of Being Located in a HIV Testing Facility Coverage Zone Across Stratified Census Tract Sociodemographic Characteristics

Variable	Adjusted Odds Ratio	95% CIs	P-value
% below Poverty	1.623	0.965,2.728	0.0676
% below Poverty (Males)	0.541	0.315,0.930	0.0261
% Uninsured ages 18-64	0.836	0.702,0.995	0.0438
% Asian with bachelor's degree	1.114	1.018,1.220	0.0192
% Black with bachelor's degree	1.209	1.011,1.444	0.0370
% White alone with bachelor's degree	0.472	0.209,1.070	0.1260

% native Hawaiian/P.C. with bachelor's degree	0.968	0.938,0.999	0.0457
% White	0.828	0.709,0.967	0.0169

To further examine the associations between access to an HIV testing facility (within 30-minute drive time) and selected sociodemographic covariates, we stratified each of the covariates conducted model selection ("a priori" literature information and univariate regression with cutoff: $p<0.2$) and ran multivariate logistic regression. The final model, results displayed in table 5, was paired down to 8 covariates, 6 of which had a statistically significant effect ($p<0.05$) in the model. Two of the six remaining covariates in the final model dealt with poverty rates and four dealt with educational attainment (bachelor's degree) stratified race/ethnicity.

Percentage of adults aged 18-64 uninsured was found to be negatively associated with one's odds of being in a HIV testing facility coverage zone. Controlling for the other covariates in the final model, % uninsured among the 18-64 age category was significantly associated with lower odds of being in an HIV testing facility coverage zone decreased. Controlling for other covariates, % male below poverty was also significantly negatively associated with lower odds of being in a HIV testing facility coverage zone (OR=0.54; 95%CI= 0.32, 0.93; $p<0.026$), as was % white (OR=0.83; 95%CI= 0.71, 0.97; $p<0.0169$). % white being significantly associated in table 5 is in contrast to the result of table IV where % white was not significantly associated with being located within a HIV testing facility coverage zone.

On the opposite spectrum, the largest positive association with access to a HIV testing facility, was among percent of blacks with a bachelor's degree or higher.

Controlling for other covariates, % blacks with a bachelor's degree was associated with higher odds of the census tract being located within a HIV testing facility coverage zone (OR=1.21; 95%CI= 1.01, 1.44; $p<0.037$). Percentage of Asians with a bachelor's degree or higher was also positively associated with a census tract's odds of being located within a HIV testing facility coverage zone (OR=1.11; 95%CI= 1.02, 1.22; p-value=0.019).

Figure 4.1 displays the average area deprivation index (ADI) score, aggregated and categorized in qunitiles (quintile 1 is least deprived and quintle 5 is most) at the county level across the U.S. South. The map shows consistently high levels of econocmic deprivation in rural parts of most states particularly in the deep south states such as Texas, Arkansas, Mississippi, Alabama and Kentucky. Texas in particular shows the stark contrast in terms of socioeconomic resources between metropolitan and rural communities as the counties considered to be in the lease deprived quintiles (1 and 2) are some of the more populous counties in the state (Austin, Dallas, and San Antonio) while the areas considered more economically deprived (quintile 4 and 5) were in the more rural northwestern portion of the state.

The more northern located of the southern states (Virginia and Maryland) had a noticable higher proportion of its counties be considered less socioeconomically deprived (quintle 1 and 2) compared to the rest of the south, as shown in figure 1.

Figure 4.2 displays the supply of HIV testing facilities (facility count per 100,000 population) at the county level across the U.S. South. Similar to figure 4.1, the lower densities of HIV testing facilities were located in the more rural areas (identified in dark and light green) while the more dense supply of HIV testing facilities were located in more urban settings though at a lesser extent than shown in figure I, after taking population size into account. Arkansas, which had a large proportion of its rural communities outside of 30-minute drive time of any HIV testing facilities (table 4.2),

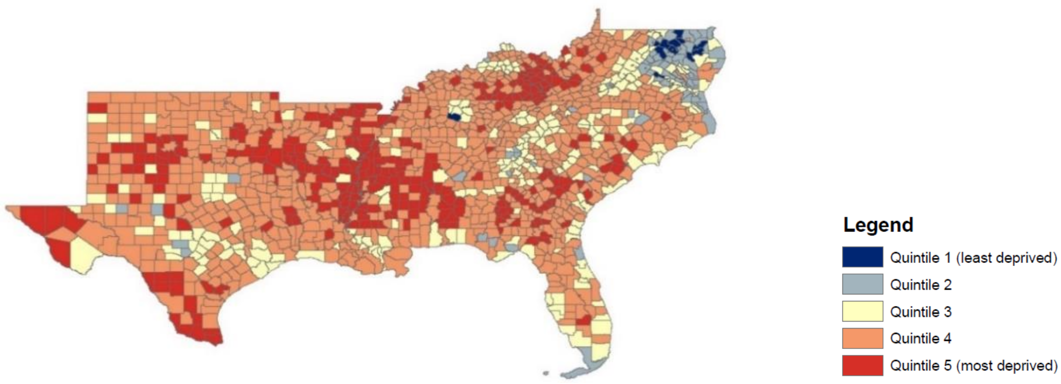

Figure 4.1 County Level Area Deprivation Index (ADI) across the U.S. South

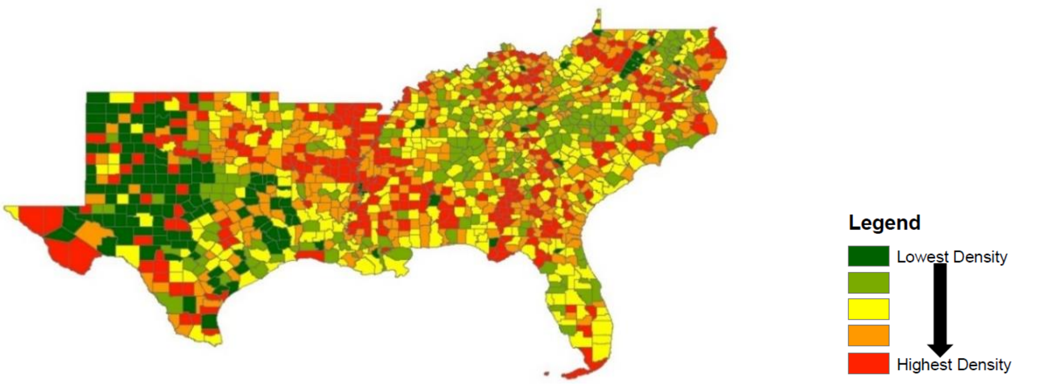

Figure 4.2 HIV Testing Facility Density (per 100,000) by County across the U.S South

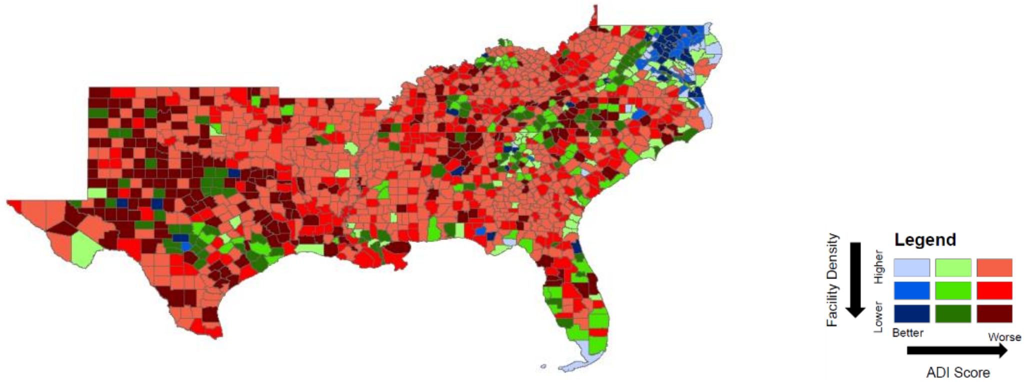

Figure 4.3. BiVariate Map of ADI with Facility Density (per 100,000)

when taking populaiton size into account is shown in table 3 as having adequate supply of facilities across most of the state. Figure 4.3 displays the overlay of the ADI and facility density at the county level across the U.S. South. In particular, the northwestern and notiblely more rural, region of Texas is shown to have a combination of high socioeconomic deprivation and lower concentrations of HIV testing facilities with a number of counties identified to have the most disadvantaged intersection (quintles 4 and 5 for both category; noted in dark red). On the opposite spectrum, there are a couple of counties that have both a high density of testing facilities and less socioeconomically disadvantaged population (Monroe County, FL for example).

Many of the counties across the U.S. South as shown in Figure III, had similar levels of area deprivation and supply of HIV testing facilities. Florida in particular, showed a lot of parallels between a county's level of economic deprivation and its supply of HIV testing facilities.

Arkansas, on the other hand, had a largely inverse association between area deprivation and supply of HIV testing facilities, as large region of counties in the southern part of the state were highlighted in blue, signifiying a high density of testing facilities in areas perceived as highly economically deprived.

4.5 Discussion

This study, examining access to HIV testing facilities across the U.S. South (provided by the CDC), shows that there is a disproportionate lack of access to HIV testing in rural areas, when compared to other area classifications. Previous literature (J.A. Pellowski; Giordano et al.; Reif et al.), has shown that transportation, lack of access to HIV services and lack of insurance are all major barriers in combatting the HIV epidemic, all of which are of even greater concern in rural areas due to scarcity of all of the mentioned resources and increased distance to services.

Another by-product of these barrier is that rurality was associated with lower odds of reporting being ever tested for HIV and being tested within the past year (Henderson et al.; Ohl and Perencevich). The lack of access to HIV testing in rural settings in the south is even more revealing when focusing on states individually, particularly in the “deep south”. Rural areas in the Deep South states of Texas, Florida and Alabama had the highest percentage of census tracts that fell outside of a 30-minute drive time of an HIV testing facility of any kind. The other three area classifications were relatively well covered as no one classification in any of the states had over 14.1% (Louisiana) of its census tracts farther than a half-hour drive to a HIV testing facility, which is the average proportion of census tracts in rural areas that were without coverage.

The average demographics of the census tracts within and outside of the coverage zone indicated disparities between the two groups. The average median income for census tracts outside of 30 minutes of a HIV testing facility was lower ($63,399) than that of a census tract within the range ($71,266). The percentage of uninsured among all age groups (aside from 65+) and genders, regardless of rurality were higher among census tracts outside of the coverage zone. The same is true of poverty rates among all age groups and genders being higher in the census tracts outside of the zone. When looking at the multivariate logistic regression model (table 5), it indicated that being a male below the poverty level and being uninsured between the ages of 18-64, was significantly associated with having lower likelihoods of having access to HIV testing. This provides further evidence to claims that previous literature (Pellowski; Reif et al.; Ohl and Perencevich) have made about the disparate lack of access to HIV services due to socioeconomic factors such as poverty and insurance status, particularly in the U.S. South. Inversely, there was a significantly positive association between % black with a bachelor's degree and access to HIV testing. As the percentage of black with a bachelor's degree (regardless of rurality) in the census tract increases, so does the likelihood of that census tract being within 30 minutes of an HIV testing facility.

Figures 4.1-4.3 further explored the socioeconomic-access to HIV testing dynamic and again highlighted the relationship that is perceived to be there. Northwest Texas (predominantly rural) had the most perilous combination of high levels of area deprivation coupled with low facility density levels. Most of the counties across the U.S. south fell in the middle of the spectrum for both factors with only a few locations showing opposite relationships between the two. Parts of Arkansas, Georgia, and Mississippi had worse levels of area deprivation coupled with higher facility count per 100,000 (though the original population in many of those areas are rather sparse). In general, the maps provide further evidence that there is a relationship between access to HIV testing and socioeconomic factors, which as mentioned, becomes more disparate and a greater concern as rurality increases.

Our study had several strengths and limitations. Major strengths of our study included the updated and comprehensive list of HIV testing facilities compiled by the CDC and the more granular degree to which we conducted our analyses (census tract level as opposed to county level). Also, the generalizability of the study is strong for rural areas as the barriers that hinder HIV testing in rural settings, while most problematic in the south, plagues rural settings across the country as a whole. Limitations include the use of the general population instead of population at risk for the HIV facility density calculations though it still provides a good basis for examining HIV testing supply based on population size. Also, this study solely focuses on access to HIV testing in the south and not the next steps in HIV care. Further research would involve examining spatial access to the full continuum of HIV services (prevention, testing, and treatment) as a whole throughout the region.

4.6 Conclusion

This study assessed the spatial accessibility to HCI testing facilities across the U.S. South and highlighted the disproportionate level of access to such services as rurality increased. That, coupled with previous work that showed the lower odds of being tested for HIV in rural settings (Henderson et al.; Ohl and Perencevich), shows the need for targeted interventions that will help to remove or reduce structural barriers in rural communities in the U.S. south, regarding easier access to HIV testing. Our findings can help policy makers and public health officials identify areas across the region that require further attention and potentially, consider alternative methods to provide HIV testing services to those areas (such as mobile clinics).

CHAPTER 5

SMALL AREA ESTIMATION OF COUNTY-LEVEL U.S. HIV PREVALENT CASES[2]

[2]Khan S, McLain A, Olatosi B. Torres M, Eberth J. to be submitted to *the Annals of Epidemiology*

5.1 Abstract

Purpose: To estimate HIV prevalence at the county level and to compare prevalence across the country to assess the burden of HIV in the United States.

Methods: We performed an area-level small area estimation (SAE) modeling technique to predict the prevalent HIV case count for all counties across the continental U.S. including unreported counties. Our model borrowed strength from neighboring counties with reported counts and auxiliary HIV risk-indicator data, including geospatial components. Cross-validation techniques were conducted to assess the precision of the estimates.

Results: Our findings showed that majority of the unreported counties, mostly in the Midwest, had low HIV prevalence levels (quintiles 1 and 2). Estimates for unreported counties in the South remained consistent with the higher levels of HIV burden (quintile 4 and 5) of the rest of the region, indicating location as a strong indicator of HIV burden.

Conclusions: HIV is most prevalent along the coastlines and across the U.S. south. The cross-validation techniques largely supported the ability of our SAE model to accurately estimate prevalent case counts at the county level. Our study provides a more complete picture of the burden of HIV across the U.S. and identifies communities in need of targeted intervention in the future.

Key words: HIV; HIV prevalence; Small area estimation; county-level estimates

5.2 Introduction

Human Immunodeficiency Virus (HIV) surveillance statistics are reported and updated frequently by governing bodies such as the Centers for Disease Control and prevention (CDC) since the disease was cast into the public spotlight in the 1980s. Accurate data is crucial in evaluating the burden of disease and assessing areas of need to better combat the HIV epidemic moving forward. However, there are numerous counties across the United States where the burden of HIV is unable to be properly assessed due to publicly available data being either missing, out of date, inexact or suppressed due to low HIV counts among other reasons. Regardless of the rationale, incomplete publicly available data can mask areas with potentially rising HIV rates, particularly rural settings with small populations ("HIV/AIDS in Rural America"). Past research has shown that the number of HIV cases proportional to the population size in rural settings can be just as great as the burden of HIV in more populated areas ("HIV/AIDS in Rural America" 1). The lack of clarity regarding the current burden of HIV in certain rural parts of the U.S., mostly in the Midwest and the South, is of great concern given that one out of every five new HIV diagnoses in those two regions, occur in rural areas ("HIV in the United States"). There is a great need to fill in these data gaps to better understand the national HIV epidemic and find potential hot-spots based on a combination of HIV rates and HIV-risk indicators such as race/ethnicity, socioeconomic status and risky health behaviors such as drug and alcohol abuse.

Given the current geospatial trends of the HIV epidemic, it can no longer being characterized as solely an urban setting issue (Ungar) hence an increased need for more accurate and available data to better target areas of need for intervention and policy change. Statistical methodologies can be used to produce expected rates of an outcome in areas with missing or masked HIV data. Recently, numerous studies have utilized unit-level and area-level small area estimation (SAE) modeling techniques (Mukhopadhyay and McDowell) to estimate real world outcomes ranging from economics (Roger et al.) to health outcomes such as under/mal-nutrition rates (Sohensen; Haslett and Isidro) and diabetes incidence rates (Barker et al). There have not yet been any studies done using SAE modeling techniques to estimate HIV prevalence rates for local areas with missing or masked data. We will utilize an area-level SAE modeling technique to tackle the issue of poor or non-existent HIV prevalence reporting, particularly in rural settings.

Hence, the purpose of our study is to estimate HIV prevalence in counties across the U.S. with missing case counts and rates as of 2014 and assess the burden of disease in those areas. We hypothesize that the HIV prevalent case counts predicted by our SAE model will be considered valid and reliable after statistical validation techniques. Our study will provide a more accurate picture of the burden of HIV across the U.S. and identify communities in need of targeted intervention in the future.

5.3 Methods

5.3.1 Data

The primary data source of prevalent HIV case counts in the continental U.S. in this study is the AIDSVu 2014 National County Level HIV prevalence data set. The data comes from the CDC national HIV surveillance database which encompasses all U.S. states, all counties in 48 of the states along with ZIP Codes in 41 major cities.

All HIV diagnoses reported in the dataset are based on an established case definition by the CDC. Medical providers, laboratories, and other organizations providing HIV testing services report HIV cases to the state or local health department who then reports it (deidentified) to the CDC for monitoring of the national HIV condition.

To obtain estimates of HIV prevalence in counties that either having missing or masked rates, the AIDSVu dataset is used in conjunction with county and state level covariate data obtained from the following secondary data sources: The Robert Wood Johnson Foundation County Health Ranking System , the U.S. Census American Community Survey, and the U.S. Department of Agriculture.

5.3.2 Small Area Estimation Methodology

The purpose of small area estimation (SAE) is to estimate outcomes corresponding with small geographic areas or subpopulations by utilizing the data available from surrounding areas (Rogers et al.). Our model borrowed strength from available HIV rates in neighboring counties and covariate data to estimate the prevalent HIV case counts. The overall modeling procedure that was used to run the small area estimation technique was a mixed-effects Poisson regression model estimated with Proc GLIMMIX in SAS v9.4. This model was chosen for use as it is equally efficient in estimating very small HIV counts as well as larger HIV counts as we anticipate a variation in count and population sizes across the country. In terms of the variable selection process, we conducted a backwards model selection (after initial variable selection through past literature) with a cutoff of $p \leq 0.2$ for covariate inclusion in the final model. Poisson regression models are suited for using area-specific auxiliary data as opposed to unit-specific data (Dey). which was appropriate for our study as all the auxiliary data is at the area level (county and state-level).

The following covariates were tested for model selection, all at the county level unless otherwise noted: median age, race (%African American, %Asian, %Hispanic, %White), gender (% female), insurance status (%Uninsured), median household income (in dollars), education level (% with bachelor's degree and % with high school degree) , excessive alcohol consumption (% of adults reporting binge or heavy drinking), chlamydia incidence rate, syphilis incidence rate, poverty level (% poverty), primary care physician to population ratio (PCP ratio), policy regarding HIV education (discussing condom use in schools or not-yes/no), regionality (breakdown discussed below) and state.

The resultant parameter estimates from the final model (general model structure shown below) were used to estimate county HIV prevalent case counts and 95% confidence intervals (CI). Furthermore, we used a combination of the observed and predicted prevalent HIV case counts to calculate the HIV prevalence rate (per 100,000) at the county-level across the country.

5.3.3 Formulas and Notation

The preliminary general modeling formula used as the structure to set up the SAE is as follows:

$$\log(\lambda_{ij}) = \log(n_{ij}) + X_{ij}\beta + b_j$$

where for county i in state j, n_{ij} is the population, X_{ij} are the covariate data, β are the regression coefficients and $b_j \sim N(0, \sigma_b^2)$ is a random effect. The above model uses covariates and a random effect at the state level. It is to be noted that the assumption for this SAE is $Y_{ij} \sim Poisson(\lambda_{ij})$ were λ_{ij} = expected (predicted) number of counts (HIV cases).

5.3.4 Spatial Modeling Component

HIV in the united states while an issue across the country, has distinct characteristics based on geography so to take location into account, spatial modeling will be included using the census bureau regional breakdown ("Geography Atlas). We choose to use the further divisional breakdown within the regions for more concise modeling purposes. The 4 regions (and divisions) used were: Northeast (New England division and Mid-Atlantic division), Midwest (East-North Central division and West-North Central division), South (South-Atlantic division, East-South Central division and West-South Central division) and the West region (Mountain division and Pacific division).

5.3.5 Validation Analysis

To assess and validate the results, we used a 10-fold cross validation technique (Kohavi) where we assigned each county a number at random and partitioned out 10% of the counties into 10 separate groups (approximately 311 counties per partition) and then we ran 10 models where one partition is left out of each model (called the validation or testing set), and the model is run with the remaining partitions (called the training set). The prediction for each county is made from the model where the county in not included. This is commonly referred to as out-of-sample (oos) prediction. Proper validation and estimation of the out-of-sample error is based on the residuals for each county in the dataset, estimated as the difference between observed and oos predicted HIV rates. Root mean-squared-error (RMSE), which is analogous to the standard deviation, is estimated then as the square-root of the average squared residual.

In addition to the 10-fold cross validation, we conducted loess smoother statistical modeling (best fit line) comparing the observed counts with the predicted counts to look at the bias on the individual level. We also calculated estimated residuals (the observed counts reported from the county minus the SAE predicted counts) and plotted the residuals for visual assessment. The closer the residual is to zero, the more precise the model was in predicting the prevalent case count for that county. To take county population size into account, we calculated the observed and predicted probabilities (the observed and predicted counts divided by the total county population) and residual probabilities. This allows us to calculate the observed (reported) and predicted proportions of the total county population that has HIV. We then found a residual proportion (observed minus predicted) or the difference of proportions for each county. To assess the overall bias of the model, we produced the overall mean, 95% CI and the standard deviation. In terms of geospatial assessment, we compared the SAE predicted counts for those counties with no observed HIV count with the case count for counties with population sizes similar (+/- 10%) to the average population size of the missing counties across the country.

After assessing the validity of the predicted data, we examined the now completed and updated data across the country and identified spatial patterns across the continental U.S. in terms of hot-spots for HIV, focusing particularly on the areas with the new estimated data has been filled in.

5.4 Results

Overall, counts (and 95% CIs) were estimated for 677 counties across the continental U.S. with the largest portion of missing counties coming from the West-North Central (WNC) division (347 counties) which is in the Midwest region (displayed in figure 5.1). The smallest portion of counties with missing counts came from the Mid-Atlantic (MA) and New England (NE) divisions (each missing 2), both in the Northeast region. The average population size of the counties with missing counts in the WNC, MA and NE in 2014 was: 8,665, 10,913 and 23,461.

The combination of reported HIV prevalent case counts, and SAE predicted counts for the missing counties are displayed in figure 5.2. Most counties with estimated counts largely fell into either quintile 1 or 2 and were located in the Midwest, West and parts of the Southern region.

Overall, there are major pockets of counties in the highest HIV prevalence quintiles (4 and 5) along the Eastern and Western coasts parts of the South, particularly in the Deep South in states such as Florida and the Carolinas. The more inland geographically, the less frequency of counties in the higher quintiles though the south had a relatively steady pattern of HIV prevalence throughout, indicating the major HIV issues in the region. There were a few outliers in the Midwest region of counties without reported HIV prevalence that had a predicted HIV prevalence in the 3rd, 4th and 5th quintile, particularly in South Dakota. Figure 5.3 displays the SAE estimated HIV prevalent cases for counties with observed cases reported by the CDC to the AIDSVu website. Similar to figure 5.1, our model estimated higher HIV prevalence along the east

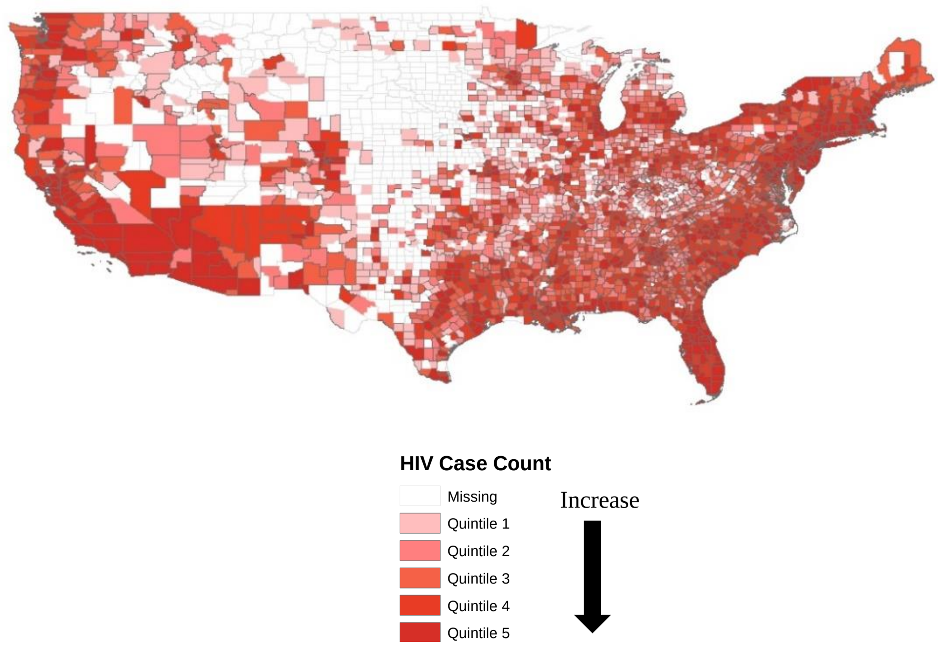

Figure 5.1 Quintile Map of Reported Prevalent HIV Counts by County, 2014

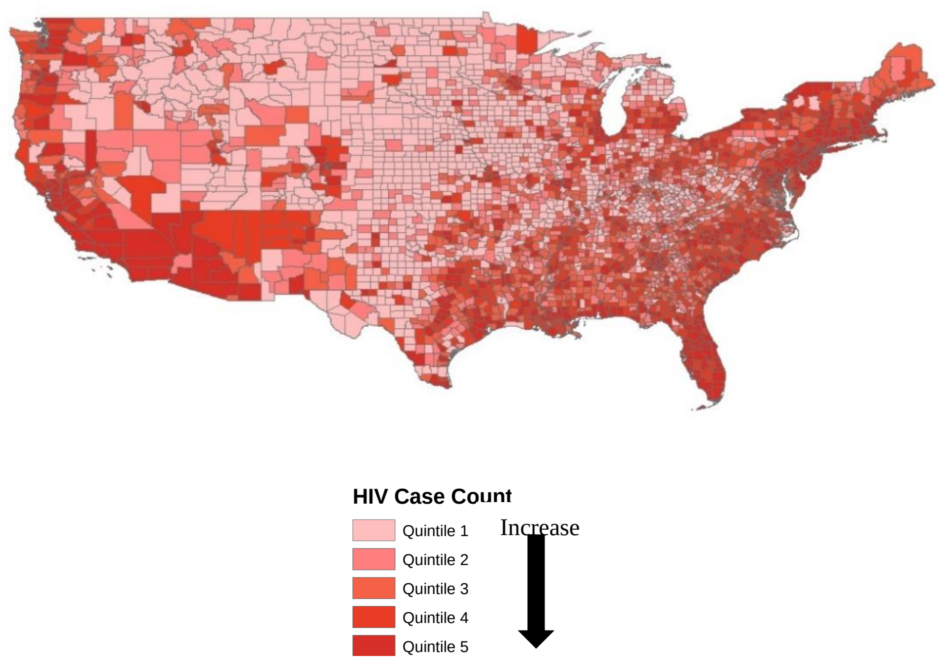

Figure 5.2 Quintile Map of Reported and SAE Estimated Prevalent Counts by County, 2014

and west coasts and across the U.S. south. The counties more inland had lower levels of HIV prevalence in both the map displaying the reported prevalence and the one displaying the SAE predicted cases.

Similar to figure 5.2 that displayed HIV prevalent cases, figure 5.4 which displays the HIV prevalence rates (per 100,000), shows higher prevalence rates along the eastern and western coasts as well as across the U.S. South region. Lower prevalence rates are apparent in the Midwestern region of the country. Also similar to figure 5.2, is that there is a small apparent cluster of higher HIV prevalence rates inland in states such as New Mexico and Colorado.

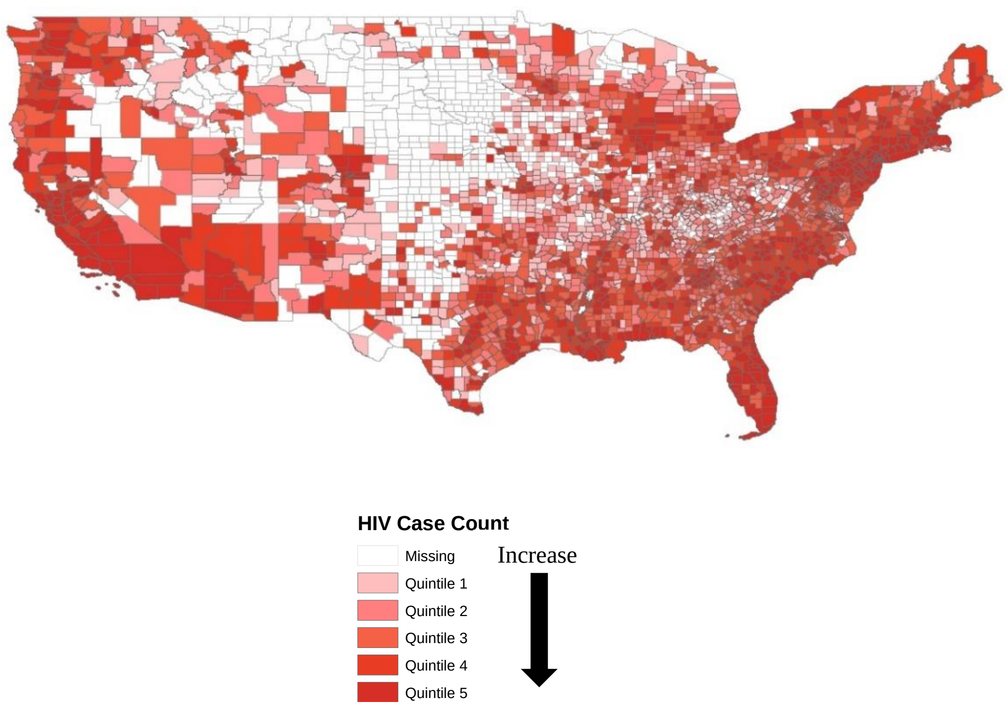

Figure 5.3 Quintile Map of SAE Prevalent HIV Case Counts by County, 2014

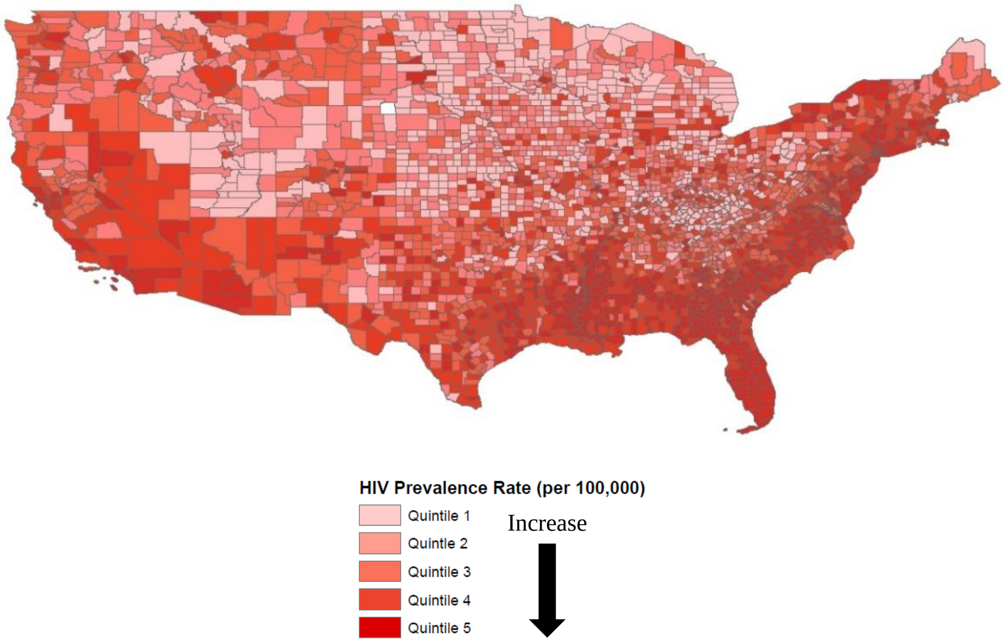

Figure 5.4 Quintile Map of Reported and SAE Estimated HIV Prevalence Rates per 100,000 by County, 2014

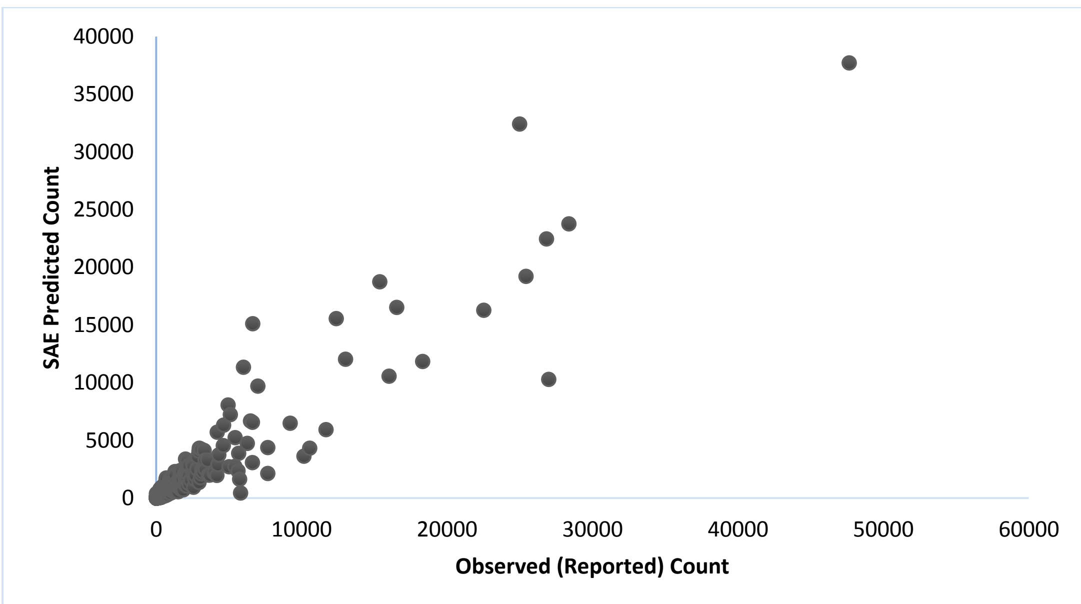

Figure 5.5 Observed (Reported) Prevalent HIV Case Count vs SAE Predicted Case Count

Validation of our model involved 10-fold cross validation, loess smoother statistical modeling (best fit line), calculation of estimate residuals (observed counts reported from the county minus the SAE predicted counts), plotting of the residuals, calculation and mapping of the percent differences between the observed and predicted counts for all counties with both values available. Figure 5.5 (above) displays the results of the 10-fold cross validation technique, displayed as a scatterplot of the observed (x-axis) HIV prevalent cases in each county (that was reported to and released by AIDSvu) compared to the predicted prevalent HIV case count estimated by our SAE model. Further assessment of the cross-validation is shown in figure 6 (displayed below) through a loess smoothing statistical modeling which created a line of best fit (smoothing parameter=0.6) to assess the relationship between the observed and predicted counts and assess an trends that may have been present.

Figure 5.7 displays the residuals (observed reported HIV count minus the SAE predicted count) for each eligible county (has both an observed and predicted count) plotting by its FIPS code. The closer the residual is to 0, the smaller the difference between the reported prevalent HIV count and the predicted count for that county based on the SAE model. The figure 5.7 scatterplot displays the clumping of residuals near the zero-value line, showing the majority of observed case counts and predicted estimates to be similar with a small amount of the 2,436 counties with residuals (having both an observed and predicted count) straying farther away from zero.

Table 5.1 further illustrates that point as the mean of the residuals was 33.46 (95%CI= 6.81, 60.12) with a root mean-squared-error (RMSE) of 670.89, which was due in part to the counties with much larger populations and hence larger residuals, as had been expected prior to analysis.

The counties with the largest residual were Kings County, NY (population size of 2,646,735; observed case count of 27,002; residual of +16701.31), Los Angeles County, CA (population size of 10,170,292; observed case count of 47,664; residual of +9930.07), Dekalb County, GA (population size of 734,871; observed case count of 6,638; residual of -8483.41) and Cook County, IL (population size of 5,238,216; observed case count of 24,996; residual of -7423.76). On the opposite end, 657 counties had residuals of +/- 5 cases (~27%) and 1,027 of the counties had residuals of +/- 10 cases (~42%).

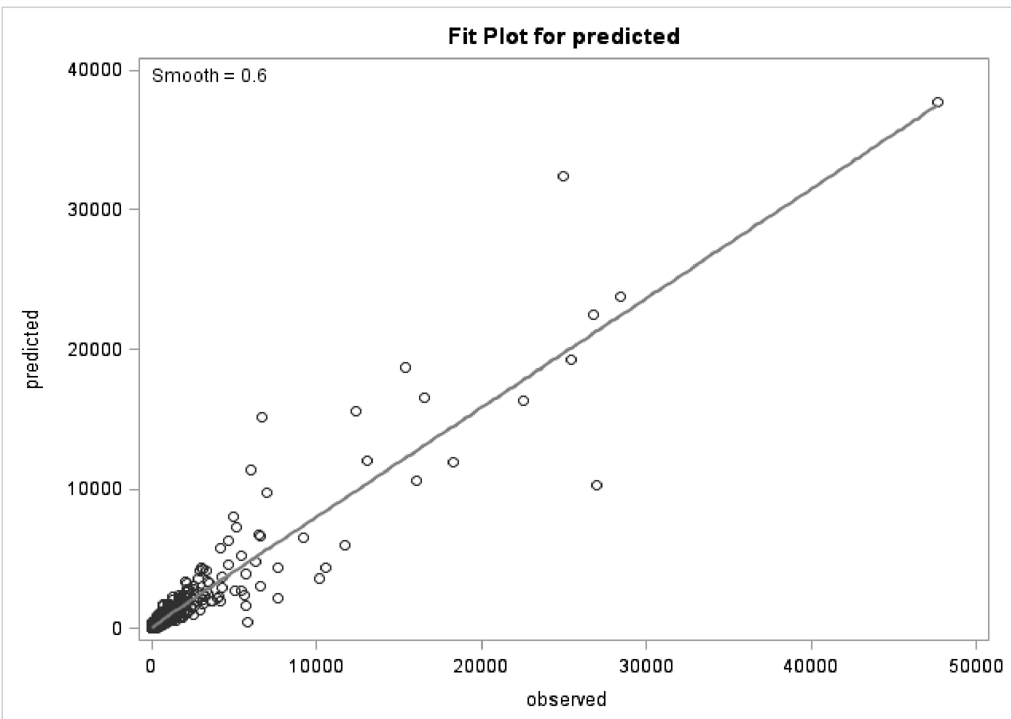

Figure 5.6 Loess Smoother Modeling of Observed vs Predicted Prevalent HIV Cases

In terms of comparing the accuracy of the model to predict case counts for the counties without observed counts which typically tend to be small due to the sparse population size (average population of these counties is ~8.312), the average residual for counties with observed case counts of 20 or less, was -5.13. The average residual for counties with observed counts and have population sizes within 10% of the average population size of missing counties was -2.19.

Figure 5.8 displays the residual proportions or the difference between the observed (reported) proportions of the total population for each county that has HIV compared to the predicted proportion (through use of SAE estimated case counts) of the same population that has HIV. The map brings to focus a few outliers although regionality largely provides large indicators for the accuracy of the model.

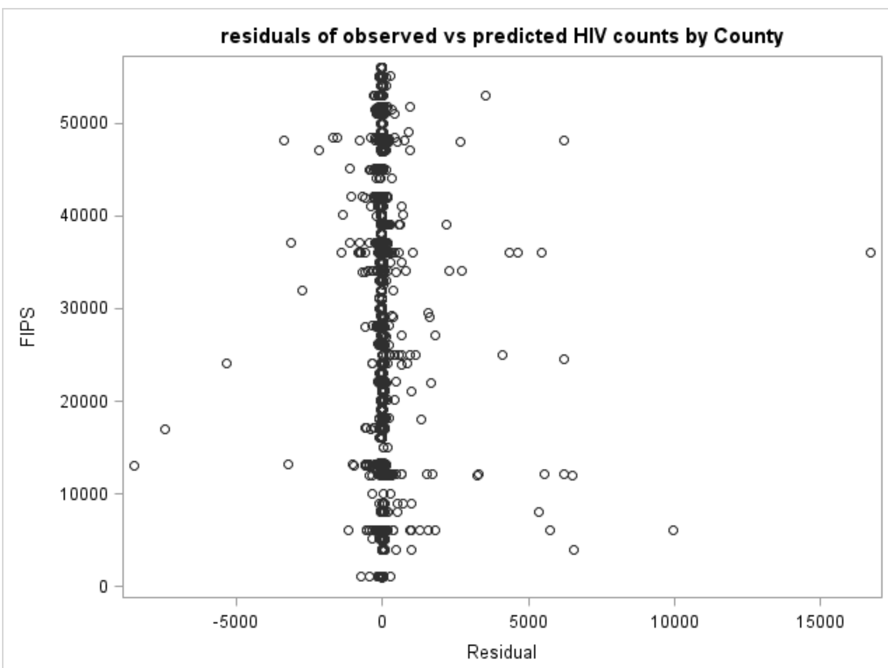

Figure 5.7 Residuals plotted by County FIPS Code

Particularly across the Midwest region, the counties are mostly clustered between quintiles 1 and 3 (denoting smaller differences between the observed and SAE predicted proportions). The largest contrast between observed and predicted proportion which occurred in Tallahatchie County, Mississippi (predicted=2.64%, observed=0.16%) and Union county, Florida (predicted=0.40%; observed=2.09%).

Table 5.1 Mean (95% CI) and Standard Deviation of the Residuals

Mean (95% CI)	Root mean-squared-error (RMSE)
33.46 (6.81,60.12)	670.89

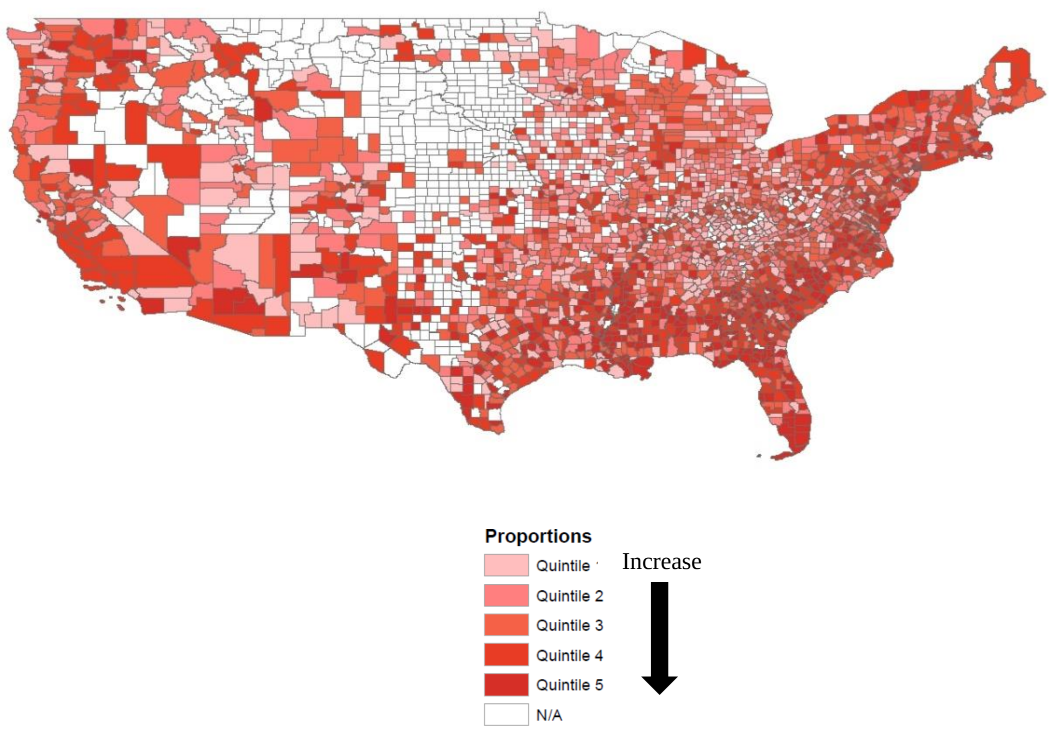

Figure 5.8 Residual Proportions of Population with HIV at the County Level, 2014

As a whole, the greater differences in observed and predicted proportions were concentrated in the South and Northeast where there are generally larger and more diverse population sizes. There are also pockets of higher proportional differences in the more urban settings within the West region. The areas with the smaller population sizes tended to have smaller differences between the observed and predicted proportions of HIV as had been expected.

The results indicate that as population size increases (and diversity of the population demographics increases) our predictive model is less accurate when compared to predicting prevalence in smaller counties with more homogenous population demographics. The results do align with our objective of predicting HIV burden in counties without previously reported prevalence. Population sizes in those publicly unreported counties tended to be small and more rural, which matches well with the strengths of our predictive model.

5.5 Discussion

We used small area estimation modeling techniques to estimate prevalent HIV case counts for counties where the prevalence was unreported for 2014 (either missing or suppressed). Due to the nature of the counties with missing data (majority are counties with sparse population sizes) and auxiliary data available to us (all area-level), we utilized a Poisson regression model with fixed and random effects. Over half of the missing counts came from counties in the Midwest region of the U.S. (59%), due in part to the data suppression of HIV prevalence in counties (mostly rural) with sparse populations and potentially small HIV case counts but also due in part to missing reports and it is not noted if the data for that county is suppressed or simply gone unreported. It is to be noted that previous literature (Vyayaharkar; Hall et al.) has indicated that the number of HIV cases proportional to population size in rural settings can be just as great as the burden of HIV in more populated areas and hence the need to report those numbers for surveillance purposes.

The majority of the counties that our model estimated HIV prevalence for that did not have it previously reported, fell within the lower quintiles (lower HIV burden). However, there were a few outlier counties particularly in South and North Dakota. Sioux county, North Dakota for example was placed in quintile 5 (highest level of HIV burden) in part due to high rates of co-morbidities (syphilis and chlamydia incidence rates) and also has high percentage of American Indians which is a race that research has shown infectious diseases to have a significant effect in the cause of morbidity (Cheek et al.). Pennington and Walworth Counties (both in South Dakota) also had high levels of co-morbidities and Pennington in particular has one of the largest counties population wise in the state. These results could indicate that population size and burden of HIV co-morbidities are strong drivers in our SAE model.

Our study had a few strengths and limitations. A strength of our study was the utilization of readily available secondary area-level covariate data, all of which are pertinent-HIV risk indicators. Due to the regional characteristics of HIV, we also used spatial factors such as regionality to borrow further strength for our model. While a limitation was the lack of individual unit-level covariate data, our unique approach does provide a basis for future studies to utilize secondary, area-level data for predictive modeling of health outcomes, if individual level data is not readily available. A limitation in our dataset was the lack of data on intravenous drug use (IDU) as it would have provided further strength to our model given the strong relationship between HIV high risk behaviors such as IDU and HIV burden. Another strength of our study was our use of multiple validation techniques to assess the precision of the data. We believe that the validation analyses strengthened the confidence in our SAE model to estimate HIV case counts, particularly in areas with missing data.

Our study was done to provide a more complete picture of the prevalence of HIV across the country and identify communities in need of targeted intervention in the future. The results from this study can be of use to those who have never had concise data on these areas before such as public health practitioners who can use the data when determining outreach efforts. Policy makers may use this data to help drive funding decisions for areas that may have potential for future HIV outbreaks based on current data. Organizations such as AIDSVu and others who track and map HIV prevalence, can replicate the estimation process and update the prevalence for missing counties, annually.

5.6 Conclusion

To properly assess the state of HIV burden across the country, a complete picture of the data is needed. Our study utilized unique small area estimation statistical methodology to provide a projected picture of the burden of HIV in areas where data was not publicly available. Our findings can be used by policy makers and public health professionals in creating targeted outreach efforts, policies and to drive potential funding of interventions. Future steps involve further exploration of this data through geospatial assessment to identify clusters and hot-spots of HIV prevalence across, counties, states, regions and nationwide.

CHAPTER 6

TRENDS IN HIV TESTING AMONG U.S. ADULTS: AN ANALYSIS OF 2011-2017 BEHAVIORAL RISK FACTOR SURVEILLANCE SYSTEM DATA[3]

[3]Khan S, Torres M, Olatosi B, McLain A, Eberth J. to be submitted to *AIDS and Behavior*

6.1 Abstract

We used 2011-2017 BRFSS data to examine HIV testing temporal trends and assess relationships between key individual factors and the likelihood of reporting as ever tested for HIV and tested within the past year. Our analysis included sub-analyses for years data was collected on sexual orientation and HIV high risk behaviors. Results showed an average of 35.01% reporting ever being tested for HIV, with an average annual percent change (APC) of +1.20% from 2011 to 2017 though percentages within the past year slightly declined (-0.29% APC). Females, individuals with health insurance, those who identify as lesbian/gay and partake in high risk behaviors were more likely to report being tested for HIV compared to males, individuals without insurance, identify as straight and do not partake in high risk behaviors. Our findings indicate the need for further targeted interventions and outreach efforts to increase HIV testing throughout the U.S.

Key words: HIV testing, BRFSS, HIV, Screening

6.2 Introduction

Organizations such as the Centers for Disease Control and Prevention (CDC) and the U.S. Preventative Services Task Force (USPSTF) have long called for the reduction of barriers to HIV testing (“HIV Surveillance Report”; “Final Recommendations Statement”). Still, a reported 40% of new HIV infections are transmitted by people living with HIV (PLWH) who are unaware of their status (“HIV Surveillance Report”). Not knowing ones’ HIV status is highly problematic because those living with undiagnosed HIV infection are more likely to transmit the infection and have poorer health outcomes (Oppong). A targeted focus on increasing HIV testing rates across the country is needed, particularly among vulnerable populations such as racial/ethnic and sexual minorities and those living in rural areas where late HIV diagnosis is an issue (Adler; Trepka). In 2006, the CDC introduced an HIV testing “opt-out approach” recommendation (Galletly) to increase HIV testing rates nationally, however results showed a temporary increase in rates before leveling out again among certain populations (Ford). The recommendations have also not helped alleviate stigma associated with HIV testing (Mahajan). Poor HIV testing rates lead to late diagnosis and lower CD4+ counts at time of diagnosis which are indicators of advanced progression of the disease which lower chances of successful viral load suppression (Trepka).

Continuous monitoring of HIV testing rates is necessary to assess and identify disparities that can be targeted through policy or programmatic changes. However, there are gaps in the literature exist for HIV testing utilization across the country. Previous literature has mostly either examined testing in a specific location (Ansa), a specific age bracket (Ford) or how specific policy changes affect testing (Gaines). There haven’t been any recent studies that have examined HIV testing rates across the country, across all ages and over a considerable period of time. Of the few studies examining HIV testing across the U.S., most only do so using a single year of the survey data (Henderson), limiting our ability to identify trends in HIV testing rates over time and explore policy, environment, or socio-demographic drivers. Due to the one-year time frames in past studies, there hasn't been much peer-reviewed literature that tracked the changes in rates due to efforts to increase HIV testing or the lack of a change in vulnerable populations. This is of particular importance in areas with historically lower rates of testing such as the south and among minorities to see if HIV testing is improving or not (Trepka).

The purpose of this study is to explore HIV testing percentages and individual-level determinants among different population subgroups over time using self-reported BRFSS data from 2011-2017. Based on prior work (Ford; Gaines), we hypothesize that utilization of HIV testing will be lower among minority groups, individuals without insurance and among males in general. While there have been major strides made in increasing access to HIV testing through national interventions and technological advancements, such as using social media to promote HIV testing (Cao), the progress is not shared equally across all segments of the U.S. population. Even among minority groups, the burden of disease generally follows socioeconomic lines, with the greatest burden observed among the poor (Pellowski). The results from this study will provide further insight on the current state of the utilization of HIV testing resources across the U.S. and chart the progress or lack thereof regarding self-reported testing rates among different, vulnerable subpopulations.

6.3 Methods

6.3.1 Study Design

This is a cross-sectional study done by analyzing self-reported HIV testing data from the 2011-2017 *Behavioral Risk Factor Surveillance System* (*BRFSS*) which is a nationally representative survey. It is the largest continually conducted health survey in the world and collects data from over 400,000 adults annually.

6.3.2 Sample and Data Source

BRFSS is a nationally representative phone-based survey for all 50 states and the District of Columbia and comprehensively explores health behaviors, chronic health conditions and healthcare use. Since 2011, the sampling methodology for the BRFSS has been altered ("Methodological Changes"), including an update to its data weighting methodology and incorporating cellular phone-based surveying. From 2011-2017, the BRFSS has surveyed over 3 million adults across the nation. Of those, our study included all who answered the question "Have you ever been tested for HIV, excluding tests as part of a blood donation?" and excluded those who refused or did not choose to answer the HIV-related questions.

6.3.3 Measures

The main dependent variable looked at was overall self-reported HIV testing percentages which was assessed via the set of questions asked in the 2011-2017 BRFSS about if the participant had ever been tested for HIV, excluding tests as part of a blood donation. If the participant answered 'yes', further questioning assessed the date and location of the last HIV test. Secondarily, we are interested in assessing past-year HIV testing percentages. We created a binary variable (yes vs no) identifying if they had been tested within 12 months prior to the interview to assess this objective based on reported date of last HIV test taken.

The independent variables include demographic data and health behavior indicators which were collected at the individual level. Data on variables associated with HIV testing were collected across the targeted 7-year range of surveys and included: age in years (18–24, 25–34, 35–44, 45–54, 55–64, or 65+), sex (male or female), race/ethnicity (non-Hispanic (NH) white, NH black, NH Asian, NH Native American/Alaskan, NH Native Hawaiian/Pacific Islander or Hispanic), educational attainment (<high school, high school graduate, some college and college graduate), current employment status (employed, self-employed, out of work <1 year, out of work> 1 year, homemaker, student, retired or unable to work) annual household income in United States Dollar (USD (<$25,000, $25,000-$50,000, $50,000-$75,000 and $75,000+)), marital status (married, divorced, widowed, separated, or never married,); healthcare coverage (yes/no). Risky health behavior measures were also included such as being classified as a binge drinker (yes/no), current smoking status (everyday, some days or not at all) and engaging in any of the following HIV risk behaviors in the past year (HIV high-risk situations (yes/no)) - use of intravenous drugs, treatment for sexually transmitted disease, giving or receiving money or drugs for sex, or having anal sex without a condom. The list of the exact BRFSS survey questions and answer choices used for each variable is provided in the appendix C.

6.3.4 Analysis

We obtained the weighted percentages of respondents who had ever been tested for HIV stratified by the socio-demographic and health behavior indicators listed above. Additionally, we calculated the average weighted percentage and average annual percent change over the 7-year period to assess reporting trends during that time. We ran regression analyses to assess the association between ever being tested for HIV and the socio-demographic variables listed above, using data pooled from 2011-2017. We also ran a regression model to assess the association between being tested for HIV within the past year and socio-demographic variables. The estimates in both regression models were adjusted for by the demographic variables and selected health behavior indicators (age, gender, race/ethnicity, educational attainment, current employment status, annual household income, healthcare insurance coverage, marital status, binge drinker status and smoking status). We also conducted sub-analyses using the populations from years that the BRFSS collected data on sexual orientation (2014-2017) and a separate analysis using the years that the BRFSS collected data on HIV high risk activity exposure (from 2011-2012 and 2016-2017).

To account for differences in data collection (nonresponse, respondent selection, and telephone non-coverage), the data was weighted using built-in calculated weights from the BRFSS dataset ("Weighting BRFSS Data"). Odds ratios, 95% confidence intervals and p-values will be obtained from the regression analyses. Regression analyses were run using survey logistic modeling as opposed to standard logistic regression due to the complex sampling design of the survey (Berglund).

6.4 Results

Across the U.S., an average of 36.07% of respondents reported having ever been tested for HIV, from 2011 to 2017. The weighted percentages of those, by year of interview, the average percentage across all 7 years and the APC are shown in table 6.1. All variables included in table I had a significant effect on the dependent variable of having ever been tested for HIV ($P<0.0001$). The weighted proportion of those who reported ever being tested for HIV has increased from 2011 to 2017 (35.92% to 38.45%). Among age categories, the 25-34 age group had the highest reported average weighted percentages of ever having been tested (53.34%), though there was a slight decline in the percentage ever tested over the 7-year period (-2.08% average annual percent change/APC). A weighted average of 44.92% of those classified as binge drinkers (males having five or more drinks on one occasion, females having four or more drinks on one occasion) reported as ever having an HIV test as opposed to 34.88% of those classified as non-binge drinkers. College graduates had higher reported percentages of ever having been tested for HIV from 2011-2017 (38.67% average weighted percentage) while H.S. graduates had the highest average APC (+8.85%).

A greater weighted proportion of females (37.12%), NH blacks (58.83%), persons with < $25,000 annual median household income, respondents without health insurance (42.82%) and those that are separated but not divorced (53.12%) reported having ever been tested for HIV from 2011 to 2017 than the other subcategories. A higher weighted proportion of those self-reporting as gay/lesbian reported having ever having been tested for HIV compared to those self-classified as straight (67.88% vs 35.01%).

Table 6.1. Weighted Proportions to Have Ever Been Tested for HIV Stratified by Select Characteristics (n=Unweighted Frequency), 2011-2017

Category	2011	2012	2013	2014	2015	2016	2017	AVG (%)	Average % Change	P-value
Overall										<.001
Yes	35.92 (n=133,239)	35.22 (n=129,846)	35.86 (n=132,093)	34.32 (n=117,007)	36.10 (n=113,779)	36.60 (n=136,267)	38.45 (n=127,137)	36.07	7.04	
Age										<.001
18-24	33.59 (n=7,246)	31.63 (n=7,694)	31.47 (n= 7,797)	28.75 (n=6,283)	29.75 (n=6,059)	29.58 (n=7,116)	31.1 (n=7,038)	30.84	-7.41	
25-34	55.29 (n=24,871)	53.43 (n=23,929)	54.00 (n=23,591)	51.50 (n=19,905)	52.96 (n=18,878)	52.04 (22,917)	54.14 (n=21,301)	53.34	-2.08	
35-44	51.81 (n=31,248)	51.74 (n=29,449)	52.86 (n=28,773)	49.86 (n=24,650)	53.63 (n=23,539)	54.13 (27,284)	56.96 (n=25,051)	53.00	9.94	
45-54	37.89 (n=31,290)	37.82 (n=29,397)	40.13 (n=29,914)	38.66 (n=26,493)	42.23 (n=25,878)	43.36 (30,330)	46.49 (n=27,861)	40.94	22.70	
55-64	23.86 (n=25,097)	25.35 (n=24,293)	26.43 (n=25,457)	26.15 (n=23,366)	28.01 (n=23,211)	29.44 (n=27,759)	31.89 (n=26,082)	27.30	33.65	
65+	9.94 (n=13,487)	11.49 (n=15,084)	11.97 (n=16,561)	12.46 (n=16,310)	12.88 (n=16,214)	13.82 (20,861)	14.92 (n=19,804)	12.50	50.10	
Binge Drinkers										<.001
No	34.27 (n=107,232)	34.13 (n=105,655)	35.11 (n=108,117)	33.7 (n=96,210)	34.95 (n=93,343)	35.42 (n=110,652)	36.61 (n=102,648)	34.88	6.83	
Yes	46.23 (n=24,195)	43.94 (n=22,079)	44.06 (n=21,982)	42.81 (n=18,898)	44.37 (n=18,601)	45.22 (n=23,049)	47.83 (n=22,282)	44.92	3.46	
Educational Attainment										<.001
Less than H.S.	34.15 (n=10,825)	34.11 (n=10,478)	35.07 (n=10,415)	33.49 (n=8,786)	35.22 (n=8,287)	35.51 (n=10,531)	37.02 (n=8,764)	34.94	8.40	
H.S. Graduate	31.64 (31,272)	31.32 (n=31,081)	31.39 (n=30,723)	30.87 (n=26,837)	32.04 (n=25,542)	33.1 (n=32,373)	34.44 (n=29,034)	32.11	8.85	
Some College	38.98 (38,912)	36.9 (n=37,695)	38.06 (n=38,962)	36.59 (n=34,127)	37.73 (n=33,079)	38.47 (n=39,505)	40.44 (n=37,194)	38.17	3.75	
College Graduate	38.31 (52,035)	38.32 (50,389)	38.82 (n=51,743)	36.44 (n=47,016)	38.93 (n=46,591)	38.83 (n=53,556)	41.01 (n=51,845)	38.67	7.05	

Employment Status										<.001
Employed	40.5 (n=68,521)	39.66 (n=66,482)	40.84 (n=67,411)	39.06 (n=59,812)	41.66 (n=58,582)	42.28 (n=68,787)	44.82 (n=65,107)	41.26	10.67	
Self-Employed	39.01 (n=11,593)	37.97 (n=11,400)	38.82 (n=11,768)	36.56 (n=10,439)	38.91 (n=10,188)	39.59 (n=12,651)	42.26 (n=11,893)	39.02	8.33	
Out of Work> 1 year	45.41 (n=6,460)	45.57 (n=5,650)	46.1 (n=5,407)	47.01 (n=3,959)	45.67 (n=3,506)	46.93 (n=3,933)	46.17 (n=3,964)	46.12	1.67	
Out of Work< 1 year	47.72 (n=5,688)	46.82 (n=5,125)	47.89 (n=5,052)	47.22 (n=3,884)	49.07 (n=3,491)	47.75 (n=4,143)	51.04 (n=3,835)	48.22	6.96	
Homemaker	36.27 (n=8,876)	35.77 (n=8,102)	37.07 (n=7,794)	33.89 (n=6,924)	37.9 (n=6,723)	37.42 (n=7,462)	38.22 (n=6,462)	36.65	5.38	
Student	32.98 (n=4,018)	30.26 (n=4,203)	30.09 (n=4,064)	27.58 (n=3,199)	27.62 (n=3,204)	27.26 (n=3,506)	28.87 (n=3,536)	29.24	-12.46	
Retired	12.42 (n=14,285)	13.99 (n=14,954)	14.11 (n=16,030)	14.59 (n=15,632)	14.9 (n=15,510)	16.17 (n=20,016)	17 (n=18,322)	14.74	36.88	
Unable to Work	44.58 (n=13,398)	45.45 (n=13,575)	45.08 (n=14,045)	45.56 (n=12,676)	46.07 (n=11,846)	46.99 (n=14,834)	47.86 (n=13,111)	45.94	7.36	
Gender										<.001
Male	34.84 (n=52,943)	34.27 (n=52,987)	34.40 (n=54,813)	33.04 (n=48,881)	34.94 (n=48,877)	35.65 (n=59,993)	37.48 (n=57,178)	34.95	7.58	
Female	36.94 (n=80,296)	36.11 (n=76,859)	37.23 (n=77,280)	35.54 (n=68,126)	37.19 (n=64,902)	37.49 (n=76,256)	39.36 (n=69,865)	37.12	6.55	
Risky Health Behavior Exposure*										<.001
Yes	65.13 (n=5,973)	63.94 (n=6,355)	N/A	N/A	N/A	63.8 (n=10,347)	63.74 (n=10,156)	64.15	-2.13	
No	36.44 (n=126,576)	34.89 (n=122,763)	N/A	N/A	N/A	35.47 (n=124,963)	36.83 (n=116,221)	35.91	1.07	
Don't Know	36.08 (n=90)	30.83 (n=81)	N/A	N/A	N/A	41.28 (n=102)	29.96 (n=60)	34.54	-16.96	
Income										<.001
< $25,000	41.93 (n=27,481)	41.22 (n=27,287)	41.57 (n=27,560)	40.62 (n=22,855)	42.17 (n=20,214)	42.13 (n=24,776)	44.46 (n=22,224)	41.61	6.03	
$25,000-$50,000	36.25 (n=23,344)	36.03 (n=22,714)	36.68 (n=23,113)	36.1 (n=20,199)	37.43 (n=18,536)	37.99 (n=22,884)	39.8 (n=20,808)	37.18	9.79	
$50,000-$75,000	34.19 (n=15,858)	33.64 (n=15,434)	35.39 (n=15,701)	33.66 (n=13,845)	35.93 (n=33,951)	36.53 (n=15,756)	37.52 (n=14,260)	35.27	9.74	

>$75,000	37.68 (n=35,823)	35.69 (n=34,639)	36.89 (n=35,472)	34.87 (n=33,513)	37.35 (n=6,982)	37.88 (n=39,321)	39.8 (n=38,565)	37.17	5.63	
Have any type of Insurance										<.001
Yes	34.34 (n=112,450)	33.73 (n=109,572)	34.27 (n=111,497)	33.33 (n=103,75)	35.31 (n=102,708)	35.92 (n=123,102)	37.89 (n=114,330)	34.97	10.34	
No	43.41 (n=20,497)	42.32 (n=19,992)	44.11 (n=20,271)	41.23 (n=12,953)	42.81 (n=10,745)	42.44 (n=12,767)	43.44 (n=12,457)	42.82	0.07	
Marital Status										<0.01
Married	31.54 (n=64,116)	30.57 (n=60,935)	32.22 (n=61,842)	30.37 (n=55,830)	32.39 (n=54,474)	32.84 (n=63,599)	34.82 (n=58,754)	32.11	10.40	
Divorced	44.74 (n=24,672)	45.05 (n=23,873)	44.71 (n=24,710)	43.52 (n=21,303)	45.75 (n=20,212)	45.14 (n=24,227)	47.67 (n=22,733)	45.23	6.55	
Widowed	13.82 (n=6,667)	15.19 (n=6,904)	15.31 (n=6,968)	15.7 (n=6,333)	15.91 (n=5,862)	16.8 (n=7,504)	17.96 (n=6,890)	15.81	29.96	
Separated	54.47 (n=4,885)	51.36 (n=4,568)	52.55 (n=4,765)	51.78 (n=3,963)	53.38 (n=3,884)	52.72 (n=4,710)	55.61 (n=4,175)	53.12	2.09	
Never Married	42.1 (n=26,168)	41.2 (n=26,862)	41.25 (n=26,954)	39.6 (n=23,625)	40.93 (n=23,012)	41.44 (n=28,325)	43.02 (n=27,121)	41.36	2.19	
Race/Ethnicity										<.001
NH White	31.26 (n=90,004)	29.91(n=85,957)	30.76 (n=88,514)	29.45 (n=77,890)	31.06 (n=75,458)	31.65 (n=89,753)	33.24 (n=83,525)	34.42	6.33	
NH Black	59.59 (n=18,459)	59.68 (n=19,322)	57.98 (n=17,946)	58.3 (n=16,202)	58.88 (n=15,121)	59.49 (n=19,109)	61.11 (n=16,933)	58.83	2.55	
Hispanic	40.26 (n=13,854)	40.84 (n=13,202)	41.85 (n=13,718)	38.87 (n=12,234)	42.48 (n=12,933)	41.7 (n=15,277)	44.87 (n=14,219)	42.16	11.45	
NH American Indian/Alaskan	40.76 (n=2,552)	42.49 (n=2,503)	41.36 (n=2,722)	42.18 (n=2,482)	46.07 (n=2,373)	44.52 (n=2,700)	46.9 (n=3,183)	43.14	15.06	
NH Asian	25.03 (n=1,966)	23.94 (n=2,048)	27.08 (n=2,006)	22.67 (n=1,800)	23.45 (n=2,015)	24.15 (n=2,117)	27.2 (n=2,056)	28.23	8.67	
NH Native Hawaiian/Pacific Islander	43.1 (n=559)	39 (n=555)	38.31 (n=481)	40.00 (n=502)	38.06 (n=387)	36.47 (n=420)	49.61 (n=486)	44.39	15.10	
Sexual Orientation**										<.001
Straight	N/A	N/A	N/A	33.23 (n=37,057)	34.91 (n=43,433)	34.34 (n=55,144)	37.56 (n=58,247)	35.01	13.03	
Lesbian/Gay	N/A	N/A	N/A	69.52 (n=1,176)	64.66 (n=1,453)	65.92 (n=1974)	71.42 (n=2,084)	67.88	2.73	

Bi-sexual	N/A	N/A	N/A	52.00 (n=935)	55.88 (n=1,181)	57.02 (n=1,865)	56.91 (n=2,021)	55.45	9.44	
Other	N/A	N/A	N/A	33.28 (n=116)	28.46 (n=157)	33.61 (n=263)	34.16 (n=273)	32.38	2.64	
Not Sure	N/A	N/A	N/A	28.99 (168)	30.09 (n=401)	26.14 (n=456)	27.64 (n=446)	28.22	-4.66	
Current Smoking Frequency										<.001
Every Day	47.58 (n=23,180)	47.47 (n=21,430)	47.88 (n=21,415)	47.45 (n=17,915)	49.08 (n=16,610)	49.65 (n=20,654)	51.47 (n=18,587)	48.65	8.18	
Some Day	48.34 (n=8,602)	48.47 (n=8,703)	47.74 (n=8,519)	46.54 (n=7,560)	49.73 (n=7,190)	49.94 (n=8,455)	51.93 (n=8,115)	48.96	7.43	
Not At All	33.18 (n=35,110)	32.71 (n=34,371)	33.86 (n=35,189)	32.73 (n=31,402)	34.63 (n=30,681)	35.85 (n=36,756)	37.32 (n=34,275)	34.33	12.48	

* High Risk Behavior Activity Question not asked in BRFSS, 2013-2015

**Sexual Orientation Question not asked in BRFSS, 2011-2013

Among those that responded as having ever been tested for HIV in the BRFSS survey from 2011 to 2017, an average of 14.43% of them also self-reported as having their last HIV test within 12 months prior to their interview date (table II). All variables included in table 5 had a significant effect on the dependent variable of having been tested for HIV within 12 months prior to their interview date (P<0.0001).

Based on their responses, those who were 1) not classified as a binge drinker, 2) between the age of 18-24, 3) with some college experience, 4) females, and 5) report <$25,000 median household income had a higher average proportion self-report as having their last HIV test on a date within 12 months of their interview date compared to the other subgroups in their respective categories. Also, those who reported as currently smoking (every day or some days) averaged a higher proportion who received their last HIV test within 12 months of their interview date compared to those who were surveyed and reportedly did not smoke at all.

Among those who responded to the question regarding sexual orientation and reported as having ever been tested for HIV, the highest proportion reporting a HIV test within the past 12 months was among those who self-identified as Bi-sexual (22.81% average) lesbian/gay (22.16% average) compared to any other sexual orientation. NH-blacks also reported receiving a HIV test within 12 months of their interview date at a higher weighted proportion (21.15% weighted average) compared to NH-whites (11.49% weighted average) and Hispanics (16.31% weighted average). For employment categories, the largest average weighted proportion who reported receiving their last HIV test within the past 12 months was among students (26.14%), though the largest positive APC was among the self-employed (+8.92%).

Table 6.2 Weighted Proportions to Have Been Tested for HIV within the Past-Year Stratified by Select Characteristics, 2011-2017

Category	2011	2012	2013	2014	2015	2016	2017	AVG (%)	Avg % Change	P-Value
Overall										
Yes	15.1	14.44	14.91	14.01	14.82	13.33	14.42	14.43	-4.50	
Age										<.0001
18-24	28.92	28.8	30.46	27.43	29.57	26.12	28.19	28.50	-2.52	
25-34	18.6	18.17	19.71	18.72	18.89	18.1	19.64	18.83	5.59	
35-44	12.07	12.17	12.35	11.81	13.83	11.7	12.53	12.35	3.81	
45-54	10.8	9.59	9.46	9.24	10.16	9.05	10.05	9.76	-6.94	
55-64	8.85	8.2	8.73	8.59	8.73	7.73	9.29	8.59	4.97	
65+	8.7	7.71	7.52	6.83	7.16	7.04	7.33	7.47	-15.75	
Binge Drinkers										<.0001
No	14.59	14.08	14.42	13.37	14.62	12.89	14.05	14.00	-3.70	
Yes	16.82	16.04	16.83	16.34	15.74	15.32	15.65	16.11	-6.96	
Educational Attainment										<.0001
Less than H.S.	17.14	15.13	16.19	15.36	14.46	11.68	14.26	14.89	-16.80	
H.S. Graduate	15.95	15.24	15.26	15.18	16.47	14.85	14.71	15.38	-7.77	
Some College	15.41	15.11	16.47	14.88	15.49	14.38	16	15.39	3.83	
College Graduate	12.91	12.63	12.18	11.29	12.87	11.62	12.55	12.29	-2.79	
Employment Status										<.0001
Employed	14.81	14.34	14.66	14.17	14.98	13.91	14.74	14.52	-0.47	
Self-Employed	10.88	11.75	13.02	11.65	13.26	10.88	11.85	11.90	8.92	
Out of Work> 1 yr	17.42	15.91	17.06	17.6	15.86	17.02	14.9	16.54	-14.47	
Out of Work< 1 yr	21.48	19.55	20.38	19.06	20.82	16.81	20.15	19.75	-6.19	
Homemaker	12.32	11.1	12.87	10.45	12.01	9.95	10.98	11.38	-10.88	
Student	25.82	27.69	27.11	24.62	25.56	24.87	27.31	26.14	5.77	
Retired	9.28	8.19	7.83	7.12	8.08	7.35	8.92	8.11	-3.88	
Unable to Work	14.34	13.51	14.57	13.79	14.77	11.69	13.81	13.78	-3.70	
Gender										0.0172
Male	15.3	14.62	15.62	14.64	14.94	13.97	14.78	14.84	-3.40	

Female	14.93	14.28	14.3	13.45	14.7	12.75	14.11	14.07	-5.49	
Risky Health Behavior Exposure*										<.0001
Yes	22.49	22	N/A	N/A	N/A	22.15	25.01	22.91	11.20	
No	14.59	13.9	N/A	N/A	N/A	12.31	13.2	13.50	-9.53	
Don't Know	34.62	11.11	N/A	N/A	N/A	14.16	13.87	18.44	-59.94	
Income										<.0001
< $25,000	17.65	17.09	18.41	16.52	17.34	16.02	17.69	17.25	0.23	
$25,000-$50,000	17.52	15.83	16.53	16.36	16.5	15.45	16.96	16.45	-3.20	
$50,000-$75,000	15.55	15.34	14.65	14.28	16.6	14.14	14.72	15.04	-5.34	
>$75,000	11.59	11.7	11.05	10.47	11.62	10.38	11.41	11.17	-1.55	
Have any type of Insurance										<.0001
Yes	14.74	14.2	14.74	13.64	14.81	13.3	14.38	14.26	-2.44	
No	16.26	15.18	15.43	15.91	14.71	13.59	14.58	15.09	-10.33	
Marital Status										<.0001
Married	10.32	9.48	10.06	9.39	9.83	9.25	9.97	9.76	-3.39	
Divorced	14.22	13.28	12.93	12.49	13.93	12.6	13.42	13.27	-5.63	
Widowed	9.5	9.97	9.28	8.56	10.71	8.7	9.76	9.50	2.74	
Separated	19.33	17.52	17.82	16.55	16.47	15.31	16.02	17.00	-17.12	
Never Married	21.99	21.93	24.18	22.2	23.33	20.37	22.22	22.32	1.05	
Race/Ethnicity										<.0001
NH White	11.96	11.21	11.9	11.01	12.08	10.47	11.82	11.49	-1.17	
NH Black	22.05	21.23	20.89	21.61	22.29	19.4	20.61	21.15	-6.53	
Hispanic	18.38	16.66	17	15.01	15.74	15.37	16.04	16.31	-12.73	
NH American Indian/Alaskan	14.53	14.09	16.73	18.36	14.03	13.67	15.45	15.27	6.33	
NH Asian	22.12	26.58	13.44	11.51	12.98	13.53	14.87	16.43	-32.78	
NH Native Hawaiian/Pacific Islander	16.54	16.73	18.85	16.66	26.38	14.81	24	19.14	45.10	
Sexual Orientation**										<.0001
Straight	N/A	N/A	N/A	15.17	15.59	13.07	13.78	14.40	-9.16	
Lesbian/Gay	N/A	N/A	N/A	22.51	22.86	24.01	19.26	22.16	-14.44	
Bi-sexual	N/A	N/A	N/A	26.50	23.07	18.35	23.35	22.82	-11.89	
Other	N/A	N/A	N/A	20.88	16.44	11.52	20.21	17.26	-3.21	
Not Sure	N/A	N/A	N/A	21.86	12.15	12.34	14.89	15.31	-31.88	

Current Smoking Frequency										<.0001
Every Day	15.43	14.32	15.9	15.4	15.15	13.08	14.67	14.85	-4.93	
Some Day	17.45	15.75	18.66	17.66	17.17	16.27	16.36	17.05	-6.25	
Not At All	12.13	11	10.95	10.58	11.32	10.78	11.07	11.12	-8.74	

* High Risk Behavior Activity Question not asked in BRFSS, 2013-2015

**Sexual Orientation Question not asked in BRFSS, 2011-2013

The results from the multivariate logistic regression analysis are displayed in table 6.3, which assessed associations between the pooled data on the demographic variables from 2011 to 2017 (provided in table 6.1) and having ever been tested for HIV, after model adjustment (as noted in table III, sexual orientation and high-risk behaviors were excluded due to data missing for certain years). All variables entered had a significant effect on the final model. The likelihood of ever being tested for HIV was inversely associated with levels of education lower than a college degree ($p<0.01$ for all three levels- no H.S. education, H.S. degree and some college) as well as lack of health insurance (OR=0.84; 95%CI= 0.82, 0.87; $p<0.0001$) and not being classified as a binge drinker (OR=0.96; 95%CI= 0.94, 0.99); p= 0.0038).

Non-Hispanic blacks (OR=2.53; 95%CI= 2.43, 2.62; $p<0.0001$), females (OR=1.19; 95%CI= 1.16, 1.21; $p<0.0001$), those with less than $25,000 in median household income (OR=1.07; 95%CI= 1.03, 1.11; p=0.0007), and those between the ages of 25-34 (OR=6.70; 95%CI= 6.40,7.020; $p<0.0001$) were more likely to have reported ever being tested for HIV than non-Hispanic whites, males, those who have a median household income greater than $75,000 and those 65 and older. Daily smokers (OR=1.15; 95%CI= 1.12, 1.18; $p<0.0001$) and those who were either divorced or separated but not divorced (OR= 1.6 and p-value<0.0001 for both), were also more likely to report having ever been tested for HIV than non-smokers and those that are married.

All variables entered except for gender and binge drinking status had a significant effect in the final model. The likelihood reporting having been tested for HIV within the past 12 months was negatively associated with level of educational attainment, with the lowest likelihood being among those with less than a high school degree

Table 6.3 Multivariate Logistic Regression Analysis Results of Demographic Variables Associated with Ever and within Past-Year Testing of HIV, 2011–2017

Variable*	Ever				Past-Year			
	Odds Ratio	95% Confidence Limits		P-Value	Odds Ratio	95% Confidence Limits		P-Value
Educational Attainment								
Less than H.S.	0.607	0.584	0.632	<.0001	0.771	0.717	0.829	<.0001
HS Graduate	0.628	0.61	0.646	<.0001	0.781	0.739	0.825	<.0001
Some College	0.866	0.843	0.89	<.0001	0.965	0.916	1.017	0.1783
College Graduate	REF				REF			
Current Employment Status								
Employed	REF				REF			
Self-Employed	1.158	1.114	1.204	<.0001	1.096	1.017	1.182	0.0162
Out of Work <1 year	1.273	1.205	1.345	<.0001	1.302	1.197	1.416	<.0001
Out of Work>1 year	1.292	1.223	1.365	<.0001	1.387	1.275	1.508	<.0001
Homemaker	1.168	1.114	1.224	<.0001	1.154	1.043	1.276	0.0055
Student	1.013	0.943	1.089	0.7236	1.14	1.033	1.258	0.0089
Retired	0.906	0.873	0.941	<.0001	0.912	0.826	1.007	0.0675
Unable to Work	1.48	1.427	1.535	<.0001	1.408	1.322	1.5	<.0001
Race/Ethnicity								
NH White	REF				REF			
NH Black	2.526	2.434	2.62	<.0001	2.618	2.482	2.762	<.0001
NH American Indian/Alaskan	1.343	1.249	1.444	<.0001	1.142	0.993	1.313	0.062
NH Asian	0.685	0.618	0.759	<.0001	0.932	0.769	1.13	0.4741
NH Native Hawaiian/Pacific Islander	1.25	1.058	1.478	0.0088	1.697	1.393	2.067	<.0001
Hispanic	1.257	1.209	1.307	<.0001	1.419	1.329	1.515	<.0001
Gender								
Male	REF				REF			
Female	1.187	1.163	1.212	<.0001	1.013	0.974	1.055	0.5097
Have Health Insurance								

Yes	REF				REF			
No	0.844	0.817	0.872	<.0001	0.737	0.699	0.777	<.0001
Don't Know	0.696	0.56	0.864	0.001	0.628	0.366	1.076	0.0905
Binge Drinker								
Yes	REF				REF			
No	0.961	0.936	0.987	0.0038	0.956	0.914	1.001	0.0539
Income Category								
Less than $25,000	1.068	1.028	1.109	0.0007	1.164	1.083	1.25	<.0001
$25,000-$50,000	0.995	0.962	1.029	0.7494	1.166	1.092	1.245	<.0001
$50,000-$75,000	0.979	0.945	1.013	0.2161	1.089	1.015	1.168	0.0174
$75,000+	REF				REF			
Age Category								
18-24	3.687	3.469	3.919	<.0001	8.827	7.77	10.027	<.0001
25-34	6.704	6.402	7.02	<.0001	8.114	7.229	9.108	<.0001
35-44	6.655	6.371	6.951	<.0001	5.352	4.772	6.002	<.0001
45-54	3.99	3.832	4.154	<.0001	3.316	2.962	3.713	<.0001
55-64	2.174	2.098	2.252	<.0001	2.068	1.863	2.295	<.0001
65+	REF				REF			
Current Smoking Status								
Everyday	1.151	1.123	1.18	<.0001	1.14	1.09	1.193	<.0001
Some days	1.014	0.981	1.048	0.4057	1.114	1.053	1.178	0.0001
Not at all	REF				REF			
Marital Status								
Married	REF				REF			
Divorced	1.629	1.582	1.677	<.0001	1.842	1.737	1.953	<.0001
Widowed	0.91	0.873	0.948	<.0001	1.19	1.073	1.32	0.001
Separated	1.647	1.56	1.74	<.0001	2.02	1.854	2.2	<.0001
Never Married	1.368	1.324	1.414	<.0001	1.8	1.699	1.907	<.0001

*High Risk Behaviors and Sexual Orientation were excluded from the model due to data only available for certain years

(OR=0.77; 95%CI= 0.72,0.83; p<0.0001), controlling for the other variables in the multivariate regression model.

Non-Hispanic blacks were 2.6 times (95%CI= 2.48, 2.76; p<0.0001) as likely to self-report having been tested for HIV within the past 12 months compared to NH whites. Those without health insurance had 0.74 times the odds of having been tested for HIV within the past 12 months compared to those with health insurance, controlling for the other variables in the model. The younger the participant the more likely they were to report being tested for HIV within the past year (OR=8.83 95%CI= 7.77, 10.03; p<0.0001 for the 18-24 age group) compared to those 65+. Smoking status was also positively associated with HIV testing within the past year as current smokers and those who report smoking some days were 1.1 times as likely to have reported having had an HIV test within the past 12 months compared to those who do not smoke at all, controlling for the other variables.

The results from the multivariate logistic regression analysis for years the BRFSS collected data on HIV high risk behavior exposures are displayed in table 6.4, which assessed associations between the pooled data on the demographic variables from the years with collected data (2011–2012 and 2016-2017) and having ever been tested for HIV, after model adjustment.

The odds of having ever been tested for HIV are 1.91 times (95%CI= 1.81, 2.02; p<0.0001) as likely for those who have reported HIV high risk behavior involvement compared to those who have not been involved in any of those activities, controlling for the other variables in the model. No other factor significantly changed in its relationship to HIV testing, after adjusting for high risk behaviors.

Table 6.4. Multivariate Logistic Regression Sub-Analysis of Ever and within Past-Year Testing of HIV for Years with Data on HIV High Risk Behavior Involvement, BRFSS 2011–2012, 2016-2017

Variable	Ever				Past-Year			
	Odds Ratio	**95% Confidence Limits**		**P-Value**	**Odds Ratio**	**95% Confidence Limits**		**P-Value**
Educational Attainment								
Less than H.S.	0.609	0.582	0.637	<.0001	0.736	0.667	0.812	<.0001
HS Graduate	0.636	0.615	0.657	<.0001	0.768	0.713	0.827	<.0001
Some College	0.862	0.835	0.889	<.0001	0.944	0.88	1.013	0.1107
College Graduate	REF				REF			
Current Employment Status								
Employed	REF				REF			
Self-Employed	1.212	1.159	1.267	<.0001	1.005	0.908	1.112	0.9284
Out of Work <1 year	1.346	1.269	1.427	<.0001	1.374	1.23	1.536	<.0001
Out of Work>1 year	1.255	1.178	1.337	<.0001	1.352	1.208	1.512	<.0001
Homemaker	1.244	1.179	1.312	<.0001	1.14	0.995	1.305	0.0592
Student	1.014	0.933	1.103	0.7405	1.215	1.065	1.387	0.0038
Retired	0.965	0.925	1.006	0.096	0.96	0.843	1.092	0.5331
Unable to Work	1.581	1.514	1.65	<.0001	1.402	1.288	1.525	<.0001
Race/Ethnicity								
NH White	REF				REF			
NH Black	2.992	2.866	3.123	<.0001	2.635	2.453	2.83	<.0001
NH American Indian/Alaskan	0.951	0.859	1.052	0.3274	1.085	0.883	1.335	0.3274
NH Asian	0.745	0.639	0.868	0.0002	1.14	0.865	1.503	0.0002
NH Native Hawaiian/Pacific Islander	1.329	1.187	1.488	<.0001	1.833	1.482	2.268	<.0001
Hispanic	1.343	1.283	1.406	<.0001	1.517	1.391	1.654	<.0001
Gender								
Male	REF				REF			
Female	1.195	1.167	1.224	<.0001	1.031	0.978	1.088	<.0001
Have Health Insurance								
Yes	REF				REF			
No	0.797	0.769	0.826	<.0001	0.742	0.69	0.797	<.0001

Don't Know	0.694	0.519	0.929	0.0141	0.759	0.347	1.663	0.0141
Binge Drinker								
Yes	REF				REF			
No	0.964	0.935	0.994	0.0196	0.952	0.895	1.012	0.0196
Income Category								
Less than $25,000	1.083	1.036	1.132	0.0005	1.126	1.023	1.24	0.0005
$25,000-$50,000	1.009	0.971	1.049	0.6355	1.178	1.079	1.287	0.6355
$50,000-$75,000	0.932	0.896	0.969	0.0005	1.034	0.94	1.136	0.0005
$75,000+	REF				REF			
Age Category								
18-24	4.257	3.963	4.573	<.0001	8.376	7.062	9.934	<.0001
25-34	7.946	7.532	8.383	<.0001	7.755	6.655	9.036	<.0001
35-44	7.734	7.356	8.132	<.0001	5.381	4.622	6.263	<.0001
45-54	4.298	4.105	4.501	<.0001	3.344	2.882	3.879	<.0001
55-64	2.258	2.168	2.353	<.0001	2.104	1.834	2.415	<.0001
65+	REF				REF			
Current Smoking Status								
Everyday	1.141	1.11	1.174	<.0001	1.089	1.025	1.156	<.0001
Some days	1.006	0.968	1.046	0.7586	1.069	0.993	1.152	0.7586
Not at all	REF				REF			
Marital Status								
Married	REF				REF			
Divorced	1.735	1.679	1.793	<.0001	1.843	1.704	1.994	<.0001
Widowed	0.919	0.878	0.963	0.0004	1.213	1.061	1.386	0.0004
Separated	1.665	1.561	1.776	<.0001	2.003	1.786	2.247	<.0001
Never Married	1.379	1.327	1.433	<.0001	1.699	1.572	1.836	<.0001
HIV High Risk Behavior								
Yes	1.909	1.805	2.02	<.0001	1.717	1.59	1.855	<.0001
No	REF				REF			
Don't Know	1.337	0.944	1.894	0.102	1.393	0.578	3.357	0.4606

Furthermore, the results from the logistic regression analysis for years where the BRFSS collected data on HIV high risk behavior exposures displayed in table IV, which assessed associations between the pooled data on the demographic variables from the years with collected data (2011–2012 and 2016-2017) and reporting their last HIV test as being within 12 months prior to their interview date, after model adjustment. The odds of having been tested for HIV within 12 months among those who had been involved in HIV high risk behaviors is 1.7 times (95%CI=1.59,1.86; p<0.0001) as likely as those who reported not having been involved in any HIV high risk behaviors, controlling for the other variables in the model. Several employment statuses (self-employed and homemaker) significantly changed in its relationship to HIV testing, after adjusting for HIV high risk behaviors.

The results from the multivariate logistic regression analysis for years where the BRFSS collected data on sexual orientation are displayed in table 6.5, which assessed associations between the pooled data on the demographic variables from the years the BRFSS collected data on sexual orientation (2014-2017) and having ever been tested for HIV, after model adjustment. The odds of having ever been tested for HIV are 3.3 times as likely among those who reported as lesbian/gay compared to those who reported as straight. Inversely, those who were unsure of their sexual orientation were 0.78 times as likely to have reported as ever having been tested for HIV compared to those who reported as straight, controlling for the other variables in the model.

The odds of having been tested for HIV within 12 months among those who identify as lesbian/gay are 2.0 times (95%CI= 1.66, 2.43, p<0.0001) as likely as those

Table 6.5 Multivariate Logistic Regression Sub-Analysis Results of Ever and within Past-Year Testing of HIV for Years with Data on Sexual Orientation, BRFSS 2014-2017

Variable	Odds Ratio	95% Confidence Limits		P-Value	Odds Ratio	95% Confidence Limits		P-Value
Educational Attainment								
Less than H.S.	0.609	0.582	0.637	<.0001	0.609	0.582	0.637	<.0001
HS Graduate	0.636	0.615	0.657	<.0001	0.636	0.615	0.657	<.0001
Some College	0.862	0.835	0.889	<.0001	0.862	0.835	0.889	<.0001
College Graduate	REF				REF			
Current Employment Status								
Employed	REF				REF			
Self-Employed	1.212	1.159	1.267	<.0001	1.212	1.159	1.267	<.0001
Out of Work <1 year	1.346	1.269	1.427	<.0001	1.346	1.269	1.427	<.0001
Out of Work>1 year	1.255	1.178	1.337	<.0001	1.255	1.178	1.337	<.0001
Homemaker	1.244	1.179	1.312	<.0001	1.244	1.179	1.312	<.0001
Student	1.014	0.933	1.103	0.7405	1.014	0.933	1.103	0.7405
Retired	0.965	0.925	1.006	0.096	0.965	0.925	1.006	0.096
Unable to Work	1.581	1.514	1.65	<.0001	1.581	1.514	1.65	<.0001
Race/Ethnicity								
NH White	REF				REF			
NH Black	2.992	2.866	3.123	<.0001	2.992	2.866	3.123	<.0001
NH American Indian/Alaskan	0.951	0.859	1.052	0.3274	0.951	0.859	1.052	0.3274

NH Asian	0.745	0.639	0.868	0.0002	0.745	0.639	0.868	0.0002
NH Native Hawaiian/Pacific Islander	1.329	1.187	1.488	<.0001	1.329	1.187	1.488	<.0001
Hispanic	1.343	1.283	1.406	<.0001	1.343	1.283	1.406	<.0001
Gender								
Male	REF				REF			
Female	1.195	1.167	1.224	<.0001	1.195	1.167	1.224	<.0001
Have Health Insurance								
Yes	REF				REF			
No	0.797	0.769	0.826	<.0001	0.797	0.769	0.826	<.0001
Don't Know	0.694	0.519	0.929	0.0141	0.694	0.519	0.929	0.0141
Binge Drinker								
Yes	REF				REF			
No	0.964	0.935	0.994	0.0196	0.964	0.935	0.994	0.0196
Income Category								
Less than $25,000	1.083	1.036	1.132	0.0005	1.083	1.036	1.132	0.0005
$25,000-$50,000	1.009	0.971	1.049	0.6355	1.009	0.971	1.049	0.6355
$50,000-$75,000	0.932	0.896	0.969	0.0005	0.932	0.896	0.969	0.0005
$75,000+	REF				REF			
Age Category								
18-24	4.257	3.963	4.573	<.0001	4.257	3.963	4.573	<.0001
25-34	7.946	7.532	8.383	<.0001	7.946	7.532	8.383	<.0001
35-44	7.734	7.356	8.132	<.0001	7.734	7.356	8.132	<.0001
45-54	4.298	4.105	4.501	<.0001	4.298	4.105	4.501	<.0001

55-64	2.258	2.168	2.353	<.0001	2.258	2.168	2.353	<.0001
65+	REF				REF			
Current Smoking Status								
Everyday	1.141	1.11	1.174	<.0001	1.141	1.11	1.174	<.0001
Some days	1.006	0.968	1.046	0.7586	1.006	0.968	1.046	0.7586
Not at all	REF				REF			
Marital Status								
Married	REF				REF			
Divorced	1.735	1.679	1.793	<.0001	1.735	1.679	1.793	<.0001
Widowed	0.919	0.878	0.963	0.0004	0.919	0.878	0.963	0.0004
Separated	1.665	1.561	1.776	<.0001	1.665	1.561	1.776	<.0001
Never Married	1.379	1.327	1.433	<.0001	1.379	1.327	1.433	<.0001
Sexual Orientation								
Straight	REF				REF			
Lesbian/Gay	3.267	2.817	3.789	<.0001	2.007	1.659	2.427	<.0001
Bi-sexual	2.112	1.86	2.399	<.0001	1.651	1.395	1.954	<.0001
Other	0.865	0.642	1.166	0.3401	1.252	0.636	2.465	0.5153
Not Sure	0.773	0.583	1.025	0.0736	0.942	0.55	1.614	0.8278

who identify as straight and those who identified as Bi-sexual were 1.66 times (95%CI= 1.40, 1.95; p<0.0001) as likely. Those who are reported as unsure of their sexual orientation were less likely (OR=0.94) to have been tested within 12 months of their interview date than those who reported a straight, and those the value is not considered statistically significant (95%CI=0.55, 1.62; p=0.83).

6.5 Discussion

Our study utilized BRFSS data from 2011-2017 to assess temporal trends as well as demographic and socioeconomic factors associated with HIV testing among adults across the U.S. Overall, an average of 36.07% of adults who were surveyed during those years, reported as having ever been tested for HIV (APC of 1.2%) and 4.78% (APC of -0.29%) reported as having been tested for HIV within the past 12 months prior to their interview date. After adjustment for the covariates used in the multivariate logistic regression, our findings aligned with results from previous literature (Ford; Ansa; Gaines; Henderson; Ohl) done on different parts of the county, that gender (female), race (NH-Black), age (25-34 age group), and income level (<$25,000), and being single are all positively associated with higher odds for both being tested for HIV ever and tested for HIV within the past year.

We conducted a sub-analysis for years that collected data on HIV high risk behaviors (2011-2012, 2016-2017) and our findings also aligned with previous results (Gaines; Henderson) that reported high risk behaviors were positively associated with higher odds of both reporting being tested for HIV ever and within the past year. Additionally, we conducted a sub-analysis for years that collected data on sexual orientation (2014-2017) and our findings indicated that sexual orientation (lesbian/gay and bi-sexual) was positively associated with both reporting as having ever been tested for HIV and reporting their last HIV test as within the past year.

Our study had a few strengths and limitations. A major strength of the study is the use of large nationally represented sample of BRFSS survey data, including the most recently released year (2017). Unlike other studies done targeting specific urban settings or specific age groups, our study provides an up to date comprehensive review of BRFSS data across the entire country for all adult age categories and includes updated data on major HIV risk predictors: HIV high risk behaviors and sexual orientation.

Inversely, a major limitation is the fact that the BRFSS relies on self-reported data which opens the data up to bias (recall and non-response bias based on refusal to answer) though we used survey weights to limit the potential bias. That being said, there have a been a few studies that specifically discussed the validity of self-reported HIV testing data under certain circumstances (Henderson; An) and indicated a favorable evaluation when compared to medically reported HIV tests. Due to the nature of the survey data collection methodology, there may be pockets of the population left out of the survey due to lack of access to land and cell service, particularly in rural areas.

6.6 Conclusion

The findings of our study showed that an average of slightly more than 1/3rd of those surveyed during the 2011-2017 BRFSS reported as ever having been tested for HIV (36.07%) and approximately only 1 out of every 20 surveyed, reported their last HIV test being within the past year. These results indicate the continued need for emphasis on nation-wide targeted interventions and policies to address disparities regarding the utilization of HIV testing across the country.

The impact of the CDC's HIV testing "opt-out" recommendations (Galletly) established in 2006 have seemingly plateaued as there is a slight APC in reported HIV testing percentages and hence the need for further evaluation and assessment of policies moving forward. An increase in the utilization of HIV testing has always been a key component in combating and ultimately stemming the HIV epidemic, particularly among high risk groups (minorities, high risk behavior involvement, sexual orientation and those with lower incomes). While these target groups are reporting at higher rates and hence having higher likelihoods of reporting as having been tested for HIV, there is still much work to be done to increase those percentages further, particularly regarding recent HIV testing where the percentages are quite poor across the spectrum.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The findings from this dissertation have provided further insight into HIV testing utilization trends and access to HIV testing across the U.S. south. Furthermore, we produced and validated estimated HIV prevalent case counts for all counties across the continental U.S., including counties with previously unreported counts. We did so using innovative small area estimation techniques which along with providing HIV estimates, provides a basis for future researchers to estimate area-level health outcomes using solely area-level data in the model.

Chapter 4 dealt with assessing spatial access to HIV testing facilities across the U.S. south to identify how access differs by levels of rurality and key demographic and socioeconomic factors. The results of our study confirmed that as rurality increased, so too did the percentage of CTs that were located farther than 30 minutes from a testing facility. It showed that when controlling for other covariates, the higher the rate of uninsured 18-64-year olds, the less likely that the CT is located within 30 minutes of any HIV testing facility. We also identified consistently high levels of economic deprivation in rural parts of most states particularly in the deep south states. Texas in particular, had the most visable intersection of rurality, area deprivation and poor supply of HIV testing.

In chapter 5, we provided a more complete picture of the HIV burden across the U.S. using small area estimation techniques to produce county-level HIV case counts for areas with missing or suppressed data. These estimated case counts can be useful to policymakers, public health practitioners, healthcare providers and others for identifying the best locations for outreach efforts and targeted interventions, as well as provide evidence for resource allocation/funding decisions. The use of publicly available area-level secondary data in the model is a unique feature that can be used to estimate other area-level health outcomes in a cost-effective and timely manner.

Finally, we explored temporal trends and related predictors of utilization of HIV testing across the U.S. using the BRFSS survey in chapter 6. Our findings showed slight improvement in testing percentages among those who reported having ever been tested for HIV from 2011 to 2017. There was a slight decrease among those who reported having been tested for HIV within the past year of their interview date. Our results were consistent with results reported by previous studies, though those studies focused on specific urban geographic regions or age groups while our study scale was nationwide. Females, those who identify as lesbian/gay and NH blacks were all significantly more likely to report having been tested for HIV ever and within the past year as their counterparts in each subcategory.

7.2 Recommendations

Recommendations for the use of the findings from this dissertation include using the data to support more interventions targeting HIV testing, particularly regularly HIV testing (vs. one-time/ “ever tested”). Such interventions should be targeted at areas with disproportionate barriers regarding access to HIV testing (e.g., poor transportation, farther distance to facilities, lack of health insurance, etc.). Our findings showed that only approximately 1/3rd of all respondents to the HIV section of the BRFSS had ever been tested for HIV, which sorely hampers the goal of stemming HIV transmission. HIV continues to be a major issue particularly in the rural south where the combination of high socioeconomic deprivation (such as lower rates of insurance, lower educational attainment, higher poverty rates, higher levels of social stigma among other factors), lack of supply of HIV testing and treatment facilities, and high HIV burden will continue to drive the epidemic until major action is taken to stem the transmission of HIV and address its related risk indicators (i.e., poor SES, high HIV risk behaviors) that lead to higher risk of contracting and transmitting HIV.

Recommendations for future research based off the work done in this dissertation would be 1) obtain geocoded addresses for all HIV treatment facilities in the south to spatially examine access to the full continuum of HIV care at the local level 2) use SAE or similar statistical methodology to predict future HIV estimates to identify areas that may be susceptible to HIV outbreaks based on current HIV-risk indicators and 3) case studies on successful implementation of outreach efforts to increase HIV testing utilization at the local/state level or among specific subpopulations, to identify successful strategies to bring to disseminate more broadly.

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APPENDIX A:

LIST OF VARIABLES IN THE AREA DEPRIVATION INDEX (ADI)

- Percent of the population aged 25 and older with less than 9 years of education
- Percent of the population aged 25 and older with at least a high school diploma
- Percent employed persons aged 16 and older in white-collar occupations
- Median family income in US dollars
- Income disparity
- Median home value in US dollars
- Median gross rent in US dollars
- Median monthly mortgage in US dollars
- Percent of owner-occupied housing units
- Percent of civilian labor force population aged 16 years and older who are unemployed
- Percent of families below federal poverty level
- Percent of the population below 150% of the federal poverty threshold
- Percent of single-parent households with children less than 18 years of age
- Percent of households without a motor vehicle
- Percent of households without a telephone
- Percent of occupied housing units without complete plumbing
- Percent of households with more than 1 person per room

APPENDIX B:

STANDARD ERRORS OF AVERAGE CENSUS TRACT DEMOGRAPHICS STRATIFIED BY ACCESS

Table B.1 Standard Errors of Average Demographics of Census Tracts within and Outside of 30-minutes of a Testing Facility

Variable	**No Access SE**	**Access SE**
Race (%)		
American Indian	0.134	0.018
Asian	0.121	0.033
Black	0.682	0.157
Hawaiian/Pacific Islander	0.020	0.002
Non-Hispanic White	0.801	0.161
Ethnicity (%)		
Hispanic	1.180	0.141
Not Hispanic	1.180	0.141
Education (% with bachelor's degree)		
Overall	0.778	0.122
American Indian	2.858	0.343
Asian	3.516	0.269
Black	1.295	0.150
Hispanic/Latino	1.212	0.162
Hawaiian/Pacific Islander	10.078	0.900
Non-Hispanic White	0.787	0.135
Income (average $)	1378.27	243.31
Unemployment Rate (%, ages 16+)	0.266	0.033
Uninsured (%)		
Overall	0.592	0.056
Under 18	0.718	0.048
18-64	0.683	0.078
65+	0.095	0.025
Female	0.537	0.055
Male	0.625	0.062
Poverty Rate (%)		
Overall	0.695	0.080
Under 18	1.056	0.122
18-64	0.690	0.075
65+	0.597	0.065
Female	0.668	0.086
Male	0.705	0.078

APPENDIX C:

FULL LIST OF BRFSS QUESTIONS AND ANSWER CHOICES

Table C.1 Full List of BRFSS Questions and Answer Choices

Questions	Variables	Answers	Reference Group
Have you ever been tested for HIV? Do not count tests you may have had as part of a blood donation. Include testing fluid from your mouth	HIVTST6	1=yes 0=no 7=don't know 9=refused	
Ever been Tested for HIV	HIVTST6 changed to HIVEVER	1=yes 0=no, missing, refused	
Not including blood donations, in what month and year was your last HIV test? (If response is before January 1985, code "777777".)	HIVTSTD3	_ _ _ _ _	
Tested within Past-Year	HIVTSTD3 changed to WITHIN12	1=yes 0=no	
Level of Education Completed	_EDUCAG	1= none 2=HS Graduate 3=Some College 4=College Graduate 9=Don’t know, missing	REF
Are you currently…?	(2011-2012) EMPLOY	1=employed 2=self employed	REF

	(2013-2017) EMPLOY1 New Variable EMPLOY2	3=out of work>1 yr 4=out of work <1 yr 5=homemaker 6=student 7=retired 8=unable to work 9=retired	
Race/ethnicity categories	(2011-2012) ORACE2 (2013-2017) _RACE New Variable RACE2	1=white only, non hispanic 2=black only, non hispanic 3=american indian/alaskan only, non hispanic 4=asian only, non hispanic 5=native hawaiian/P.I. only, non hispanic 6=other race only, non hispanic 7=multi-racial, non hispanic 8=hispanic 9=don't know, refused	REF
Indicate Sex of Respondent	SEX	1=male 2=female 9=refused	REF
Is your annual household income from all sources:	INCOME2	1=<10,000 2=<15,000 3=<20,000 4=<25,000 5=<35,000 6=<50,000 7=<75,000 8=>75,000 77=don't know 99=refused	REF
Annual Household Income (condensed)	New Variable INCOME3	1= <25,000 2= 25,000-50,000 3= 50,000-75,000 4= >75,000 77=don't know 99= refused	REF
Do you have any kind of health care coverage, including health care insurance, pre-paid plans such as HMOs, or	HLTHPLN1	1=Yes	REF

government plans such as medicare, or indian health services?		2=No 7=Don't Know 9=Refused	
6 level age imputed category	_AGE_G	1=18-24 2=25-34 3=35-44 4=45-54 5=55-64 6=65+	REF
I am going to read you a list. When I am done, please tell me if any of the situations apply to you. You do not need to tell me which one. You have injected any drug other than those prescribed for you in the past year. You have been treated for a sexually transmitted disease or STD in the past year. You have given or received money or drugs in exchange for sex in the past year.	(2011-2012) HIVRISK3 (2016) HIVRISK4 (2017) HIVRISK5 New variable HIVRISK	1=yes 2=no 7=don't know 9=refused	REF
Binge drinkers (males having five or more drinks on one occasion, females having four or more drinks on one occasion)	_RFBING5	1=no 2=yes 9=don't know or refused	REF
Do you now smoke cigarettes every day, some days, or not at all?	SMOKDAY2	1=every day 2=some day 3=not at all 7= don't know 9= refused	REF
Are you: (marital status)	MARITAL	1=married 2=divorced 3=widowed 4=separated 5=never married 6=member of unmarried couple 9=refused	REF

Do you consider yourself to be: (We ask this question in order to better understand the health and health care needs of people with different sexual orientations.)	SXORIENT	1=straight 2=lesbian/gay 3=bi-sexual 4=other 7=not sure	REF