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Updates to HIV transmission rate estimates along the HIV care continuum in the United States, 2019

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Abstract

Background: In 2019, there were an estimated 1.2 million persons with HIV (PWH) and 35,100 new infections in the United States. The HIV care continuum has a large influence on transmission dynamics.

Methods: We updated Progression and Transmission of HIV 3.0, an agent-based simulation model, to estimate 2019 HIV transmission rates and distribution of transmissions by the HIV care continuum, race/ethnicity, transmission group, and age group.

Results: In 2019, the estimated transmission rate in the United States was 2.94 new infections per 100 person-years (*inf/100_{p-y}*). Transmission rates decreased along the HIV care continuum; the highest transmission rate was associated with persons with acute HIV infection and unaware of their HIV status at 16.35 *inf/100_{p-y}*, followed by persons with HIV (non-acute) and unaware of their HIV status (9.52), persons aware of their HIV status and not in care (5.96), persons receiving HIV care (on antiretroviral therapy) but not virally suppressed (4.53), and persons virally suppressed (0). The highest transmission rate by transmission group was among men who have sex with men at 3.68 *inf/100_{p-y}*. Transmission rates decreased as age increased and are similar by race/ethnicity, after accounting for the HIV care continuum.

Conclusion: Our results support a continued emphasis on helping PWH move along the care continuum through early diagnosis, linkage to care, and adherence to ART, resulting in viral suppression to reduce HIV transmissions. Further, efforts should focus on reducing disparities in the provision of HIV prevention and care services, particularly for populations disproportionately affected by HIV.

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Conflicts of interest/Competing interests

The authors have no conflicts of interests or competing interests to disclose.

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Keywords

agent-based simulation; HIV transmission; care continuum; health disparities; modeling analysis

Introduction

Understanding how HIV transmissions vary by the HIV care continuum is essential to establishing HIV prevention and care intervention goals and prioritizing prevention resources to achieve the goals of the federal *Ending the HIV Epidemic in the U.S.* (EHE) initiative [1, 2, 3]. Supporting progress through the HIV care continuum, from diagnosis of HIV, to receiving effective HIV care and treatment, to achieving and maintaining viral load suppression (VLS) is effective in both improving outcomes for persons with HIV (PWH) and reducing HIV transmissions. Studies have shown that viral suppression (<200 copies of HIV/mL of blood on the most recent viral load test) prevents sexual transmission of HIV [4, 5, 6]. Therefore, ensuring that PWH achieve and maintain VLS is an effective way to reduce HIV incidence. However, despite significant advances in HIV prevention and availability of treatment, in 2019 there were an estimated 35,100 new HIV infections in the United States [7]. Further, among the estimated 1.2 million PWH in 2019, 13.7% had not received a diagnosis, 34.1% were not in care (i.e., did not receive any CD4 or viral load tests in 2019), and 43.2% were not virally suppressed [7, 8].

In this study, we build upon a previous transmission rate analysis for 2016 (and the latest official transmission rate estimates to date provided by the Centers for Disease Control and Prevention (CDC)) [2] to develop pre-COVID estimates of HIV transmission rates and the distribution of transmissions in 2019 by the HIV care continuum, transmission group, and age. We examine how the overall estimated HIV transmission rate has changed over time and how transmission rates vary for PWH along the HIV care continuum (overall and stratified by race/ethnicity and transmission group). Further, given the importance of care services for older PWH, we present transmission rate estimates for the older populations (aged 55–64 years and 65 years and older).

The goal of this study is to help identify where to focus HIV testing, prevention, and care efforts for ending the HIV epidemic and reducing health disparities across the HIV care continuum. Substantial racial/ethnic disparities exist regarding access to HIV testing, linkage to care, and treatment with antiretroviral therapy (ART) [8]. By estimating HIV transmission rates and the distribution of transmissions along the HIV care continuum stratified by race/ethnicity and transmission group, we can better understand where and to what extent barriers to testing and care are contributing to HIV transmissions.

Methods

We updated the Progression and Transmission of HIV (PATH) 3.0 model to estimate 2019 transmission rates and the distribution of transmissions by stage in the HIV care continuum (overall and stratified by race/ethnicity and transmission group), transmission group, and age group in the United States. PATH 3.0 is an agent-based model that simulates disease progression and transmissions for each person (agent) with HIV [9]. It is an expanded

version of PATH 1.0 and 2.0, which we developed since 2010 and used in previous analyses [2] [10]. Each agent in the model is characterized by the following categories: HIV status (acute infection (Stage 1), asymptomatic infection (Stage 2), symptomatic infection/acquired immune deficiency syndrome (AIDS) (Stage 3), stage in the HIV care continuum, transmission group, age group, and racial/ethnic group. Modeled stages in the HIV care continuum include unaware of HIV status (acute and non-acute, separately), aware of HIV status but not in care, receiving HIV care but not on ART, receiving HIV care (and on ART) but not virally suppressed, and virally suppressed. Note that PATH 3.0 assumes that, after 2012, all persons in care are prescribed and started ART. Transmission groups are stratified by men who have sex with men (MSM), persons who inject drugs (men and women), MSM who inject drugs, and heterosexual men and women. Age groups are defined as years 13–24, 25–34, 35–44, 45–54, 55–64, and 65 and over. Finally, the updated model incorporates three racial/ethnic groups: Black/African American, Hispanic/Latino, and Other, which includes White, Multiracial, Asian, American Indian/Alaska Native, and Native Hawaiian/other Pacific Islander of whom 88% are White. Persons without HIV are incorporated into the model at the occurrence of a transmission. We provide complete details of the model in the Supplementary Digital Content for this paper.

The simulation covers the period 2006–2019, with a time-step size of 1 month. At each time-step, the disease progression (viral load and CD4 count), HIV care continuum progression, and transmissions are computed for every modeled PWH. The HIV care continuum progression is controlled to align with data from the National HIV Surveillance System (NHSS) [11]. That is, the number of persons diagnosed, linked to care, prescribed ART, and VLS is calibrated to match the observed proportions of each of these stages in the HIV care continuum for the study years (2006–2019), stratified by transmission group. Each person with HIV in the model forms main and casual sex and injection drug use partnerships, with the probability of generating transmissions determined by sexual and injection drug use behaviors, partnership preferences, disease progression, and stage in the care continuum. The model used demographic, epidemiologic, and behavioral data from the NHSS, the National Survey of Sexual Health and Behavior, and the National HIV Behavioral Surveillance System [10]. Transmissions are tracked monthly except for the acute stage of HIV infection (first 3 months after HIV infection), where transmissions are tracked weekly. The transmission rate (number of transmissions per 100 person-years) of a subgroup in a particular year is calculated as the annual number of new transmissions associated with persons in that subgroup multiplied by 100 and divided by the number of PWH in the subgroup, averaged over 12 months.

$$\text{Transmission Rate for Group } X = \frac{100 * \sum_{i=1}^{12} (\text{New infections associated with Group } X \text{ in Month } i)}{\frac{1}{12} * \sum_{i=1}^{12} \text{Number of PWH in Group } X \text{ in Month } i}$$

We assumed a 100% reduction in transmission rate for all PWH in the model who achieved and maintained viral suppression [2]. PATH 3.0 was calibrated to 2019 data and validated against incidence and prevalence data from NHSS for the years 2015–2019 using updated data for this time period from the 2022 surveillance reports [11].

Model updates

To incorporate racial/ethnic dynamics and to update age dynamics in the PATH 3.0 model, we made the following changes.

Initial population—We assigned a race/ethnicity to each individual in the initial 2006 model population based on the proportion of PWH in the United States in 2006 by race/ethnicity [12].

Prevalence and Incidence—The calculation of prevalence in the model was updated to be stratified by race/ethnicity, age, and transmission group. To obtain the proportion of the initial 2006 model population in each race/ethnicity, age, and transmission group pair, we applied the 2006 population distribution by race/ethnicity and the 2006 population distribution by age, taken from United States Census data [13], to the existing PWH distributions by transmission group in the model. We derived prevalence distribution targets for 2006 from the NHSS [14, 15]. After 2006, PATH updated prevalence values every year based on the simulation population. Further, we incorporated incidence and prevalence estimates for age groups 55–64 and 65 and older in the model using data from the NHSS.

HIV care continuum progression—We updated the calibration of the number of persons undiagnosed, aware of HIV status but not linked to care, virally suppressed, and linked to care within 3 months of diagnosis to be stratified by both race/ethnicity and transmission group for the years 2010–2019 using data from the NHSS.

Partnerships—Race/ethnicity values of all main and casual sex and injection partners of persons with HIV were calibrated to produce model outputs that followed observed incidence and prevalence distributions by race/ethnicity from HIV surveillance data [7]. These calibrated values were informed by, and showed good agreement with, behaviors associated with race/ethnicity of selected partners reported in the literature [16, 17]. We performed an additional calibration of the sexual partnership behavior parameters by age group to ensure that output metrics by age aligned with estimates from the NHSS.

Results of our analysis represent the average (arithmetic mean) of 100 PATH 3.0 simulation runs, where each run was initiated with 10,000 PWH. Using the 100 simulation runs, we calculated 95% confidence intervals for the estimated mean transmission rates, assuming they followed a standard normal distribution. Model outputs were scaled up to match 2019 incidence.

Results

All results (including tables and figures) presented in this section are taken from the PATH 3.0 model output and scaled up to match the estimated 35,100 new HIV infections in 2019, according to the CDC HIV Surveillance Report [7]. Table 1 presents an overview of the estimated number of PWH and transmissions by stage in the HIV care continuum, transmission group, and age group. Using PATH 3.0, we estimated that the overall HIV transmission rate in 2019 was 2.94 new infections per 100 person-years. In the remainder of

the section, we denote the transmission rate of a given subgroup (i.e., new infections per 100 person-years) as $inf/100_{p-y}$.

Of the 35,100 new infections in 2019, our analysis showed that 4.1% were associated with persons with acute HIV infection and unaware of their HIV status, 41.7% were associated with persons with HIV (non-acute) and unaware of their HIV status, 41.0% were associated with persons aware of their HIV status but not in care, 13.2% were associated with persons receiving HIV care (on ART) but not virally suppressed, and 0% were associated with persons virally suppressed. As expected, transmission rates decreased with progression along the HIV care continuum. The highest transmission rate was among persons with acute HIV infection and unaware (16.35 $inf/100_{p-y}$), followed by persons with HIV (non-acute) and unaware (9.52 $inf/100_{p-y}$), persons aware but not in care (5.96 $inf/100_{p-y}$), and persons receiving HIV care (on ART) but not virally suppressed (4.53 $inf/100_{p-y}$). Figure 1 presents a comparison of the percentage of persons with HIV and the percentage of transmissions along the HIV care continuum.

Among estimated transmissions in 2019, 71.6% were associated with MSM, 7.8% were associated with men who inject drugs, 3.6% were associated with women who inject drugs, 5.4% were associated with MSM who inject drugs, 6.5% were associated with heterosexual men, and 5.1% were associated with heterosexual women. MSM represented the largest proportion of persons with HIV in 2019 at 57.4%, followed by heterosexual women (17.9%), heterosexual men (8.3%), men who inject drugs (7.1%), and MSM and women who inject drugs (4.8% and 4.6%, respectively). The highest transmission rate was among MSM (3.68 $inf/100_{p-y}$), followed by MSM who inject drugs (3.38 $inf/100_{p-y}$), heterosexual men (2.30 $inf/100_{p-y}$), men who inject drugs (3.21 $inf/100_{p-y}$), women who inject drugs (2.32 $inf/100_{p-y}$), and heterosexual women (0.84 $inf/100_{p-y}$).

By age, the largest percentage of overall transmissions (32.9%) was associated with persons aged 25–34. Persons aged 55 and older represented the largest proportion of PWH by age in 2019 at 35.5% with 23.9% aged 55–64 and 11.7% aged 65 and older. However, transmission rates decreased as age increased, with the highest rate occurring among persons aged 13–24 (7.76 $inf/100_{p-y}$) and the lowest among persons aged 55 and older (1.08 $inf/100_{p-y}$). Further, persons aged 65 and older had a lower transmission rate (0.72 $inf/100_{p-y}$) compared to persons aged 55–64 (1.27 $inf/100_{p-y}$).

Figure 2 presents a comparison of the percentage of PWH taking ART and virally suppressed and the overall transmission rate from 2012 through 2019. The model estimated a decline in the overall transmission rate (3.98 $inf/100_{p-y}$ in 2012 to 2.94 $inf/100_{p-y}$ in 2019) and a steady increase in the percentage of PWH taking ART and virally suppressed (from 45.4% in 2012 to 57.5% in 2019).

Figures 3 and 4 present the estimated transmission rates along the HIV care continuum stratified by race/ethnicity and transmission group, respectively. Transmission rates were zero for all PWH who were virally suppressed and are not shown in Figures 3 and 4. By race/ethnicity, transmission rates decreased with progression along the HIV care continuum. Among Black/African American persons, the highest transmission rate was among person

with acute HIV infection and unaware (14.7 *inf/100_{p-y}*), followed by persons with HIV (non-acute) and unaware (8.3 *inf/100_{p-y}*), persons aware but not in care (5.3 *inf/100_{p-y}*), and persons receiving HIV care (on ART) but not virally suppressed (4.3 *inf/100_{p-y}*). Among Hispanic/Latino persons, transmission rates were as follows: persons with acute HIV infection and unaware (17.5 *inf/100_{p-y}*); persons with HIV (non-acute) and unaware (10.5 *inf/100_{p-y}*); aware but not in care (6.5 *inf/100_{p-y}*); receiving HIV care (on ART) but not virally suppressed (4.4 *inf/100_{p-y}*). Similarly, among other persons, the transmission rates were as follows: persons with acute HIV infection and unaware (17.2 *inf/100_{p-y}*); persons with HIV (non-acute) and unaware (10.1 *inf/100_{p-y}*); aware but not in care (6.4 *inf/100_{p-y}*); receiving HIV care (on ART) but not virally suppressed (5.0 *inf/100_{p-y}*). By transmission group, transmission rates generally decreased with progression along the HIV care continuum, with the exception of persons with acute HIV infection and unaware for heterosexual men and women. The highest transmission rates were among MSM and MSM who inject drugs and were as follows: persons with acute HIV infection and unaware (21.2 *inf/100_{p-y}* and 18.2 *inf/100_{p-y}*, respectively); persons with HIV (non-acute) and unaware (11.7 *inf/100_{p-y}* and 12.3 *inf/100_{p-y}*); aware but not in care (7.4 *inf/100_{p-y}* and 7.8 *inf/100_{p-y}*); receiving HIV care (on ART) but not virally suppressed (5.7 *inf/100_{p-y}* and 6.3 *inf/100_{p-y}*).

Figures S1 and S2 at the beginning of the Supplemental Digital Content present a comparison of the percentage of persons with HIV and the percentage of transmissions along the HIV care continuum stratified by race/ethnicity and transmission group, respectively.

Discussion

The transmission estimates from this analysis update the latest set of estimates from CDC in 2019 [2]. Our analysis suggested that in 2019 the overall transmission rate in the United States was 2.94 new infections per 100 person-years, and the number of persons with HIV was an estimated 1.2 million. Further, this analysis shows steady progress in improving the percentage of PWH taking ART and achieving viral suppression, which has led to a decrease in the overall transmission rate over time.

Approximately 87% of the estimated transmissions in 2019 were associated with persons who were either unaware of their HIV status (both acute and chronic infection, 45.8%) or aware of their HIV status but not in care (41.0%). In addition, the estimated transmission rate was greatest among persons with undiagnosed HIV. These results emphasize the importance of the goals of the EHE initiative, namely, the first two pillars of the strategic initiative: 1) diagnose all individuals with HIV as early as possible after infection and 2) treat HIV infection rapidly and effectively to achieve sustained viral suppression [1] To achieve early diagnosis and increase awareness of HIV status, a combination of routine HIV screening and testing, as well as increased HIV testing for prioritized groups is essential. These efforts could have a major impact in reducing the approximately 46% of transmissions associated with the 14% of PWH unaware of their HIV status. Further, expanding rapid linkage to care strategies within testing programs and scaling up effective data-to-care interventions and other strategies that remove barriers to, or facilitate entry into, care could

have an impact in reducing the estimated 41% of transmissions associated with PWH who are aware of their HIV status but not in care. Finally, sustained viral suppression is key to eliminating HIV transmission. Strategies focusing on helping PWH who are already in care but not virally suppressed to achieve and maintain viral suppression would help to reduce the approximately 13% of transmissions in 2019 associated with this group.

By transmission group, MSM accounted for the largest proportion of PWH (57%) and were associated with 71.6% of transmissions in 2019. Further, the highest estimated transmission rates by transmission group were among MSM and MSM who inject drugs. These results suggest that prioritized prevention and treatment strategies to address the care continuum gaps in these populations could help decrease HIV transmission rates. By age group, persons aged 13–24 had the highest estimated transmission rate and represented the smallest proportion of PWH by age in 2019. This suggests that prevention and treatment services that are successful in reaching and serving younger PWH may have a bigger impact on preventing new infections.

For all transmission groups except for MSM, PWH aware and not in care were associated with the largest proportion of transmissions and accounted for the largest proportion of PWH within that group (excluding persons virally suppressed) (Fig S2). Therefore, it is critical to prioritize efforts to link PWH to effective care and treatment with ART within these groups. Among MSM, the largest proportion of transmissions (51.6%) was associated with the 16% who were unaware of their HIV status, which suggests that expanding the reach of testing programs for MSM is critically important. Across transmission groups, men who inject drugs had the lowest proportions of PWH who were virally suppressed (50.4%). Focusing on improving the care continuum gaps previously identified, in addition to providing support for ART use and adherence to achieve viral suppression should be prioritized among these populations.

Our results show that HIV transmission rates vary significantly by stage in the HIV care continuum. After accounting for where persons are along the HIV care continuum, transmission rate estimates appear to be similar by race/ethnicity. This means that where PWH are along the care continuum drives the risk of HIV transmission, regardless of race/ethnicity. The largest proportion of transmissions was associated with persons unaware of their HIV status for Hispanic/Latino persons (52%) and Other persons (46%). This proportion was 41% for Black/African American persons. Focusing intervention strategies on the gaps and barriers to testing is important across all races/ethnicities, and in particular, among Hispanic/Latino persons. Black/African American persons had a larger proportion of transmissions associated with persons receiving care (on ART) and not virally suppressed (16.9%) compared to Hispanic/Latino persons (9.0%) and other persons (12.3%). Therefore, there is a need for intervention strategies to eliminate barriers related to increasing adherence to ART and achieving VLS among persons in care. Focusing on this stage in the HIV care continuum could have significant impact on preventing HIV among Black/African American persons. These results highlight the evident health disparities and inequities with respect to effective HIV treatment and care continuum services by race/ethnicity. Previous studies, including the CDC *HIV Surveillance Reports*, have shown that substantial racial/ethnic disparities exist regarding access to and use of prevention, care, and

treatment services [8, 18, 19, 20]. Therefore, EHE activities should focus on progression of PWH along the HIV care continuum, and testing, treatment, and prevention efforts should prioritize populations disproportionately affected by HIV to decrease health disparities.

The overall transmission rate declined in 2019 compared to the 2016 estimate in our previous analysis [2]. This decline occurred in the different subgroups with the exception of the transmission rates for the population who were unaware of their HIV infection and the younger age (13–24 and 25–24) population. While the minimal increase in the transmission rate for the unaware population was driven by a combination of the modeling changes and data updates, the increases in the younger age groups were primarily driven by the data updates, as recent surveillance data suggest increased incidence among these two age groups.

The major contributions of this modeling analysis are the updated estimated HIV transmission rates by subgroups, the estimation of HIV transmission rates by race/ethnicity, and showing the interaction of these rates with the stages of the HIV care continuum. Although our previous modeling analysis [2] also focused on transmission rates by subgroup, monitoring transmission rates over time is crucial for intervention response towards achieving the incidence reduction goals of the *Ending the HIV Epidemic in the U.S. (EHE)* initiative. Our transmission rate estimates for those in the acute and non-acute phases of infection are similar to the sexual transmission rates previously reported in the static models of Pinkerton [21, 22] and Prabhu and colleagues [23]. Our estimates are also similar to those of Skarbinski and colleagues [24] where both models reported both sexual transmissions and injection drug use transmissions from PWID. However, those authors used a static model based on surveillance data in contrast to our dynamic PATH 3.0 model, which was designed to generate over time both the PWH transmission subgroups and the number of new transmissions from each subgroup.

The findings in this analysis are subject to limitations, including the fact that model inputs and parameters were constrained by available data and estimates from the literature.

While our results show progress with a decline in overall estimated HIV transmission rates and a steady increase in the percentage of PWH who are taking ART and virally suppressed from 2012–2019, further progress needs to be made to achieve the goals of the EHE initiative to reduce annual new HIV infections in the US by 90% by 2030 [1]. Additionally, COVID-19-related disruptions to HIV prevention and treatment services are likely to have affected HIV transmission and care continuum measures, as well as HIV incidence and prevalence estimation [25, 26, 27, 28, 29, 30, 31, 32, 33]. By examining pre-COVID transmission rates and transmissions by stage in the care continuum, we established a baseline from which further studies can assess the impact of COVID-19-related disruptions. Our study emphasized the importance of moving PWH along the HIV care continuum through rapid diagnosis, linkage to care, and adherence to ART to improve patient outcomes and reduce HIV transmissions. Furthermore, to decrease health disparities, interventions and prevention strategies should focus on removing existing barriers across the HIV care continuum to improve access to these services for all, especially populations disproportionately affected by HIV.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

- [1]. Fauci AS, Redfield RR, Sigounas G, Weahkee MD and Giroir BP, "Ending the HIV Epidemic: A Plan for the United States," JAMA, pp. 844–845, 2019. [PubMed: 30730529]
- [2]. Li Z, Purcell DW, Sansom SL, Hayes D. and Hall I, "HIV Transmission Along the Continuum of Care—United States, 2016," CDC MMWR Vital Signs, vol. 68, no. 11, pp. 267–272, 2019.
- [3]. Zang X, Mah C, My Lin Quan A, Eun Min J, Armstrong WS, Behrends CN, Del Rio C, Dombrowski JC, Feaster DJ, Kirk GD, Marshall B, Mehta SH, Metsch LR, Pandya A, Schackman BR, Shoptaw S, Strathdee SA, Krebs E. and Nosyk B, "Human Immunodeficiency Virus transmission by HIV Risk Group and Along the HIV Care Continuum: A Contrast of 6 US Cities," JAIDS, vol. 89, no. 2, pp. 143–150, 2022. [PubMed: 34723929]
- [4]. Bavinton BR, Pinto AN, Phanuphak N, Grinsztejn B, Prestage GP, Zablotska-Manos IB, Jin F, Fairley CK, Moore R, Roth N, Bloch M, Pell C, McNulty AM, Baker D, Hoy J, Kiem Tee B, Templeton DJ, Cooper DA, Emery S, Kelleher A. and Grulich AE, "Viral suppression and HIV transmission in serodiscordant male couples: an international, prospective, observational, cohort study," Lancet HIV, vol. 5, no. 8, pp. e438–e447, 2018. [PubMed: 30025681]
- [5]. Cohen MS, Chen YQ, McCauley M, Gamble T, Hosseinipour MC, Kumarasamy N, Hakim JG, Kumwenda J, Grinsztejn B, Pilotto JH, Godbole SV and Chariyalertsak S, "Antiretroviral Therapy for the Prevention of HIV-1 Transmission," The New England Journal of Medicine, pp. 830–839, 2016. [PubMed: 27424812]
- [6]. Rodger AJ, Cambiano V. and Bruun T, "Sexual Activity Without Condoms and Risk of HIV Transmission in Serodifferent Couples When the HIV-Positive Partner is Using Suppressive Antiretroviral Therapy," JAMA, vol. 316, no. 2, pp. 171–181, 2016. [PubMed: 27404185]
- [7]. Centers for Disease Control and Prevention, "Estimated HIV incidence and prevalence in the United States, 2018–2022," HIV Surveillance Supplemental Report, vol. 29, no. 1, May 2024.
- [8]. Centers for Disease Control and Prevention, "Monitoring selected national HIV prevention and care objectives by using HIV surveillance data—United States and 6 dependent areas, 2019," HIV Surveillance Supplemental Report, vol. 26, no. 2, 2021.
- [9]. BIngham A, Shrestha RK, Khurana N, Jacobson EU and Farnham PG, "Estimated Lifetime HIV-Related Medical Costs in the United States," Sexually Transmitted Diseases, vol. 48, no. 4, pp. 299–304, 2021. [PubMed: 33492100]
- [10]. Gopalappa C, Farnham PG, Sansom SL and Chen Y-H, "Progression and Transmission of HIV/ AIDS (PATH 2.0): A New, Agent-Based Model to Estimate HIV Transmissions in the United States," Medical Decision Making, vol. 37, no. 2, pp. 224–233, 2016. [PubMed: 27646567]
- [11]. Satcher Johnson A, Peruski A, Oster AM, Balaji A, Siddiqi A-E-A, Sweeney P. and Hernandez A, "Enhancements to the National HIV Surveillance System, United States, 2013–2023," Public Health Reports®, vol. 139, no. 6, pp. 654–661, 2024. [PubMed: 38822672]
- [12]. Centers for Disease Control and Prevention, "Monitoring selected national HIV prevention and care objectives by using HIV surveillance data—United States and 6 dependent areas—2010," HIV Surveillance Supplemental Report, vol. 17, no. 3, 2012.

- [13]. “Our Changing Population: United States,” USA Facts, [Online]. Available: <https://usafacts.org/data/topics/people-society/population-and-demographics/our-changing-population?endDate=2021-01-01&startDate=2006-01-01>. [Accessed 2022].
- [14]. Centers for Disease Control and Prevention, “HIV/AIDS Surveillance Report, 2006,” U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, vol. 18, 2008.
- [15]. Centers for Disease Control and Prevention, “HIV Surveillance Report, 2011,” vol. 23, 2013.
- [16]. Morris M, Goodreau S. and Moody J, “Sexual Networks, Concurrency, and STD/HIV,” in Sexually Transmitted Diseases, McGraw-Hill Medical, 2007, pp. 109–126.
- [17]. Lasry A, Sansom SL, Hicks KA and Uzunangelov V, “Allocating HIV prevention funds in the United States: recommendations from an optimization model,” PLoS One, vol. 7, no. 6, p. e37545, 2012.
- [18]. Beer L, Oster AM, Mattson CL and Skarbinski J, “Disparities in HIV transmission risk among HIV-infected black and white men who have sex with men, United States, 2009,” AIDS, vol. 28, pp. 105–114, 2014. [PubMed: 23942058]
- [19]. Crepaz N, Dong X, Wang X, Hernandez AL and Hall I, “Racial and Ethnic Disparities in Sustained Viral Suppression and Transmission Risk Potential Among Persons Receiving Care—United States, 2014,” CDC Morbidity and Mortality Weekly Report, vol. 67, no. 4, pp. 113–118, 2018. [PubMed: 29389918]
- [20]. Jeffries WL, Dailey AF, Jin C, Carter JW Jr. and Scales L, “Trends in Diagnosis of HIV Infection, Linkage to Medical Care, and Viral Suppression Among Men Who Have Sex with Men, by Race/Ethnicity and Age—33 Jurisdictions, United States, 2014–2018,” CDC Morbidity and Mortality Weekly Report, vol. 69, no. 38, pp. 1337–1342, 2020. [PubMed: 32970045]
- [21]. Pinkerton SD, “HIV Transmission Rate Modeling: A Primer, Review, and Extension,” AIDS Behav, vol. 16, no. 4, pp. 791–6, May 2012. [PubMed: 21928097]
- [22]. Pinkerton SD, “How many sexually-acquired HIV infections in the USA are due to acute-phase HIV transmission?,” AIDS, vol. 21, no. 12, pp. 1625–9, 31 Jul 2007. [PubMed: 17630558]
- [23]. Prabhu VS, Hutchinson AB, Farnham PG and Stephanie SL, “Sexually acquired HIV infections in the United States due to acute-phase HIV transmission: an update,” AIDS, vol. 23, no. 13, pp. 1792–4, 24 Aug 2009. [PubMed: 19684485]
- [24]. Skarbinski J, Rosenberg E, Paz-Bailey G, Hall HI, Rose CE, Viall AH, Fagan JL, Lansky A. and Mermin JH, “Human immunodeficiency virus transmission at each step of the care continuum in the United States,” Jama Internal Medicine, vol. 175, no. 4, pp. 588–596, April 2015. [PubMed: 25706928]
- [25]. DiNenno EA, Delaney KP, Pitasi MA, MacGowan R, Miles G, Dailey A, Courtenay-Quirk C, Byrd K, Thomas D, Brooks JT, Daskalakis D. and Collins N, “HIV Testing Before and During the COVID-19 Pandemic—United States, 2019–2020,” CDC MMWR, vol. 71, no. 25, pp. 820–824, 2022. [PubMed: 35737573]
- [26]. Huang YLA, Zhu W, Wiener J, Kourtis AP, Hall IH and Hoover K, “Impact of Coronavirus Disease 2019 (COVID-19) on Human Immunodeficiency Virus (HIV) Pre-exposure Prophylaxis Prescriptions in the United States—A Time-Series Analysis,” Clinical Infectious Diseases, vol. 75, no. 1, pp. e1020–e1027, 2022. [PubMed: 35040928]
- [27]. Zhu W, Huang Y.-I. A., Wiener J, Neblett-Fanfair R, Kourtis AP, Hall IH and Hoover KW, “Impact of the coronavirus disease 2019 pandemic on prescriptions for antiretroviral drugs for HIV treatment in the United States, 2019–2021,” AIDS, vol. 36, no. 12, pp. 1697–1705, 2022. [PubMed: 35848572]
- [28]. Viguerie A, Song R, Johnson AS, Hernandez A, Farnham PG and Lyles CM, “Isolating the Effect of COVID-19-Related Disruptions on HIV Diagnoses in the United States in 2020,” J Acquir Immune Defic Syndr, vol. 92, no. 4, pp. 293–299, 2023. [PubMed: 36515707]
- [29]. Zhu W, Huang Y.-I. A., Song R, Wiener J, Neblett-Fanfair RN, Kourtis AP and Hoover KW, “An estimate of excess deaths among people with HIV during the coronavirus disease 2019 pandemic in the United States, 2020,” AIDS, vol. 37, no. 5, pp. 851–853, 2023. [PubMed: 36779489]
- [30]. Viguerie A, Song R, Bosh K, Lyles CM and Farnham PG, “Mortality among persons with HIV in the United States during COVID-19 pandemic: a population-level analysis,” medRxiv, 2023.

- [31]. Mann LM, Sanchez T, Stephenson R, Sullivan PS and Jenness SM, “The impact of the COVID-19 Pandemic on Sexual Behavior and HIV Prevention and Treatment Services Among U.S. Men Who Have Sex with Men in the Post-Lockdown Era,” *American Journal of Men’s Health*, vol. 17, no. 2, 2023.
- [32]. Goodreau SM, Delaney KP, Zhu W, Smith DK, Mann LM, Sanchez TH, Hamilton DT and Hoover KW, “Impacts of COVID-19 on sexual behaviors, HIV prevention and care among men who have sex with men: A comparison of New York City and Metropolitan Atlanta,” *PLoS ONE*, vol. 18, no. 3, 2023.
- [33]. Viguierie A, Song R, Satcher Johnson A, Lyles CM, Hernandez A. and Farnham PG, “COVID-19-related excess missed HIV diagnoses in the United States in 2021,” *AIDS*, vol. 38, no. 6, pp. 907–911, 2024. [PubMed: 38181069]

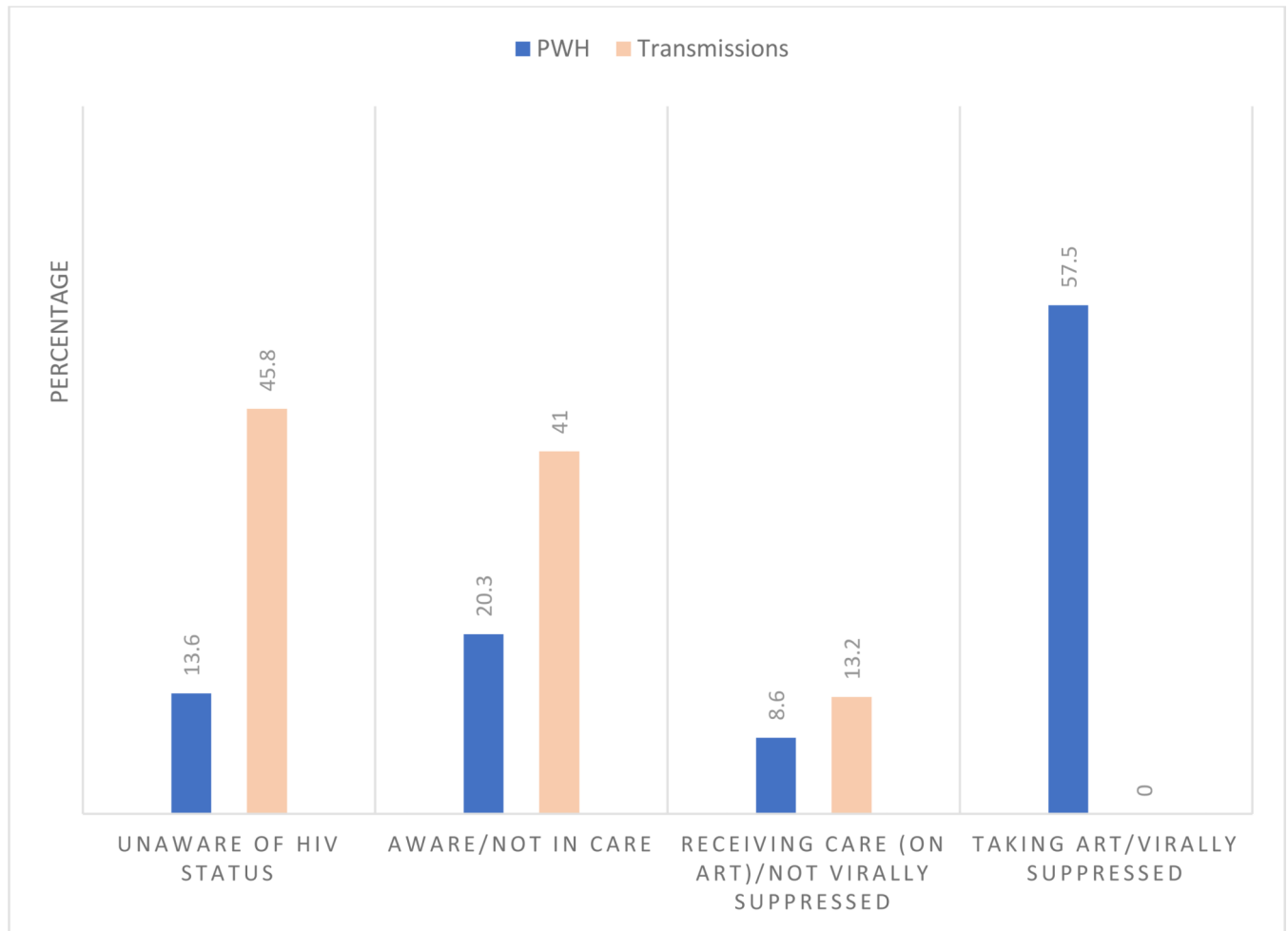


Fig. 1.

Percentage of persons with HIV (PWH) and percentage of transmissions along the HIV care continuum—United States, 2019^a

Abbreviations: ART (antiretroviral therapy); PWH (Persons with HIV)

^a All results represent the mean of 100 PATH 3.0 simulation runs, where each run was initiated with 10,000 persons with HIV.

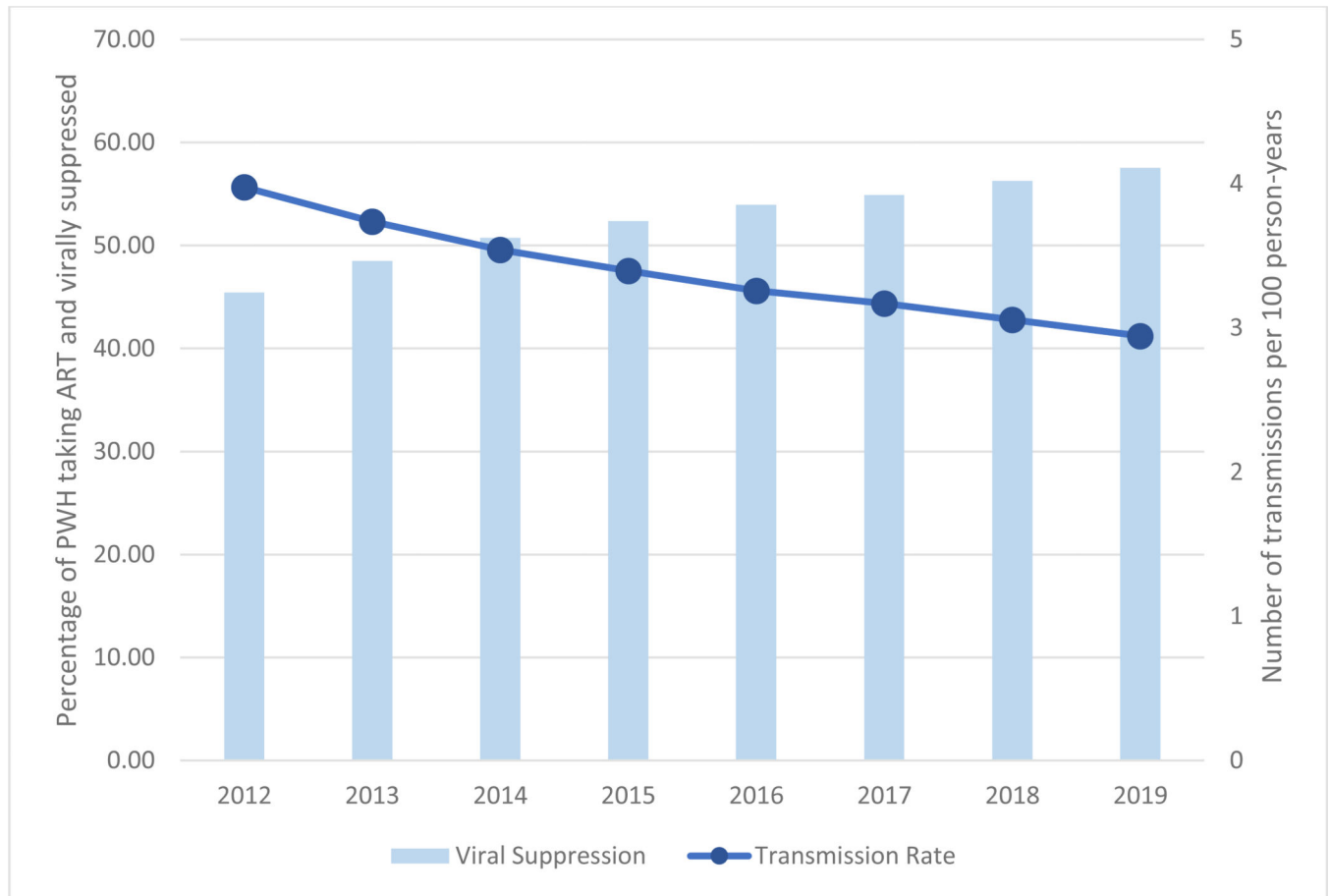
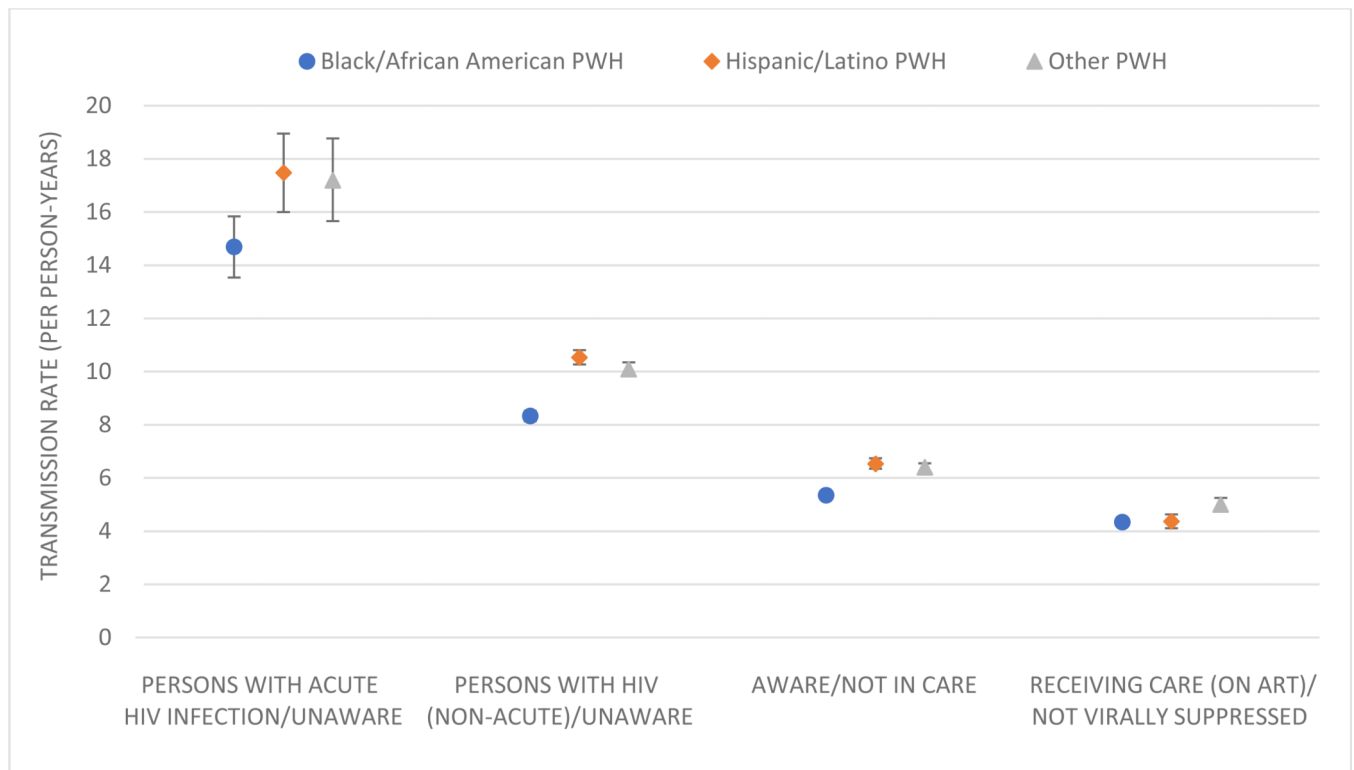


Fig. 2.
Percentage of persons with HIV (PWH) who are taking ART and virally suppressed, and overall HIV transmission rate — United States, 2012–2019^a
Abbreviations: ART (*antiretroviral therapy*); PWH (*Persons with HIV*)
a All results represent the mean of 100 PATH 3.0 simulation runs, where each run was initiated with 10,000 persons with HIV.

**Fig. 3.**

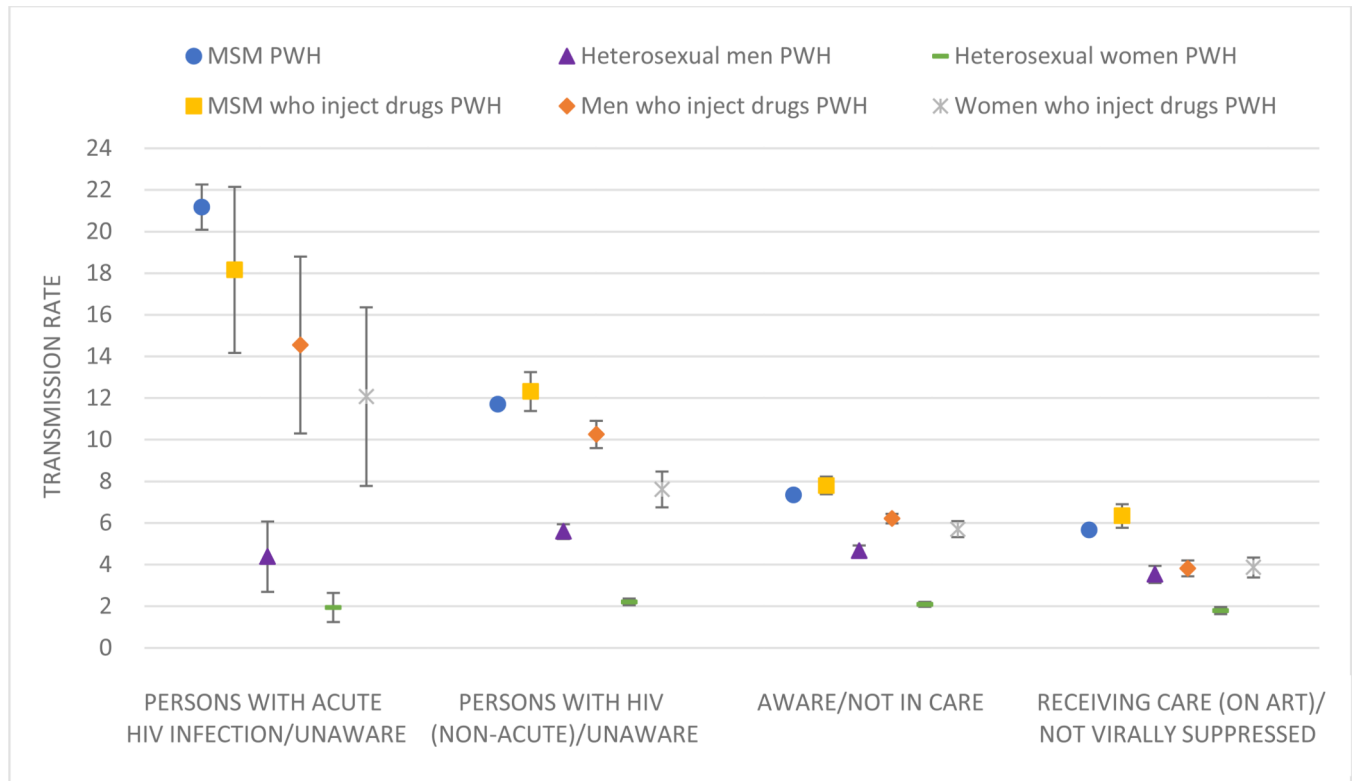
Estimated transmission rates[†] along the HIV care continuum, stratified by race/ethnicity of persons with HIV (PWH) —United States, 2019^a

Abbreviations: *PWH (Persons with HIV)*

[†] The mean number of transmissions per 100 person-years and 95% confidence interval.

^a All results represent the mean of 100 PATH 3.0 simulation runs, where each run was initiated with 10,000 persons with HIV.

* Other includes American Indian/Alaska Native, Asian, Native Hawaiian/other Pacific Islander, White, and Multiracial

**Fig. 4.**

Estimated transmission rates[†] along the HIV care continuum, stratified by transmission group of persons with HIV (PWH) —United States, 2019^a

Abbreviations: *PWH* (*Persons with HIV*); *MSM* (*men who have sex with men*)

[†] The mean number of transmissions per 100 person-years and 95% confidence interval.

^a All results represent the mean of 100 PATH 3.0 simulation runs, where each run was initiated with 10,000 persons with HIV.

Table 1

Estimated number of persons with HIV (PWH) and transmissions by selected characteristics—United States, 2019^a

Characteristic	Transmission Rate ^b mean (lb, ub)	Persons in subgroup ^c no. (%)	Transmissions ^d no. (%)
HIV care continuum			
Persons with acute HIV infection and unaware	16.35 (15.55, 17.15)	8,800 (0.7)	1,400 (4.1)
Persons with HIV (non-acute) and unaware	9.52 (9.38, 9.66)	153,800 (12.9)	14,600 (41.7)
Aware and not in care	5.96 (5.89, 6.04)	241,500 (20.3)	14,400 (41)
Receiving HIV care (on ART) but not virally suppressed	4.53 (4.40, 4.65)	102,000 (8.6)	4,600 (13.2)
Taking ART and virally suppressed	0 (0, 0)	683,400 (57.5)	0 (0)
Transmission group			
MSM	3.68 (3.63, 3.72)	683,400 (57.4)	25,100 (71.6)
Men who inject drugs	3.21 (3.12, 3.31)	84,800 (7.1)	2,700 (7.8)
Women who inject drugs	2.32 (2.20, 2.44)	54,900 (4.6)	1300 (3.6)
MSM who inject drugs	3.38 (3.25, 3.51)	56,700 (4.8)	1,900 (5.4)
Heterosexual men	2.30 (2.21, 2.39)	98,700 (8.3)	2,300 (6.5)
Heterosexual women	0.84 (0.80, 0.88)	213,200 (17.9)	1,800 (5.1)
Age group (yrs.)			
13–24	7.76 (7.56, 7.96)	60,500 (5.1)	4,700 (13.4)
25–34	5.98 (5.88, 6.09)	192,700 (16.2)	11,500 (32.9)
35–44	3.71 (3.63, 3.79)	234,500 (19.7)	8,700 (24.8)
45–54	1.98 (1.93, 2.03)	280,300 (23.5)	5,600 (15.8)
≥55	1.08 (1.06, 1.11)	423,600 (35.5)	4,600 (13.1)
<i>Older age group split</i>			
55–64	1.27 (1.23, 1.30)	284,400 (23.9)	3,600 (10.2)
≥65	0.72 (0.67, 0.76)	139,200 (11.7)	1,000 (2.8)
Total	2.94 (2.92, 2.97)	1,191,600 (100)	35,100 (100)

Abbreviations: ART (antiretroviral therapy); MSM (men who have sex with men)

^aAll results represent the mean of 100 PATH 3.0 simulation runs, where each run was initiated with 10,000 persons with HIV. Model outputs were scaled up to match 2019 incidence.

^bThe mean number of transmissions per 100 person-years and 95% confidence interval (lb, ub). We report transmission rates with two decimals.

^cThe mean number (%) of PWH in each subgroup in the model, averaged over 12 months and rounded to the nearest 100 (1/10th). Numbers and percentages might not sum to total value due to rounding.

^dThe mean number (%) of transmissions from the model by each subgroup and rounded to the nearest 100 (1/10th). Numbers and percentages might not sum to total value due to rounding.