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The Undiagnosed HIV Epidemic in Mexico: Factors Associated With HIV-Testing Behaviors in Mexican Men Who Have Sex With Men

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An abstract of
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James T. Laney School of Graduate Studies of Emory University
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Abstract

The Undiagnosed HIV Epidemic in Mexico:
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By Marisol Valenzuela Lara

Background: Mexico has the third-largest number of people living with HIV (PLWH) in the Americas. HIV testing and early diagnoses are crucial to engage PLWH in the HIV continuum of care and prevent new HIV infections. Like many other regions, Mexican men who have sex with men (MSM) are disproportionally affected by HIV. However, one-third of MSM in Mexico have never been tested for HIV, and more than half of MSM living with HIV are unaware of their infection. Despite significant progress to scale up HIV treatment in Mexico, undiagnosed PLWH remains the most crucial challenge of the national HIV response and is exacerbated as new HIV infections continue to accrue. Mexico's new HIV infection estimates have not been consistent over time, and results have not been desegregated by key populations. Robust HIV incidence estimates and differentiated HIV testing strategies are crucial for guiding Mexico's HIV strategy and reducing new HIV infections within all subpopulations and geographic settings.

Goal: The overarching goal of this dissertation was to generate improved knowledge about awareness of HIV status among Mexican MSM by elucidating the geographical distribution of undiagnosed PLWH in Mexico, comparing factors associated with HIV testing frequency among Mexican MSM in Mexico and the United States, and estimating the impact of improving HIV testing frequency among MSM in Mexico's HIV epidemic.

In **Aim 1**, using data from Mexico's National HIV Surveillance Systems and CDC's most recent methodology, an effective alternative to estimate new HIV infections and monitor subnational HIV response without the need for historical data is proposed. Important disparities in the geographical distribution of undiagnosed PLWH in Mexico were found, particularly in the South region, where HIV testing advances at a slower pace, disproportionally affecting MSM.

In **Aim 2**, the cross-sectional association between HIV testing frequency and predisposing, enabling, and perceived needs factors for health services utilization in Mexican MSM living in Mexico and the U.S. was examined. Results showed that recent STI diagnosis and PrEP awareness, independently of PrEP use, were strongly associated with more frequent HIV testing. However, these associations were stronger among Mexican-born MSM living in the U.S., suggesting that further public health policies should be implemented in Mexico to promote PrEP and ensure HIV testing during STI diagnosis.

In **Aim 3**, the impact of increasing HIV testing frequency among MSM on HIV incidence was estimated by adapting a compartmental HIV transmission model to simulate the HIV epidemic among MSM in Mexico. Reductions in new HIV infections were observed in the low uptake scenario. However, nationwide targets were only reached when substantial increases in HIV testing frequency among the youngest group and those never tested were implemented.

The results of this dissertation have improved our understanding of the HIV epidemic in Mexico, providing essential information for effectively allocating HIV testing and prevention resources and guiding the development of targeted interventions to increase HIV testing rates among Mexican MSM. The long-term goal is to increase awareness of HIV status and reduce HIV transmission among MSM.

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Fifty-five months have come since I arrive at the Department of Epidemiology at Emory University, and all I can think is that it takes a village, in this case, to conclude a doctoral dissertation. I want to express my deepest gratitude and appreciation to everyone who has contributed to the work presented in this document. First, to those who inspired me to be here by showing me the path, my parents Dra. Blanca E. Lara Enríquez and Dr. José Ángel Valenzuela García. There are not enough words to convey my gratitude for all the support and guidance throughout my life. To those who have helped me find my path in the public health field, particularly Dr. Carlos Magis, to whom I will be ever grateful for believing in me and mentoring me during my time at Censida.

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1 INTRODUCTION

1.1 BACKGROUND

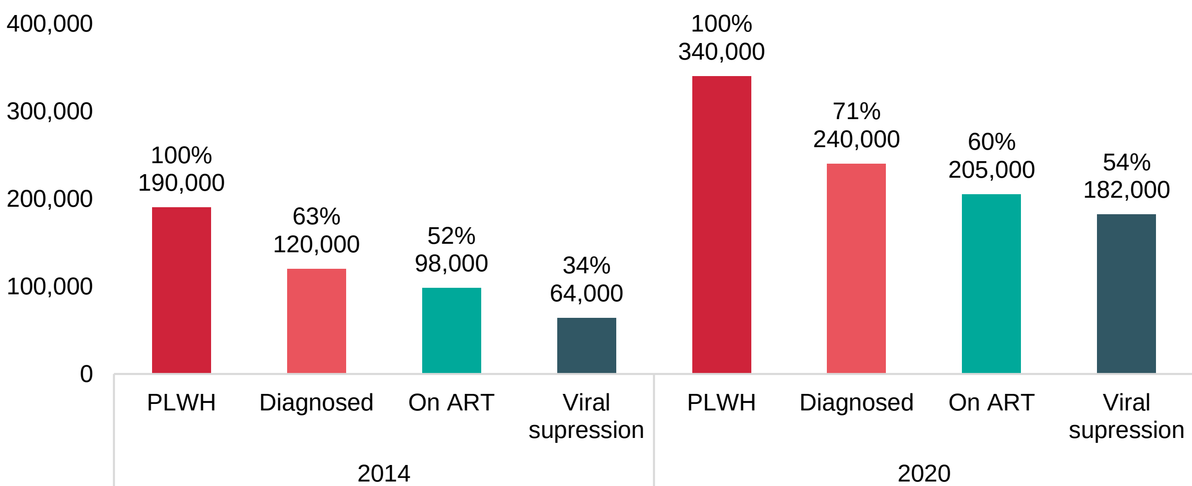
HIV infection continues to be a global public health problem. In 2022, an estimated 38.4 million people were living with HIV (PLWH) globally, 1.5 million were newly infected, and 650 thousand people died of AIDS-related illness (1). The progress of HIV programs by countries and regions is monitored using the HIV continuum of care, which begins with HIV testing. This public health framework helps identify gaps in HIV-related services and monitor the progress of the United Nations' 95 targets (2,3). This set of ambitious targets as released by the Joint United Nations Programme on HIV/AIDS (UNAIDS) in December 2020 as an update of the 90-90-90 targets and was adopted in 2021 by the United Nations Member to end the AIDS epidemic as a public health threat by 2030 (4).

UNAIDS 95-95-95 targets called for 95% of PLWH to know their HIV status, 95% of all diagnosed PLWH to receive sustained antiretroviral therapy (ART), and 95% of all PLWH on ART to achieve viral suppression, within all sub-populations and age groups, by 2025 (4,5). By 2021, globally, about 5.9 million people remained unaware they were living with HIV, meaning 15% of PLWH were unaware of their status (1). Although this is an improvement in the number of PLWH who knew their status in comparison with 2016 (when only 73% of PLWH were diagnosed), it remains far from the 95% set for 2025 (6).

The onset of the COVID-19 pandemic imposed a great weight on health systems worldwide, exacerbated social and economic inequalities, and threatened the progress made in the last 40 years in the fight to end the AIDS pandemic (6). The resource reallocation needed to respond to the COVID-19 pandemic delayed the global AIDS response, especially concerning access to medicines, treatments, and diagnosis, slowing the decline in global new HIV infections and even flipping the decreasing incidence trends observed in some countries years before the COVID-19 pandemic(7). For example, the annual growth of the number of PLWH on ART was slower in 2021 than the average annual growth in the prior decade, and although 75% of diagnosed people were on treatment globally, this percentage was lower for in some groups: 70% among males, 69% for people in Latin America, and only 61% in Mexico (6). Furthermore, the annual number of new HIV infections in Latin America has not decreased since 2010, most likely driven by a slowdown in diagnosis and, in consequence, in ART expansion among young gay men and other MSM living with HIV (4,7). Unfortunately, information regarding HIV status awareness by key populations in Mexico is scarce, and access to HIV testing is not equitable in the country (8,9).

1.1.1 HIV Epidemic in Mexico

Figure 1.1. HIV Continuum of Care, Mexico 2014-2019



Source: Ministry of Health of Mexico, CENSIDA. (10–12)

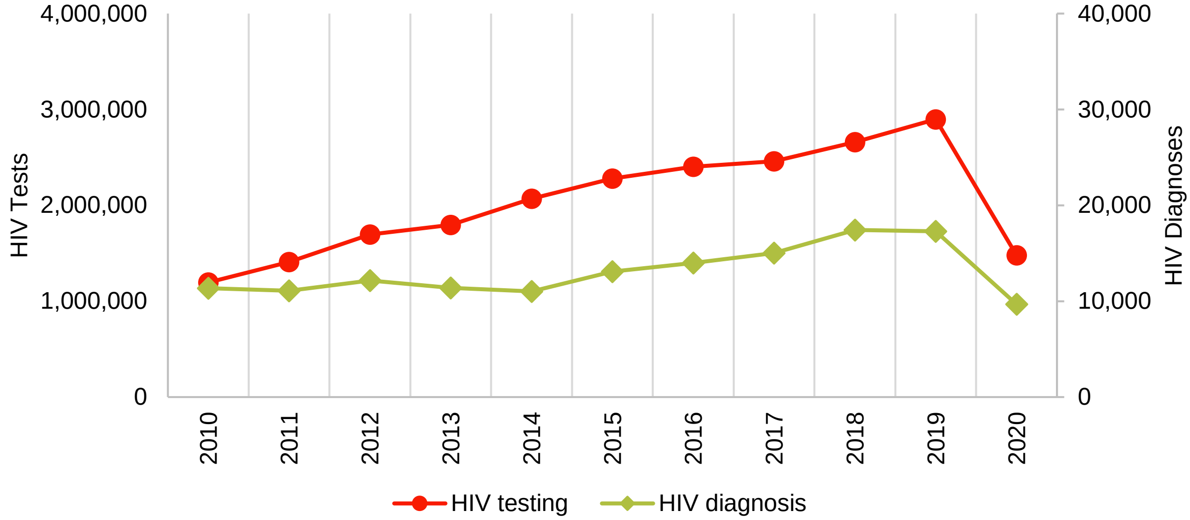
Since the first AIDS case in Mexico was reported 38 years ago, the HIV epidemic response in the county has encountered enormous changes. In 1983, the estimated number of PLWH was barely in the hundreds, the survival of those diagnosed was less than six months, and there were no effective treatments against the infection (13). At the end of 2020, according to UNAIDS estimates, 340,000 people were living with HIV (Figure 1.1), 60% had free access to antiretroviral treatment (ART) and 90% of those receiving ART had achieved viral suppression, preventing new HIV infections (10). Mexico has the third-largest number of PLWH in the Americas, after Brazil (900,000) and the United States (1.2 million) (14,15).

Mexico's government has implemented strategies to guarantee access to ART since 2001, and in the last few years, significant efforts have been made to scale up ART. For example, in 2014, the National HIV Treatment Guidelines were updated to include the recommendation to treat all PLWH, regardless of CD4 counts. Between 2014 and 2019 (Figure 1.1), ART coverage among PLWH increased from 52 to 63%, and viral suppression increased from 34 to 57% (10,11). By the end of 2019, 85% of all diagnosed people were on treatment, and 90% of people on ART achieved viral suppression (10).

However, there were still 17,000 PLWH on ART who had not reached viral suppression, 30,000 people already diagnosed who had not initiated treatment, and 70,000 PLWH who did not know their serological status and therefore did not have access to HIV treatment and prevention strategies (10). This latter is the largest gap across the continuum of care in Mexico and remained practicably unchanged during 2014-2019. Even more alarming, it might have widened during 2020, given the large decreases in the number of tests and diagnoses associated with the COVID-19 pandemic (Figure 1.2) (16,17).

Like the U.S. and many other regions of the world, Mexico’s HIV epidemic is concentrated among key populations, including gay, bisexual and other men who have sex with men (MSM), people who inject drugs, transgender people, sex workers, and prisoners (10). Between 2016 to 2019, Community Detection Centers, a community testing model funded by the federal government and implemented by civil society organizations, reported an average HIV prevalence of 6.5% among MSM presenting for HIV testing (min-max: 2.2 to 9.3%) (18,19).

Figure 1.2. HIV Diagnoses and Testing in Mexico, 2010-2020

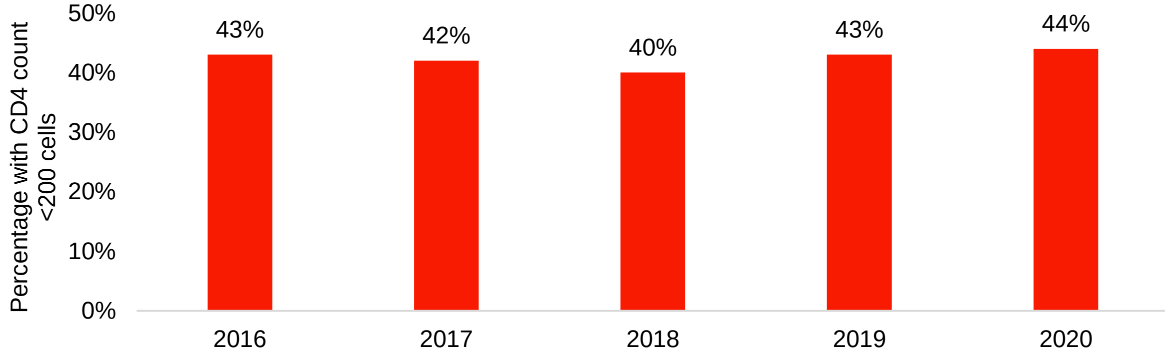


Source: Ministry of Health of Mexico, CENSIDA. (16,17)

During 2013-2018, HIV-specialize clinics reported an HIV test positivity for MSM between 12.0 to 16.9% (20); and in 2017, the National Institute of Public Health reported prevalence of 20.7% from a seroprevalence survey in seven urban areas in the south region of Mexico (21). However, only 40% of MSM living with HIV are diagnosed, meaningfully lower than the diagnosed proportion for all Mexican PLWH of 70% (14,21–23).

Furthermore, among those who are diagnosed, large proportions are not being diagnosed early enough. For example, between 2016-2020, on average, 42% of PLWH newly diagnosed that initiated care in the Ministry of Health was already at a late stage of disease (Figure 1.3). Late-stage disease (ten years on average from time of infection) results in immune system deterioration with CD4 counts below 200 cells/ml and increased vulnerability to opportunistic infections (24,25). People in the late stage of infection are most likely to have high viral loads, which increases the risk of HIV transmission. This long and slow evolution of HIV infection is the main reason why in settings where late diagnosis is so prevalent, the number of HIV-diagnosed cases cannot be used as a direct proxy of HIV incidence.

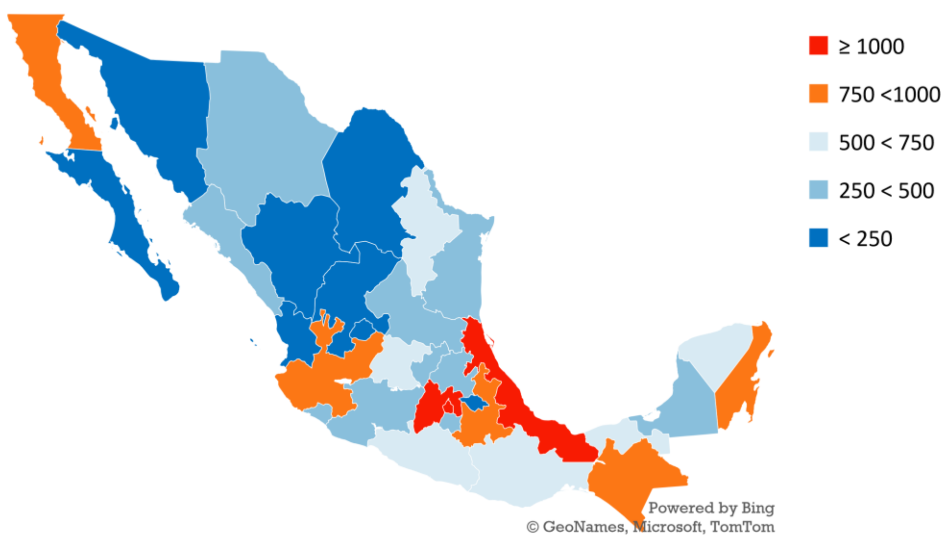
Figure 1.3. Late Diagnosis of HIV Infection in Mexico, 2016-2020



*Late diagnosis was defined as first-reported CD4 cell count <200 cell/μL
Source: Ministry of Health, CENSIDA. 2016-2021. (19,20,26–28)

The Mexican HIV epidemic is further characterized geographical heterogeneity, with structural conditions of inequality reinforcing these inequities. It is marked by persistent disparities in the prevention and care of PLWH. For example, newly diagnosed HIV cases were concentrated in urban areas at the beginning of the epidemic (10). By 2013-2018, important clusters of municipalities with high rates of HIV diagnosis were observed in the country's southeast. This is the same area historically marked by educational deprivation and poverty. On average, 60% of the population of these municipalities have median incomes below the well-being line, and 23.5% present academic lag (10).

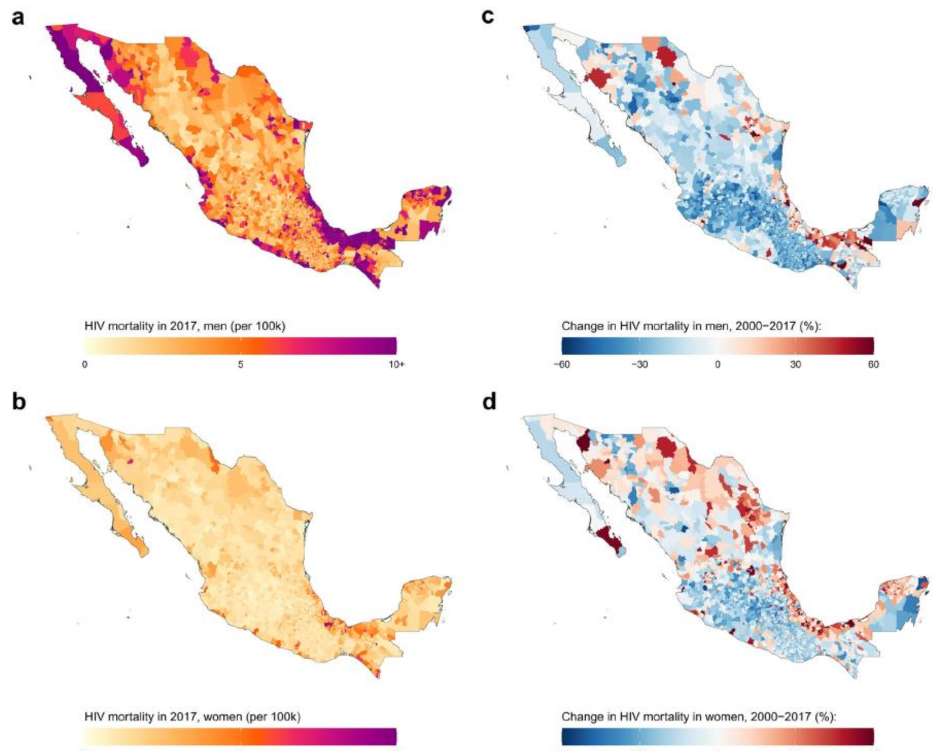
Figure 1.4. New HIV Diagnoses in Mexico by state, 2019



Source: Ministry of Health of Mexico, DGE (29)

In 2019, more than half of the new HIV diagnoses occurred in only 8 states: Veracruz, State of Mexico, Mexico City, Quintana Roo, Puebla, Chiapas, Jalisco, and Baja California. In Figure 1.4 we can observe these states, marked in orange and read, locate largely in the south and center regions of the country. However, among region-specific data, Jalisco and Mexico City reported the largest proportion of new HIV diagnoses among men, and the state of Guerrero had the largest number of diagnoses among women (17). These geographic variations can also be observed in the geographic distribution of HIV prevalence in the country's different regions and HIV-related deaths (30,31).

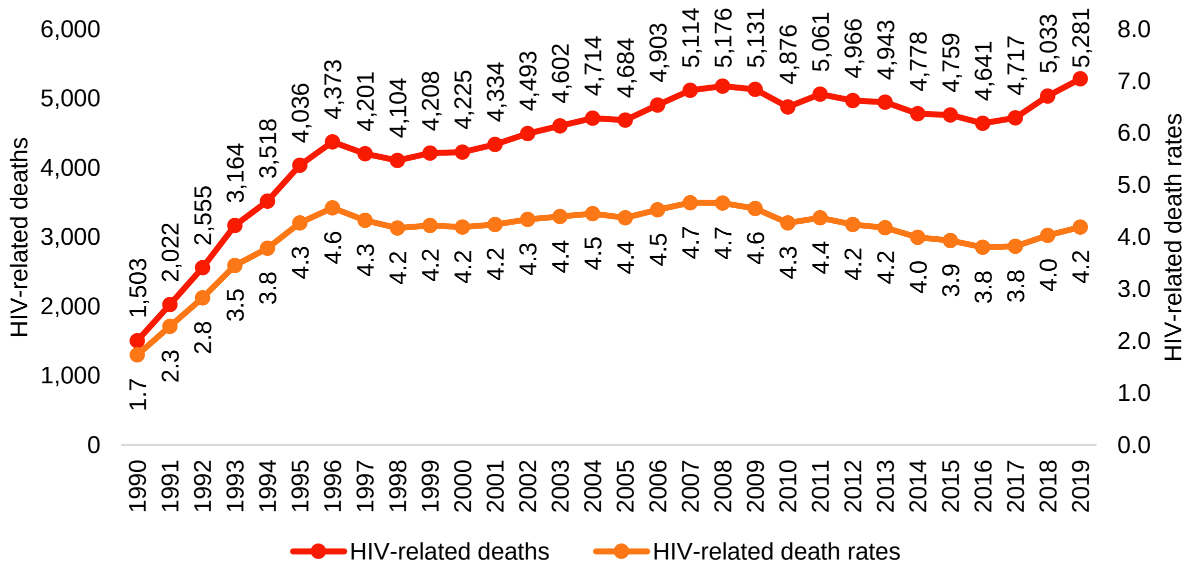
Figure 1.5. HIV Mortality Among Men and Women in Mexico by Municipality, 2017: HIV Mortality per 100,000 by Municipality in Mexico in 2017 Among Men (a) and Women (b). Relative Change in HIV Mortality Between 2000 and 2017 Among Men (c) and Women (d)



Source: Cork et al., 2021. (30)

Although there have been significant decreases in HIV mortality rates in the country, these reductions have not been consistent throughout the country, and geographic inequalities in mortality rates have increased significantly. Between 2000 and 2017 (Figure 1.5), the HIV mortality rate decreased by 23.5% in men (9.0 vs. 6.9 per 100,000 inhabitants) and by 5.2% in women (2.0 vs. 1.9 per 100,000 inhabitants) (30). Furthermore, disparities in mortality by key populations remain unknown because the reports of the epidemiological surveillance system of HIV in Mexico do not present data separately for MSM, male sex workers, or transgender women (17). Finally, the highest number (N=5,281) of HIV-related deaths since the beginning of the epidemic was reported in 2019 (Figure 1.6). Although the HIV mortality rate was not among the highest of the epidemic, the previously observed declining trend in mortality rate reversed (17,32). The largest proportion of deaths occurred in men (82%), and almost half of them were men between 25 and 44 years old (n=2,575). Between January and August 2020, HIV-associated deaths were the eighth and tenth most common causes of death among men aged 25 to 34 years and 35 to 44 years.

Figure 1.6. HIV-Related Deaths in Mexico, 1990-2019



Source: Ministry of Health, 2021. (17). Bravo-Garcia et al., 2021. (33)

1.1.2 Mexico's National HIV Surveillance System

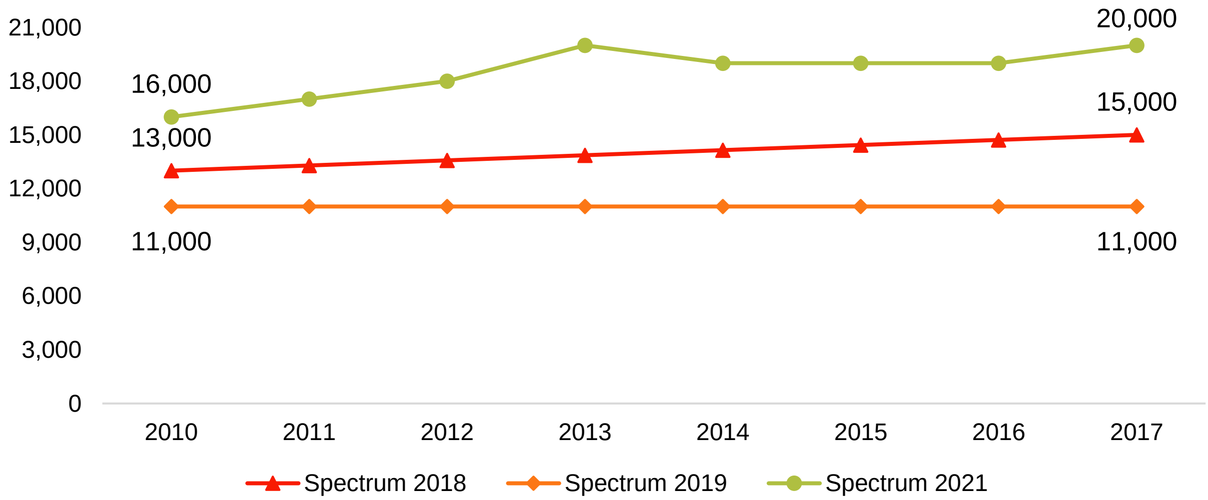
The Mexican HIV surveillance system collects information through two different registries of the Ministry of Health (34,35). The first is the National Registry of HIV and AIDS Cases, run by the National Centre for Epidemiology. This registry collects basic demographic information and the mode of transmission of every person diagnosed with HIV in any public or private health institution since 1986. PLWH are linked to care in one of the health institutions of the public health sector depending on their labor status. For example, people working in the private sector will receive care in the Mexican Institute for Social Security (IMSS). People without social health insurance will receive care through federal and state providers. At least 3 of every five people diagnosed with HIV in Mexico receive care in one of the 140 HIV-specialized clinics of the Ministry of Health, and patients who receive care in these clinics are registered in the Antiretroviral Management, Logistic, and Surveillance System (SALVAR). At first, SALVAR was created for the management and distribution of antiretroviral drugs, but it expanded to collect socio-demographic information, viral loads, CD4 counts, ARV regimens, comorbidities, viral resistance, and more information on PLWH.

Mexico's estimated number of people living with HIV, number of new HIV infections, and ART coverage are obtained in collaboration with the UNAIDS Reference Group on Estimates, Modelling, and Projections, using the projection package Spectrum (36). Avenir Health developed this software to support policy decisions concerning public health and included an HIV module named the AIDS Impact Model (AIM). This module is used by UNAIDS to estimate key indicators by country or region and provides output by age and sex. The estimates and projections are based on country-specific demographic, HIV surveillance, survey, and programmatic data, combined with global epidemic patterns (36).

However, this model performance depends on quality of and level of disaggregation of available data. Research on new HIV infections in Mexico is sparse; HIV incidence studies have occurred only at the national level or in a couple of urban centers. There is almost no information about new HIV infections for MSM or other key populations. Most of the information reported regarding new HIV infections corresponds solely to surveillance data of the observed diagnosed cases; however, as explained before, a large proportion of PLWH are not diagnosed in a ti mely way, and the time between HIV infection and diagnosis has not been measured systematically in Mexico (19,20,26–28). This lack of data desegregation by key populations and the scarce research on new HIV infections (incidence) are some of the main challenges of this method.

Annually, UNAIDS produces country-specific modeled estimates of the number and trends of new HIV infections (37). However, the model and assumptions are updated regularly (38). Therefore, Spectrum estimates are not consistent over time, representing a challenge to the National HIV Programs to monitor and evaluate prevention strategies (39,40). To illustrate (Figure 1.7), UNAIDS estimates published in 2018 showed a 12% increase in new HIV infections between 2010 and 2017 (41). UNAIDS's recent estimates published in 2019 reported new HIV infections have remained stable at 11,000 cases per year since 2010; finally, the latest estimates published in 2021 showed an increase of 25% for the same period (14). All estimates were far from the goals established by UNAIDS to reduce new infections by 75%; this reduction, if it had been achieved, would have led to 3,000 new infections annually in Mexico by 2020.

Figure 1.7. Comparison of the Number of New HIV Infections Estimated by Spectrum for Mexico, 2010-2017



Source: Ministry of Health/UNADIS/Spectrum. 2018, 2019, 2021(14,41)

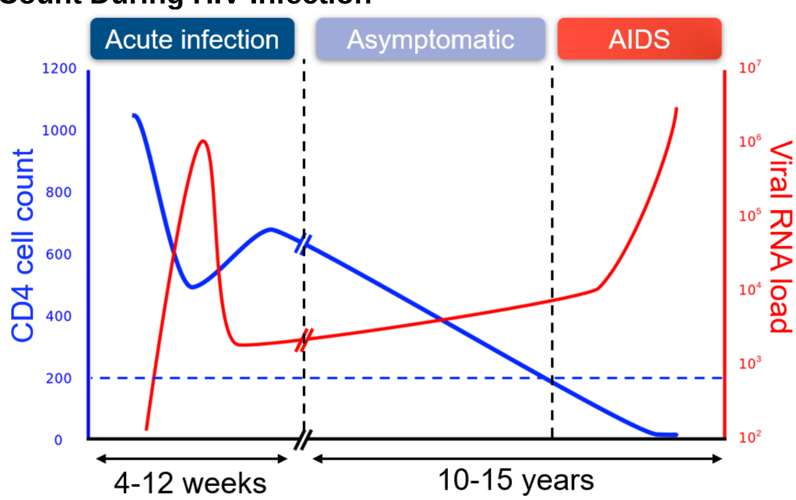
In a setting where late HIV diagnoses are highly prevalent and heterogeneously distributed across the country, considering new HIV diagnoses as a proxy of where new infections have occurred could be misleading. Accurate information examining regional and state variation of estimated HIV new infections and PLWH who are unaware of their status are fundamental for evaluating and guiding future HIV interventions to increase the percentage of diagnosed HIV individuals.

1.1.3 Modeling Methods for Estimating HIV Incidence

HIV incidence is one of the six HIV indicators use by the CDC to monitor the progress towards Ending the HIV Epidemic in the U.S. goals (42). HIV incidence refers to the estimated number of new HIV infections during a specified period, whether or not thee infections have been diagnosed (43,44). Accurate numbers on HIV incidence are crucial to track the effectiveness of the HIV epidemic response. However, the complex and slow progression of the natural history of HIV infection adds additional challenges to modeling HIV incidence. For example, during the first 2-4 weeks (acute stage) of the infection, the virus replicates rapidly, the viral load increase to very high levels (>10 million copies/mL), and large proportions of CD4 cells are permanently lost (45). Later, the immune system produces antibodies (seroconversion), and viral loads are reduced to a stable level (asymptomatic stage) over a median of 8-11 years. Finally, viral load increases and CD4 count levels decrease, resulting in the onset of AIDS. These large variations on viral loads, CD4 count levels, biomarkers (antibodies, p24 antigen) and the long asymptomatic stage are some of the challenges when estimating HV incidence (45).

Mathematical models provide an opportunity to evaluate the impact of HIV prevention and intervention strategies to increase the testing frequency and guide public health policy, particularly in resource-constrained settings (22). Multiple mathematical and statistical modeling approaches to estimate the number of new HIV infections (incidence) have been used in the past. To estimate HIV incidence at the national level, the U.S. has used the biomarker approach, the back-calculation method, and the method based on CD4+ cell depletion in recent years (46). However, the biomarker method cannot estimate the number of undiagnosed infections because it only estimates the HIV incidence for the time the biomarker data is available; and the back-calculation method requires the annual number of new diagnoses stratified by stage of disease for the entire epidemic history to estimate undiagnosed infections (46). In 2017, a new method was published to estimate HIV incidence and the number of undiagnosed infections (46). Since then, HIV incidence estimates for the United States produced by the CDC have used this method based on the CD4+ Depletion Model. This approach uses the HIV surveillance system data, each patient's first CD4 test results, which are usually near the time of diagnosis and before treatment is initiated to estimate the duration since infection, and use this information to estimate the original time of infection. The CD4 depletion model is a mathematical equation that describes the rate at which the CD4 cells decline (46–50).

Figure 1.8. CD4 Count During HIV Infection



Source: Adapted from Jurema Oliveira, CC BY-SA 3.0, https://commons.wikimedia.org/wiki/File:Hiv-timecourse.png, via Wikimedia Commons

CD4+ T-lymphocytes are the cells of the immune system primarily targeted by HIV. During infection (Figure 1.8), HIV attaches to the CD4 cell and uses it to replicate itself. In doing this, the host CD4 cells are killed, and the CD4 cell count declines to critical levels leaving the body vulnerable to opportunistic infections and the, eventually, development of AIDS. The CD4+ Depletion Method uses the first CD4 cell count (i.e. at the time of HIV diagnosis) to estimate the time since HIV infection at the date of the CD4 test, under the assumption that no treatment has been received. In the absence of treatment, the decline of CD4 cells, on a square root scale, has been modeled as a linear function of time since infection:

$$\sqrt{CD4^{+}count(t)} = a_i + b_i t + e_{it}$$

where t is the time from HIV infection to date of first CD4 count, with a different slope (b_i) and intercept (a_i) according to sex, age group, and transmission risk (46).

However, estimates of model parameters are based on a subset of the Concerted Action on Seroconversion to AIDS and Death in Europe (CASCADE), a collaboration of 25 cohorts from Europe, Australia, Canada, and sub-Saharan Africa (46,49). These cohorts had few Latinx persons from the Americas (51), and did not explore whether the rate of CD4 decline differs by ethnicity (48,49). Racial and ethnic differences in HIV testing behaviors, presence of other STIs, repeated HIV infections, and symptomatic seroconversion have been observed (52–56). These factors are also associated with a more rapid CD4 cell decrease and disease progression (48,55). Model parameters have been updated for the U.S. population living with HIV but have not been stratified by race and ethnicity.

1.1.4 HIV Testing Behaviors in Mexican MSM

HIV testing services are crucial to engage PLWH in the HIV continuum of care and increase the percentage of diagnosed HIV individuals. Even though MSM is one of the most affected groups by the HIV epidemic, and both the Mexican and US CDC guidelines recommend at least one HIV test every year for MSM and other key populations, studies have found that one-third of MSM in Mexico have never been tested for HIV, and only 44% have had an HIV test in the last 12 months (8). This figure is alarming if we consider that national seroprevalence surveys have shown that even among MSM who have had a negative HIV test in the last year, at the time of the next test, 14% of them were already living with HIV (21). Furthermore, Mexican recommendations for testing are only based on the evidence developed by the CDC using data from US MSM; those Mexican recommendations for testing frequency are not based on data from any studies of Mexican people. For the treatment-as-prevention strategy to have the greatest impact on reducing the number of HIV transmissions, it is necessary to increase the proportion of diagnosed individuals and generate evidence specific to Mexico (22).

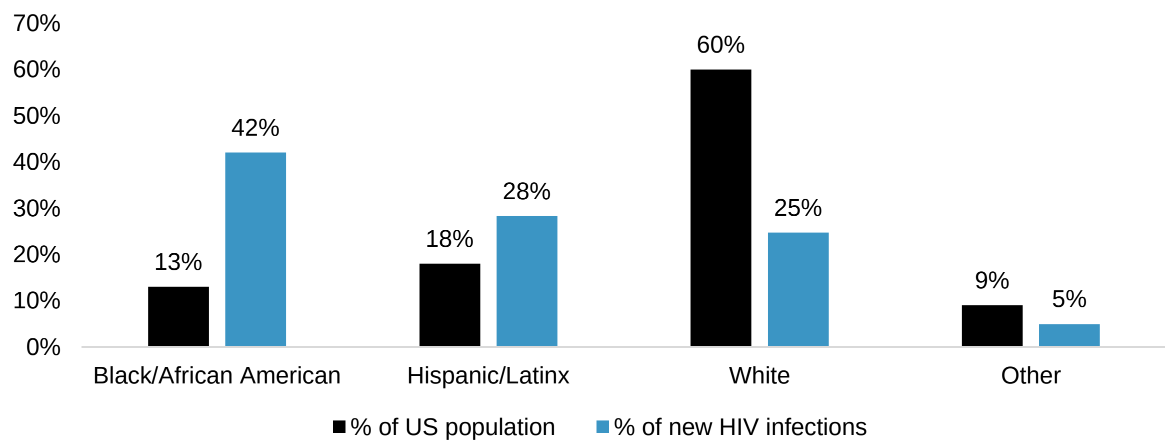
It is important to point out that with the proper detection strategies and programs, increasing HIV testing frequency is possible. For example, according to the Mexican National Survey of Health and Nutrition (ENSANUT) 2018-2019, the highest HIV screening coverage in Mexico was found among pregnant women: 78% of women between the ages of 20 and 49 with a live birth in the last five years reported having received an HIV test (57). However, the lack of similar tailored strategies for men has resulted, through 20XX, in only 35% of male adults between 20 to 49 years old having had an HIV test at some point in their life. This represents an 22% increase compared to 2012 data from the ENSANUT, but it is far from the coverage necessary to reach the more than 70,000 people who do not know they are living with HIV (57).

Stigma and discrimination, regulatory barriers, lack of HIV knowledge, and low self-perceived risk may contribute to unequal access to timely diagnosis and care (30,58). For example, preliminary results of the 2017 Mexican Men’s Internet Survey show that the main reason MSM were not getting HIV tested was not feeling at risk, followed by fear of the result and shame of talking to a counselor. Shame was more prevalent among the younger population and might explain, in part, why younger MSM are less likely to be tested for HIV.

These experiences, combined with differences in the exposure to HIV information and HIV services in Mexico, might also impact the utilization of HIV testing services of Mexican MSM living in the U.S. Between 2013 and 2018, 870,000 people migrated from Mexico to the U.S. (59). Two-thirds of them were men and 72% were 18 to 44 years old (60). Previous research has reported limited HIV prevention knowledge and condom use among Mexican migrants to the U.S. (61). These individual characteristics in combination with the contextual ones of the migration process pose an increased risk for HIV and late diagnosis in Mexican migrants in the U.S. (61).

People of Mexican origin in the U.S. are now the largest origin group (62%) among the US Hispanic/Latinx population, and the second-largest racial/ethnic group (18.7%), with 62 million people in 2020 (62). Hispanic/Latinx persons are a multicultural and diverse group, yet most U.S. studies analyze this population as a homogenous group (55). Furthermore, for many Hispanic/Latinx people, country of origin is the variable they choose to describe their identity instead of race or ethnicity (30). For example, a 2019 survey from Pew Research Center showed that 47% of Hispanic/Latinx individuals most often describe themselves by their family's country of origin (63).

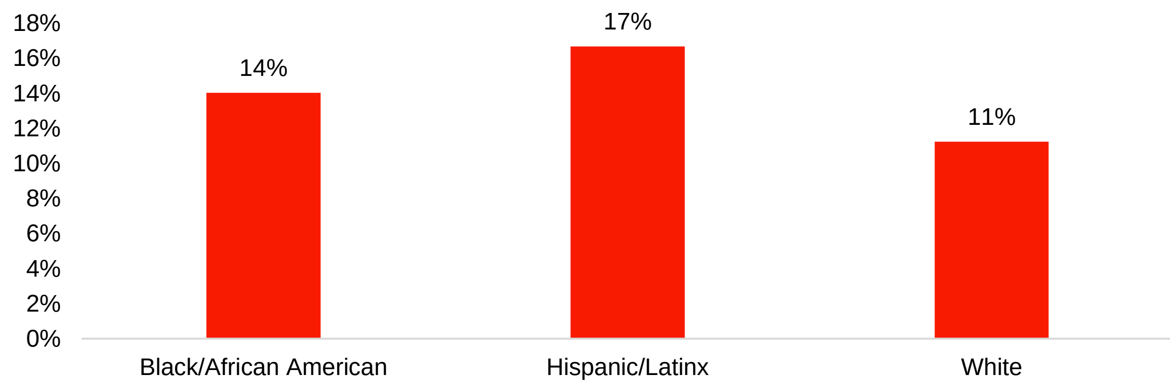
Figure 1.9. Estimated New HIV Infections and U.S. Population by Race and Ethnicity, 2018



Source: Centers for Disease Control and Prevention, 2020. (44)

Hispanic/Latinx persons in the United States are disproportionately affected by HIV (Figure 1.9) (44). For example, in 2018, Hispanic/Latinx individuals represented 28% of estimated new HIV infections but less than 18% of the U.S. population. In 2018, Hispanic/Latinx people living with HIV were 50% more likely to not to be aware of their status than white PLWH (Figure 1.10), remaining as the group with the highest percentage of undiagnosed HIV infections in the U.S. (17%) (44). Latinx is the only racial/ethnic group where new HIV infections increased between 2010 and 2016, from 9200 to 10500. This increase among Hispanic/Latinx persons was driven entirely by increases among MSM (52,53).

Figure 1.10. . Proportion of PLWH unaware of their status in the U.S. by Race/Ethnicity, 2018



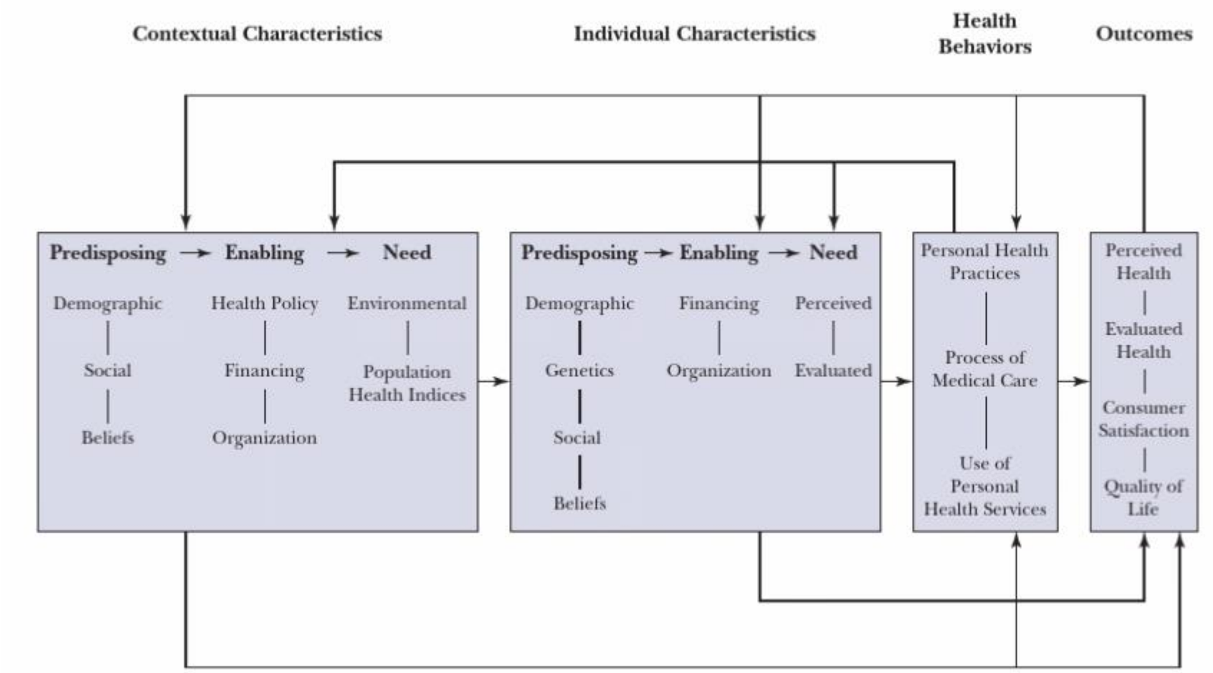
Source: Centers for Disease Control and Prevention, 2020. (44)

Disparities along the HIV continuum of care between Latinx foreign-born and US-born persons have also been identified (54). For example, being foreign-born has been associated with delayed diagnosis (55), and Mexicans living in the U.S. are 2.2 times more likely to experience late diagnosis than Hispanic/Latinx persons born in the US.(44). Healthcare practices in Mexico may also contribute to health disparities of Mexican-born individuals living in the US (56). The differences in the exposure to HIV information and services in the country of origin may impact the utilization of HIV testing services in the United States. Nevertheless, research about disparities among Latinx persons from different regions or countries of Latin America is scarce (55). Considering the large representation of Mexicans among the Latinx population in the U.S., understanding the factors associated with HIV testing services among US MSM of Mexican origin may contribute to reducing the disparities in access to HIV testing services in the United States.

1.1.5 Andersen's Behavioral Model of Health Services Use

Andersen's Behavioral Model (ABM) of Health Services Use (Figure 1.11) provides a theoretical framework for understanding how contextual and individual characteristics impact health behaviors and outcomes, and in this case, HIV testing behaviors (64). Contextual characteristics are the circumstances and environment of health care access, including health organization, provider-related factors, and community characteristics. These characteristics are aggregated by units as small as the family or as large as the national health care system. The individual characteristics are categorized into predisposing, enabling, and need factors. However, the model's primary focus remains on individuals' health behaviors and predisposing, enabling, and need characteristics (64).

Figure 1.11. ABM of Health Services Use (6th revision*)*



Source: Andersen, 2007. Changing the U.S. health care system: key issues in health services policy and management. (64)

Individual Predisposing Characteristics include factors that explain the propensity of individuals to use health services, such as demographic characteristics and individual beliefs, attitudes, and knowledge about health services (64). Individual Enabling Characteristics are resources individuals have available to finance the use of health services and include income and healthcare coverage. Finally, Individual Need Characteristics include how people perceive their general health and the importance attributed to symptoms, conditions, and health status requiring health services (51,55,64–66).

1.2 Overarching Goal and Specific Aims

Low HIV testing rates constitute a significant barrier to “treatment as prevention” strategies to reduce HIV transmission and mortality, and represent missed opportunities to identify men at risk and offer HIV prevention options. To reduce new HIV infections, a combination of behavioral, structural, and biomedical interventions to prevent HIV are needed. For example, sex education and decriminalization of drug use, easy access to condoms, lubricant, and PrEP, and access to clean needles and syringes are all important determinants of epidemic trajectories. Most of these strategies are focused on those at greatest risk of HIV infection. However, treatment-as-prevention is a highly effective prevention strategy focused on all PLWH. It involves initiating treatment as early as possible and reaching and maintaining undetectable viral loads to reduce the risk of transmitting HV through sex. Thus, HIV testing is the first step towards improving HIV care outcomes and preventing new transmissions.

The overall goal of this dissertation is to generate knowledge that improves awareness of HIV status in Mexican MSM and informs programmatic responses by elucidating the geographical distribution of new HIV cases and undiagnosed PLWH in Mexico **(Aim 1)**, identifying factors associated with HIV testing frequency among Mexican MSM **(Aim 2)**, and estimating the impact of improving HIV testing frequency among MSM in Mexico's HIV epidemic **(Aim 3)**.

Aim 1. Analyze the geographical distribution of new HIV cases and undiagnosed PLWH in Mexico

- **Aim 1a:** Estimate the number of new HIV infections and undiagnosed HIV infections in Mexico by transmission category and geographical regions
- **Aim 1b:** Analyze the CD4 depletion model for Mexican population by sex and transmission category

Aim 2. Identify factors associated with HIV testing frequency among Mexican MSM

- **Aim 2a:** Compare the strength of the association between HIV Testing Frequency and Predisposing, Enabling and Need Factors for Health Services Utilization Associated among Mexican MSM in Mexico and the U.S.
- **Aim 2b:** Estimate the annual screening rates stratified by predisposing, enabling and need factors for health service utilization

Aim 3. Model the effect of increasing HIV testing frequency among MSM in Mexico's HIV epidemic

- **Aim 3a:** Estimate the probability of diagnosis within one year of HIV acquisition among MSM in Mexico
- **Aim 3b:** Estimate the frequency of HIV testing needed in Mexico to achieve reductions in HIV incidence among MSM

1.3 Data Sources

1.3.1 Mexico's EHSS: Mexico's Epidemiological HIV Surveillance System

Mexico's EHSS or RNC for its acronym in Spanish (Registro Nacional de Casos de VIH y Sida), was created in 1986 and includes all HIV cases diagnosed in any of the institutions of the National Health System (including the Minister of Health and private medical services) (34). This HIV Epidemiological Surveillance System includes the information reported on the HIV case notification formats: sociodemographic data, date of diagnoses, and mode of transmission. Mexico's EHSS dataset used in this study contains the record of 269,269 PLWH diagnosed with HIV in Mexico between 1983 and 2017.

1.3.2 SALVAR: Antiretroviral Management, Logistic and Surveillance System

SALVAR, for its acronym in Spanish (Sistema de Administración y Vigilancia de Antirretrovirales), was created in 2006 to manage the acquisition and distribution of antiretroviral drugs through the Ministry of Health (67). However, after a few years, it became the tool for the surveillance of people living with HIV receiving healthcare through the Ministry of Health. SALVAR is a web-based secure information system implemented in 140 specialized clinics across the 32 states of Mexico. This seroprevalent cohort contains the patient's socio-demographic information, mode of transmission, antiretroviral regimens, viral loads, and CD4 counts. The dataset of SALVAR that will be used in this study contains the records of more than 145,000 PLWH linked to care in the Ministry of Health between 2008-2018. More than 57,000 of these patients can be linked to the Mexico's EHSS.

1.3.3 AMIS: American Men's Internet Survey

AMIS is a cross-sectional online HIV behavioral survey of MSM living in the United States.(68) This survey is conducted annually. Between 2018-2020, 2,830 HIV-negative or unknown MSM with Mexican heritage participated in this study, and 398 of them were born in

Mexico. Participants provided electronic consent before beginning the self-administered survey. Eligibility criteria included identifying as a cisgender male, aged ≥15 years, residing in the U.S., and report of oral or anal sex with a male partner at least once in their life. The survey collected demographics, sexual behaviors, substance use behaviors, HIV status, HIV testing behaviors, STI history, HIV knowledge, and stigma information. All variables are self-reported by participants.

1.3.4 ESEH: Mexican Men's Internet Survey

ESEH, for its acronym in Spanish (Encuesta de Sexo entre Hombres), was an online sexual health survey of adult Mexican MSM that captured data of 15,889 eligible MSM living in Mexico between May and June of 2017 (69). ESEH methodology was modeled after the American Men's Internet Survey in the United States. Potential participants were invited through advertisements placed on popular social networking websites and dating applications used by MSM. Participants provided electronic consent before beginning the self-administered survey. The questionnaire was designed in Spanish using elements from the AMIS study and the Mexican MSM's HIV Seroprevalence Study. The survey collected information about demographics, sexual behaviors, substance use behaviors, HIV status, HIV testing behaviors, STI history, HIV knowledge, and stigma. Eligibility criteria included identifying as a cisgender man, 18+ years of age, previous oral/anal sex with a male partner at some time in their life, and Mexican residence.

2 GEOGRAPHICAL VARIATION OF NEW HIV CASES AND UNDIAGNOSED PLWH IN MEXICO

2.1 INTRODUCTION

Mexico's government has implemented strategies to guarantee universal access to antiretroviral therapy (ART) since 2001, and in the last few years, significant efforts have been made to reduce the cost of antiretroviral drugs to expand access to ART. In addition, in 2014 and following the World Health Organization recommendations, the National HIV Treatment Guidelines were updated to treat all PLWH, regardless of CD4 counts and symptoms (6,70,71). This contributed that of the 200,000 PLWH diagnosed in 2019 in Mexico, 85% were under treatment and 90% of those on ART reached viral suppression. In addition, the odds of virologic failure decreased a 50% in 2014-2017 (6,70). Nevertheless, because ongoing HIV transmissions outpace prevalence cases being diagnosed, the number of PLWH unaware of their serological status continues climbing (10). Undiagnosed cases represent the largest gap across the continuum of care in Mexico, and remained practicably unchanged during 2014-2019.

To get on track to end AIDS as a public health threat by 2030 as established by the United Nations General Assembly, it is essential to reduce the number of people unaware of their status under 5% by 2025, so they can have access to HIV treatment and prevention strategies (10). Mexico's estimated number of people living with HIV, number of new HIV infections, and ART coverage are obtained in collaboration with the UNAIDS Reference Group on Estimates, Modelling, and Projections, using the projection package Spectrum (36). Annually, Mexico uses Spectrum to produce country-specific modeled estimates of the number and trends of new HIV infections (37). However, recent updates on the methodology of the model Spectrum has changed not only the new estimates, but also the historical estimates. These changes in past estimates represent a challenge for the National HIV Programs to monitor the progress of the HIV response and to evaluate programs on the sub-national level. For example, UNAIDS estimates published in 2018 showed an increase in new HIV infections from 13,000 to 15,000 between 2010 and 2017 (41). Later, UNAIDS's estimates published in 2019 reported new HIV infections remained stable at 11,000 cases per year since 2010; estimates published in 2021 showed an increase from 16,000 to 20,000 for the same period (14).

Robust HIV incidence estimates and differentiated HIV testing strategies are crucial for guiding Mexico's HIV strategy and reducing new HIV infections within all subpopulations and geographic settings. To add to the scarce research on new HIV infections for MSM or other key populations in Mexico, the objective of this study is to estimate the number of new HIV infections and undiagnosed HIV infections in Mexico by transmission category and regions.

2.2 METHODS

2.2.1 Data Source

We performed a secondary data analysis the Antiretroviral Management, Logistic and Surveillance System (SALVAR, for its acronym in Spanish) and Mexico's Epidemiological HIV Surveillance System (Mexico's EHSS). SALVAR is a web-based secure information system implemented in all the 140 HIV-specialized clinics of the Ministry of Health across the 32 states of Mexico, where two-thirds of people on ART in Mexico receive health care. This seroprevalent cohort contains the patient's socio-demographic information, transmission category, antiretroviral regimens, viral loads, and CD4 counts. EHSS includes the information reported on the HIV case notification formats: sociodemographic data, date of diagnosis, and mode of transmission.

2.2.2 Study Design

Data from PLWH aged 13 years or older at diagnosis and linked to healthcare in the Ministry of Health registered in SALVAR between January 1, 2008, and December 31, 2018 were used to estimate the distribution of diagnosis delay. For this, HIV infection date was estimated based on CD4 depletion model and first CD4 cell count. PLWH that initiated ART more than 30 days before the first CD4 cell count were excluded from this analysis. Transmission category was classified as: men who have sex with men, including MSM who inject illicit drugs, heterosexual contact, injection drug use and others. Age at HIV diagnosis was group as 13 to 19, 20 to 24, 25 to 34, 35 to 44, 45 to 54, and 55 and older. Multiple imputations were used to predict missing values on transmission category based on reported location, sex and year of birth (72,73).

Figure 2.1. Geographical regions of Mexico

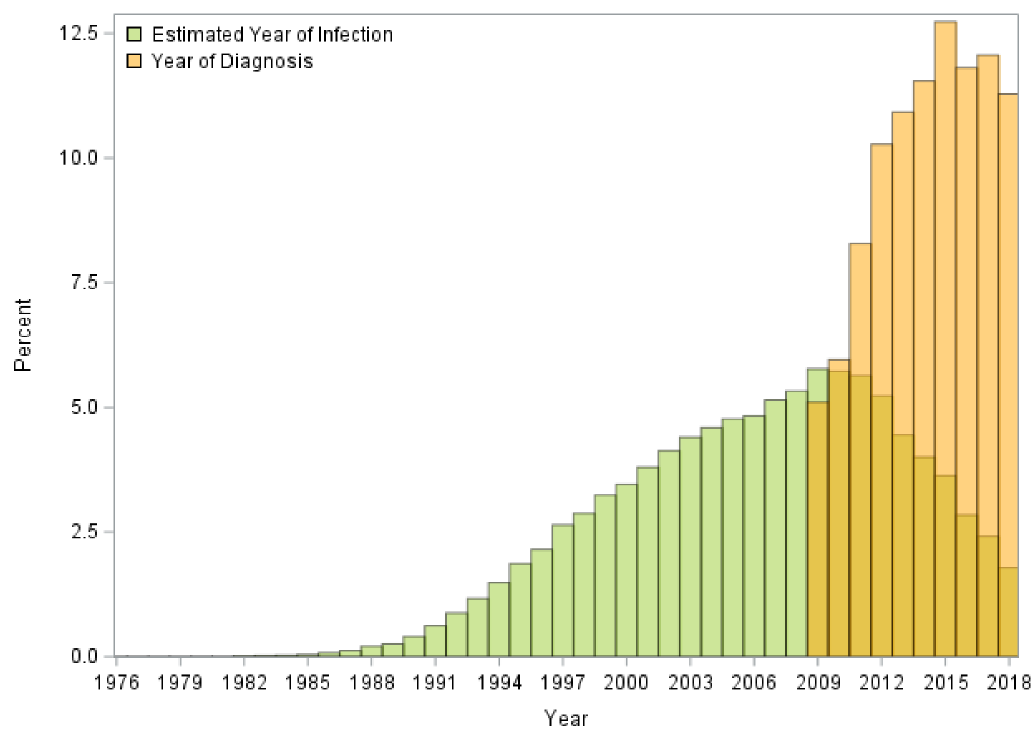
Reported state of residency was stratified into 6 geographical regions (Figure 2.1): 1-*Northwest* (Baja California, Baja California Sur, Sonora, Sinaloa, Chihuahua, and Durango); 2-*Northeast* (Coahuila, Nuevo León, Tamaulipas, San Luis Potosí, and Zacatecas); 3-*Mexico City & State of Mexico* (Ciudad de México and Estado de México); 4-C*enter* (Hidalgo, Puebla, Tlaxcala, Morelos, Guerrero, and Veracruz); 5-*West & Bajío* (Aguascalientes, Nayarit, Jalisco, Colima, Guanajuato, Michoacán, and Querétaro); and 6-*South* (Oaxaca, Tabasco, Chiapas, Campeche, Yucatán, and Quintana Roo).

2.2.3 Statistical Analysis

The number of new HIV infections by year, transmission category and region were estimated by using the CD4 depletion model parameters and first CD4 cell count before ART initiation to estimate the date of HIV infection following the methodology described by the U.S. Center for Disease Control and Prevention (46,47) were the CD4 decline rate is a linear function of time since infection, where a_i is the intercept and b_i the slope for each transmission category, age group and sex (Figure 2.2):

$$Date\ of\ infection = Date\ of\ the\ first\ CD4\ cell\ count - \frac{\sqrt{first\ CD4\ cell\ count} - a_i}{b_i}$$

Figure 2.2. Comparison of the Distribution of Year of HIV Diagnosis and Estimated Year of Infection



Weights were assigned to each case with a CD4 cell count to account for the total number of diagnosed cases between 2008 and 2018, registered in Mexico's EHSS without CD4 cell counts. Weights were the reciprocal of the proportion of cases with CD4 cell count based on the year of HIV diagnosis, sex, transmission category and region. Afterwards, the diagnosis delay probability ($P(x)$), define as the probability that a person with HIV would have been diagnosed within x units of time after infection (46), was estimated using survival analysis (Supplemental material). Later, this probability was used to estimate the diagnosis delay weight to account for undiagnosed cases, $W(x) = {}^{1}/_{P(x)}$. Diagnosis delay weights were estimated by sex, transmission category and region, and assigned to each person according to the estimated infection date. Finally, new HIV infections and undiagnosed HIV infections in a calendar year were estimated based on the estimated new HIV infections, observed new HIV diagnosis and reported cumulative deaths.

2.2.4 Sensitive analysis

Maximum likelihood linear mixed models with random intercept and random slope on the square root of CD4 cell count were used to estimate the rate of CD4 cell decline and the mean CD4 cell count change among PLWH without treatment in the seroprevalent SALVAR cohort. Square root transformation was used to normalize the distribution of CD4 cell counts. The correlation within individuals was handled through an unstructured covariance matrix of random effects (49) . Time of origin was defined as the date of diagnosis. CD4 cell decline was estimated from the linear random effect model:

$$\sqrt{CD4_{ij}} = \beta_0 + \beta 1 t_{ij} + bi0 + bi1 t_{ij} + e_{ij}$$

We used CD4 cell count data from PLWH linked to healthcare in the Ministry of Health registered in SALVAR between January 1, 2008, and December 31, 2017, with transmission category reported and two or more CD4 cell counts registered before ART initiation date. Follow-up was censored at the earlier of the last alive date, the last CD4 before antiretroviral therapy initiation, or December 31, 2018. Since CD4 cell decline is expected to differ across subpopulations, models were stratified by age groups, sex and transmission category and adjusted by stage of HIV infection at diagnosis. PLWH that first CD4 cell count was after 3 months from diagnosis, or that initiated ART before the second CD4 cell count, or individuals aged less than 15 years at the time of the first CD4 cell count were excluded from this sub-analysis.

2.3 Results

2.3.1 Sample description

Between January 1, 2008, and December 31, 2018, there were 148,738 individuals living with HIV linked to healthcare in the Ministry of Health and registered in SALVAR (Table 2.1). Of these PLWH, 74.4% (110,602/148,738) had a valid date of diagnosis, of whom 86.0% (97,096/110,0) were diagnosed between 2009 and 2018. Our final analytic sample comprised 95,713 PLWH diagnosed between 2009 and 2018 aged ≥13 years at diagnosis, of whom 85,986 had ≥1 CD4 cell count before ART initiation (Table 2.1).

Table 2.1. Description of the Study and Sample Population, SALVAR

	SALVAR	Registered date of diagnosis		Diagnosed from 2009 to 2018*		CD4 cell count before ART	
	n	n	%	n	%	n	%
All	148,738	110,602	74.4	95,713	86.5	85,986	89.8
Sex							
Cisgender women	30,571	21,253	69.5	17,980	84.6	15,941	88.7
Cisgender men	117,288	88,291	75.3	77,051	87.3	69,441	90.1
Transgender women	870	779	89.5	674	86.5	598	88.7
Transgender men	9	9	100.0	8	88.9	6	75.0
Region							

	SALVAR	Registered date of diagnosis		Diagnosed from 2009 to 2018*		CD4 cell count before ART	
	n	n	%	n	%	n	%
Northwest	15,611	12,032	77.1	9,951	82.7	8,983	90.3
Northeast	15,105	10,277	68.0	9,011	87.7	7,653	84.9
CDMX & Mexico State	39,918	26,495	66.4	22,931	86.5	20,810	90.8
Center	29,160	21,775	74.7	19,208	88.2	17,185	89.5
West & Bajio	20,260	16,400	80.9	13,688	83.5	12,591	92.0
South	28,684	23,623	82.4	20,924	88.6	18,764	89.7
Transmission category for cisgender men							
Male-to-male sexual contact	90,800	69,448	76.5	61,656	88.8	55,650	90.3
Heterosexual contact	22,995	16,500	71.8	13,664	82.8	12,257	89.7
Injection drug use	1,906	1,367	71.7	1,129	82.6	1,008	89.3
Other	1,587	976	61.5	602	61.7	526	87.4
Transmission category for cisgender women							
Heterosexual contact	29,559	20,943	70.9	17,855	85.3	15,832	88.7
Injection drug use	80	65	81.3	54	83.1	48	88.9
Other	932	515	55.3	71	13.8	61	85.9

*13 years or older at diagnosis
Abbreviations: SALVAR, Antiretroviral Management, Logistic and Surveillance System (SALVAR, for its acronym in Spanish); ART, antiretroviral therapy.

Most were cisgender men (80.8%), with an overall median first CD4 cell count at linkage to care of 228.0 (IQR: 83, 410). Variations in CD4 at linkage were observed across age groups (Table 2.2): the highest median CD4 cell count was among those aged 13 to 19 years old (357, IQR: 217.0, 521.0), and the lowest median CD4 cell count was among those aged ≥55 years (143, IQR: 54.0, 290.0) (Figure 2.3).

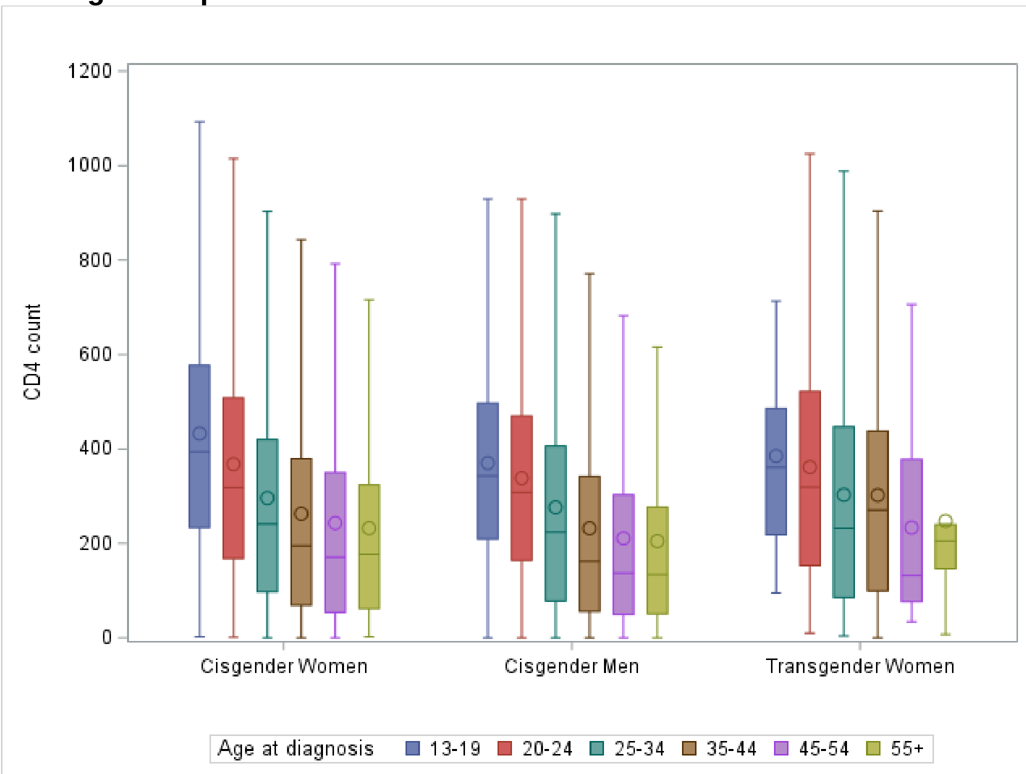
Table 2.2. First CD4 Cell Counts of PLWH Diagnosed in 2009-2018, SALVAR

Participants Characteristics	Diagnosed in 2009-2018 n= 85,986			
	n	%	Median	IQR
Sex				
Cisgender Women	15941	18.5	244	99, 434
Cisgender Men	69441	80.8	224	80, 404
Transgender Women	598	0.7	260	101, 447
Age				
13 to 19	4829	5.6	357	217, 521
20 to 24	17169	20.0	309	165, 476

Participants Characteristics	Diagnosed in 2009-2018			
	n= 85,986			
	n	%	Median	IQR
25 to 34	34016	39.6	227	81, 409
35 to 44	18624	21.7	170	59, 351
45 to 54	8366	9.7	145	50, 316
55+	2982	3.5	143	54, 290
Year of diagnosis				
2009	4392	5.1	215	87, 392
2010	5122	6.0	236	91, 427
2011	7122	8.3	238	94, 438
2012	8838	10.3	218	77, 404
2013	9393	10.9	206	68, 391
2014	9930	11.5	224	79, 399
2015	10952	12.7	232	82, 412
2016	10157	11.8	237	84, 412
2017	10376	12.1	236	87, 415
2018	9704	11.3	234	85, 415
Region				
Northwest	8983	10.4	349	96, 452
Northeast	7653	8.9	223	77, 402
CDMX & Mexico State	20810	24.2	245	92, 419
Center	17185	20.0	213	77, 393
West & Bajio	12591	14.6	246	80, 443
South	18764	21.8	205	78, 378
Transmission category for cisgender men				
Male-to-male sexual contact	55650	80.1	242	90, 420
Heterosexual contact	12257	17.7	151	52, 326
Injection drug use	1008	1.5	195	63, 382
Other	526	0.7	153	55, 281
Transmission category for cisgender women				
Heterosexual contact	15832	99.3	244	99, 434
Injection drug use	48	0.3	293	82, 513
Other	61	0.4	272	104, 442

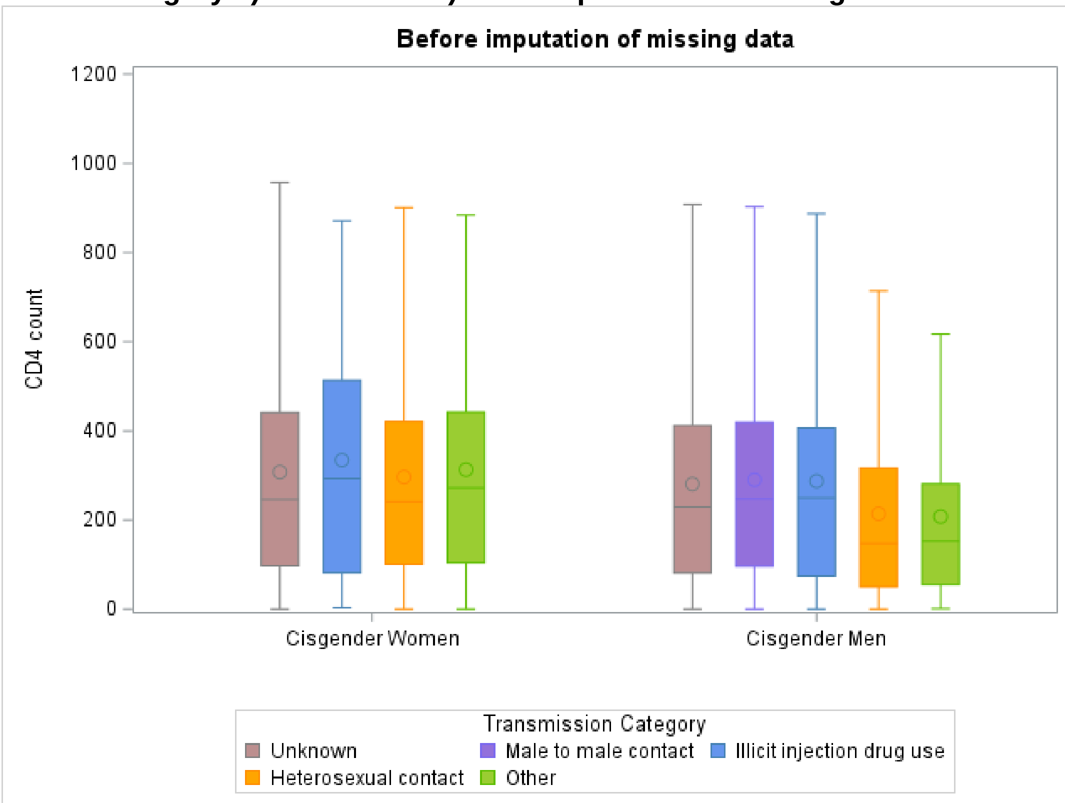
Abbreviations: SALVAR, Antiretroviral Management, Logistic and Surveillance System (SALVAR, for its acronym in Spanish); IQR, Interquartile Range.

Figure 2.3. Box Plot Showing Median (IQR) First CD4 Cell Count after Diagnosis by Gender and Age Groups



In Figure 2.4a we can observe the first CD4 cell count before imputation for missing transmission category. The median CD4 count for cisgender men with an unknown transmission category is similar to the count for MSM and heterosexual men. MSM were the group with the lowest median CD4 initial cell count (151, IQR: 52.0, 326.0, and cisgender women the group with the highest median initial CD4 cell count (244, IQR: 99.0, 434.0) (Figure 2.4 b).

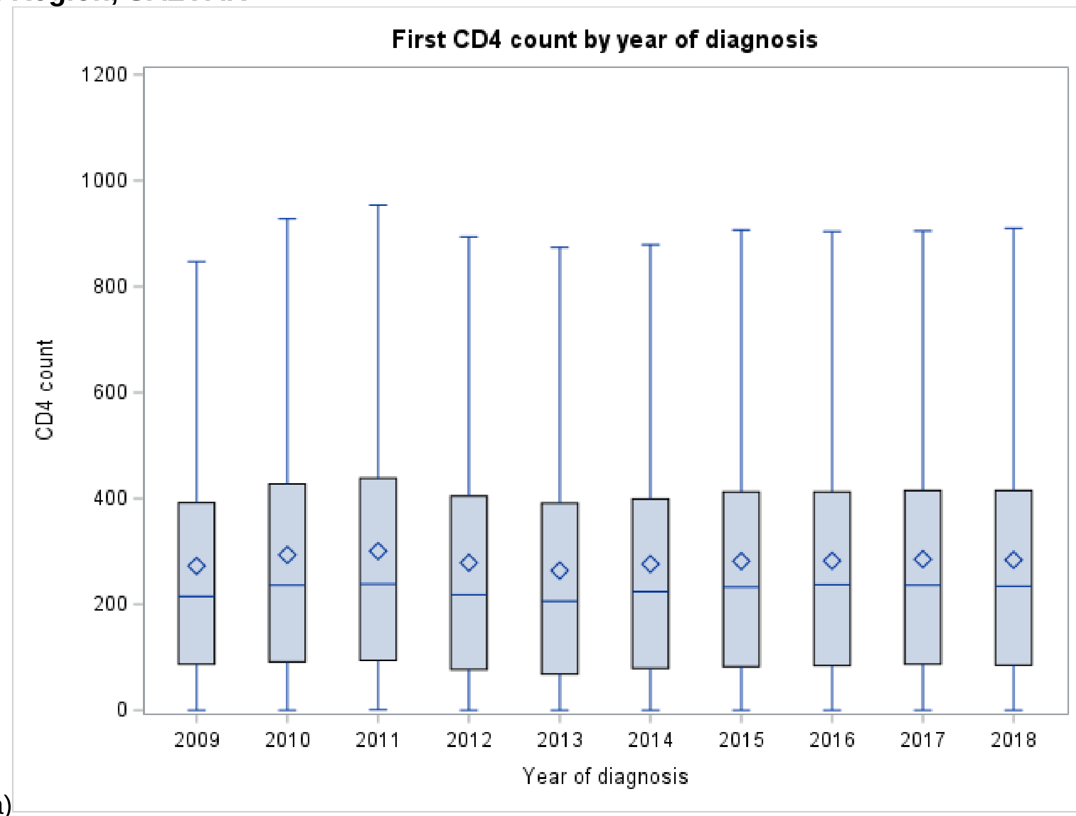
Figure 2.4. Box Plot Showing Median (IQR) First CD4 Cell Count by Gender and Transmission Category a) Before and b) After Imputation of Missing Data



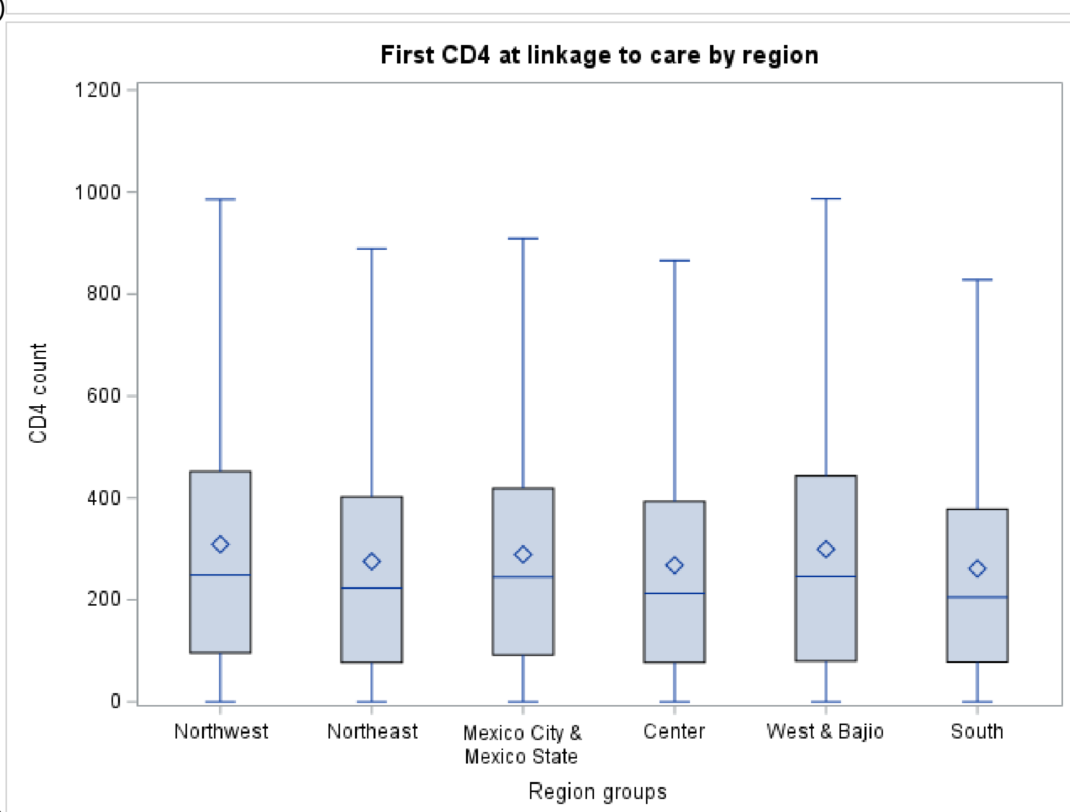
a)

b)

Figure 2.5. Box Plot Showing Median (IQR) First CD4 Cell Count by a) Year of Diagnosis and b) Region, SALVAR



a)



b)

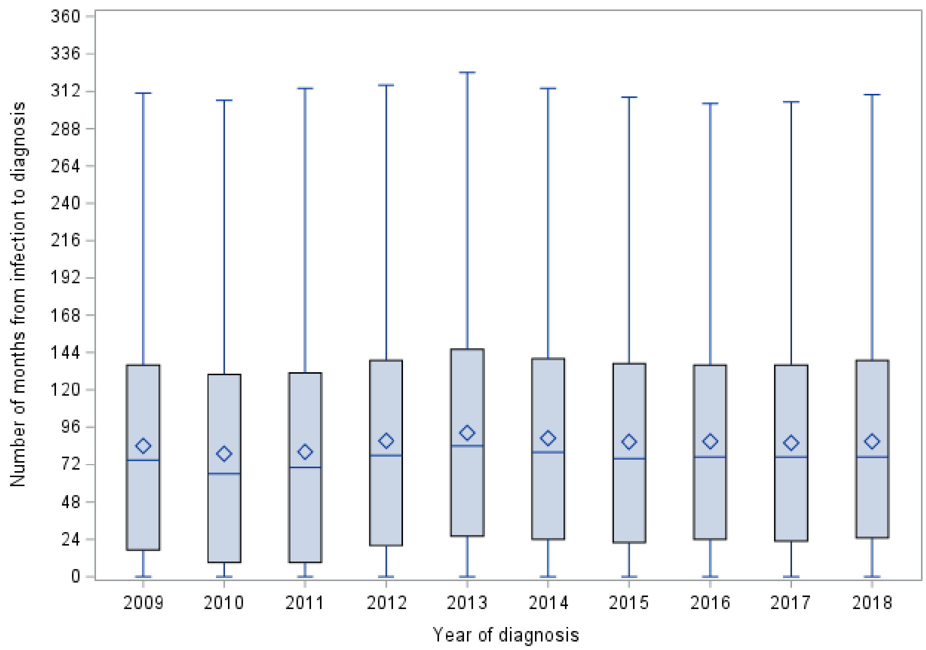
Table 2.3. Years Living with HIV at the Time of Diagnosis in 2009 and 2018, SALVAR

Participants Characteristics	2009				2018			
	CD4 count at diagnosis	Years living with HIV at diagnosis			CD4 count at diagnosis	Years living with HIV at diagnosis		
	Median	Median	IQR		Median	Median	IQR	
All	215	6.3	1.4	11.3	234	6.4	2.1	11.6
Sex								
Cisgender Women	247	5.6	0.9	10.3	247	5.7	0.8	11.3
Cisgender Men	205	6.4	1.6	11.5	231	6.6	2.3	11.6
Age at diagnosis								
13 to 19	329	3.3	0.0	5.8	370	3.6	0.4	5.6
20 to 24	291	5.5	0.1	8.9	323	5.4	1.3	8.8
25 to 34	207	7.4	1.6	13.8	236	7.2	2.0	13.5
35 to 44	180	6.8	1.8	11.0	157	7.8	2.8	13.0
45 to 54	171	6.6	2.4	11.8	132	8.3	3.4	13.2
55+	176	6.2	2.8	10.4	155	7.0	3.2	11.8
Region								
Northwest	212	5.8	1.1	11.7	274	5.1	0.9	10.6
Northeast	223	6.1	2.4	10.9	250	5.9	1.7	10.8
CDMX & Mexico State	269	4.9	0.0	9.7	245	6.3	2.0	11.3
Center	188	7.7	2.6	11.9	222	6.9	2.7	11.7
West & Bajio	223	5.8	0.8	11.0	250	5.8	1.3	11.8
South	187	7.1	2.3	12.2	210	7.2	2.8	12.1
Transmission category for cisgender men								
Male-to-male sexual contact	229	6.2	1.2	10.8	241	6.5	2.3	11.3
Heterosexual contact	160	7.5	2.2	13.3	134	8.4	2.5	14.0
Transmission category for cisgender women								
Heterosexual contact	245	5.6	0.9	10.3	247	5.7	0.8	11.3

From 2009 to 2018, the median CD4 cell count at linkage to care increased from 215 to 234 (9%); however, this increase was not homogenous across all regions (Table 2.3), and variations on the first CD4 cell count across regions were also observed (Figure 2.5). For example, PLWH in the South of Mexico presented the lowest CD4 cell counts at linkage to care (205, IQR: 78, 378), 41% below PLWH in the Northwest, the region with the highest CD4 cell count at linkage to care (349, IQR: 96, 452), and although an increase of 12% in the median CD4 cell count at linkage to care was observed between 2009 to 2018 for PLWH in the South of Mexico, this change remained below the 29% increase observed in the Northwest (Table 2.3).

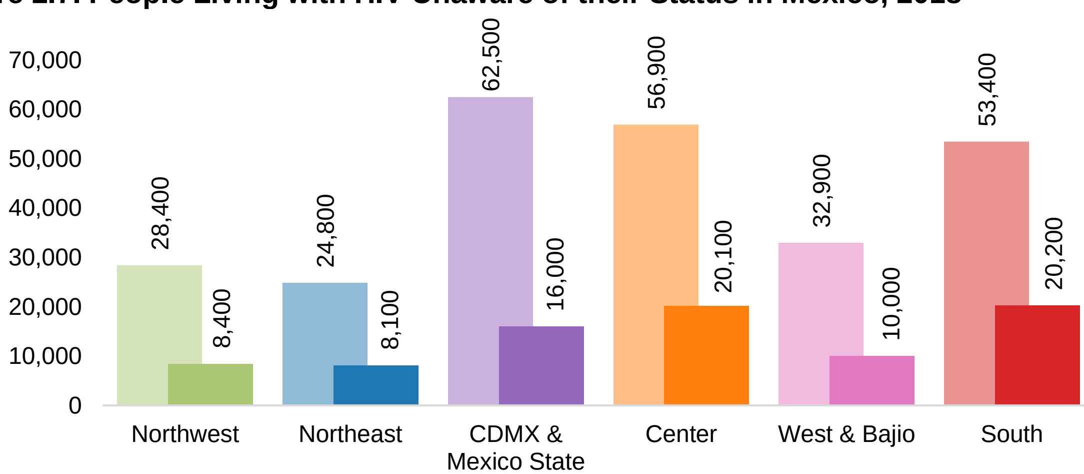
From 2009 to 2018, delays in infection to diagnosis did not change overall (Figure 2.6), with 50% of persons diagnosed with HIV in 7.4 years among those diagnosed in 2009 compared with 7.2 years among those diagnosed in 2018. Increases in delays were observed among those aged 35 years and older, PLWH diagnosed in Mexico City and Mexico State region and males with heterosexual transmission (Table 2.3).

Figure 2.6. Box-plot Showing the Time Between Infection to Diagnosis by Year of Diagnosis, SALVAR 2009-2018



2.3.2 Estimated new HIV infections, prevalent cases and undiagnosed proportion

Figure 2.7. People Living with HIV Unaware of their Status in Mexico, 2018



We estimated there were 258,600 people living with HIV in 2018 (95% CI 247,900 – 269,900). Of them 82,400 (95% CI 71,700 – 93,700) were unaware of their status. Of all estimated PLWH in 2018, 58% (150,100/258,600) were MSM, 22% (56,300/258,600) were male non-MSM and 20% were women (52,200/258,600) (Table 2.4). The largest number of PLWH was found in the Mexico City and Mexico State region, and the largest number of people unaware of their status in 2018 for all transmission categories was found in the Southern region (Figure 2.7).

Table 2.4. Estimated Number of HIV Incident, Prevalent and Undiagnosed Cases by Region and Transmission Category, Mexico 2018

	New HIV Infections			HIV Prevalence			Undiagnosed cases			Undiagnosed %
	Estimate	(95% CI)		Estimate	(95% CI)		Estimate	(95% CI)		
All	**12,600**	**11,800**	**13,500**	**258,600**	**247,900**	**269,900**	**82,400**	**71,700**	**93,700**	**31.9%**
Northwest	1,400	1,200	1,500	28,300	26,800	29,900	8,400	6,900	10,000	**29.6%**
Northeast	1,100	1,000	1,200	24,800	23,400	26,200	8,000	6,700	9,500	**32.4%**
CDMX & Mexico State	2,300	2,200	2,500	62,400	60,500	64,400	15,900	14,000	18,000	**25.6%**
Center	2,900	2,800	3,100	56,900	54,700	59,100	20,000	17,900	22,300	**35.2%**
West & Bajio	1,800	1,700	1,900	32,800	31,200	34,500	9,900	8,300	11,600	**30.2%**
South	3,100	2,900	3,300	53,400	51,200	55,700	20,100	17,900	22,400	**37.7%**
Male-to-male sexual contact	**8,300**	**7,900**	**8,700**	**150,100**	**145,000**	**155,400**	**49,800**	**44,700**	**55,100**	**33.2%**
Northwest	790	740	850	14,900	14,200	15,600	4,400	3,800	5,100	**29.6%**
Northeast	680	630	740	14,400	13,800	15,100	4,900	4,200	5,500	**33.7%**
CDMX & Mexico State	1,800	1,700	1,900	44,600	43,500	45,700	11,600	10,500	12,700	**25.9%**
Center	1,800	1,800	1,900	29,100	28,200	30,100	11,200	10,200	12,200	**38.3%**
West & Bajio	1,200	1,100	1,300	19,700	18,900	20,500	6,100	5,400	6,900	**31.1%**
South	1,900	1,800	2,000	27,300	26,300	28,400	11,700	10,700	12,700	**42.7%**
Male Heterosexual contact	**2,100**	**1,900**	**2,300**	**56,300**	**53,400**	**59,400**	**18,400**	**15,500**	**21,500**	**32.7%**
Northwest	310	280	350	7,200	6,800	7,700	2,500	2,000	3,000	**34.6%**
Northeast	170	150	200	5,500	5,200	5,900	1,900	1,500	2,300	**33.9%**
CDMX & Mexico State	260	230	290	9,400	9,000	9,900	2,400	2,000	2,900	**25.7%**
Center	460	420	500	13,700	13,100	14,300	4,900	4,300	5,500	**35.9%**
West & Bajio	360	320	400	6,900	6,500	7,400	2,300	1,900	2,800	**33.8%**
South	510	470	560	13,500	12,900	14,100	4,400	3,800	5,000	**32.5%**
Female Heterosexual contact	**2,300**	**2,100**	**2,500**	**52,200**	**49,500**	**55,100**	**14,200**	**11,500**	**17,100**	**27.2%**

	New HIV Infections			HIV Prevalence			Undiagnosed cases			Undiagnosed %
	Estimate	(95% CI)		Estimate	(95% CI)		Estimate	(95% CI)		
Northwest	260	230	290	6,200	5,800	6,600	1,500	1,100	1,900	**23.8%**
Northeast	260	230	290	4,900	4,500	5,200	1,300	1,000	1,700	**26.7%**
CDMX & Mexico State	240	210	270	8,300	7,900	8,800	2,000	1,500	2,400	**23.5%**
Center	630	580	680	14,000	13,400	14,600	3,900	3,300	4,600	**28.1%**
West & Bajio	230	200	260	6,200	5,800	6,600	1,500	1,100	1,900	**23.5%**
South	680	630	730	12,600	12,000	13,200	4,100	3,500	4,700	**32.2%**

The estimated proportion of undiagnosed infections decreased from 47.2% (95%CI 46.3 – 48.1) in 2009 to 31.9% (95%CI 28.9 – 34.7) in 2018, and the estimated number of undiagnosed people living with HIV decreased after 2015 (Table 2.5). This decrease was observed across all regions and transmission categories. The largest decreased between 2009 and 2018 was observed among MSM in the South region, with a decreased of 33%. However, despite this meaningful reduction, the Southern region remained as the region with the largest percentage and number of MSM living with HIV unaware of their status,

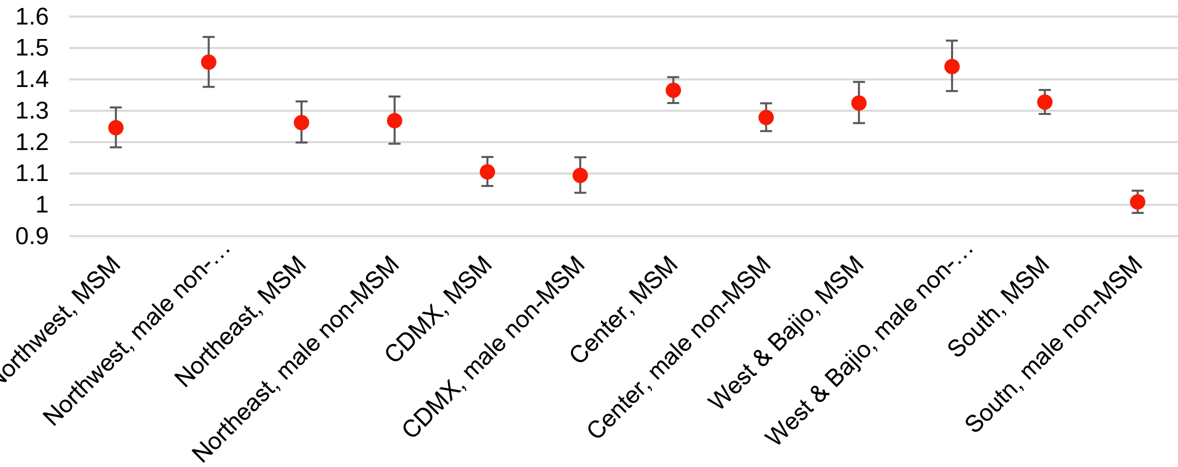
Table 2.5. Estimated Number of New HIV Infections, PLWH and Undiagnosed Prevalence by Year, Mexico

Year	Number of new HIV Infections (95% CI)	Number of people living with HIV (95% CI)	Number of undiagnosed cases (95% CI)	Undiagnosed proportion (95% CI)
2009	11.8 (11.0 – 12.7)	193.7 (190.5 – 197.0)	91.5 (88.3 – 94.8)	47.2% (46.3 – 48.1)
2010	12.6 (11.7 – 13.5)	201.4 (197.3 – 205.6)	92.9 (88.8 – 97.1)	46.1% (45.0 – 47.2)
2011	12.3 (11.4 – 13.2)	208.6 (203.7 – 213.7)	94.1 (89.2 – 99.3)	45.1% (43.8 – 46.4)
2012	12.2 (11.3 – 13.1)	215.8 (210.1 – 221.8)	94.2 (88.4 – 100.2)	43.6% (42.1 – 45.2)
2013	11.7 (10.8 – 12.5)	222.5 (216.0 – 229.4)	93.6 (87.0 – 100.5)	42.0% (40.3 – 43.8)
2014	11.6 (10.8 – 12.5)	229.4 (222.0 – 237.1)	93.0 (85.6 – 100.7)	40.5% (38.6 – 42.5)
2015	11.5 (10.7 – 12.4)	236.1 (227.9 – 244.8)	92.4 (84.1 – 101.0)	39.1% (36.9 – 41.3)
2016	11.9 (11.1 – 12.8)	243.4 (234.4 – 252.9)	90.3 (81.2 – 99.8)	37.1% (34.7 – 39.4)
2017	12.3 (11.5 – 13.2)	251.0 (241.1 – 261.4)	87.3 (77.4 – 97.7)	34.8% (32.1 – 37.4)
2018	12.6 (11.8 – 13.5)	258.6 (247.9 – 269.9)	82.4 (71.7 – 93.7)	31.9% (28.9 – 34.7)

[a] Results are in thousands to reflect model uncertainty, 95% confidence intervals were estimated following a Poisson distribution

Overall, males had a higher proportion of undiagnosed infections than women (33.1%, 95% CI 30.4 – 35.7 vs. 27%, 95% CI 23.1 – 31.0) and were more likely to remained undiagnosed (Figure 2.8). MSM living with HIV were significantly more likely to remained undiagnosed compared to women in the South region (cPR = 1.33; 95%CI: 1.29, 1.37).

Figure 2.8. Crude prevalence ratio with 95% confidence intervals for undiagnosed HIV infection by region and transmission category, compared to women



Based on Mexico's HIV surveillance data we estimated that between 2009 and 2018 there were 120.5 thousand new HIV infections, with an average of 12 thousand HIV infections every year (Table 2.6). Of all of them, male-to-male sexual contact accounted for more than one half of HIV infections every year (59 to 68%). Of the estimated 12,600 new HIV infections in 2018, 25% were in the South, 23% in the Center and 18% in the Mexico City and Mexico State region.

Table 2.6. Estimated Distribution of New HIV Infections by Year of Diagnosis, Mexico

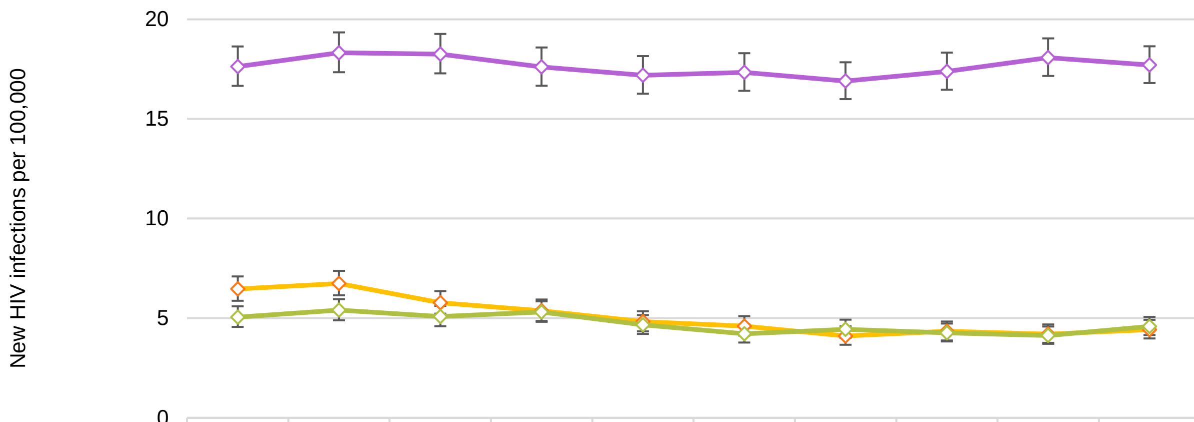
Year of HIV infection	Year of HIV Diagnosis 2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total	Diagnosis delay weight	New HIV infections [a]
≤2008	8,678	8,416	7,860	8,613	8,360	7,600	6,610	6,861	6,841	6,874	76,714	1.2	90,000
2009	1,924	440	418	546	556	605	682	835	819	989	7,814	1.5	11,800
2010		2,368	459	469	534	599	639	801	858	935	7,661	1.6	12,600
2011			2,256	408	457	539	653	781	801	917	6,813	1.8	12,300
2012				2,110	433	504	566	736	827	938	6,113	2.0	12,200
2013					1,916	405	465	642	818	974	5,222	2.2	11,700
2014						1,953	452	605	673	926	4,610	2.5	11,600
2015							2,076	511	616	796	3,999	2.9	11,500

Year of HIV infection	Year of HIV Diagnosis 2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total	Diagnosis delay weight	New HIV infections [a]
2016								2,248	559	749	3,556	3.4	11,900
2017									2,451	672	3,123	3.9	12,300
2018										2,731	2,731	4.6	12,600
(all)	10,602	11,224	10,993	12,147	12,256	12,205	12,143	14,020	15,264	17,502			

[a] Results are rounded to the nearest hundred

Using estimates from the National population Council of Mexico we calculated HIV incidence estimates por MSM, males non-MSM and women. On average, we observed an HIV incidence rate of 4.7 (95% CI 4.3 – 5.2) new HIV infections among women and 22.7 (95% CI 21.3 – 24.2) new HIV infections among men. In Figure 2.9, incidence rates for males are differentiated by MSM and males non-MSM.

Figure 2.9. Estimated HIV Incidence Rate per 100,000 People by Transmission Category, Mexico 2009-2018



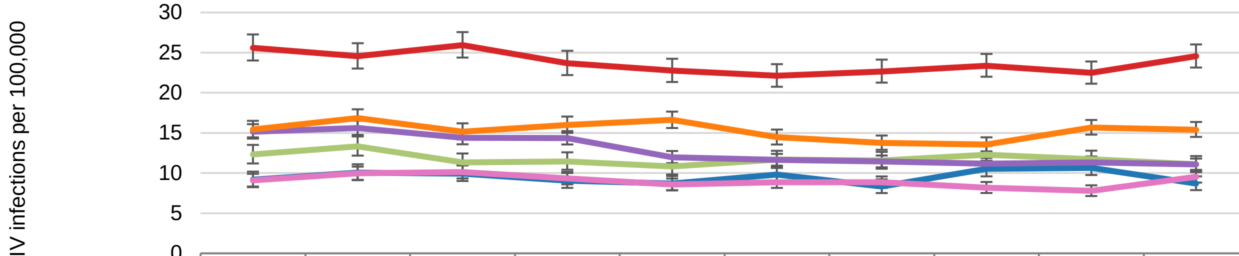
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
MSM	17.6	18.3	18.3	17.6	17.2	17.3	16.9	17.4	18.1	17.7
Male Non-MSM	6.5	6.7	5.8	5.4	4.8	4.6	4.1	4.3	4.2	4.4
Women	5.1	5.4	5.1	5.3	4.7	4.2	4.5	4.3	4.1	4.6

MSM Male Non-MSM Women

No changes in the HIV incidence rates on the national level were observed between 2009 and 2018. However, disparities across regions were found for men and women. In 2018, the overall HIV incidence rate per 100,000 people (Figure 2.10) in the South region was 24.5

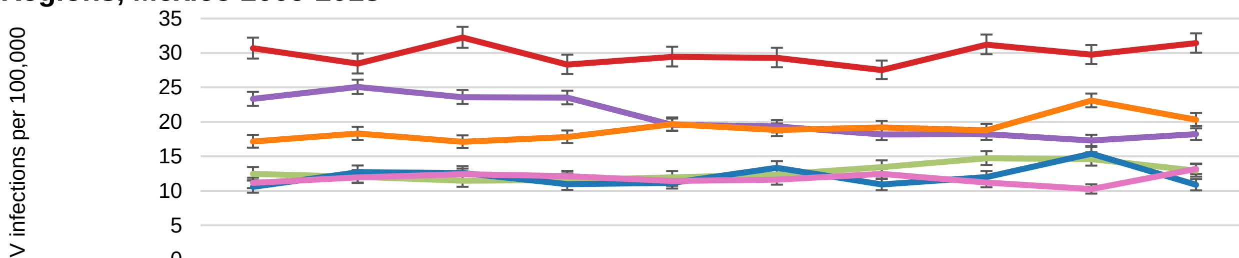
(95%CI 23.1 – 26.0), while in the West and Bajio region it was of 9.5 (95%CI 8.8 – 10.3). Among MSM (Figure 2.11), the largest rate was again the Southern region with 31.4 (95% CI 30.0 – 32.9) new HIV infections per 100,000 men, three times more than in the Northeast (10.9, 95%CI 10.1 – 11.7). Among women (Figure 2.12), HIV incidence in the South (10.3, 95%CI 9.5 – 11.1) was almost 5 times more than in the Mexico City and Mexico State region (2.2, 95%CI 1.9 – 2.5).

Figure 2.10. Estimated HIV Incidence Rate per 100,000 People by Geographical Regions, Mexico 2009-2018



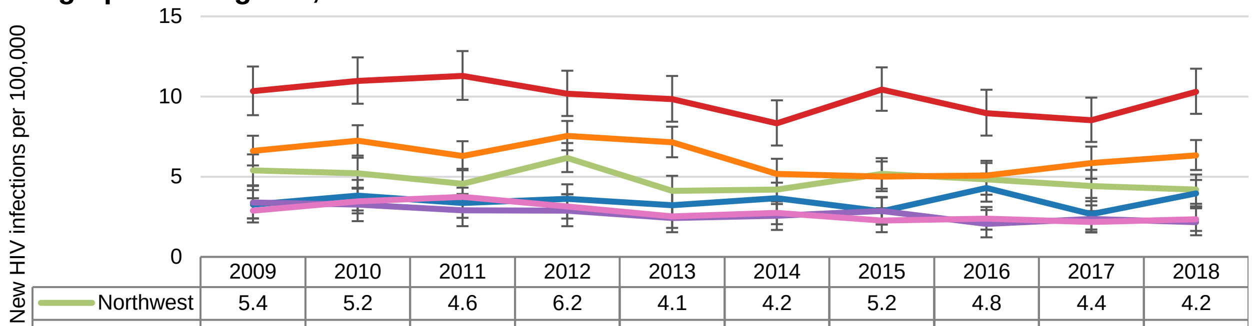
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Northwest	12.3	13.3	11.3	11.5	10.8	11.7	11.6	12.3	11.7	11.1
Northeast	9.2	10.1	9.9	9.0	8.7	9.8	8.3	10.5	10.6	8.7
CDMX	15.2	15.6	14.4	14.4	12.0	11.6	11.4	11.2	11.3	11.1
Center	15.5	16.9	15.2	16.0	16.6	14.5	13.8	13.6	15.7	15.4
West	9.1	10.0	10.1	9.3	8.6	8.9	8.8	8.2	7.8	9.5
South	25.6	24.6	25.9	23.7	22.8	22.1	22.7	23.4	22.5	24.5

Figure 2.11. Estimated HIV Incidence Rate Among MSM per 100,000 Men by Geographical Regions, Mexico 2009-2018



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Northwest	12.5	12.1	11.5	11.6	11.9	12.4	13.4	14.7	14.6	12.9
Northeast	10.6	12.7	12.6	11.0	11.2	13.3	10.9	12.0	15.4	10.9
CDMX	23.3	25.1	23.6	23.5	19.6	19.3	18.2	18.2	17.3	18.2
Center	17.2	18.3	17.1	17.8	19.7	18.8	19.2	18.8	23.1	20.3
West	11.1	12.0	12.4	12.1	11.5	11.6	12.5	11.2	10.3	13.2
South	30.7	28.4	32.2	28.3	29.4	29.3	27.5	31.2	29.7	31.4

Figure 2.12. Estimated HIV Incidence Rate Among Women per 100,000 Women by Geographical Regions, Mexico 2009-2018



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Northwest	5.4	5.2	4.6	6.2	4.1	4.2	5.2	4.8	4.4	4.2
Northeast	3.3	3.8	3.4	3.6	3.2	3.7	2.8	4.3	2.7	4.0
CDMX	3.4	3.3	2.9	2.9	2.4	2.6	2.9	2.1	2.4	2.2
Center	6.6	7.2	6.3	7.5	7.1	5.2	5.0	5.1	5.9	6.3
West	2.9	3.5	3.7	3.1	2.5	2.8	2.3	2.4	2.2	2.4
South	10.3	11.0	11.3	10.2	9.8	8.3	10.4	9.0	8.5	10.3

2.4 Discussion

On the national level, new HIV infections remained stable. Moreover, disparities across regions were observed. As expected, the largest number of PLWH was found in the Mexico City and Mexico state region, region where the Greater Mexico City is located, which its the largest city of Mexico and the most densely populated city in North America. However, the largest number of people unaware of their status was found in the southern region, with 20 thousand people living with HIV unaware of their status. This region is also characterized by important social and economic inequalities within Mexico, as an area historically marked by educational deprivation, poverty and social exclusion .

Also, the largest number of new HIV infections among MSM, and men and women with heterosexual contact were observed in the South region, and the largest proportions of undiagnosed PLWH were observed in the South and Center regions of the country. Mexico City and Mexico state remain as the regions with the largest number of people living with HIV. However, efforts on early detection and HIV prevention should prioritize the South region were more than 3,000 new HIV infections occurred every year and more than 20,000 PLWH are unaware of their status.

Some of the limitations of this methods is that it relies on the accuracy of the CD4 depletion model, and there is limited evidence regarding the accuracy of the model for different demographic groups. Model parameter estimates used in this study were updated by Song et al using a subset of the Concerted Action on Seroconversion to AIDS and Death in Europe (CASCADE) to specifically represent a population with predominantly HIV subtype B infections. Although it has been previously published that Subtype B is largely predominated in Mexico's population (74), CASCADE cohort had few Latinx persons from the Americas (51), and did not explore whether the rate of CD4 decline differs by ethnicity (48,49). For this reason, we have used a maximum likelihood linear mixed models to analyzed the rate of CD4 decline in our study population. Differences between CDC parameters and results from this analysis, particularly among women (Table 2.10), did not have a substantial impact on HIV incidence estimates or percentage of undiagnosed population estimates with an overlap of all 95% CIs (Figure 2.12).

Another limitation is the effect that the high variability of CD4 cell count at the individual level may have on the precision estimates. To address this, we use multiple imputation as recommended. Furthermore, in this analysis acute HIV infections were not excluded, period during which CD4 cell counts may experience steep declines and recoveries. However, the expected effect of this rapid changes at the population level are minimum because most of PLWH in Mexico are not diagnosed during that period. Finally, one of the assumptions of this estimation is that diagnosis delay distribution of people on ART at social security clinics is the same as people on ART at the Ministry of Health clinics, and that it does not change over time. Although, two-thirds of people of ART in Mexico are treated at the Ministry of Health clinics, SALVAR does not includes data form social security clinics (75).

When compared to UNADIS estimates for 2010-2017 published in 2018, 2019 and 2021, our estimates of 96,200 new HIV infections were 15% lower than 2018 estimates, 9% higher than 2019 and 35% lower than 2021 estimates. However, our estimations consistently overlapped with overlaps with estimated 95% CIs for 2019 estimates. Given the important variations year by year of UNAIDS estimates, this propose an effective alternative method using surveillance information to guide national and subnational HIV response in Mexico.

Prevalence estimates for 2010-2018 were similar to previously published UNAIDS epidemiological estimates. For example, in 2019 UNAIDS estimated there were 230,000 PLWH in Mexico in 2018 and 180,000 in 2010. In comparison, our study estimated 247,000 for 2018, and 182,000 for 2010. However, they differ meaningfully from UNAIDS recently published estimates were between 290,000 and 360,000 thousand people were living with HIV in Mexico in 2018. Given this method only requires data from cases diagnosed in recent years, estimates are more accurate than other methods like back calculation models. This estimation provides additional information to calibrate future Spectrum models for the Mexican setting.

2.5 Supplemental material

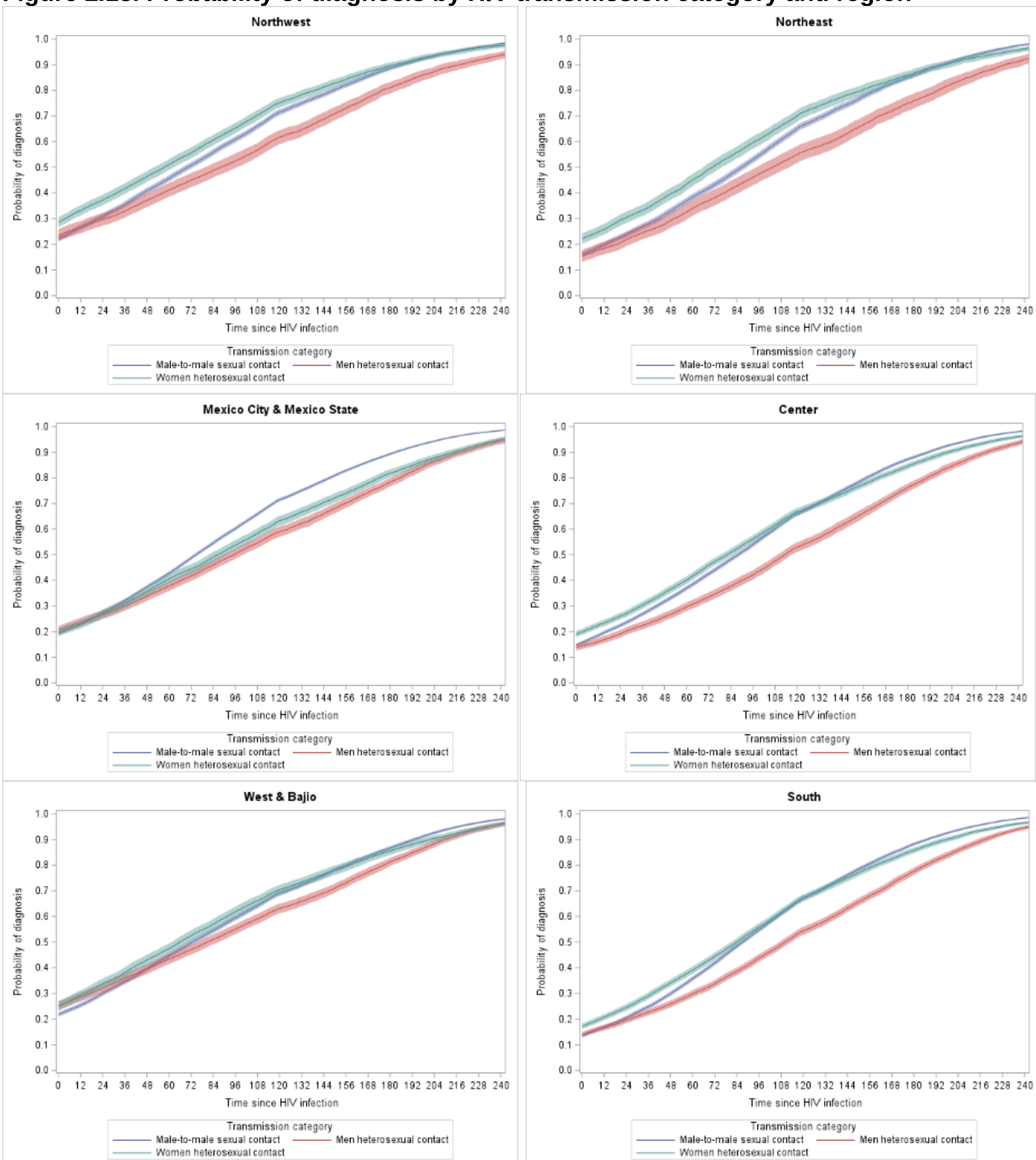
2.5.1 Probability of diagnosis

Probability of diagnosis was estimated by region and transmission category. Overall, the probability that a person living with HIV in Mexico would have been diagnosed within 12, 24 and 60 months since infection was 0.22, 0.26 and 0.40. Important differences in the probability of diagnosis were observed by transmission category. Except for Mexico City and the Mexico State region, the probability of diagnosis among women during the first 12, 24 and 60 months of infection was higher than probability of diagnosis among men (Figure 2.5). However, this was not because probability of diagnosis among women in Mexico City and Mexico State was lower than in the other regions, but because probability of diagnosis among MSM in this region was higher than women (Table 2.4). MSM and women living in the Northwest region were the group more likely to be diagnosed during the first 12, 24 and 60 months, and MSM and women living in the South were the group less likely to being diagnosed during the same periods (Table 2.4).

Table 2.7. Probability of Diagnosis within 12, 24 and 60 Months of HIV Infection by Region and Transmission Category, SALVAR 2009-2018

Transmission Category	Northwest (95%CI)	Northeast (95%CI)	CDMX & Mexico State (95%CI)	Center (95%CI)	West & Bajio (95%CI)	South (95%CI)
Male-to-male sexual contact						
12 months	26.6	19.8	23.0	18.5	25.4	16.9
	(25.5 – 27.7)	(18.7 – 20.9)	(22.4 – 23.7)	(17.8 – 19.2)	(24.5 – 26.3)	(16.2 – 17.6)
24 months	30.8	23.8	27.3	22.4	30.0	20.6
	(29.7 – 31.9)	(22.6 – 24.9)	(26.6 – 28.0)	(21.6 – 23.2)	(29.1 – 30.9)	(19.8 – 21.3)
60 months	45.6	38.3	42.7	37.0	44.8	35.8
	(44.4 – 46.8)	(37.0 – 39.6)	(42.0 – 43.5)	(36.1 – 37.9)	(43.8 – 45.9)	(34.8 – 36.7)
Male heterosexual contact						
12 months	26.5	18.3	23.7	16.1	28.6	16.7
	(24.2 – 29.0)	(16.0 – 20.9)	(22.1 – 25.4)	(14.8 – 17.5)	(26.9 – 30.4)	(15.6 – 17.8)
24 months	29.6	21.8	26.6	19.1	32.0	19.6
	(27.2 – 32.2)	(19.2 – 24.6)	(25.0 – 28.4)	(17.7 – 20.6)	(30.2 – 33.9)	(18.4 – 20.8)
60 months	41.1	34.0	37.7	29.7	43.4	29.8
	(38.5 – 43.9)	(31.0 – 37.1)	(35.9 – 39.7)	(28.0 – 31.4)	(41.5 – 45.3)	(28.4 – 31.3)
Women heterosexual contact						
12 months	33.2	25.8	22.8	22.5	29.3	20.7
	(31.2 – 35.2)	(23.8 – 27.9)	(21.3 – 24.5)	(21.3 – 23.7)	(27.4 – 31.2)	(19.5 – 21.9)
24 months	37.2	30.4	26.8	26.0	33.8	24.5
	(35.3 – 39.2)	(28.3 – 32.6)	(25.2 – 28.6)	(24.7 – 27.3)	(31.9 – 35.8)	(23.3 – 25.8)
60 months	51.0	45.0	40.6	40.1	47.4	39.0
	(48.9 – 53.1)	(42.6 – 47.4)	(38.7 – 42.5)	(38.6 – 41.6)	(45.4 – 49.5)	(37.7 – 40.5)

Figure 2.13. Probability of diagnosis by HIV transmission category and region



2.5.2 Sensitivity Analysis

Overall, 11,060 individuals had at least two CD4 counts before ART initiation; these individuals comprised the final analytic sample used to estimate the rate of CD4 cell depletion.

Overall, median CD4 count at diagnosis in this sample was 438 (IQR: 279, 594), most participants were 25 to 34 years old (39.8%) cisgender men (82.4%) (Table 2.9).

Table 2.8. Description of the sample, SALVAR

Participants Characteristics	Analytic sample n= 10,965		CD4 count at diagnosis	
	n	%	Median	IQR
Sex				
Cisgender Women	2041	18.6	468.0	327.0, 643.0
Cisgender Men	8924	82.4	432.0	271.0, 585.0
Age at diagnosis				
15 to 19	836	7.6	480.5	371.5, 616.0
20 to 24	2769	25.3	459.0	319.0, 610.0
25 to 34	4361	39.8	437.0	276.0, 600.0
35 to 44	2037	18.6	406.0	211.0, 567.0
45 to 54	747	6.8	403.0	182.0, 559.0
55+	215	2.0	382.0	190.0, 541.0
Year of diagnosis				
2007	255	2.3	277.0	96.0, 476.0
2008	733	6.7	353.0	146.0, 513.0
2009	711	6.5	418.0	264.0, 558.0
2010	831	7.6	459.0	352.0, 606.0
2011	1168	10.7	496.0	385.5, 667.5
2012	1653	15.1	472.0	359.0, 621.0
2013	1991	18.2	429.0	259.0, 575.0
2014	1762	16.1	427.5	259.0, 589.0
2015	1037	9.5	439.0	266.0, 608.0
2016	506	4.6	383.5	218.0, 564.0
2017	318	2.9	397.5	250.0, 573.0
Region				
Northwest	1089	9.9	478.0	325.0, 646.0
Northeast	846	7.7	411.5	257.0, 551.0
CDMX & Mexico State	3833	35.0	393.0	222.0, 554.0
Center	1701	15.5	474.0	369.0, 621.0
West & Bajio	1800	16.4	461.0	298.0, 620.5
South	1696	15.5	456.0	327.0, 596.5
Transmission category for cisgender men				
Male-to-male sexual contact	7404	83.0	437.0	284.0, 591.0
Heterosexual contact	1344	15.1	407.5	200.0, 557.0
Injection drug use	115	1.3	402.0	222.0, 536.0

Participants Characteristics	Analytic sample n= 10,965		CD4 count at diagnosis	
	n	%	Median	IQR
Transmission category for cisgender women				
Heterosexual contact	2026	99.3	467.5	326.0, 642.0
Injection drug use	10	0.5	604.5	408.0, 678.0

Figure 2.14. Distribution of original and square root transformed CD4 cell counts

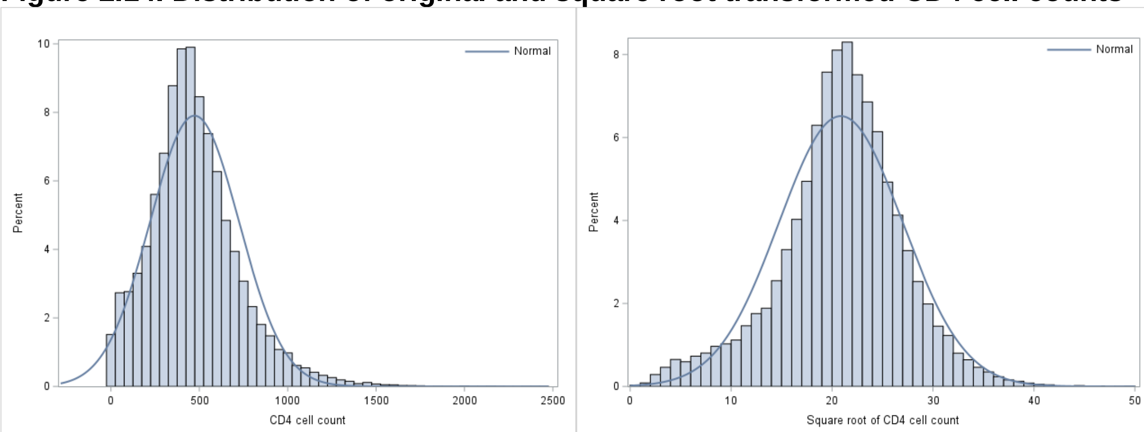


Figure 2.14 depicts normalized CD4 cell counts after square root transformation. Although the purpose of this analysis was to compare the estimated mean CD4 cell count change with those reported in the literature from other seroprevalent cohorts, the results from this analysis do not provide enough evidence to conclude the CD4 decline rate in Mexican population differ from that reported in the literature (Figure 2.11, Table 2.10). Results from the sensitivity analysis showed that increases on the CD4 cell depletion rate of 50% did not have a substantial impact on HIV incidence estimates (Figure 2.12).

Figure 2.15. Comparison of rate of CD4 cell decline/year on the square root transformed scale

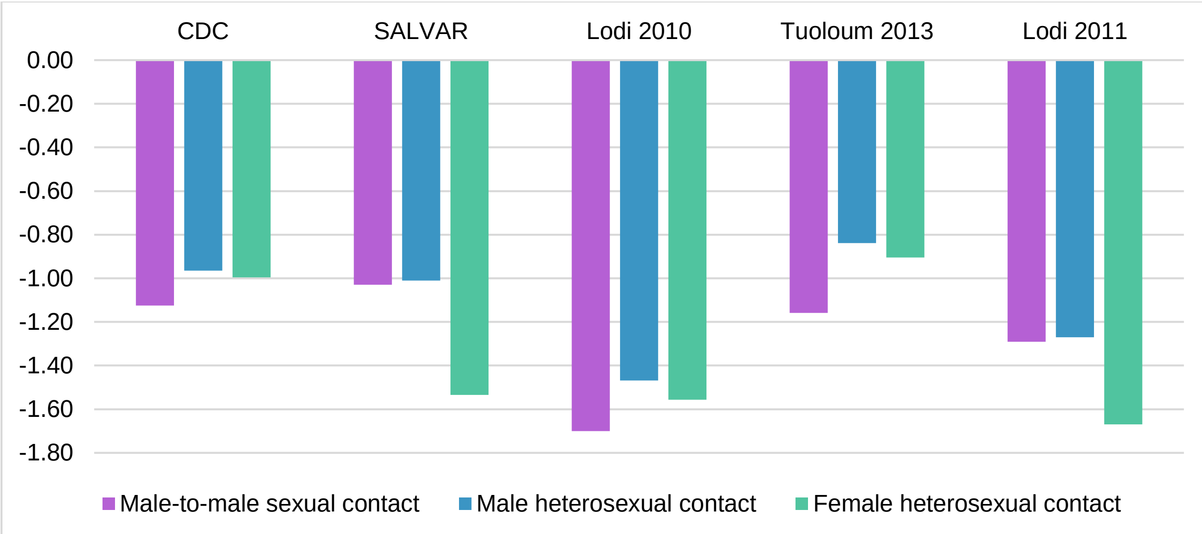


Figure 2.16. Estimated number of new HIV infections by year and model parameters implemented

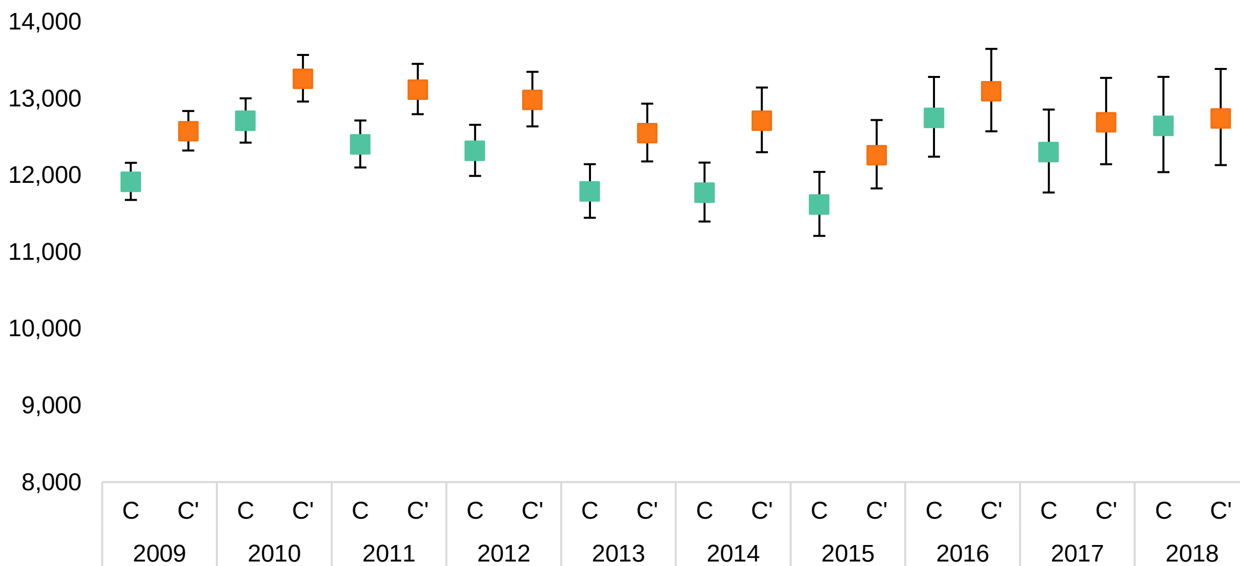


Table 2.9. Comparison of model coefficients of rate of CD4 cell decline/year on the square root transformed scale

	CDC		SALVAR		
	Slope	SE	n	Slope	SE
Male-to-male sexual contact					
15-19	-0.99	0.12	594	-1.24	0.13
20-24	-0.93	0.07	2,170	-1.19	0.08
25-34	-1.11	0.06	3,106	-0.99	0.07
35-44	-1.19	0.07	1,160	-0.93	0.12

45-54	-1.35	0.08	320	-0.48	0.25
55+	-1.18	0.11	54	-0.39	0.35
All	-1.13		7,404	-1.03	0.04
Male heterosexual contact					
15-19	-0.83	0.13	56	-1.16	0.28
20-24	-0.77	0.09	186	-1.07	0.20
25-34	-0.95	0.08	430	-1.30	0.18
35-44	-1.03	0.08	369	-0.91	0.17
45-54	-1.19	0.09	209	-0.90	0.28
55+	-1.02	0.12	94	0.60	0.49
All	-0.97		1,344	-1.01	0.09
Female heterosexual contact					
15-19	-0.86	0.12	183	-1.46	0.22
20-24	-0.8	0.08	390	-1.59	0.16
25-34	-0.98	0.08	751	-1.30	0.18
35-44	-1.06	0.08	448	-1.42	0.17
45-54	-1.22	0.09	193	-1.43	0.29
55+	-1.05	0.11	61		
All	-1.00		2,026	-1.54	0.08

3 FACTORS ASSOCIATED WITH HIV TESTING FREQUENCY AMONG MEXICAN MSM

Comparison of determinants for HIV testing in Mexican MSM living in Mexico and the U.S.

3.1 INTRODUCTION

In June 2021, the United Nations General Assembly adopted the 2021 Political Declaration on HIV and AIDS to end the AIDS epidemic as a public health threat by 2030 and pledged to reach the new 95-95-95 testing, treatment, and viral suppression targets across all populations (76). However, over the past years, the overlapping crises worldwide have threatened the global AIDS response. Declines in HIV infections and AIDS-related deaths are slowing rather than accelerating, driven by barriers in the availability of HIV services: prevention, testing, and treatment (7).

UNAIDS estimated that key populations and their sexual partners accounted for 70% of new HIV infections worldwide. Mexico is no exception, and HIV disproportionately affects gay, bisexual and other men who have sex with men (MSM), with a reported prevalence between 5.7% and 20.7% (20,21). However, access to HIV testing is not equitable in the country (8,31), and less than half of MSM living with HIV were aware of their infection (21). Furthermore, the largest gap in the HIV continuum of care in Mexico is at diagnosis. Although 85% of those diagnosed were on antiretroviral therapy (ART) and 89% of those treated were on viral suppression, only 71% of the 340,000 people living with HIV (PLWH) in Mexico knew their HIV status in 2020 (12).

HIV testing services are crucial to engage PLWH in the HIV continuum of care, increase the number of people on ART and viral suppression and avert new transmissions. Consistent with the U.S. Centers for Disease Control and Prevention (CDC) (77), Mexico's National HIV Program recommends in its HIV testing guide published in 2018, to offer an HIV test at least once a year to MSM and other key populations (78). However, this recommendation is solely based on research on the U.S. population (79). In addition, the CDC concluded that the evidence suggesting the potential benefits of increasing HIV screening frequency for MSM in the U.S. to every 3-6 months remains insufficient due to uncertainty of the underlying model parameters and uncertainty on the association between recent risk behavior and preferred screening interval (79–81). Understanding the latter is essential for the validity of the model results and for evaluating the evidence for changing the recommendation. Research estimating the annual screening rates of HIV among MSM and its heterogeneity by demographic factors in Mexico and the U.S. is limited. Furthermore, evidence regarding HIV testing behaviors of the different U.S. Latinx communities is scarce (82). In this study, we compared the strength of the association between HIV testing frequency and health service utilization factors among Mexican MSM living in Mexico and the U.S. and estimated the annual screening rates.

3.2 METHODS

3.2.1 Study Design

We performed a secondary data analysis of the Mexican Men's Internet Survey (ESEH, for its acronym in Spanish) (83) and the American Men's Internet Survey (AMIS) cross-sectional studies. AMIS is an online sexual health behavioral survey of MSM living in the United States that is conducted annually (68). For this analysis, data from AMIS 2018, 2019, 2020, and 2021 iterations were used, corresponding to the sixth (September-December 2018), seventh (September-December 2019), eighth (October 2020 – January 2021), and ninth (September 2021 – February 2022) cycles of data collection. Only participants that reported being born in Mexico were included in the final sample.

ESEH was modeled after AMIS and collected data from 15,875 eligible MSM living in Mexico between May-July 2017 (69). The sample size was calculated to ensure sufficient representation was obtained from each of the six geographical regions in Mexico, with at least 1,296 valid responses from each one. Both surveys collected information about demographics, sexual behaviors, substance use behaviors, HIV status, HIV testing behaviors, STI history, HIV knowledge, and stigma. The final analytic sample for both surveys was restricted to HIV-negative or unknown status MSM.

3.2.2 Measures

The primary outcome was HIV testing prevalence operationalized into three ordinal levels: frequent defined as at least one HIV test in the last 12 months, infrequent defined as most recently HIV tested more than 12 months prior, and never tested. HIV testing frequency in AMIS was assessed by the close-ended questions: Have you ever been tested for HIV? (No, Yes, I prefer not to answer, Don't know), When did you have your most recent HIV test? (Month/Year), Have you had an HIV test in the past 12 months? (No, Yes, I prefer not to answer, Don't know). HIV testing frequency in ESEH was assessed by the close-ended questions: Have you ever been tested for HIV? and Have you had an HIV test in the past 12 months?. Annual HIV screening rates among Mexican MSM living in the US in AMIS were estimated based on the question: In the past 2 years, how many times have you been tested for HIV?. The reported frequency was divided by two to obtain the number of HIV tests per year per person. This question was not included in the administered ESEH survey.

Predisposing factors analyzed to explain the propensity of individuals to use health services included (64): age group (18-24, 25-29, 30-39, 40+), education (No high school graduation, High school graduation, Some college, College or postgrad degree), PrEP/testing familiarity (yes/no) as a proxy of knowledge about health services, and disclosure of sexual orientation to healthcare providers (yes/no) as proxy of positive beliefs and attitudes towards health services. Type of healthcare coverage (None, Private only, Public only, Other/multiple) and household income, categorized as individuals living in households in the bottom 20th percentile of income in Mexico and less than $20,000 annually in the United States or more, were analyzed as part of the factors enabling the use of health services. Perceived need factors were analyzed through the variables: STI diagnosis in last 12 months (yes/no) substance use in last 12 months (yes/no), condomless anal sex with male partner in the last 12 months (yes/no).

Participants living in Mexico were stratified into 6 geographical regions based on the reported state of residence: 1-*Northwest* (Baja California, Baja California Sur, Sonora, Sinaloa, Chihuahua, and Durango); 2-*Northeast* (Coahuila, Nuevo León, Tamaulipas, San Luis Potosí, and Zacatecas); 3-*Mexico City & State of Mexico* (Ciudad de México and Estado de México); 4-C*enter* (Hidalgo, Puebla, Tlaxcala, Morelos, Guerrero, and Veracruz); 5-*West & Bajío* (Aguascalientes, Nayarit, Jalisco, Colima, Guanajuato, Michoacán, and Querétaro); and 6-*South* (Oaxaca, Tabasco, Chiapas, Campeche, Yucatán, and Quintana Roo).

3.2.3 Statistical Analysis

Descriptive statistics were calculated using frequencies and percentages for categorical variables and mean with interquartile range (IQR) for continuous variables. Ordinal logistic regression was performed to determine the association between predisposing, enabling, and perceived need characteristics and HIV testing frequency in the both populations. Proportional Odds Assumption was tested using a score test for each one of the independent variables. The null hypothesis was all possible coefficients except intercepts are equal (i.e. the proportional odds assumption is met). In addition, given the large sample size, the Proportional Odds Assumption was also tested by comparing separate binary logistic regressions and the empirical logit plot graphical method (Supplement tables). Data were analyzed using SAS Studio® (SAS Institute, Cary, NC).

Odds ratios (OR) and their 95% confidence intervals (CI) were obtained via ordinal logistic regression models for those associations that met the proportional odds assumption. Control variables that we hypothesized would confound the association were selected for each model per directed acyclic graph theory and literature review. Adjusted prevalence ratios (aPR) and their 95% confidence intervals (CI) were obtained via Poisson regression models with robust variance estimates for dichotomous outcomes.

The estimated number of HIV tests per year per person in Mexican MSM in Mexico was estimated by multiple imputation (n=20) using FCS regression method built of the HIV testing rates in Mexican MSM living in the U.S. The mean number of HIV tests per year per person and standard error for each imputed dataset were estimated from each imputed dataset. Finally, these estimates were combined and 95% confidence interval were estimated.

3.3 Results

3.3.1 Findings among the ESEH population

Between May-July 2017, a total of 15,875 eligible participants completed the ESEH Mexican survey. Of those 1,650 participants were excluded from the final analytic sample due to self-report of HIV-positive status.

Figure 3.1. HIV Status of ESEH Study Sample

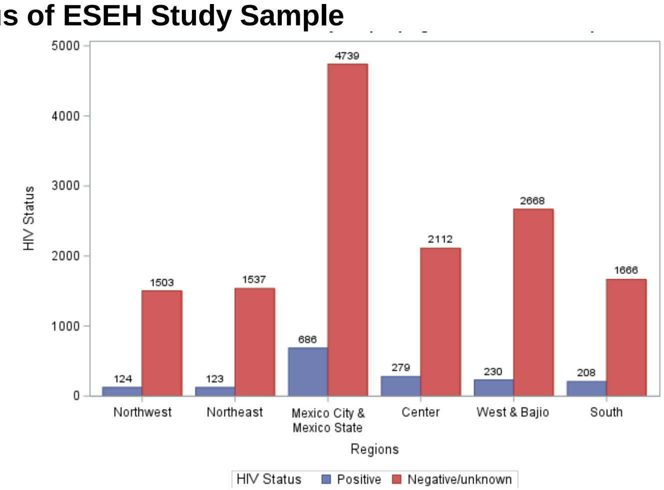


Table 3.1 presents the self-reported HIV status by region and shows that 93.4% (14,225/15,233) of the eligible participants reported an HIV-negative or unknown status. The majority of participants that reported an HIV negative or unknown status resided in the Mexico City region (33.3%), followed by the West & Bajio region (18.8%), Center (14.9%), South (11.7%), Northeast (10.8%), and the Northwest (10.6%).

Table 3.1. HIV Status by Region Among Men Who Have Sex with Men in Mexico – ESEH, 2017

Region	HIV Status		N
	Positive (%)	Negative/unknown (%)	
Northwest	124 (7.6)	1,503 (92.0)	1,627
Northeast	123 (7.4)	1,537 (92.3)	1,660
Mexico City & Mexico State	686 (12.7)	4,739 (82.8)	5,425
Center	279 (11.7)	2,112 (87.8)	2,391
West & Bajio	230 (7.9)	2,668 (91.7)	2,898
South	208 (11.1)	1,666 (88.5)	1,874
Total	1,650 (10.4)	14,225 (89.2)	15,875

Abbreviations: HIV, human immunodeficiency virus; ESEH, Encuesta de Sexo Entre Hombres

Table 3.2 presents the characteristics of the ESEH study sample. Overall, 65.4% of the ESEH participants (9,300 /14,225) reported ever being tested for HIV, 40.8% (5,808/14,225) reported frequent HIV testing, and 24.6% (3,492/14,225) infrequent HIV testing. Most ESEH participants had a College degree or postgraduate education (64.2%), and received healthcare services through a public institution only (69.1%); 42.2% (6,002 /14,225) were aged 18-24 years, 46.7% (6,480/13,887) have disclosed their sexual orientation to a healthcare provider, 54.9% (4,762/8,667) of those ever tested have heard about PrEP, 16.1% (1,797/11,179) had a low income, 8.0% (1,115/13,961) reported receiving an STI diagnosis in the last 12 months, 31.6% (4,281/13,557) using illicit non-injection drugs in the last 12 months, and 61.9% (7,202/11,637) engaging in condomless anal sex with a male partner in the last 12 months.

Table 3.2. Descriptive Sample Characteristics of Men Who Have Sex with Men in Mexico – ESEH, 2017

Participants Characteristics	MSM living in Mexico n = 14,225	
	n	%
Predisposing Characteristics		
Age		
18 to 24	6002	42.2
25 to 29	3686	25.9
30 to 39	3272	23.0
40+	1265	8.9
Education		
No high school diploma	368	2.6
High school diploma	3261	23.3
Some college/Technical degree	1370	9.8
College degree or postgraduate education	8977	64.2
Disclosure of sexual orientation to a healthcare provider		
No	7407	53.3
Yes	6480	46.7
PrEP awareness [a]		
No	3905	45.1
Yes	4762	54.9
Enabling Characteristics		
Health insurance coverage		
None	1845	14.9
Private only	588	4.7
Public only	8578	69.1
Other/Multiple	1409	11.3
Income		
Low	1797	16.1
Other	9382	83.9
Perceived Need Characteristics		
STI diagnosis in last 12 months		
No	12846	92.0
Yes	1115	8.0
Illicit non-injection drug use in the last 12 months		
No	9276	68.4
Yes	4281	31.6
Condomless anal sex with male partner in the last 12 months		
No	4435	38.1
Yes	7202	61.9

Participants Characteristics	MSM living in Mexico n = 14,225	
	n	%
HIV testing history		
Frequent	5808	40.8
Infrequent	3492	24.5
Never	4925	34.6

[a] Only among participants whose self-reported ever tested for HIV.
Abbreviations: ESEH, Encuesta de Sexo Entre Hombres; MSM, men who have sex with men; HIV, human immunodeficiency virus; PrEP, preexposure prophylaxis; STI, sexually transmitted infections.

In crude analysis, significant variations in HIV testing frequency were observed by predisposing, enabling, and need factors and can be found in Table 3.3. MSM aged 25 or more were two times (OR = 1.97; 95%CI: 1.83, 2.13) more likely to have a more recent HIV test, compared to participants aged 18 to 24 years old (Table 3.3). Compared to no high school diploma, participants with at least a high school diploma were significantly more likely to have a more recent HIV test (OR = 1.90; 95%CI: 1.56, 2.31). The odds of having a more recent HIV test were 1.43 times higher for MSM with private health insurance compared to participants without healthcare coverage. No significant differences were observed between MSM with a public healthcare coverage and without healthcare coverage. Participants that reported a low income were 34% less likely to have a more recent HIV test (OR = 0.66; 95%CI: 0.61, 0.73). MSM that had disclosed their sexual orientation to a healthcare provider were more likely to have a more recent HIV test. Among participants ever tested, those that have heard about PrEP prior the survey (OR = 1.60; 95%CI: 1.46, 1.74) were more likely to have a more recent HIV test. Participants that reported an STI diagnosis in the past 12 months (OR = 2.32; 95%CI: 2.06, 2.62) or illicit non-injection drug use in the last 12 months (OR = 1.42; 95%CI: 1.33, 1.52) were more likely to have a more recent HIV test. Participants residing in Northwest, Northeast, Center, West & Bajio, and South were significantly less likely to have a more recent HIV test than participants residing in Mexico City. There was no significant association between HIV testing frequency and anal sex without a condom with a male partner in the last 12 months.

Table 3.3. Crude Analysis of Predisposing, Enabling and Need Factors for Health Services Utilization Associated with HIV Testing Frequency Among Mexican MSM Living in Mexico – ESEH, 2017

Participants characteristics	Never n (%)	Infrequent n (%)	Frequent n (%)	HIV Testing frequency OR[a] (95% CI)
Predisposing Characteristics				
Age				
18 to 24	2953 (49.2)	923 (15.4)	2126 (35.4)	1.00
25 to 29	1039 (28.2)	985 (26.7)	1662 (45.1)	1.97 (1.83, 2.13)
30 to 39	697 (21.3)	1126 (34.4)	1449 (44.3)	2.19 (2.02, 2.37)
40+	236 (18.7)	458 (36.2)	571 (45.1)	2.33 (2.08, 2.61)
Education				
No high school diploma	183 (49.7)	85 (23.1)	100 (27.2)	1.00
High school diploma	1623 (49.8)	594 (18.2)	1044 (32.0)	1.09 (0.89, 1.34)
Some college/Technical degree	538 (39.3)	318 (23.2)	514 (37.5)	1.58 (1.27, 1.96)
College degree or postgraduate education	2487 (27.7)	2441 (27.2)	4049 (45.1)	2.37 (1.94, 2.88)
Region				
Northwest	552 (36.7)	391 (26.0)	560 (37.3)	0.77 (0.69, 0.87)
Northeast	560 (36.4)	373 (24.3)	604 (39.3)	0.78 (0.69, 0.88)
Mexico City & Mexico State	1468 (31.0)	1143 (24.1)	2128 (44.9)	1.00
Center	792 (37.5)	528 (25.0)	792 (37.5)	0.75 (0.67, 0.83)
West & Bajio	986 (37.0)	656 (24.6)	1026 (38.5)	0.77 (0.69, 0.85)
South	567 (34.0)	401 (24.1)	698 (41.9)	0.87 (0.77, 0.98)
Disclosure of sexual orientation to healthcare provider				
No	3795 (51.2)	1655 (22.3)	1957 (26.4)	1.00
Yes	1019 (15.7)	1748 (27.0)	3713 (57.3)	4.42 (4.14, 4.72)
PrEP awareness [b]				
No	NA	1683 (43.1)	2222 (56.9)	1.00
Yes	NA	1532 (32.2)	3230 (67.8)	1.60 (1.46, 1.74)
Enabling Characteristics				
Income				
Low	799 (44.5)	350 (19.5)	648 (36.1)	0.66 (0.61, 0.73)
Other	3031 (32.3)	2329 (24.8)	4022 (42.9)	1.00
Health insurance coverage				
None	665 (36.0)	491 (26.6)	689 (37.3)	1.00
Private only	170 (28.9)	142 (24.2)	276 (46.9)	1.43 (1.20, 1.70)
Public only	3064 (35.7)	2014 (23.5)	3500 (40.8)	1.09 (0.99, 1.19)
Other/Multiple	356(25.3)	356 (23.2)	726 (51.5)	1.72 (1.51, 1.95)
Perceived Need Characteristics				

Participants characteristics	Never n (%)	Infrequent n (%)	Frequent n (%)	HIV Testing frequency OR[a] (95% CI)
STI diagnosis in last 12 months				
No	4589 (35.7)	3184 (24.8)	5073 (39.5)	1.00
Yes	200 (17.9)	252 (22.6)	663 (59.5)	2.32 (2.06, 2.62)
Illicit non-injection drug use in the last 12 months				
No	3402 (36.7)	2299 (24.8)	3575 (38.5)	1.00
Yes	1228 (28.7)	1046 (24.4)	2007 (46.9)	1.42 (1.33, 1.52)
Condomless anal sex with male partner in the last 12 months				
No	1546 (34.9)	999 (22.5)	1890 (42.6)	1.00
Yes	2379 (33.0)	1821 (25.3)	3002 (41.7)	1.02 (0.95, 1.09)

[a] Odds ratios (OR) and their 95% confidence intervals (CI) were obtained via ordinal logistic regression models for those associations that met the proportional odds assumption; otherwise, separate bivariate logistic regressions were estimated.
[b] Only among participants whose self-reported ever tested for HIV.
Abbreviations: ESEH, Encuesta de Sexo Entre Hombres; MSM, men who have sex with men; HIV, human immunodeficiency virus; PrEP, preexposure prophylaxis; STI, sexual transmitted infections.

3.3.2 Findings among AMIS 2018-2021 Mexican participants

During the four AMIS cycles 2018-2021 a total of 42,401 eligible participants completed the survey. Of them 3,735 participants reported an HIV-positive status and therefore were excluded from the analytic sample for this study. Of the 38,666 participants that reported an HIV negative or unknown status 61.9% (23,934) were non-Latinx white, 9.4% (3,618) were non-Latinx Black, 6.9% (2,671) were non-Mexican Latinx, 7.7% (2,966) reported a Mexican heritage and 547 were born in Mexico. Table 3.4 shows the HIV status of AMIS eligible participants by AMIS cycles. The largest proportion of Mexican MSM living in the US that reported an HIV-negative or unknown status was collected during the 2020 and 2021 AMIS cycles.

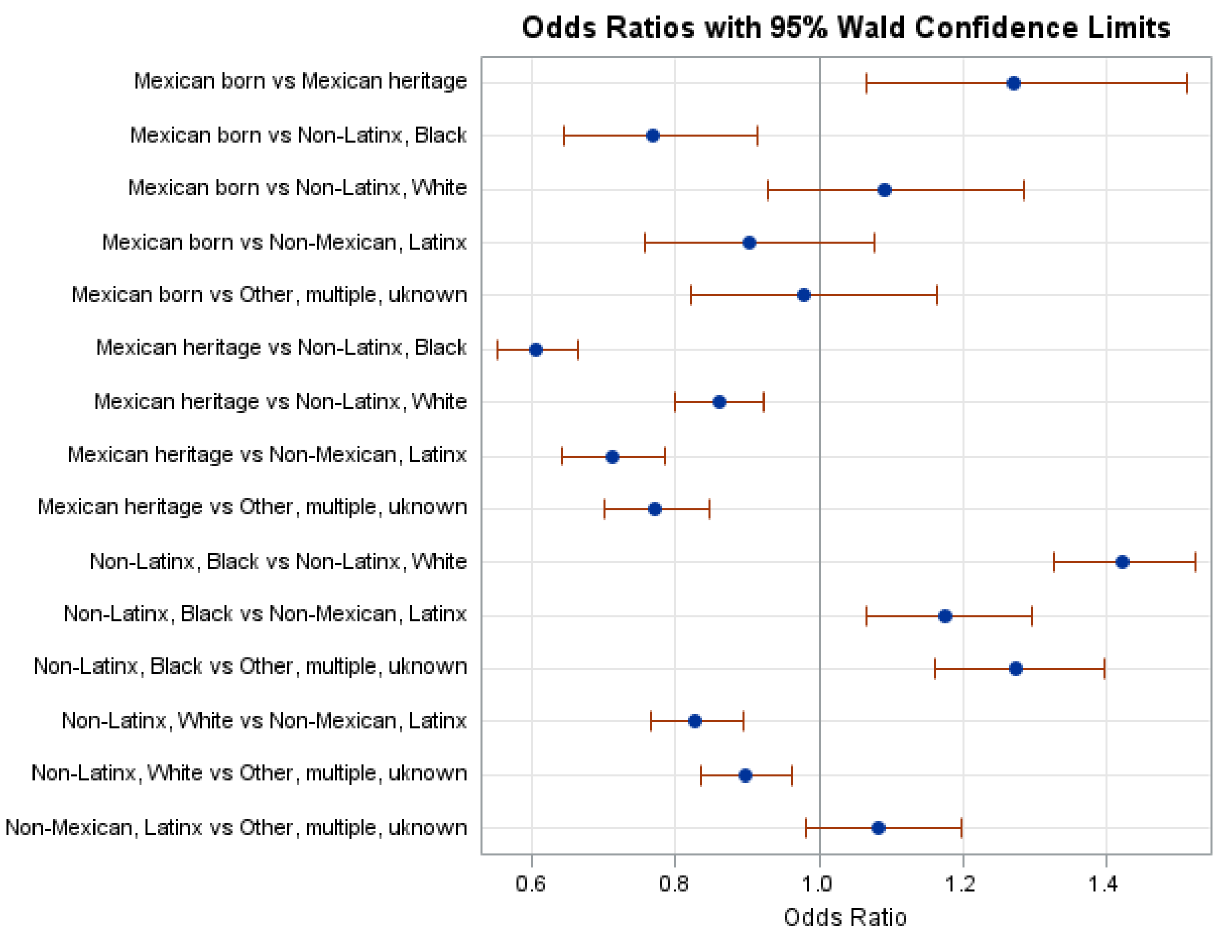
Table 3.4. HIV Status Among Men Who Have Sex with Men in the U.S. – AMIS, 2018-2021

Cycle	N	HIV Status		Mexican MSM	HIV Status	
		Positive (%)	Negative/unknown (%)		Positive (%)	Negative/unknown (%)
2018	10,129	616 (6.1)	9,513 (93.9)	107	5 (4.7)	102 (95.3)
2019	10,130	903 (8.9)	9,227 (91.1)	103	5 (4.9)	98 (95.1)
2020	13,081	915 (7.0)	12,166 (93.0)	194	6(3.1)	188 (96.9)
2021	9,061	1,301 (14.4)	7,760 (85.6)	175	16 (9.1)	159 (90.9)
Total	42,401	3,735 (8.8)	38,666 (91.2)	579	32 (5.5)	547 (94.5)

Abbreviations: HIV, human immunodeficiency virus; AMIS, American Men's Internet Survey

The largest proportion of frequent HIV testing was among participants self-identified as non-Latinx Black (62.1%), and the largest proportion of participants that reported never being tested for HIV was those with Mexican heritage (28.4%). In adjusted analyses, non-Latinx Black were more likely to being more frequently tested and MSM of Mexican heritage were less likely to being tested, compare to all other race/ethnicity groups (Figure 3.2).

Figure 3.2. Adjusted analysis of HIV Testing Frequency by Ethnicity/Race groups Among HIV Negative/Unknown Status Men Who Have Sex with Men – AMIS, 2018-2021



*Adjusted odds ratios (aOR) and their 95% confidence intervals (CI) were obtained via ordinal logistic regression models and adjusted for age, education and insurance type.

Participants with a Mexican heritage were 30% (aOR = 0.69; 95%CI: 0.62, 0.76) less likely to have a more recent HIV test compared to non-Latinx Black participants. Non-Mexican Latinx participants (aOR = 0.87; 95%CI: 0.78, 0.96), and non-Latinx White participants (aOR =

0.60, 95%CI: 0.55, 0.64) were also significantly less likely to have received a more recent HIV test compared to non-Latinx Black participants (Table 3.5).

Table 3.5. Frequencies and aOR of HIV Testing Frequency by Ethnicity Among HIV Negative/Unknown Status Men Who Have Sex with Men – AMIS, 2018-2021

	Frequent testing n/N (%)	Infrequent testing n/N (%)	Never testing n/N (%)	aOR[a] (95%CI)	p-value
Mexican born	304/547 (55.6)	127/547 (23.2)	116/547 (21.2)	0.85 (0.71, 1.02)	0.272
Mexican heritage	1529/2966 (51.6)	596/2966 (20.1)	841/2966 (28.4)	0.69 (0.62, 0.76)	< 0.001
Non-Mexican Latinx	1582/2671 (59.2)	509/2671 (19.1)	580/2671 (21.7)	0.87 (0.78, 0.96)	0.005
Non-Latinx Black	2247/3618 (62.1)	741/3618 (20.5)	630/3618 (17.4)	1.00	
Non-Latinx White	12640/23934 (52.8)	6093/23934 (25.5)	5201/23934 (21.7)	0.60 (0.55, 0.64)	<0.001
Total	20173/36993 (54.5)	8695/36993 (23.5)	8125/36993 (22.0)		

[a] Adjusted odds ratios (aOR) and their 95% confidence intervals (CI) were obtained via ordinal logistic regression models and adjusted for age, education and insurance type.
Abbreviations: HIV, human immunodeficiency virus; AMIS, American Men's Internet Survey

The largest proportion of the 528 Mexican MSM included in the final analytic sample (Table 3.6) had at least a college degree or postgraduate education (37.8%), followed by some college or technical degree (35.3%). The median age was 28 (IQR: 23-37), and the majority of AMIS participants were 29 years old or younger (54.8%). Most participants reported frequent HIV testing (55.6%), received healthcare service through a private institution (54.1%), and almost a third had no healthcare coverage (31.8%).

Table 3.6. Descriptive Sample Characteristics of Mexican MSM Living in the United States – AMIS, 2018-2021

Participants Characteristics	Mexican MSM living in the U.S. n = 547	
	n	%
Predisposing Characteristics		
Age*		
18 to 24	177	32.4
25 to 29	123	22.5
30 to 39	128	23.4

Participants Characteristics	Mexican MSM living in the U.S. n = 547	
	n	%
40+	119	21.8
Education*		
No high school diploma	40	7.4
High school diploma	105	19.5
Some college/Technical degree	190	35.3
College degree or postgraduate education	204	37.8
Disclosure of sexual orientation to a healthcare provider*		
No	111	24.0
Yes	352	76.0
PrEP awareness*		
No	110	20.1
Yes	437	79.9
Enabling Characteristics		
Health insurance coverage		
None	165	31.8
Private only	281	54.1
Public only	46	8.9
Other/Multiple	27	5.2
Income		
Low	80	16.1
Other	417	83.9
Perceived Need Characteristics		
STI diagnosis in last 12 months*		
No	472	86.3
Yes	75	13.7
Illicit non-injection drug use in the last 12 months*		
No	388	71.2
Yes	157	28.8
Condomless anal sex with male partner in the last 12 months *		
No	155	28.3
Yes	392	71.7
HIV testing history*		
Frequent	304	55.6
Infrequent	127	23.2
Never	116	21.2

*ANOVA p-value < 0.05.
Abbreviations: AMIS, American Men's Internet Survey; MSM, men who have sex with men; HIV, human immunodeficiency virus; IQR, interquartile range; SD, standard deviation; PrEP, preexposure prophylaxis; STI, sexual transmitted infections.

Table 3.7 shows the variations in HIV testing frequency by predisposing, enabling, and need factors. Frequent testing was more prevalent among Mexican MSM that reported an STI diagnosis in the last 12 months (82.7%) or have disclosed their sexual orientation to a healthcare provider (65.3%). Mexican MSM that reported an STI diagnosis in the last 12 months (OR = 4.60; 95%CI 2.47, 8.59) or that have disclosed their sexual orientation to a healthcare provider (OR = 5.11; 95%CI: 3.36, 7.76) were 5 times more likely to have a more recent HIV test, compared to those that did not.

Table 3.7. Crude Analysis of Predisposing, Enabling and Need Factors for Health Services Utilization Associated with HIV Testing Frequency Among Mexican MSM Living in the United States – AMIS, 2018-2021

Participants characteristics	Never	Infrequent	Frequent	HIV Testing Frequency
	n (%)	n (%)	n (%)	OR[a] (95% CI)
Predisposing Characteristics				
Age				
18 to 24	56 (31.6)	30 (16.9)	91 (51.4)	1.00
25 to 29	26 (21.1)	33 (26.8)	64 (52.0)	1.23 (0.80, 1.90)
30 to 39	15 (11.7)	30 (23.4)	83 (64.8)	2.12 (1.35, 3.33)
40+	19 (16.0)	34 (28.6)	66 (55.5)	1.47 (0.94, 2.30)
Education				
No high school diploma	11 (27.5)	8 (20.0)	21 (52.5)	1.00
High school diploma	36 (34.3)	21 (20.0)	48 (45.7)	0.73 (0.37, 1.45)
Some college/Technical degree	41 (21.6)	45 (23.7)	104 (54.7)	1.18 (0.62, 2.26)
College degree or postgraduate education	26 (12.7)	50 (24.5)	128 (62.7)	1.74 (0.91, 3.33)
Disclosure of sexual orientation to healthcare provider				
No	50 (45.0)	26 (23.4)	35 (31.5)	1.00
Yes	38 (10.8)	84 (23.9)	230 (65.3)	5.11 (3.36, 7.76)
PrEP awareness				
No	36 (32.7)	40 (36.4)	34 (30.9)	1.00
Yes	80 (18.3)	87 (19.9)	270 (61.8)	2.89 (1.94, 4.28)
Enabling Characteristics				
Health insurance coverage				
None	36 (21.8)	37 (22.4)	92 (55.8)	1.00
Private only	44 (15.7)	71 (25.3)	166 (59.1)	1.22 (0.84, 1.78)
Public only	12 (26.1)	6 (13.0)	28 (60.9)	1.09 (0.58, 2.06)
Other/Multiple	9 (33.3)	6 (22.2)	12 (44.4)	0.59 (0.28, 1.27)

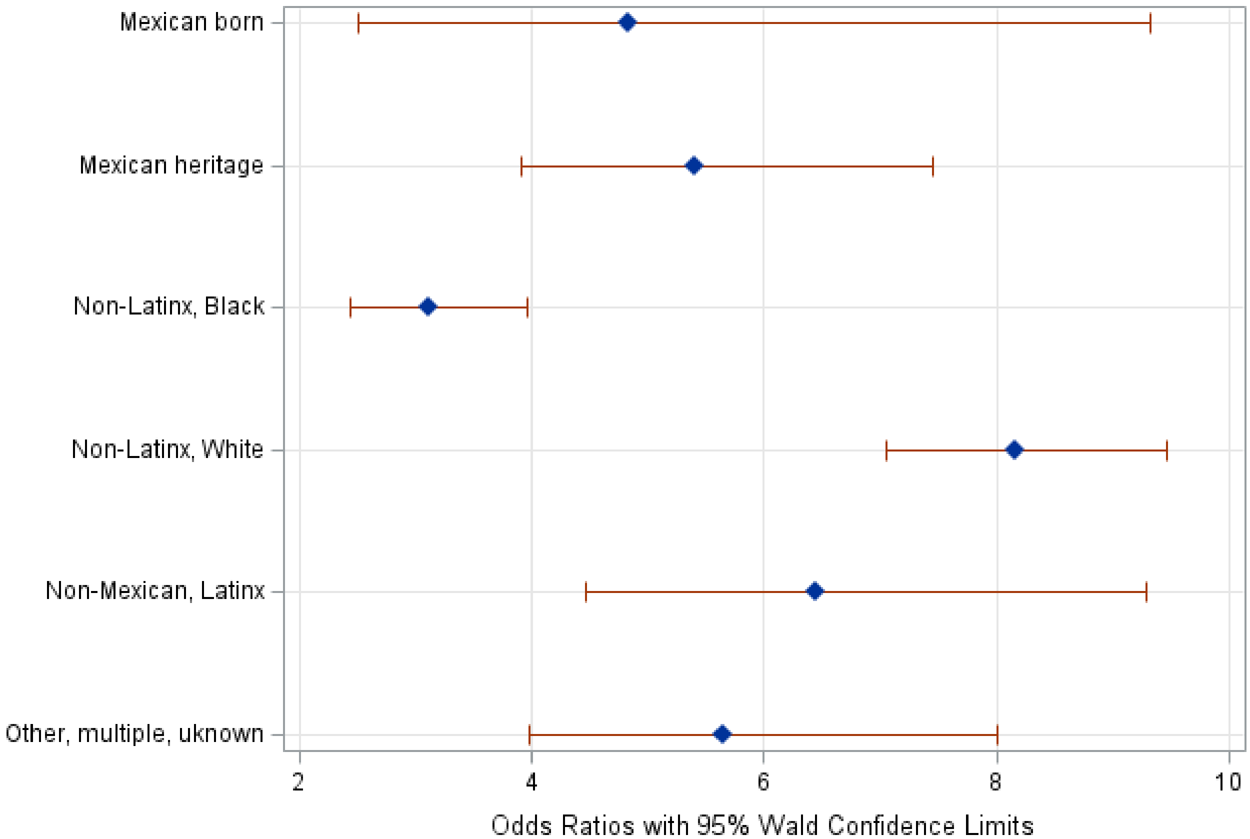
Participants characteristics	Never	Infrequent	Frequent	HIV Testing Frequency
	n (%)	n (%)	n (%)	OR[a] (95% CI)
Income*				
Low	20 (25.0)	14 (17.5)	46 (57.5)	0.95 (0.60, 1.50)
Other	80 (19.2)	103 (24.7)	234 (56.1)	1.00
Perceived Need Characteristics				
STI diagnosis in last 12 months				
No	112 (23.7)	118 (25.0)	242 (51.3)	1.00
Yes	4 (5.3)	9 (12.0)	62 (82.7)	4.60 (2.47, 8.59)
Illicit non-injection drug use in the last 12 months				
No	87 (22.4)	92 (23.7)	209 (53.9)	1.00
Yes	28 (17.8)	35 (22.3)	94 (59.9)	1.29 (0.90, 1.86)
Condomless anal sex with male partner in the last 12 months				
No	53 (34.2)	36 (23.2)	66 (42.6)	1.00
Yes	63 (16.1)	91 (23.2)	238 (60.7)	2.29 (1.61, 3.27)

[a] Odds ratios (OR) and their 95% confidence intervals (CI) were obtained via ordinal logistic regression models for those associations that met the proportional odds assumption; otherwise, separate bivariate logistic regressions were estimated. Abbreviations: AMIS, American Men's Internet Survey; MSM, men who have sex with men; HIV, human immunodeficiency virus; PrEP, preexposure prophylaxis; STI, sexual transmitted infections.

The odds of having a more recent HIV test were 1.44 times (95%CI: 1.17, 1.77) higher for Mexican MSM with private insurance compare to participants without healthcare coverage. Participants that reported being aware about PrEP (OR = 2.89; 95%CI: 1.94, 4.28) or had condomless anal sex with a male partner in the past 12 months (OR = 2.29; 95%CI: 1.61, 3.27) were more likely to have a more recent HIV test. No associations between HIV testing frequency and education, income or illicit non-injection drug use in the last 12 months were observed (Table 3.7).

Given the strong association between HIV testing frequency and STI diagnosis we decided to examined the strength of this association by race and ethnicity (Figure 3.3). Although we did not find effect modification for Mexican born MSM (aOR = 4.84; 95%CI 2.51 – 9.32) or MSM with Mexican heritage (aOR = 5.41; 95%CI 3.91 - 7.46), compared to the other race/ethnicity groups; we found that Non-Latinx Black MSM (aOR = 3.11; 95%CI 2.43 – 3.97) were 2 to 3 times less likely to have a more recent HIV test when diagnosed with an STI than Non-Latinx White (8.17; 95%CI 7.05 – 9.47).

Figure 3.3. Adjusted association of HIV Testing Frequency and STI Diagnosis in last 12 Months by Race and Ethnicity, AMIS



*Adjusted odds ratios (aOR) and their 95% confidence intervals (CI) were obtained via ordinal logistic regression models and adjusted for age, education, income and insurance type.

3.3.3 Comparison of the two populations

When comparing Mexican MSM living in Mexico and the US, the median age for ESEH and AMIS participants was similar, 26 years old (IQR: 22-31) and 28 (IQR: 23-37), respectively. However, the proportion of Mexican MSM aged 40 years or older was significantly higher for those living in the U.S. compared to those living in Mexico (21.8% vs 8.9%; p<0.001). While approximately two-thirds (66.1%) of Mexican MSM living in Mexico, that participated in the ESEH survey, reported a college degree or postgraduate education, only one-third (37.8%) of

Mexican AMIS participants had at least a college degree. When including those with some college or technical degree, the proportions were very similar (74.0% vs. 73.1%). However, after adjusting by age, Mexican MSM living in the U.S. were significantly less likely to have at least a high school diploma (aPR = 0.95; 95%CI: 0.93, 0.97) and some college education (aPR = 0.90; 95%CI: 0.85, 0.96) compared to MSM in Mexico (Table 3.8).

Table 3.8. Comparison of the Individual Characteristics of Mexican MSM Living in Mexico and the U.S. – ESEH, 2017 & AMIS, 2018-2021

Participants Characteristics	**MSM living in Mexico n = 14,225**		**Mexican MSM living in the U.S. n = 547**		**aPR[a]**	
	n	%	n	%	(95% CI)	**p-value**
Predisposing Characteristics						
High school diploma [b]	13,608	97.4	499	92.6	0.95 (0.93, 0.97)	<0.001
Some college education [b]	10,347	74.0	394	73.1	0.90 (0.85, 0.96)	<0.001
Disclosure of sexual orientation to a healthcare provider [c]	6,480	46.6	352	76.0	1.45 (1.37, 1.53)	<0.001
Heard about PrEP [d,e]	4762	54.9	437	79.9	1.60 (1.52, 1.69)	<0.001
Enabling Characteristics						
Health insurance coverage [f]						
None vs. some	1845	14.9	165	31.8	2.00 (1.74, 2.30)	<0.001
Private only vs. not private only	588	4.7	281	54.1	13.31 (11.88, 14.90)	<0.001
Public only vs. not public only	8578	69.1	46	8.9	0.13 (0.10, 0.17)	<0.001
Low income [g]	1797	16.1	80	16.1	0.86 (0.69, 1.06)	0.165
Perceived Need Characteristics						
STI diagnosis in last 12 months [h]	1115	8.0	75	13.7	1.74 (1.39, 2.19)	<0.001
Illicit non-injection drug use in the last 12 months [h]	4281	31.6	157	28.8	0.98 (0.85, 1.12)	0.845
Condomless anal sex with male partner in the last 12 months [h]	7202	61.9	392	71.7	1.19 (1.12, 1.26)	<0.001

Abbreviations: ESEH, Encuesta de Sexo Entre Hombres; MSM, men who have sex with men; HIV, human immunodeficiency virus; PrEP, preexposure prophylaxis; STI, sexually transmitted infections.
[a] Adjusted prevalence ratios (aPR) and their 95% confidence intervals (CI) were obtained via Poisson regression models with robust variance estimates for each outcome.[b] Adjusted for age [c] Adjusted for age, education, health coverage and HIV testing [d] Adjusted for age, education, health coverage, HIV testing, and PrEP use [e] Only among participants whose self-reported ever tested for HIV [f] Adjusted for age and education [g] Adjusted for age, education and health coverage [h] Adjusted for age, education, health coverage and HIV testing.

Compared to Mexican MSM living in Mexico, Mexican MSM living in the U.S were significantly more likely to report no healthcare coverage, independently of age or education, to have disclosed their sexual orientation to a healthcare provider (aPR = 1.45; 95%CI: 1.37, 1.53), to have heard about PrEP prior the survey (aPR = 1.60; 95%CI: 1.52, 1.69), to report STI diagnosis (aPR =1.74; 95%CI: 1.39, 2.19) in the past 12 months, and to report anal sex without a condom (aPR = 1.19; 95%CI: 1.12, 1.26) in the last 12 months.

Overall, 34.6% of the ESEH participants reported never being tested and 40.8% reported frequent testing; while 21.2% of Mexican MSM in AMIS and 55.6% reported the same respectively. In adjusted analysis, Mexican MSM living in the U.S were approximately 2 times (aOR = 1.91; 95%CI: 1.60, 2.28) more likely to report a more recent HIV test, compared to Mexican MSM living in Mexico, independently of age, education, and health coverage.

Disclosure of sexual orientation to a healthcare provider was significantly associated with a more recent HIV test in both Mexican MSM living in Mexico and in the United States, independently of low income, age, education and healthcare coverage (Table 3.9). However, only 46.6% of MSM in Mexico reported disclosing their sexual orientation to a healthcare provider vs 76% in the US. This could indicate higher positive beliefs and attitudes towards health services in the US vs. Mexico.

PrEP awareness prior to the survey, independently of PrEP use, was also associated with more frequent HIV testing among MSM in both populations. However, this association was stronger for Mexican MSM living in the US where the odds of having a more recent HIV test were 7 times higher for Mexican MSM that has heard about PrEP, compared to Mexican MSM that were unaware of PrEP. STI diagnosis in the past 12 months was significantly associated with a more recent HIV test in both Mexican MSM living in Mexico and in the United States, independently of low income, age, education and healthcare coverage (Table 3.9). These odds were higher among Mexican MSM with an STI diagnosis in the last 12 months living in the U.S.

(aOR = 4.57; 95%CI: 2.38, 8.77) than for MSM living in Mexico with an STI diagnosis in the last 12 months (aOR = 2.32; 95%CI: 2.01, 2.68), compared to MSM without an STI diagnosis.

Table 3.9. Adjusted Analysis of Predisposing, Enabling and Need Factors for Health Services Utilization Associated with HIV Testing Frequency Among Mexican MSM Living in Mexico and in the United States

Factors associated with HIV testing	ESEH, 2017 aOR[a] (95% CI)	AMIS, 2018-2021 aOR[a] (95% CI)	p-value
Predisposing Factors			
High school diploma	1.88 (1.50, 2.36)	1.39 (0.69, 2.79)	0.4161
Some college education	1.67 (1.53, 1.82)	1.75 (1.18, 2.59)	0.8217
Disclosure of sexual orientation	4.11 (3.80, 4.44)	4.03 (2.57, 6.32)	0.9312
Heard about PrEP	1.64 (1.47, 1.82)	6.93 (4.16, 11.55)	<0.0001
Enabling Factors			
Low income	0.87 (0.50, 1.85)	1.38 (0.85, 2.26)	0.0672
Health insurance coverage [c]			
None	0.88 (0.79, 0.97)	1.15 (0.78, 1.68)	0.1778
Private only	1.12 (0.94, 1.33)	0.95 (0.66, 1.35)	0.4015
Public only	0.92 (0.85, 1.00)	1.03 (0.55, 1.95)	0.7382
Perceived Need Factors	0.86 (0.78, 0.96)	1.34 (0.80, 2.26)	
STI diagnosis in last 12 months	2.32 (2.01, 2.68)	4.57 (2.38, 8.77)	0.0467
Illicit non-injection drug use in the last 12 months	1.51 (1.39, 1.64)	1.42 (0.95, 2.10)	0.7498
Condomless anal sex in the last 12 months	1.11 (1.03, 1.21)	2.21 (1.49, 3.27)	0.0009

Adjusted odds ratios (aOR) and their 95% confidence intervals (CI) were obtained via ordinal logistic regression models. Education was adjusted for low income and age; low income was adjusted for age, education and health coverage; PrEP awareness, disclosure of sexual orientation, STI diagnosis, drug use and condomless anal sex were adjusted for age, education, income and health coverage.
PrEP awareness was analyzed only among participants whose self-reported ever tested for HIV and never using PrEP.
Interaction terms were used to test effect modification by migration status

3.3.4 Annual HIV screening rates estimates for Mexican MSM in Mexico and in the U.S.

The overall estimated annual HIV screening rate was on average 1.19 (95%CI 1.09, 1.3-0) tests per year for Mexican MSM living in the U.S. and 0.93 (95%CI 0.91, 0.96) tests per year for MSM living in Mexico (Table 3.10). HIV screening rates among Mexican MSM aged 24 years old or younger (0.76; 95%CI: 0.73, 0.79) were significantly lower when compared to the other age groups (Table 3.10). Among Mexican MSM living in the US, HIV screening rates were higher for those with a college degree or postgraduate education (1.57; 95% CI: 1.38, 1.76)

Report of condomless anal sex with male partner in the last 12 months was associated with a higher HIV screening rate (1.35; 95% CI: 1.22, 1.48 vs. 0.79; 95% CI: 0.63, 0.94) among Mexican MSM living in the U.S., but not for Mexican MSM living in Mexico (0.94; 95% CI: 0.91, 0.97 vs 0.92; 95% CI: 0.89, 0.96). STI diagnosis in the last 12 months, illicit non-injection drug use in the last 12 months, unprotected anal sex in the last 12 months and PrEP awareness, were all associated with higher HIV screening rates (Table 3.10).

Table 3.10. Observed annual HIV screening rates for Mexican MSM living in the U.S. and estimated annual HIV screening rates for MSM in Mexico

Participants Characteristics	MSM in Mexico		Mexican MSM in the U.S.	
	Mean	95% CI	Mean	95% CI
All	0.93	0.91, 0.96	1.19	1.09, 1.30
Age				
18 to 24	0.76	0.73, 0.79	0.97	0.80, 1.13
25 to 29	1.03	0.99, 1.07	1.18	0.97, 1.40
30 to 39	1.07	1.03, 1.11	1.33	1.12, 1.54
40+	1.12	1.05, 1.18	1.38	1.13, 1.62
Education				
No high school diploma	0.62	0.53, 0.71	0.94	0.60, 1.27
High school diploma	0.71	0.67, 0.74	0.87	0.67, 1.07
Some college/Technical degree	0.83	0.78, 0.89	1.00	0.86, 1.14
College degree or postgraduate education	1.04	1.00, 1.08	1.57	1.38, 1.76
Health insurance coverage				
None	0.84	0.79, 0.89	1.03	0.87, 1.19
Private only	1.05	0.97, 1.13	1.27	1.13, 1.42
Public only	0.91	0.88, 0.94	1.24	0.88, 1.60
Other/Multiple	1.13	1.07, 1.19	1.22	0.66, 1.78
Income				
Low	0.78	0.73, 0.83	1.05	0.83, 1.27
Other	0.96	0.93, 0.99	1.22	1.10, 1.33
Disclosure of sexual orientation to a healthcare provider				
No	0.63	0.60, 0.66	0.58	0.44, 0.73
Yes	1.28	1.25, 1.32	1.44	1.31, 1.56
PrEP awareness				
No	0.81	0.77, 0,85	0.59	0.45, 0.73
Yes	1.05	1.00, 1.09	1.34	1.22, 1.46
STI diagnosis in last 12 months				

Participants Characteristics	MSM in Mexico		Mexican MSM in the U.S.	
	Mean	95% CI	Mean	95% CI
No	0.90	0.87, 0.93	1.08	0.98, 1.19
Yes	1.34	1.26, 1.41	1.86	1.57, 2.15
Illicit non-injection drug use in the last 12 months				
No	0.88	0.85, 0.91	1.10	0.98, 1.21
Yes	1.05	1.01, 1.09	1.42	1.21, 1.63
Condomless anal sex with male partner in the last 12 months				
No	0.92	0.89, 0.96	0.79	0.63, 0.94
Yes	0.94	0.91, 0.97	1.35	1.22, 1.48
Region				
Northwest	0.88	0.83, 0.93		
Northeast	0.90	0.85, 0.96		
Mexico City & Mexico State	1.01	0.97, 1.05		
Center	0.87	0.82, 0.91		
West & Bajio	0.88	0.84, 0.92		
South	0.94	0.89, 1.00		

3.4 Discussion

Results showed that disclosure of sexual orientation to a healthcare provider, recent STI diagnosis and PrEP awareness, independently of PrEP use, were strongly associated with more frequent HIV testing. However, MSM living in Mexico were less likely to disclose their sexual orientation to a healthcare provider, in comparison to Mexican MSM living in the United States. Disclosure of sexual orientation to a healthcare provider is a predisposing factor associated with positive beliefs and attitudes towards health service utilization (66). Therefore, results from this analysis may indicate a higher fear of stigma and discrimination in the Mexican setting, suggesting more stigma reduction interventions in healthcare settings in Mexico are needed.

CDC recommends HIV testing for all persons seeking STI evaluation as a routine test at the time of the STI evaluation, regardless of whether the patient reports any specific behavioral risks for HIV. If HIV testing is not performed at the initial STI evaluation and screening it should be performed at the time of STI diagnosis and treatment. Our analysis showed that 14% of

Mexican born AMIS participants and 8% of ESEH participants reported a STI diagnosis in the last 12 months. However, 41% and 17% respectively were not screened for HIV, representing a missed opportunity for HIV testing. In the US, new HIV infections between 2010 and 2019 decreased among White MSM but not among Black or Latinx MSM and even increased among some age groups within these populations (15,42,44). MSM of Mexican heritage the group less likely to get tested for HIV and non-Latinx black MSM were 2 to 3 times less likely to have a more recent HIV test when diagnosed with an STI than Non-Latinx White. Further research is needed to understand differences in HIV testing within the Latinx community, and to strength policy implementation in all subpopulation to reduce observed disparities and promote PrEP and ensure HIV testing during STI diagnosis in both the Mexican and US setting.

Some limitations exist with this approach. First, surveys used a web-based recruitment method, which is a convenience sample, and therefore, results are not generalizable to all Mexican MSM living in Mexico or the US, or to all MSM online. Also, data were self-reported, which may result in misclassification bias due to recall bias or social desirability. However, participants completed the survey online without facing an interviewer which might have reduced some of this social desirability bias. This study presents two important strengths. First, it’s one of the few studies comparing the results of Mexican MSM living in Mexico and in the United States. Elucidating important information regarding similarities and differences of the Mexican MSM experience in different settings. Secondly, by using an ordinal regression for the analysis we were able to use the data at its fullest, by preserving the ordering of the main outcome and increasing the statistical power of the sample.

3.6 Supplemental materials

Table 3.11. Bivariate Logistic Regression of Predisposing, Enabling and Need Factors for Health Services Utilization Associated with HIV Testing Frequency Among Mexican MSM Living in Mexico – ESEH, 2017

Participants characteristics	Binary Logistic Regression	
	Frequent vs. Not frequent OR[a] (95% CI)	**Not never vs. Never** OR[a] (95% CI)
Predisposing Characteristics		
Age		
18 to 24	1.00	1.00
25 to 29	1.52 (1.39, 1.65)	2.55 (2.33, 2.79)
30 to 39	1.50 (1.37, 1.64)	3.80 (3.43, 4.21)
40+	1.57 (1.38, 1.79)	5.17 (4.37, 6.11)
Education		
No high school diploma	1.00	1.00
High school diploma	1.30 (1.01, 1.68)	1.01 (0.80, 1.26)
Some college/Technical degree	1.71 (1.31, 2.23)	1.57 (1.24, 2.00)
College degree or postgraduate education	2.34 (1.84, 2.99)	2.70 (2.17, 3.35)
Region		
Mexico City & Mexico State	1.00	1.00
Center	0.74 (0.66, 0.82)	0.75 (0.67, 0.83)
Northwest	0.74 (0.66, 0.84)	0.78 (0.69, 0.89)
Northeast	0.80 (0.71, 0.90)	0.78 (0.69, 0.88)
West & Bajio	0.76 (0.69, 0.84)	0.76 (0.68, 0.84)
South	0.88 (0.78, 0.98)	0.86 (0.76, 0.97)
Disclosure of sexual orientation to healthcare provider		
No	1.00	1.00
Yes	3.9 (3.63, 4.20)	6.21 (5.71, 6.77)
PrEP awareness[b]		
No	1.00	NA
Yes	1.60	NA
Enabling Characteristics		
Health insurance coverage		
None	1.00	1.00
Private only	1.55 (1.28, 1.88)	1.44 (1.17, 1.77)
Public only	1.15 (1.04, 1.28)	1.02 (0.92, 1.14)
Other/Multiple	1.80 (1.56, 2.08)	1.69 (1.45, 1.98)
Income		
Low	0.74 (0.66, 0.82)	0.58 (0.52, 0.64)

Participants characteristics	Binary Logistic Regression	
	Frequent vs. Not frequent OR[a] (95% CI)	Not never vs. Never OR[a] (95% CI)
Other	1.00	1.00
Perceived Need Characteristics		
STI diagnosis in last 12 months		
No	1.00	1.00
Yes	2.29 (2.01, 2.60)	2.70 (2.29, 3.20)
Illicit non-injection drug use in the last 12 months		
No	1.00	1.00
Yes	1.40 (1.30, 1.51)	1.42 (1.31, 1.54)
Condomless anal sex with male partner in the last 12 months		
No	1.00	1.00
Yes	0.95 (0.88, 1.03)	1.07 (0.99, 1.16)

[a] Odds ratios (OR) and their 95% confidence intervals (CI) were obtained via ordinal logistic regression models for those associations that met the proportional odds assumption; otherwise, separate bivariate logistic regressions were estimated.
[b] Only among participants whose self-reported ever tested for HIV.
Abbreviations: ESEH, Encuesta de Sexo Entre Hombres; MSM, men who have sex with men; HIV, human immunodeficiency virus; PrEP, preexposure prophylaxis; STI, sexual transmitted infections.

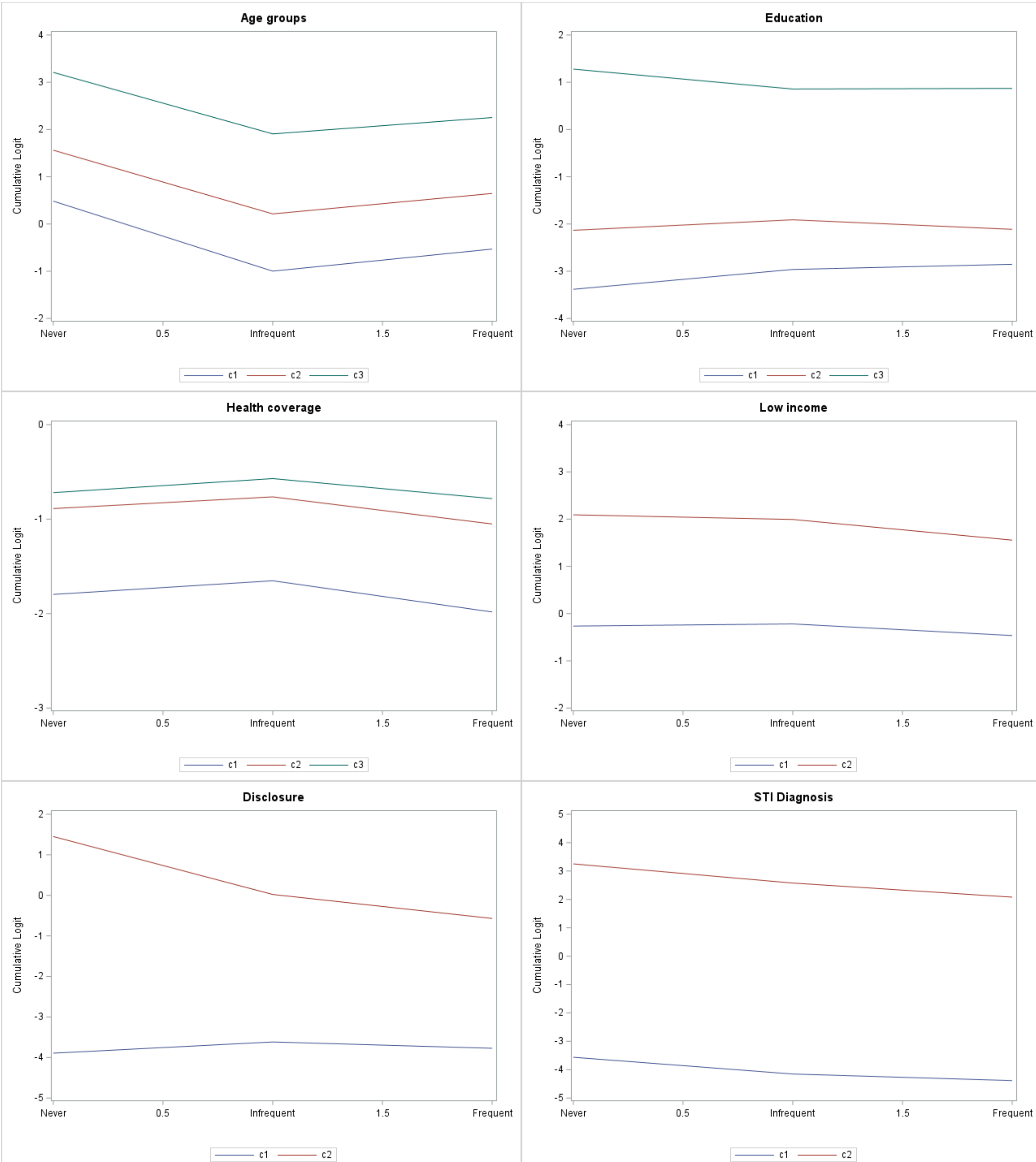
Table 3.12. Bivariate Logistic Regression of Predisposing, Enabling and Need Factors for Health Services Utilization Associated with HIV Testing Frequency Among Mexican MSM Living in the United States – AMIS, 2018-2021

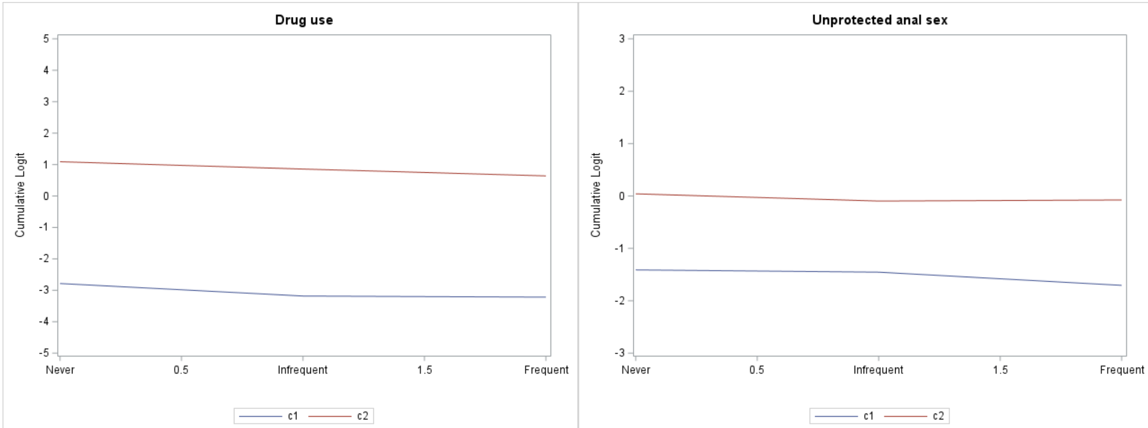
Participants characteristics	Binary Logistic Regression	
	Frequent vs. Not frequent OR[a] (95% CI)	Not never vs. Never OR[a] (95% CI)
Predisposing Characteristics		
Age		
18 to 24	1.00	
25 to 29	1.03 (0.65, 1.63)	1.73 (1.01, 2.95)
30 to 39	1.74 (1.09, 2.78)	3.49 (1.87, 6.51)
40+	1.18 (0.74, 1.88)	2.44 (1.36, 4.37)
Education*		
No high school diploma	1.00	
High school diploma	0.76 (0.37, 1.58)	0.73 (033, 1.62)
Some college/Technical degree	1.09 (0.55, 2.17)	1.38 (0.64, 2.99)
College degree or postgraduate education	1.52 (0.77, 3.02)	2.60 (1.16, 5.82)
Disclosure of sexual orientation to healthcare provider		
No	1.00	
Yes	4.09 (2.59, 6.46)	6.77 (4.10, 11.20)

<table>
<tr><th rowspan="2">Participants characteristics</th><th colspan="2">Binary Logistic Regression</th></tr>
<tr><th>Frequent vs. Not frequent
OR[a] (95% CI)</th><th>Not never vs. Never
OR[a] (95% CI)</th></tr>
<tr><td>PrEP awareness</td><td></td><td></td></tr>
<tr><td>No</td><td colspan="2">1.00</td></tr>
<tr><td>Yes</td><td>3.61 (2.31, 5.66)</td><td>2.17 (1.36, 3.46)</td></tr>
<tr><td>Enabling Characteristics</td><td></td><td></td></tr>
<tr><td>Health insurance coverage</td><td></td><td></td></tr>
<tr><td>None</td><td>1.00</td><td></td></tr>
<tr><td>Private only</td><td>1.15 (0.78, 1.69)</td><td>1.44 (1.17, 1.77)</td></tr>
<tr><td>Public only</td><td>1.23 (0.63, 2.41)</td><td>1.02 (0.92, 1.14)</td></tr>
<tr><td>Other/Multiple</td><td>0.64 (0.28, 1.44)</td><td>1.69 (1.45, 1.98)</td></tr>
<tr><td>Income*</td><td></td><td></td></tr>
<tr><td>Low</td><td>1.06 (0.65, 1.72)</td><td>0.71 (0.41, 1.23)</td></tr>
<tr><td>Other</td><td>1.00</td><td></td></tr>
<tr><td>Perceived Need Characteristics</td><td></td><td></td></tr>
<tr><td>STI diagnosis in last 12 months</td><td></td><td></td></tr>
<tr><td>No</td><td colspan="2">1.00</td></tr>
<tr><td>Yes</td><td>4.53 (2.43, 8.46)</td><td>5.52 (1.97, 15.46)</td></tr>
<tr><td>Illicit non-injection drug use in the last 12 months</td><td></td><td></td></tr>
<tr><td>No</td><td colspan="2">1.00</td></tr>
<tr><td>Yes</td><td>1.28 (0.88, 1.86)</td><td>1.33 (0.83, 2.14)</td></tr>
<tr><td>Condomless anal sex with male partner in the last 12 months</td><td></td><td></td></tr>
<tr><td>No</td><td colspan="2">1.00</td></tr>
<tr><td>Yes</td><td>2.08 (1.43, 3.04)</td><td>2.71 (1.77, 4.16)</td></tr>
</table>

[a] Odds ratios (OR) and their 95% confidence intervals (CI) were obtained via ordinal logistic regression models for those associations that met the proportional odds assumption; otherwise, separate bivariate logistic regressions were estimated.
[b] Only among participants whose self-reported ever tested for HIV.
Abbreviations: AMIS, American Men's Internet Survey; MSM, men who have sex with men; HIV, human immunodeficiency virus; PrEP, preexposure prophylaxis; STI, sexual transmitted infections.

Figure 3.4. Empirical logit plot to test the proportional odds assumption for each independent variable – ESEH, 2017


Age groups
Education
Health coverage
Low income
Disclosure
STI Diagnosis
Cumulative Logit
Never
0.5
Infrequent
1.5
Frequent
c1
c2
c3



Drug use
Cumulative Logit
5
4
3
2
1
0
-1
-2
-3
-4
-5
Never
0.5
Infrequent
1.5
Frequent
c1
c2
Unprotected anal sex
Cumulative Logit
3
2
1
0
-1
-2
-3
Never
0.5
Infrequent
1.5
Frequent
c1
c2

4 EFFECT OF INCREASING HIV TESTING FREQUENCY AMONG MSM IN MEXICO'S HIV EPIDEMIC

4.1 INTRODUCTION

Trends in new HIV infection and AIDS-related deaths worldwide are driven by the availability of HIV prevention, testing, and treatment services (7). UNAIDS estimates that 1.5 million new HIV infections occurred worldwide in 2021, a decrease of only 3.6% compared to 2020, showing that global progress is slowing (7). Transmission of HIV occurs primary during unprotected sex or when in contact with non-sterile syringes and needles. Multiple strategies exist to prevent HIV infection, such as sterile syringe services, condom distribution programs, STI diagnosis and treatment, male circumcision, HIV testing, Pre-exposure Prophylaxis (PrEP), and Treatment as Prevention (TaP). TaP consist on the use of antiretroviral therapy to achieve and maintain viral suppression in people who are living with HIV; PrEP is a medication people at risk of HIV takes to prevent HIV infection during unprotected sex or when injection drug use. When taken as prescribed, both PrEP and TaP are highly effective strategies to reduce the transmission of HIV infection.

HIV testing services are an essential part of the HIV prevention toolkit, not only because testing reduces the severity of HIV infection through early detection and prompt care. But also, because testing helps reduce the incidence of HIV transmission by being the first step to reaching viral suppression. The "status neutral" continuum of care also propose the use of HIV testing as the entry point to engage people in the continuum of care, independently of their HIV status, meaning both HIV prevention services like PrEP and HIV treatment services can be reached from the HIV testing entry point.

In Mexico, Universal access to ART has been in place since 2001, and great efforts have been made to reduce the cost of antiretroviral drugs to scale up its access. Furthermore, following the World Health Organization recommendations, the Mexican HIV Treatment Guidelines were updated in 2014 to expand universal access to ART to all PLWH independently of their CD4 cell counts and symptoms. This contributed to that of the 200,000 people diagnosed in 2019, 85% were under treatment, and 90% of them reached viral suppression. Despite these advances in the country, the annual number of new infections among adults has hardly changed over the past years, driven by the large proportion of PLWH unaware of their status, ranging from 26 to 38% in some regions, and from 31 to 43% among MSM. Furthermore, during the Covid-19 pandemic in 2020 the National Center for HIV Control and Prevention reported a 49% decrease in the number of annual HIV tests and a 44% decrease in the number of people diagnosed with HIV (16).

Mathematical models provide an opportunity to evaluate the impact of HIV prevention interventions by simulating the transmission dynamics of HIV within a population (22). These models can be use to estimate the number of new HIV infections that would occur under different scenarios of HIV testing uptake. The objective of the study was to develop a dynamic compartmental model of HIV transmission among adult MSM in Mexico (18 to 64 years) to estimate the impact of increasing HIV testing frequency on HIV incidence to inform public health policies for HIV prevention.

4.2 Methods

4.2.1 Study Design

We adapted and extended a dynamic compartmental model of HIV transmission among MSM which was originally built to estimate the impact of later ART initiation in HIV incidence among MSM in Mexico (22). The extended model included a new set of compartments and parameters for never and ever testers divided into young and adult groups. The model was specified by a set of differential equations (Table 4.1) to simulate the HIV epidemic among MSM in Mexico for 120 months, starting in 2021 (Figure 4.1). Each compartment of the model represents one of the steps of the HIV continuum of care: susceptible MSM (S), MSM living with HIV unaware of their status (IU), MSM living with HIV aware of their status (IA), in Antiretroviral treatment with a detectable viral load (TD), and in ART with an undetectable viral load (TU). The model included only sexual transmission of HIV between MSM and did not include HIV transmissions by sharing needles, syringes, or other injection equipment among MSM who had injected illicit drugs.

The assumptions of this model are that unaware PLWH and people not HIV-infected are tested at the same rate, awareness of HIV-positive status changes the HIV transmission risk behaviors (84), that treatment is offered to everyone living with HIV, regardless of CD4 count, and that viral suppression reduces the probability of transmission and mortality. Given no changes in HIV testing frequency after 25 years old were observed on the ESEH survey, the population was divided into two age groups $k \in \{y\ (18-24),\ a(25-64)\}$. MSM in each age group entered the susceptible population by aging (α_y) or by initiating sex with other men (ν_k). Individual left the modeled population by aging from the adult population (α_o), or due to a non-HIV related death (m) or death from HIV-related causes (μ). The model was implemented in the R programming language with the EpiModel library.

Table 4.1. Compartmental Model Equations

$$\frac{\mathrm{d}S_y}{\mathrm{dt}} = \nu_y U_y - S_y\left(\lambda_y + m_y + \alpha_y\right)$$

$$\frac{dIU_{yN}}{dt} = S_y \varepsilon_y \lambda_y - IU_{yN}\left(\theta_y + m_y + \mu_y + \alpha_y\right)$$

$$\frac{dIU_{yE}}{dt} = S_y(1 - \varepsilon_y)\lambda_y + IU_{yN}\theta_y - IU_{yE}\left(\delta_y + m_y + \mu_y + \alpha_y\right)$$

$$\frac{dIA_y}{dt} = \delta_y IU_{yE} - IA_y\left(\rho + m_y + \mu_y + \alpha_y\right)$$

$$\frac{dTD_y}{dt} = \rho IA_y + \gamma TU_y - TD_y\left(\sigma + m_y + \mu_y + \alpha_y\right)$$

$$\frac{dTU_y}{dt} = \sigma TD_y - TU_y(\gamma + m_y + \alpha_y)$$

$$\frac{dS_o}{dt} = \nu_o U_o + S_y \alpha_y - S_o(\lambda_o + m_o + \alpha_o)$$

$$\frac{dIU_{oN}}{dt} = S_o \varepsilon_o \lambda_o + IU_{yN}\alpha_y - IU_{oN}(\theta_{oN} + m_o + \mu_o + \alpha_o)$$

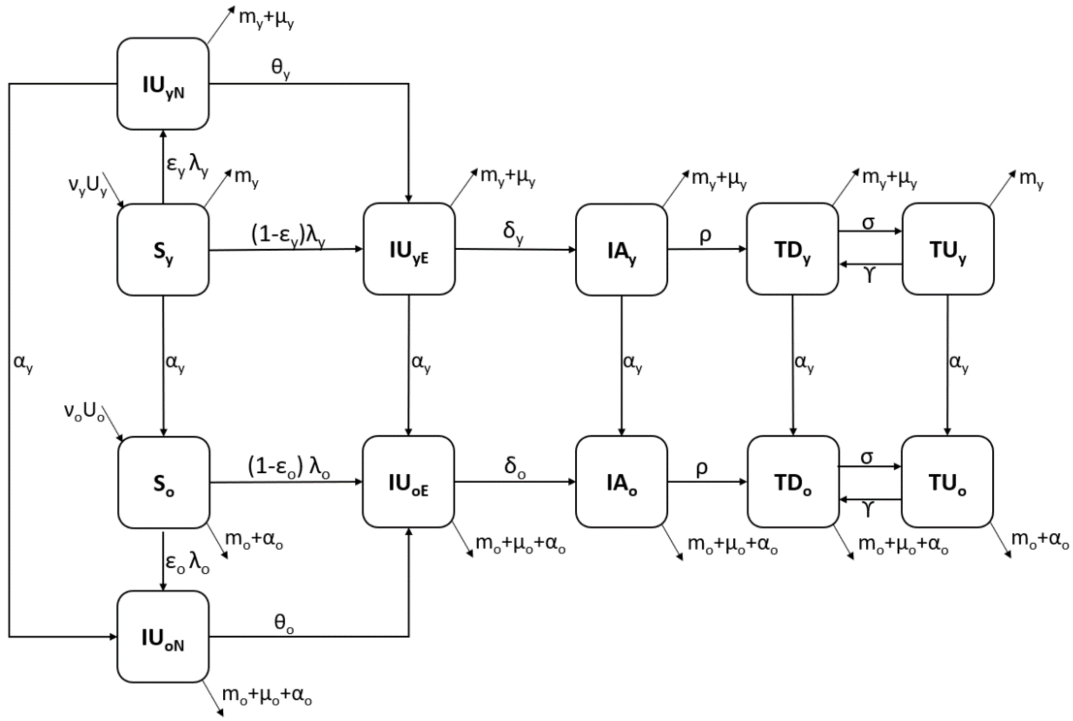
$$\frac{dIU_{oE}}{dt} = S_o(1 - \varepsilon_o)\lambda_o + IU_{oN}\theta_o + IU_{yF}\alpha_y - IU_{oE}(\delta_o + m_o + \mu_o + \alpha_o)$$

$$\frac{dIA_o}{dt} = \delta_o IU_{oE} + IA_y \alpha_y - IA_o(\rho + m_o + \mu_o + \alpha_o)$$

$$\frac{dTD_o}{dt} = \rho IA_o + TD_y \alpha_y + \gamma TU_o - TD_o(\sigma + m_o + \mu_o + \alpha_o)$$

$$\frac{dTU_o}{dt} = \sigma TD_o + TU_y \alpha_y - TU_o(\gamma + m_o + \alpha_o)$$

Figure 4.1. Model of HIV Transmission and Testing



$$N_k(t) = S_k(t) + IU_{kN}(t) + IU_{kF}(t) + IA_k(t) + TD_k(t) + TU_k(t)$$

$$\lambda_k(t) = \lambda IU_{kN}(t) + \lambda IU_{kF}(t) + \lambda IA_k(t) + \lambda TD_k(t) + \lambda TU_k(t)$$

Where
U is the total number of men between 18 to 64 years old in 2020 in Mexico
ν_k is the monthly recruitment rate into the susceptible population age group k
N_k is the total population size of MSM in Mexico
S_k is the number of MSM susceptible to HIV
IU_{kN} is the number of MSM living with HIV unaware of their status never tested
IU_{kE} is the number of MSM living with HIV unaware of their status ever tested
IA_k is the number of MSM living with HIV aware of their status without ART
TD_k is the number of MSM living with HIV in ART with a detectable viral load
TU_k is the number of MSM living with HIV in ART with an undetectable viral load
λ_k is the force of HIV infection
$\varepsilon_k$is the proportion of MSM who have never tested for HIV
θ_k is the transition rate from never testing to ever testing
δ_k is the diagnosis rate
ρ is the rate of ART initiation
σ is the rate of viral suppression
γ is the rate of treatment failure
m is the non-HIV mortality rate among men in Mexico
μ is the HIV-related mortality rate among men in Mexico
α_k is the aging rate for each age group

4.2.2 Model parameterization

Model parameterization (Table 4.2) was performed with epidemiological data from the Mexico's Epidemiological HIV Surveillance System (Mexico's EHSS), the Antiretroviral Management, Logistic and Surveillance System (SALVAR), and the Mexican Men's Internet Survey (ESEH, for its acronym in Spanish). Mexico's EHSS includes all HIV cases diagnosed in Mexico since 1983 and is used to monitor new HIV diagnoses and transmission mechanism. Mexico's EHSS latest annual reports and data from 2017 and earlier years were used for model parameterization. SALVAR is a prospective longitudinal cohort used to monitor ART of PLWH receiving healthcare through the Ministry of Health, and contains patient's socio-demographic information, mode of transmission, antiretroviral regimens, viral loads, and CD4 counts. ESEH was a cross-sectional online sexual health survey of adult MSM living in Mexico between May and June of 2017 (69).

Table 4.2. List of Parameters

	Parameter description	Value	Source
ν_k	Monthly recruitment rate into the susceptible population	$\nu_y = \frac{1}{17y} \times 15.6\%$ $\nu_o = \frac{1}{18y} \times 2.6\%$	Median age at first anal intercourse derived from ESEH & ENDISEG
m_k	Non-HIV-related monthly mortality rate	m_Y =0.000155 m_o =0.000445	(85)
μ_k	HIV-related monthly mortality rate	μ_Y =0.0007 μ_O =0. 0009	(85)
α_k	Aging rate for each age group	$\alpha_y = 1/7y$ $\alpha_o = 1/40y$	
ε_k	Proportion of never testers among infrequent testers	$\varepsilon_y = 0.50$ $\varepsilon_o = 0.25$	Derived from ESEH
θ_k	Transition rate from never testing to sometimes testing and from sometimes to frequent testing	$\delta_y = 1/90$ $\delta_o = 1/90$	Derived from ESEH

	Parameter description	Value	Source
δ	Monthly diagnosis rate	$\theta_y = 1/180$ $\theta_o = 1/90$	(22)
ρ	Monthly rate of ART initiation	${}^{1}/{}_{18}\ to\ {}^{1}/{}_{12}$	Derived from SALVAR
σ	Monthly rate of viral suppression	${}^{1}/{}_{12}\ to\ {}^{1}/{}_{6}$	(86)
γ	Monthly rate of treatment failure	0.0023 + 0.009275	(87,88)

Abbreviations: ART, Antiretroviral therapy; ESEH, Encuesta de Sexo Entre Hombres; HIV, human immunodeficiency virus; d, duration. Treatment failure includes virologic failure and LTFU

HIV testing frequencies and sexual behavior characteristics, including median age at first anal intercourse with males among MSM by age group (18 to 24 median = 17; IQR: 15, 18; 25 to 64 median = 18; IQR: 15, 21), the average number of male sex partners per month and the proportion of anal sex acts protected by condoms were derived from ESEH. Approximately half of MSM aged 18 to 24 had 4 or more male sex partners per year (IQR: 2, 8) and half of MSM aged 25 to 64 had 5 or more male sex partners per year (IQR: 2, 10). The number of anal sex acts per partnership was calculated based on the assumption of 45.9 annual anal intercourse contacts per male partnership for those with 3 or fewer partners (84). Table 25 list the parameters used to estimate the transition rates between compartments.

Figure 4.2. HIV Testing Frequency by Age Group Among MSM in Mexico, ESEH 2017

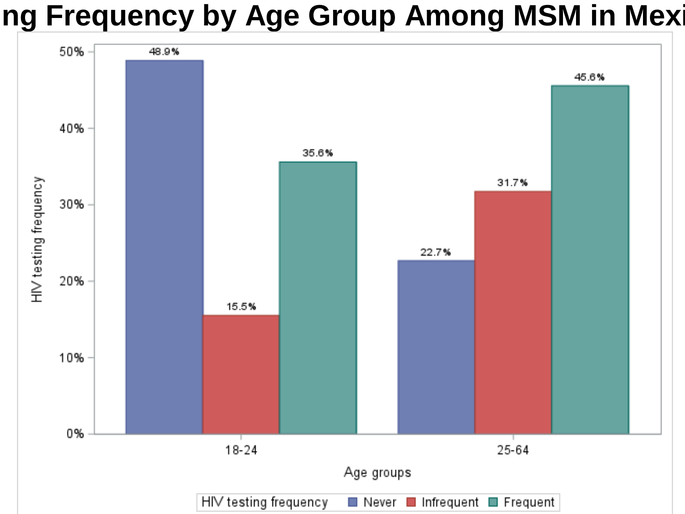


Figure 4.3. Age at First Anal Intercourse Among MSM and Annual Number of Male Sex Partners by Age Group and Self-Reported HIV Status in Mexico, ESEH 2017

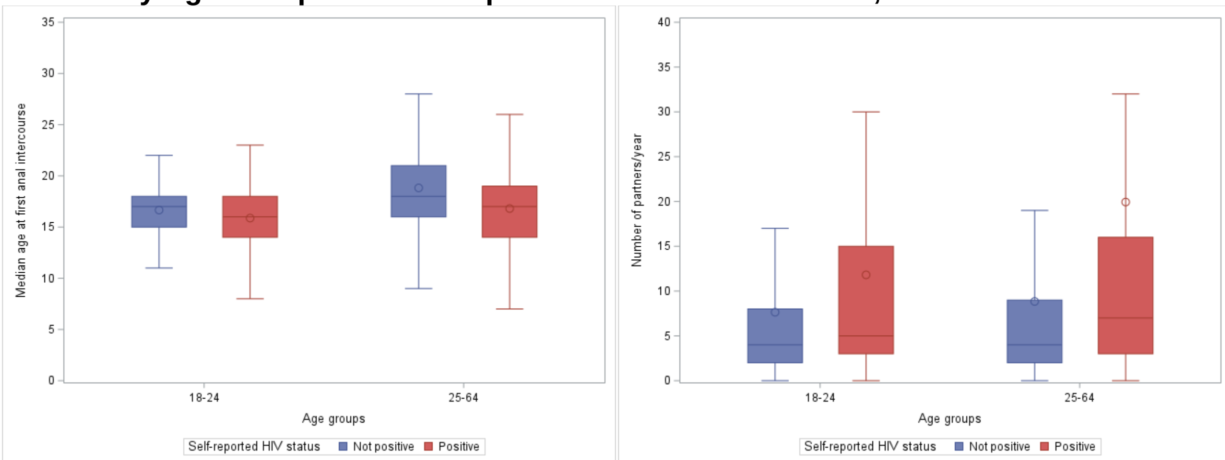


Figure 4.4. STI Diagnosis in the Last Year by HIV Testing Frequency and Age Group Among MSM in Mexico, ESEH 2017

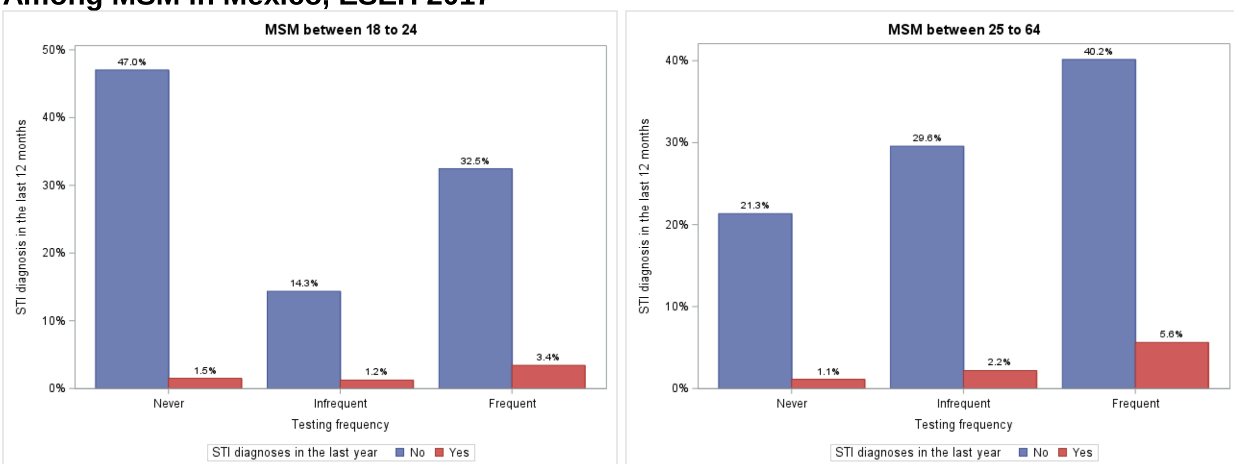


Figure 4.5. Unprotected Anal Sex in the Last Year by HIV Testing Frequency and Age Group Among MSM in Mexico, ESEH 2017

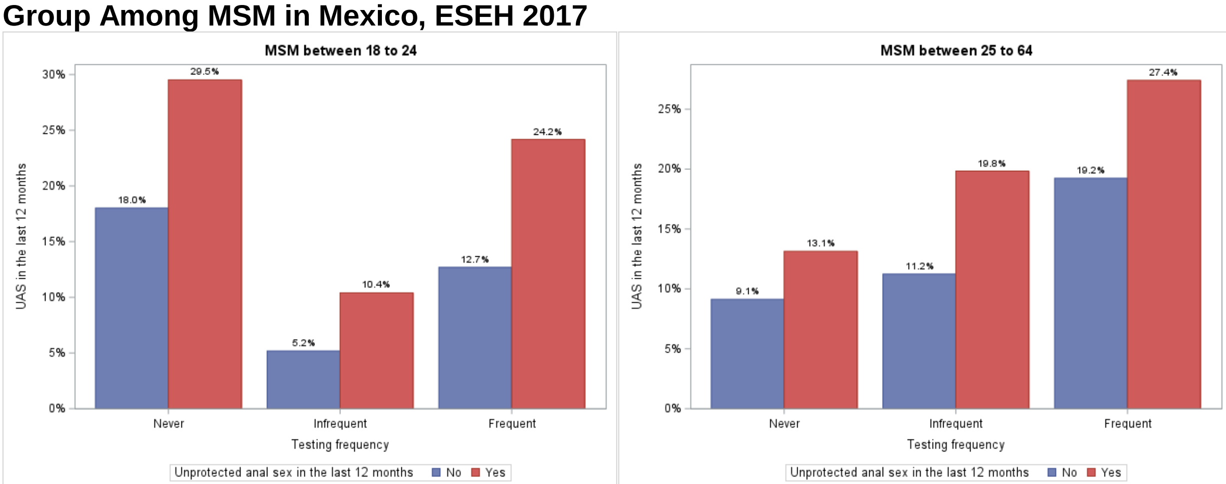
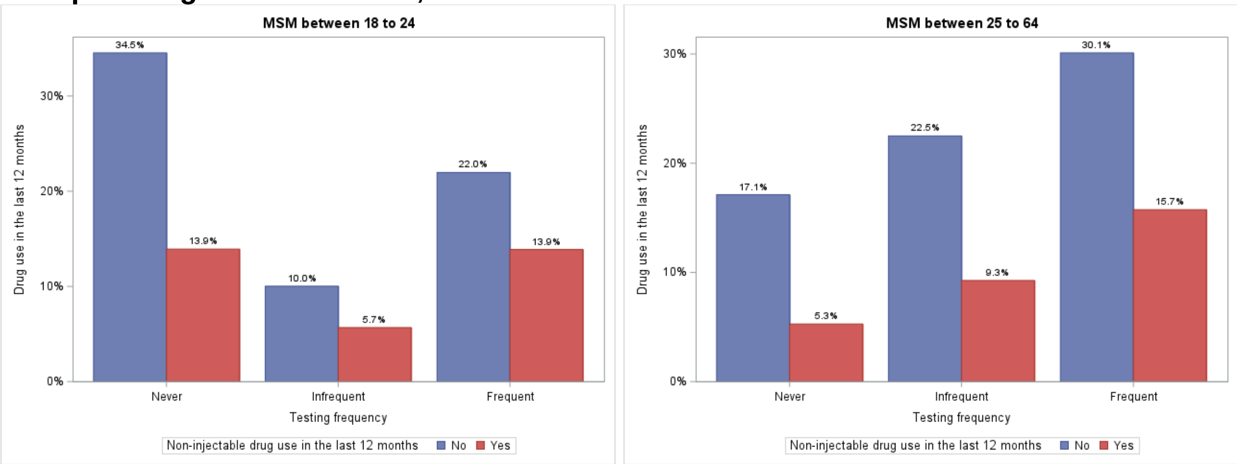


Figure 4.6. Non-Injectable Drug Use in the Last Year by HIV Testing Frequency and Age Group Among MSM in Mexico, ESEH 2017



The age-specific force of HIV infection is the sum of the estimated force of infection for each infected compartment X, where $X \epsilon\ IU_{kN}\ , IU_{kE}, IA_k,\ TD_k,\ TU_k$:

$$\lambda_k(\mathrm{t}) = \lambda\mathrm{IU_{kN}}(\mathrm{t}) + \lambda\mathrm{IU_{kS}}(\mathrm{t}) + \lambda\mathrm{IU_{kF}}(\mathrm{t}) + \lambda\mathrm{IA}_k(\mathrm{t}) + \lambda\mathrm{TD_k}(\mathrm{t}) + \lambda\mathrm{TU_k}(\mathrm{t})$$

The force of infection for compartment X was based on a 2x2 mixing matrix where the total force of infection for age group k is the sum of the of the force of infection for k-k contacts and k-k' contacts:

$$\lambda\mathrm{X}_k(\mathrm{t}) = \lambda\mathrm{X_{kk}}(\mathrm{t}) + \lambda\mathrm{X_{kk'}}(\mathrm{t})$$

The force of infection for k-k contacts and k-k' were estimated using the following equations:

$$\lambda X_{kk}(t) = \beta_x \frac{x}{N_k} \qquad \lambda X_{kk'}(t) = \frac{\beta_{x'}}{2}\left(\frac{x}{N}\right)$$

Where x is the number of MSM living with HIV in each compartment (IU, IA, TD, TU), N is the total number of MSM, and β_x is the transmission probability for each compartment, weighted by sexual activity group $j \in \{\mathrm{H}, \mathrm{L}\}$. The probability of transmission by sexual contact between an MSM living with HIV and a susceptible MSM is a function of (Table 4.3) the number of sexual contacts per partner, the number of sexual partners per month, the proportion of acts protected by condom, and the role during anal sex (insertive or receptive). For this we used the following expression (22) to differentiate the effective contact rate per sexual contact by viral suppression and status awareness:

$$\beta_x = \sum_j w_j \cdot f_j[1 - (1 - ce_x)^{n_j}]$$

$$ce_x = (1 - c_{ka}e)[\tau_{kr}r + \tau_{ki}(1 - r)]$$

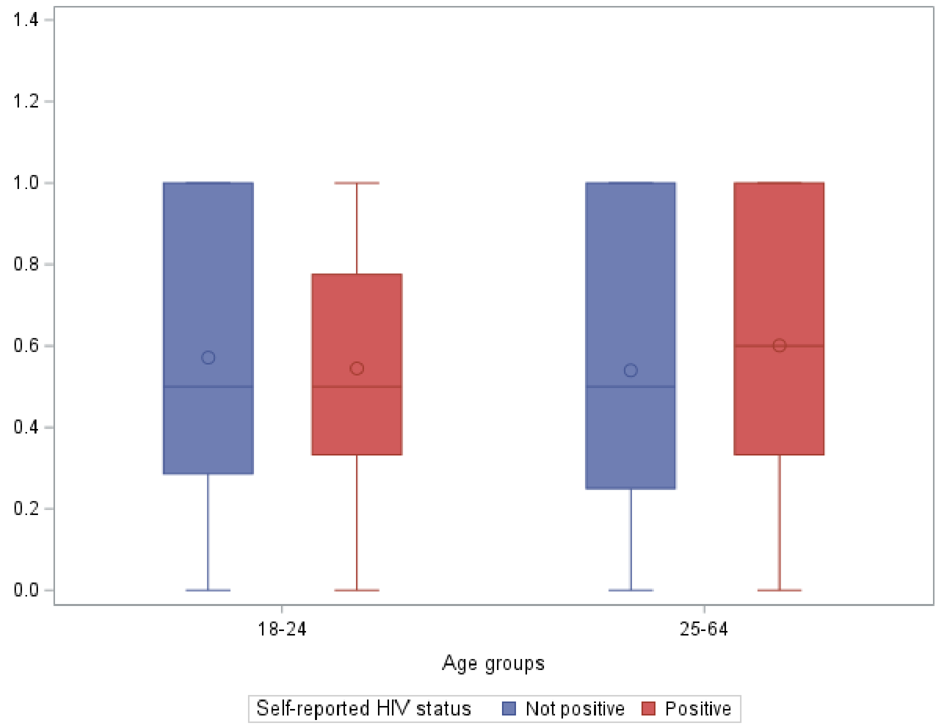
Table 4.3. Parameters Use to Estimate the Force of Infection of Parameters

	Parameter description	Value	Source
c_{ka}	Proportion of sexual contacts with condom by age group and awareness status (1=aware, 0=unaware)	$c_{y0} = 0.5$ $c_{y1} = 0.5$ $c_{o0} = 0.5$ $c_{o1} = 0.6$	Derived from ESEH (84)
e	Condom efficacy	$e = 0.85$	(89)
τ_x	Per-contact HIV transmission probability by sexual role (r=receptive, i=incertive) and age group	$\tau_{yr} = 0.0285$ $\tau_{yi} = 0.0168$ $\tau_{or} = 0.0143$ $\tau_{oi} = 0.0062$	(22,90)
r_k	Probability of being receptive	r_y =0.8 r_o =0.6	(0.6 to 0.8) (31)
w	Proportion with 4 or more sexual partners per year	$w = 0.6$	Derived from ESEH
n_j	Number of sexual contacts per partner per month in each sexual activity group $j \in \{\mathrm{H}, \mathrm{L}\}$	$n_L = 45.9/12$ $n_H = 1$	(22,84)
f_j	Number of sexual partners per month in each sexual activity group $j \in \{\mathrm{H}, \mathrm{L}\}$	$f_{yL} = 0.20$ $f_{yH} = 1.30$ $f_{oL} = 0.20$ $f_{oH} = 1.30$	Derived from ESEH

[a] Based on the number of partners an individual has in a year
Abbreviations: ART, Antiretroviral therapy; ESEH, Encuesta de Sexo Entre Hombres; HIV, human immunodeficiency virus; rd, receptive detectable; ru, receptive undetectable; id, insertive detectable; iu; insertive undetectable; VL, viral load; d, duration

A condom efficacy of 91% was assumed (89), and to simulate the effect of awareness of HIV-positive status on sexual behaviors different rates of condom use were applied to the unaware (Median 50%; IQR: 25%, 100%) and aware compartments (Median: 60%; IQR: 33%, 100%) for the older group (25 to 64). However, these differentiated rates for condom use were not observed among the younger participants and therefore a condom use rate of 50% were applied to both status awareness groups.

Figure 4.7. Proportion of Condomless Anal Sex with a Male Partner in the Last Year among MSM in Mexico, ESEH 2017



The population of inference was defined as adult men aged 18 to 64 years who have sex with men in Mexico (n = 2,122,000; Table 4.4). This value was estimated using the total number of men18 to 64 years (N=37,229,053) reported from the 2020 Mexico Census from INEGI (91) and the reported proportion (5.7%) of men who have had sex with men in the publicly available data from the 2021 National Survey on Sexual and Gender Diversity (ENDISEG) (92).

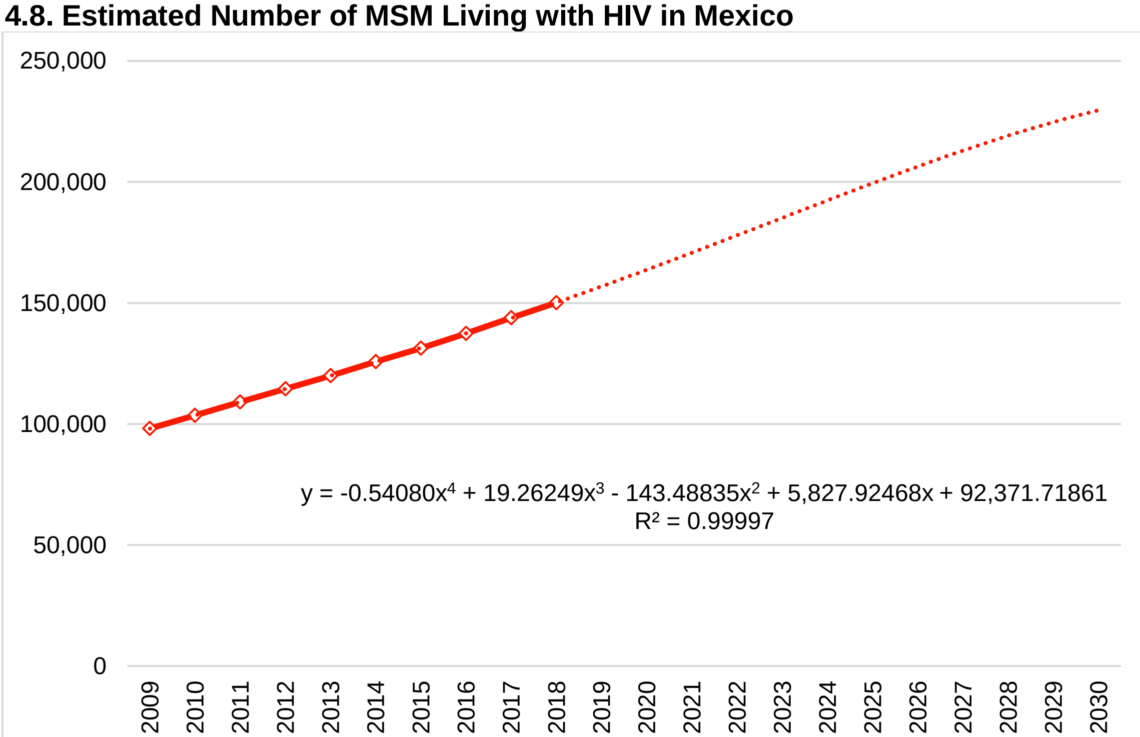
Table 4.4. Estimated MSM Susceptible to HIV and Living with HIV in Mexico by Age Group in 2020

Age group	Male population $U(0)$	MSM[b] $N(0)$	MSM(+)[c]	Susceptible $S(0)$
18 to 24[a]	7,350,744	418,990	14,100	404,890
25 to 64	29,878,309	1,703,060	150,900	1,552,160
Total	**37,229,053**	**2,122,050**	**165,000**	**1,957,050**

[a]18 to 19 population was obtained from the CENSUS data by taking the 15-19 age group and multiplying by 2/5ths to estimate 18-19-year-olds.
[b] Assuming 5.7% of men are MSM according to ENDISEG
[c] In 2017, 75% of all notified males living with HIV diagnosed between 2016-2017 were MSM and 85% of young males living with HIV are MSM.

The numbers of susceptible MSM and MSM living with HIV were defined based on reported estimates in Chapter 2 and UNAIDS epidemiological estimates for 2022 of the proportion of young (15 to 24 years) males living with HIV in Mexico in 2020 (6). Assuming in 2018 there were 150,000 MSM living with HIV in Mexico, 165,000 MSM living with HIV in 2020 were forecasted using a 4th degree polynomial model, from which 8.6% were aged 18 to 24 years old according to UNAIDS epidemiological estimates (Table 4.4).

Figure 4.8. Estimated Number of MSM Living with HIV in Mexico



The overall number of undiagnosed MSM living with HIV in 2020 was forecasted using a linear regression model and reported percentage of undiagnosed MSM (33%). We estimated 111,000 MSM living with HIV were aware of their status, and 54,000 were undiagnosed (Table 4.5).

Given that in 2017 there were only 4,400 MSM living with HIV aged 18 to 24 years in Mexico's EHSS, that only 6% of diagnosed MSM in Mexico's EHSS were aged 18 to 24 years old, and that HIV screening is less frequent among younger populations (8), we assumed a diagnosed proportion of 35% for the young group of MSM. Finally, according to Censida in 2020, 85% of all diagnosed PLWH were in treatment and 89% of PLWH on ART were virally suppressed.

Table 4.5. Estimated MSM Living with HIV in Mexico by Stage in the Continuum of Care by Age Group in 2020

Age group	Undiagnosed $\boldsymbol{IU(0)}$	Diagnosed without ART $\boldsymbol{IA(0)}$	On ART and detectable $\boldsymbol{TD(0)}$	On ART and undetectable $\boldsymbol{TU(0)}$
18 to 24	9,165	745	460	3,730
25 to 64	44,835	15,905	9,920	80,240
Total	**54,000**	**16,650**	**10,380**	**83,970**

The study evaluated the effect on the MSM Mexican HIV epidemic of a set of 5 different scenarios of HIV testing frequency that could be included in future HIV screening recommendations. The base case scenario was established using current practice estimates of HIV testing base on ESEH 2017 results. The primary outcome was defined as the number of HIV infections averted during a 10-year period (2021 – 2030) among MSM aged 18 to 64 years. To simulate different scenarios of HIV testing frequency we varied the proportion of never testers (ε_k, θ_k) and the diagnosis rate (δ_k) (Table 4.6).

Table 4.6. Scenario of Monthly HIV Testing Frequency

Scenario	Description	$\boldsymbol{\varepsilon_k}$	$\boldsymbol{\delta_k}$	$\boldsymbol{\theta_k}$
0	Base case: 50% and 25%	$\varepsilon_y = 0.50$ $\varepsilon_o = 0.25$	$\delta_y = 1/90$ $\delta_o = 1/90$	$\theta_y = 1/180$ $\theta_o = 1/90$
1	Double screening frequency (50% and 23%)	$\varepsilon_y = 0.50$ $\varepsilon_o = 0.25$	$\delta_y = 1/45$ $\delta_o = 1/45$	$\theta_y = 1/90$ $\theta_o = 1/45$
2	Increase screening frequency and reduce never testers to 40% and 20%	$\varepsilon_y = 0.50$ $\varepsilon_o = 0.25$	$\delta_y = 1/36$ $\delta_o = 1/36$	$\theta_y = 1/45$ $\theta_o = 1/36$
3	Increase screening frequency and reduce never testers to 25% and 11%	$\varepsilon_y = 0.25$ $\varepsilon_o = 0.25$	$\delta_y = 1/36$ $\delta_o = 1/30$	$\theta_y = 1/45$ $\theta_o = 1/18$
4	Increase screening frequency and reduce never testers to 13% and 7%	$\varepsilon_y = 0.10$ $\varepsilon_o = 0.10$	$\delta_y = 1/36$ $\delta_o = 1/24$	$\theta_y = 1/45$ $\theta_o = 1/18$

4.2.3 Model calibration and validation

To calibrate the dynamic compartment model, we ran it with available data from Mexico for 2015 and estimated the number of new HIV infections and diagnoses in MSM between 2016 and 2020. For this we assumed the following initial conditions for the year 2010, based on official records reports(93,94): Uy(0) = 7,021,252, Sy(0) = 386,810, IUy(0) = 10,720, IAy(0) = 540, TDy(0) = 710 , TUy(0) = 1,430; Uo(0) = 24,120,085, So(0) = 1,283 240, IUo(0) = 43,280, IAo(0) = 9,660, TDo(0) = 12,890 , TUo(0) = 25,770. We later compared the results with the reported number of estimated new HIV infections among MSM in Mexico in Chapter 2. In comparison, the estimated number of our model for the 10-year period was 75,242 new HIV infections among MSM vs. 78,300 (Table 4.7).

Table 4.7. Comparison of the Estimated Number of New HIV Infections Among MSM in Mexico Using CD4 Depletion Model and Dynamic Compartment Model

Year of infection	CD4 Depletion Model Estimates	Comparment Model Estimates
2011	7,600	7,600
2012	7,500	7,310
2013	7,400	7,286
2014	7,600	7,332
2015	7,500	7,402

Year of infection	CD4 Depletion Model Estimates	Comparment Model Estimates
2016	7,900	7,483
2017	8,300	7,569
2018	8,300	7,659
2019	8,100	7,753
2020	8,100	7,848
Total	**78,300**	**75,242**

We assumed the following initial conditions for the year 2010: Uy(0) = 7,021,252, Sy(0) = 386,810, IUy(0) = 10,720, IAy(0) = 540, TDy(0) = 710 , TUy(0) = 1,430; Uo(0) = 24,120,085, So(0) = 1,283 240, IUo(0) = 43,280, IAo(0) = 9,660, TDo(0) = 12,890 , TUo(0) = 25,770.

4.3 RESULTS

Under the current adoption of the annual HIV testing recommendations, MSM living with HIV who have been tested spent an average of 7.5 years after infection before diagnosis. This baseline model estimated that 79,145 cumulative new HIV infections among MSM aged 18 to 64 years old would occur over the next 10 years, with 30 thousand originating among young MSM (Table 4.8), and with an expected HIV prevalence of 7.4% for 2030 (Figure 4.9).

Figure 4.9. Projected HIV Prevalence Among MSM Over 10 Years in Mexico Under Various Scenarios for HIV Testing Frequency

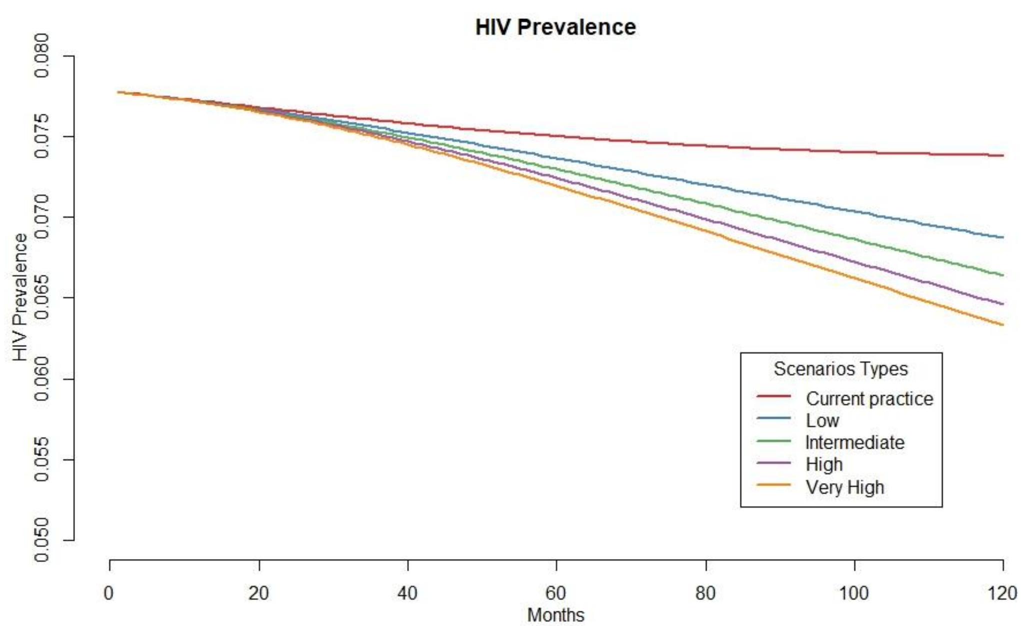


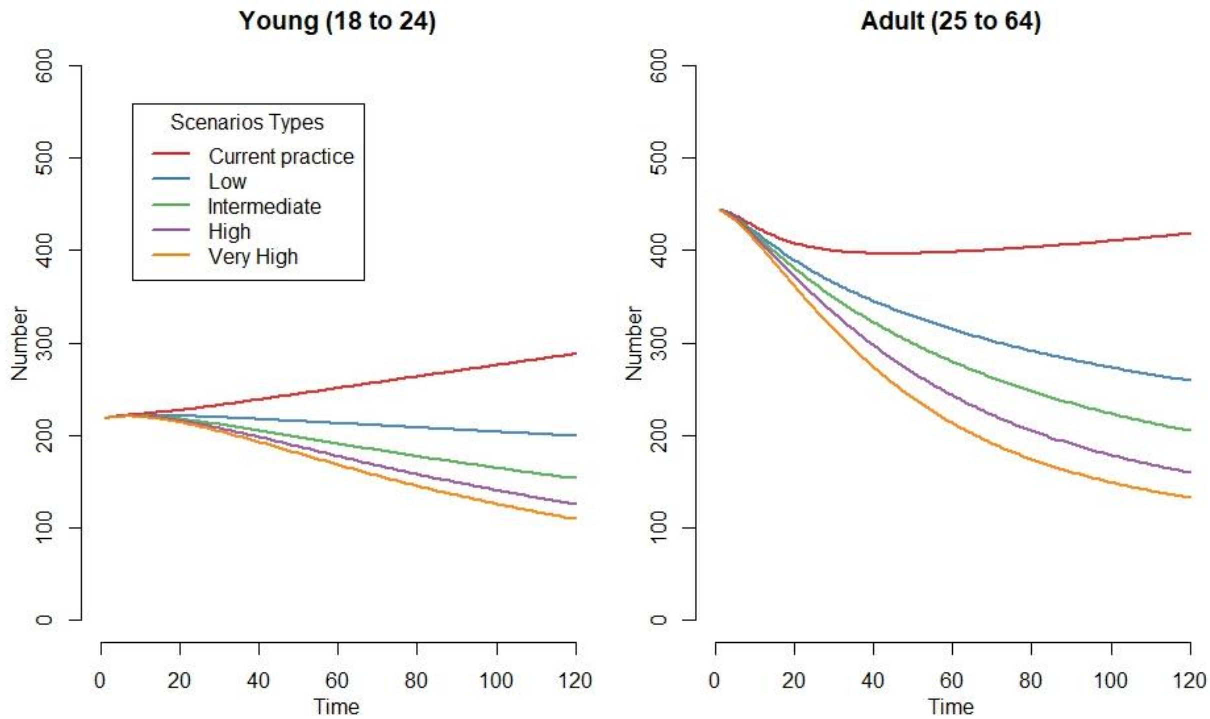
Table 4.8. Reduction in New HIV Infections Over 10 Years for MSM in Mexico Under Various Scenarios for HIV Testing Frequency

	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Number of new HIV infections averted		14,464	20,858	26,102	29,913
18 to 24		4,775	7,401	9,002	10,041
25 to 64		9,688	13,457	17,101	19,872
Cumulative incidence (10-years)	79,145	64,681	58,287	53,043	49,232
18 to 24	30,230	25,455	22,829	21,228	20,189
25 to 64	48,915	39,227	35,458	31,814	29,043
Cumulative diagnoses (10-years)	52,987	74,598	80,393	84,773	86,748
18 to 24	7,752	12,071	14,427	15,530	16,036
25 to 64	45,235	62,527	65,966	69,242	70,723
Number needed to diagnosed		5.2	3.9	3.2	2.9
18 to 24		2.5	1.9	1.7	1.6
25 to 64		6.5	4.9	4.0	3.6
Proportion of never testers	31.2%	31.2%	27.2%	16.0%	9.0%
18 to 24	50.0%	50.0%	40.8%	24.4%	12.0%
25 to 64	25.6%	23.7%	21.7%	11.6%	7.0%
Proportion of diagnosed MSM in 2030	67.6%	82.3%	83.6%	91.8%	94.2%
18 to 24	28.0%	46.0%	58.3	66.0%	70.7%
25 to 64	72.1%	86.0%	90.45	94.1%	96.3%
Number of MSM living with HIV in 2030	185,911	173,085	167,244	162,716	159,528
Total number of MSM 18-64 in 2030*	2,518,293	2,518,707	2,518,740	2,518,982	2,519,228

*Based on CONAPO estimates for 2030 a total of 2,576,400 MSM between 18 to 64 was estimated.
Scenario 0: Base case; Scenario 1: Double screening frequency; Scenario 2: Increase screening frequency and reduce never testers to 40% in the young group and 20% in the older group; Scenario 3: Increase screening frequency and reduce never testers to 25% in the young group and 11% in the older group; Scenario 4: Increase screening frequency and reduce never testers to 13% in the young group and 7% in the older group.

Under the low uptake scenario, MSM who have ever been tested lived with HIV on average 3 years and 9 months before diagnosis, and a total of 64,681 cumulative new HIV infections were estimated. Although no reductions on the proportion of never testers were made in this scenario, and only an increase on HIV testing frequency among those already testing was made, 14464 new HIV infections were averted, representing a reduction of 19.5% on the number of new HIV infections among MSM, primarily among those aged 25 to 64 years old.

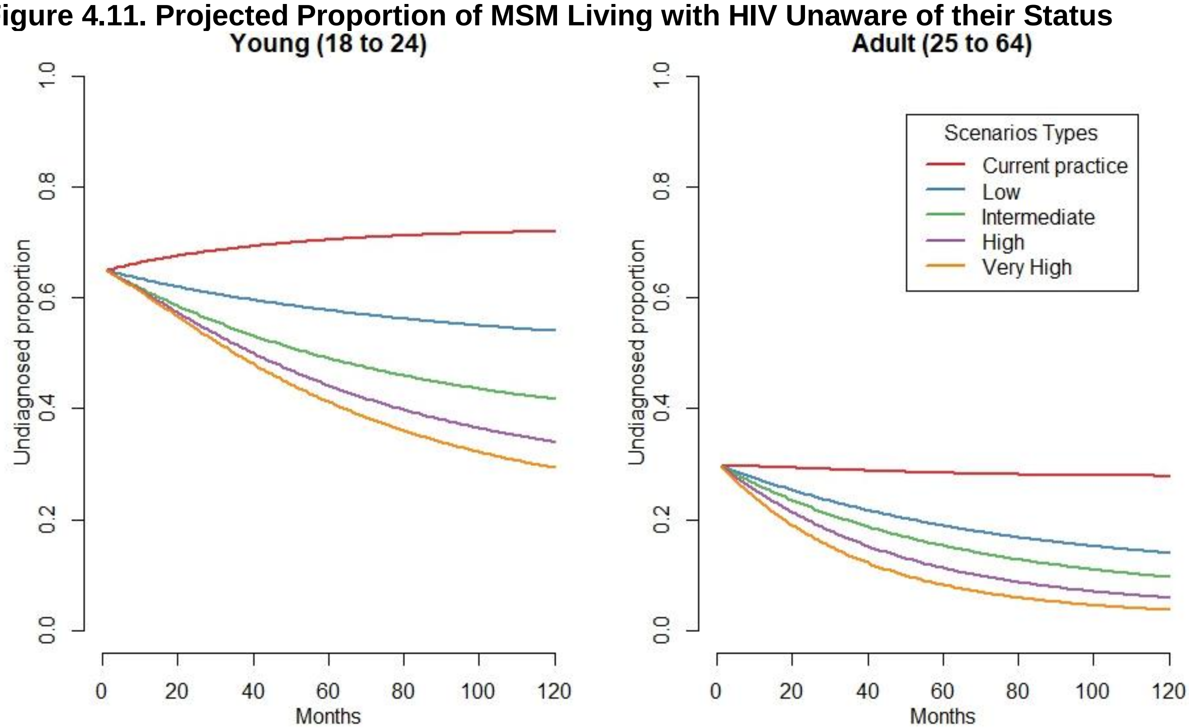
Figure 4.10. Projected New HIV Infections Among MSM Over 10 Years in Mexico Under Various Scenarios for HIV Testing Frequency



The intermediate scenario modeled an average time of 3 years before diagnosis. This is the first scenario were MSM who have never been tested to HIV were reached and the proportion was reduced from 50% to 40% in the young MSM group and from 25% to 20% in the adults group. In this scenario, 20858 new HIV infections were averted, meaning a reduction of 26% in comparison with the current practice scenario. In the high uptake scenario the average time between HIV infection and diagnosis in the adult group was reduced to 2.5 years assuming a more frequent testing than the younger group, and the proportion of never testers was reduced in half from 50 to 25 % at the end of the period in the young group and from 25 to 11% in the adult group. In this scenario 26,102 new HIV infections were averted. Finally, in the very high uptake scenario the proportion of never testers was reduce to 13% in the young group and

7% adult group, resulting in 10,041infections averted among young MSM and 19,872 among MSM aged 25 to 64, a reduction of almost 40%. In all scenarios, the age group with the relative larger reduction is among those aged 25 to 64. (16.25-33.36% vs. 20.9-42.6%).

Figure 4.11. Projected Proportion of MSM Living with HIV Unaware of their Status



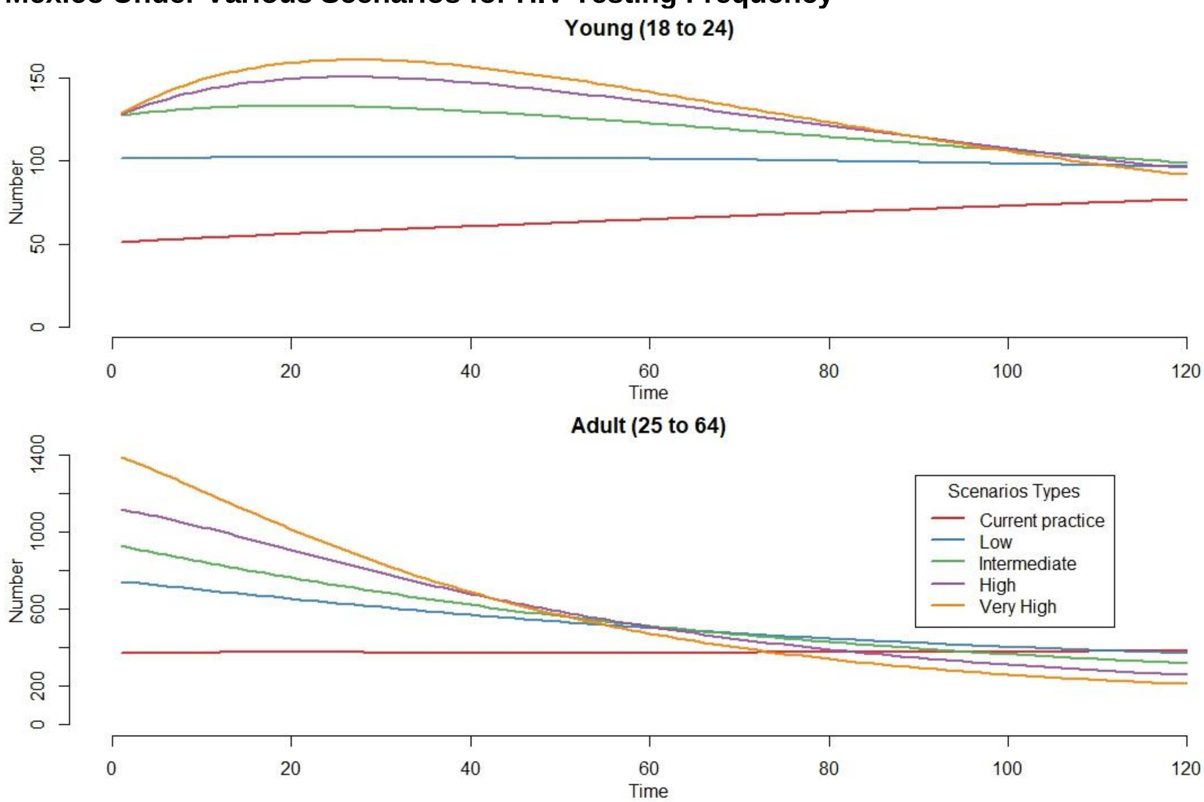
Also, reductions in new diagnosis were observed in all scenarios (Figure 4.12) due to a reduction in the number of new HIV infections and in the proportion of undiagnosed MSM living with HIV (Figure 4.11). The high and very high scenarios require a larger cumulative number of diagnoses, particularly during the first years of the model, as observed in figure 4.12; however, the number needed to be diagnosed to prevent one HIV infection were the lower compared to the other scenarios.

4.4 DISCUSSION

We estimated the impact of increasing HIV testing frequency among MSM on HIV incidence by adapting a compartmental HIV transmission model to simulate the HIV epidemic among MSM in Mexico. Reductions in new HIV infections were observed since the low uptake scenario. However, nationwide targets were only reached when substantial increases in HIV testing frequency among the youngest group and those never tested were implemented.

Some limitations of this study are that the data analyzed to parametrize the model may not be representative of all MSM living with HIV in Mexico. Furthermore, the calibration of the model occurred only with national-level epidemiological data, and study have shown regional variations in the HIV continuum of care exist. Another limitation is that the model did not include the potential effects of scale-up of PrEP in Mexico and only included sexual transmission of HIV infection between MSM. However, under these assumptions, we would only expect the estimates to be more conservative.

Figure 4.12. Projected New HIV Diagnoses Among MSM Living with HIV Over 10 Years in Mexico Under Various Scenarios for HIV Testing Frequency



5 CONCLUSIONS

Between 2000 and 2017, Mexico's HIV mortality reduced by more than 20%. (15,21) This decline will not be sustained if the proportion of MSM aware of their status does not increase, and the frequency of late diagnoses does not decrease. (11) HIV prevention remains a critical public health issue in Mexico. While significant progress has been made in expanding access to antiretroviral therapy and reaching viral suppression, new HIV infections continue to disproportionately impact key populations and certain regions of the country. The results of this dissertation have improved our understanding of the HIV epidemic in Mexico, providing essential information for effectively allocating HIV testing and prevention resources and guiding the development of targeted interventions to increase HIV testing rates among Mexican MSM.

HIV testing is an essential component of HIV prevention efforts. However, efforts to expand access to HIV testing in Mexico have been insufficient. Low testing rates remain a major barrier to "treatment as prevention" and to reducing HIV transmission in Mexico. Stronger recommendations for HIV testing at least once every 12 months for MSM and during STI evaluation are essential. The current Official Mexican Standards or NOMs clearly states that every person diagnosed with TB or every pregnant woman diagnosed with syphilis should be tested for HIV, and although in 2018 the National HIV Program published the HIV testing guide and recommended to offer an HIV test at least once a year to key populations, there is no mention of the recommendation of at least one HIV test every 12 months for MSM in the Official Mexican Standards (78). The introduction of new HIV testing technologies, like HIV self-testing, and new testing strategies are urgently needed to reach those that have never been tested, particularly among the young MSM (95). Further research is needed to examine the spatial patterns of new HIV infection rates and identify geographic hotspots of new HIV infections among MSM and associated socioeconomic factors in Mexico's South and Center regions.

Some other factors associated with unequal access to HIV diagnosis are stigma and discrimination (56,66,96). Results from this research suggest that greater investment to promote stigma-free testing environments, inside and outside healthcare settings, as well as the integration of testing with other healthcare services is still needed to increase HIV testing rates within all key populations. Evidence has shown that the HIV epidemic is driven by social, economic, racial and gender inequalities, and that significant barriers to HIV testing remain, particularly in rural and indigenous communities and among MSM and other key populations (4,7,41). These inequalities exist not only between countries, but also within countries and subpopulations. Addressing these barriers will require further research to improve the desegregation of subnational estimate and analyze the difference in HIV testing within Mexico and the Latinx community in the U.S.

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