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Projecting the age-distribution of men who have sex with men receiving HIV treatment in the United States

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Abstract

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Supplementary materials

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Background: The age-distribution of men who have sex with men (MSM) continues to change in the 'Treat-All' era as effective test-and-treat programs target key-populations. However, the nature of these changes and potential racial heterogeneities remain uncertain.

Methods: The PEARL model is an agent-based simulation of MSM in HIV care in the US, calibrated to data from the North American AIDS Cohort Collaboration on Research and Design (NA-ACCORD).

Results: PEARL projects a gradual decrease in median age of MSM at ART initiation from 36 to 31 years during 2010–2030, accompanied by changes in mortality among Black, White, and Hispanic MSM on ART by −8.4%, 42.4% and −19.6%. The median age of all MSM on ART is projected to increase from 45 to 47 years from 2010–2030, with the proportion of ART-users age ≥60y increasing from 6.7% to 28.0%. Almost half (49.7%) of White MSM ART-users are projected to age ≥60y by 2030, compared to 19.5% of Black and 17.2% of Hispanic MSM.

Conclusions: The overall age of US MSM in HIV care is expected to increase over the next decade, and differentially by race/ethnicity. As this population age, HIV programs should expand care for age-related causes of morbidity and mortality.

Keywords

HIV; Aging; Sexual and Gender Minorities; Racial disparities; Hispanic ethnicity; People who inject drugs; Computer simulation

Introduction

As a result of improvements in effectiveness of antiretroviral therapy (ART) and initiation of HIV treatment without delay after diagnosis in the 'Treat-All' era (2015-present), people with HIV (PWH) are surviving to older ages in the United States (US).(1, 2) Increased survival with HIV contributes to more PWH in the US, rising from 936,971 in 2014 to 1,035,317 in 2018.(3, 4) Despite concentration of new infections among younger ages, the proportion of PWH age ≥60y increased from 6% to 10% from 2014 to 2018.(5)

As PWH age, they experience a higher burden of age-related comorbidities, including non-AIDS malignancies, metabolic, cardiovascular, renal and hepatic disease.(4, 6–10) In a setting of limited resources, a clear projection of future population size and age composition can help decision-makers plan for the future care needs of PWH, and to prioritize interventions targeting the leading causes of age-related morbidity and mortality. Even more useful would be the ability to project the age distribution in sub-groups defined by sex, race/ethnicity and HIV acquisition risk as heterogeneity exists in new diagnoses and mortality.(3)

Despite improvements in the public health response, the US HIV epidemic continues to have a disproportionate effect on certain sub-populations including men who have sex with men (MSM) and Black/African Americans (Black). In 2018, MSM accounted for 66% (24,933/37,968) of all new HIV diagnoses and 81% (24,933/30,691) of new diagnoses in men.(3) Black MSM accounted for the largest number of new HIV diagnosis (9,444), followed by Hispanic (7,653) and White MSM (6,372).

Although the total number of new HIV diagnoses among MSM is declining (from 26,801 to 24,933 during 2014–2018), racial/ethnic disparities remain significant (comparing a 17% relative reduction in new diagnoses among White MSM to 3% and 4% reduction among Hispanic and Black MSM from 2014–2018).(3) In 2018, 67.3% (333,758/495,978) of MSM received HIV medical care and were virally suppressed, including 72.9% (136,216/186,899) of White, 60.6% of Black (94,170/155,319), 65.9% (78,744/119,475) of Hispanic MSM diagnosed by year-end 2017 and alive at year-end 2018. (11) Among all persons alive at year-end in 2018, the percentage of those who were virally suppressed increased with age, ranging from 60% among those age 13 to 24 to 67% among those age 67 years and older. (11) New HIV diagnoses among MSM are concentrated among those <35y, accounting for 56% of new diagnoses in White, 59% in Black, and 65% in Hispanic MSM in 2018.(3) Deaths*, however, continue to occur at older ages among PWH, with deaths among those age ≥60y rising from 29% (4,798/16,619) in 2014 to 38% (6,052/15,821) in 2018 (3); surveillance data for the number of deaths by age among race/ethnicity groups of MSM were not available. As such, the changes in age distribution of US MSM on ART over the next decade remains uncertain.

The objective of our study was to project the age distribution of Black, White, and Hispanic MSM on ART as the essential first step of our long-term goal: to project multimorbidity and polypharmacy among all sub-groups of PWH (by gender, age, race, and risk group) in the US. To this end, we developed an agent-based simulation model (ProjEcting Age, multimoRbidity, and poLypharmacy in adults with HIV [PEARL]) of MSM in HIV care and projected the age distributions in three race/ethnicity groups to 2030.

Materials and Methods

Simulated MSM are characterized by several attributes corresponding to their age (between the ages of 15 to 85), race/ethnicity (categorized as White, Black, and Hispanic), ART use status (ART-user and non-user), and CD4 cell count (Figure 1). The race/ethnicity subgroups in NA-ACCORD are formed in the following order: 1) Hispanic MSM including all MSM reported as Hispanic, including Black Hispanic, 2) Black MSM including all non-Hispanic Black/African American MSM, and 3) White MSM including all non-Hispanic White MSM. Non-Hispanic multiracial, Asian, indigenous, and those patients missing information on race were excluded from the analysis. The model is initiated in 2009 and is calibrated through 2017 using data from the North American AIDS Cohort Collaboration on Research and Design (NA-ACCORD) (Supplement 1.1). (12) HIV surveillance reports by the US Centers for Disease Control and Prevention (CDC),(5, 13–20) and peer-reviewed literature.

Model parameterization

All simulation parameters are fit separately for Black, White and Hispanic MSM (unless stated otherwise). We refer readers to the PEARL website at https://pearlhivmodel.org, and the online supplement for a comprehensive review of methodology (Supplement 1).

Initial population in 2009

The total number of MSM ART-users in 2009 was extracted from CDC (17, 21), and age distributions were modeled using a set of two-component mixed normal distribution from NA-ACCORD. Assuming an original year of ART initiation ≥2000, we estimated the proportion of MSM initiating ART from 2000–2009 in NA-ACCORD (Table S4) and applie d a normal distribution with dynamic parameters to describe $\sqrt{\text{CD4 count}}$ at ART initiation in each year (changes in distribution's mean and standard deviation were modeled as a linear function of time – Table S5).

First-time ART initiators from 2010–2030

To project the future number of MSM diagnosed with HIV over time, we experimented with several candidate models to fit the CDC's reported number of new HIV diagnoses among MSM from 2009–2018 (5, 13–20). After removing inferior models, predictions from the remaining models were combined to generate a range for the number of new diagnoses in each year (Figure S3). We further modeled a gradual increase in the percentage of people linking to HIV care (13–20, 22) and initiating ART (23) over time.

Using NA-ACCORD data between 2010–2017, the age distribution of ART initiators was modeled via a two-component mixed normal distribution with dynamic parameters as a function of time. Similarly, we estimated a normal distribution with dynamic parameters to project changes in $\sqrt{\text{CD4 count}}$ at ART initiation to 2030.

Annual population dynamics

ART disengagement: ART disengagement was defined to have occurred if ≥2y elapsed without a CD4 count or viral load measurement in NA-ACCORD. The probability of disengagement was estimated via logistic regression as a function of a) age (modeled as a restricted quadratic spline), b) calendar year, c) $\sqrt{\text{CD4 count}}$ at ART initiation, and d) ART initiation period (≤2010 and >2010) (Supplement 1.4.1).

ART reengagement: Using aggregated data from all MSM in the NA-ACCORD (to ensure a large enough sample size), the probability of ART reengagement was estimated via a normalized Poisson distribution for up to seven years post disengagement (Supplement 1.4.2).

Mortality on ART: Using NA-ACCORD data on MSM receiving ART between 2009–2017, the probability of mortality was estimated using a logistic regression model with generalized estimating equations (GEE) as a function of a) age, b) $\sqrt{\text{CD4 count}}$ at ART initiation, c) ART initiation year (all modeled as restricted cubic splines), and d) calendar year (Supplement 1.4.3).

Mortality off ART: Given the lack of data from population off ART, we modeled potential increase in HIV mortality as a function of reduction in CD4 count in absence of treatment. To this end, we used data from the NA-ACCORD in care population (above) and applied a logistic regression model with GEE to estimate the probability of dying out of care as a function of a) age, b) $\sqrt{\text{current CD4 count}}$ (both modeled as restricted cubic splines) and c) calendar year (Supplement 1.4.4).

CD4 count dynamics: Changes in CD4 count on ART was modeled via a set of linear regression models (separately for each race) with GEE as a function of a) number of years since ART initiation, b) $\sqrt{\text{CD4 count}}$ at ART initiation, c) age (10-year age-groups), and interactions between b and c (Supplement 1.4.5). Collapsing all sub-groups to ensure adequate sample size, the rate of CD4 decline off ART (i.e. the difference in the log of CD4 count at ART disengagement and reengagement) was modeled via a linear regression model as a function of a) number of years off ART, and b) $\sqrt{\text{CD4 count}}$ at ART disengagement (Supplement 1.4.6).

Validation

To ensure the model's ability to project realistic aging patterns, we compared PEARL's projected age distribution of ART-users from 2010–2017 (calibration period) with NA-ACCORD data that were not directly applied in the process of calibration. The results of this comparison and further model checks are provided in Supplement 2.1.

Sensitivity analysis

To assess the uncertainty of results due to variation in modeling assumptions and parameters, we performed a one-way sensitivity analysis at the lower and upper 95% confidence limits for all parameters. The impact of changes was assessed based on the proportion of ART-users aged ≥60y in 2030. Additional outputs are discussed in Supplement 4.1. Further analysis that varied the number of future HIV diagnoses is presented in Supplement 4.2.

Results

Simulated population in 2009

The baseline simulation models a population of 195,465 MSM on ART in 2009, of whom 49.9% were White, 29.2% were Black, and 20.9% were Hispanic (Table 1). The median age among ART-users was estimated to be 44y and varied by race/ethnicity (White 46y, Black 42y, and Hispanic 41y). The median CD4 count was 451 cells/mm^3 for all MSM on ART, with the highest median among White MSM (492 cells/mm^3) and the lowest among Black MSM (405 cells/mm^3). Furthermore, PEARL projects a median population of 24,064 [95% Uncertainty Range (95%UR): 23,055–24,998] PWH not on ART in 2009.

Population of first-time ART initiators 2010–2030

PEARL projects a 2.3% annual increase in the number of ART initiators from 2010–2030, driven largely by the increase in the number of Hispanic MSM initiating ART (9.2% annual increase), and mitigated by a reduction in the number of White MSM initiating ART (−2.2% annual reduction, Table 1). The median CD4 count at ART initiation increased from 317 [312 – 322] cells/mm^3 in year 2010 to 513 [447 – 584] cells/mm^3 by 2030 (a 61.8% increase) among all MSM (Table 1). This increase was most pronounced among Hispanic MSM with a 75.7% increase in median CD4 count at ART initiation during this period, followed by Black and White MSM with 59.9% and 53.4% increases respectively (Figure 2).

The results further suggest a bimodal distribution of age at ART initiation in early years (Figure 3), shifting toward a left skewed distribution (younger ages) over time (i.e., comparing median age of 36y [36y – 37y] in 2010 to 31y [29y – 33y] in 2030 - Table 1). The most dramatic changes in the age at ART initiation are projected among White MSM with a 7-year reduction in median age from 2010–2030.

Simulated population of MSM ART-users and non-users

The population of MSM ART-users is projected to increase over time, from 210,633 [210,341 – 210,903] in 2010 to 582,498 [553,259 – 610,372] MSM by 2030 (Table 1). This increase is influenced by the projected increase in the number of Hispanic and Black MSM initiating ART (Table 1), as well as changes in mortality rates among Black, White, and Hispanic MSM on ART by −8.4%, 42.4% and −19.6% over this time (Table S23).

Furthermore, PEARL projects a gradual reduction in the rate of ART disengagement, from 6,567 [6,451 – 6,657] per 100,0 00 PY's in 2010 to 2,089 [2,045 – 2,134] in 2030, accompanied by an increase in ART reengagement rate from 41,546 [40,869 – 42,207] per 100,000 PY's to 53,251 [52,626 – 53,883] during 2010–2030. As a result, the overall size of the population of ART non-users (ever received treatment but off ART in a given year) remains relatively small at 23,404 [22,165 – 24,649] individuals by 2030 (Table 1).

Projected age distribution of MSM using ART

PEARL projects a gradual increase in median age of MSM on ART from 45y [45y – 45y] to 47y [46y – 48y] from 2010–2030, accompanied by an increase in proportion of ART-users age ≥60y from 6.7% [6.6% – 6.8%] to 28.0% [27.0% – 29.1%] during this time. White MSM experience the largest increase in the median age (at 12 years) from 2010–2030 (Figure 4). While the median ages among Black and Hispanic MSM on ART do not change significantly over this time period, the temporal changes in bimodal age distribution suggest an increase in the proportion of ART-users age ≥60y from 2010–2030 (e.g., projecting an increasing from 3.9% [3.8% – 4.1%] to 19.5% [18.6% −20.4%] among Black MSM, and from 3.5% [3.3% −3.7%] to 17.2% [15.9% −18.6%] among Hispanic MSM).

Sensitivity analysis

Using a threshold of 10% to identify significant changes relative to baseline, the proportion of ART-users age ≥60y was robust to one-way variation of most model parameters (Figure 5). Among all parameters, variations in mortality rate among ART-users, the number of ART initiators, and the age distribution of MSM in 2009 had the greatest impact on projected outcomes. Subtle variations were observed in racial/ethnic-specific outcomes to these parameters; for example, the proportion of Hispanic PWH on ART age ≥60y was sensitive to an increase in the mortality rate among people on ART.

Conclusions

Our results suggest that while the population of MSM initiating ART in the US is getting younger, the age distribution of ART-users has shifted towards older ages since 2010 and that this trend is likely to continue over the next decade, with 28.0% of ART-users projected to age ≥60y by 2030. The projected age distribution is heterogeneous by race/ethnicity, with an older age distribution among White MSM compared to Black and Hispanic MSM (Figure 4). Importantly, the age distributions within all race/ethnicity subgroups evolve to a bimodal distribution that is shifting toward older ages over time. These findings suggest that HIV programs will need to provide care for an aging population of MSM in the US. However, there are significant differences in the shifting age distributions by race/ethnicity that will impact future care needs among these subpopulations.

The age distribution of ART-users is influenced by improved long-term survival on treatment which can be attributed to improvements in effectiveness of ART regimens and more aggressive test-and-treat strategies in the 'Treat-All' era – a heterogeneous factor by race/ethnicity. Racial/ethnic disparities in ART prescription and viral suppression exist, especially among White-Black subgroups.(24) In a recent study using NA-ACCORD data, race/ethnicity disparities in life expectancy among MSM narrowed but persisted from 2004–2015.(2) Our modeling results confirm the existence of racial disparities in the ages of ART-users (older age among White MSM) and suggest that these disparities will persist over the next decade.

The US national test-and-treat strategies have focused on subgroups in which HIV incidence has remained stably high, including all MSM and specifically MSM of color.(25, 26) Recent CDC estimates of HIV incidence from 2010–2016 showed a decrease in the annual number of HIV infections among White MSM, no difference among Black MSM, and an increase among Hispanic MSM; with the majority of infections occurring in men <35y.(27) Moreover, the number of new HIV diagnoses from 2014–2018 decreased in White and Black MSM, but remained unchanged in Hispanic MSM.(3) These estimates suggest that existing test-and-treat strategies may be more effective at reducing the time to diagnosis and ART initiation for White and potentially Black MSM, but not Hispanic MSM. Multi-level interventions addressing barriers to HIV care are most likely to be effective in improving HIV outcomes for Hispanic MSM. CDC is funding a demonstration project in four areas (New York City, New York state, Houston, and the state of Texas) to identify molecular clusters of active transmission and implement HIV interventions among Hispanic MSM. Examples of these interventions include using partner services and social network strategies to assess transmission and risk networks, linkage to or re-engagement of people with HIV in care, linkage of high-risk HIV-negative individuals to PrEP, and additional activities addressing social and structural barriers for access to and participation in HIV-related services by Hispanic MSM (28, 29).

Our results align with previous studies projecting changing in age distribution of ART-users over time. (30–33) A study of PWH in Australia (32) estimated a 6-month annual increase in mean age from 2010–2020, with the proportion of all PWH age ≥50y growing from 25.3% to 44.2%. These results align closely with PEARL's projections at 29.7% in 2010 and

44.8% in 2020 for US MSM in HIV care (Table S23). In the Netherlands, Smit et. al. (2015) projected changes in the median age of PWH on ART from 43.9y in 2010 to 56.6y in 2030. (33) Using a similar model, they estimated an increase in the proportion of US ART-users age ≥50y from 39% in 2015 to 74% in 2035.(30) These results exceed the aging pattern suggested by PEARL, likely due to a combination of factors relating to differences in model structure (specifically how sex, race, and HIV acquisition risk-groups were included or not) and calibration data (applying data from a population of commercially-insured PWH in the US which may over-represent patients with low barriers to care and subsequent survival benefit).

Overall, PEARL's projections in 2018 aligns with the CDC's HIV surveillance estimates. In 2018, the CDC estimated that 20% of men with HIV were age ≥60y (3), compared to 14.3% of MSM age ≥60y in PEARL. Although CDC's surveillance data includes those who have not initiated ART and is not tailored to MSM (but men in general), the two estimates do not diverge significantly.

Given the complexities involved in modeling the HIV transmissions among all MSM subgroups at a national-level, and limitations of existing HIV models in capturing age and race/ethnicity compositions (34–36), we interpolated available HIV surveillance data from CDC on new HIV diagnoses from 2010–2018 and projected the future trends among Black, White, and Hispanic MSM. PEARL's projections, however, are unlikely to capture the potential reductions in HIV incidence due to earlier diagnoses in the 'Treat-All' era, improvements to the HIV care continuum, and preventive measures such as pre- or post-exposure prophylaxis for HIV prevention among MSM over the next decade. To address this limitation, we experimented with additional scenarios that allowed for accelerated increase/decline in HIV diagnosis from 2019–2030 and found that additional reductions in the number of new diagnoses can accelerate the aging pattern among ART-users by 2030 (see Supplement 4.2).

As with all modeling studies, PEARL's results are limited by simplifying assumptions. The simulated population is limited to Black, White, and Hispanic MSM, and other race/ethnicity groups are excluded due to insufficient sample sizes in the NA-ACCORD. Furthermore, due to sparsity of empirical data to inform parameters for individuals >85y, the simulated ages were capped at 85y. As a natural limitation of data, we could not detect a true event of discontinuation of ART and, instead, relied on loss-to-follow-up in NA-ACCORD (a gap of ≥2y in CD4 or HIV RNA laboratory measurements). Furthermore, the NA-ACCORD criteria of linkage-to-care by having ≥2 visits in a 12-months period (compared to CDC's criteria of ≥1 visit in the first 3-months post-diagnosis) may result in a selection bias toward a population that is more likely to retain in care and could underestimate the true rate of ART disengagement. Moreover, we may underestimate the size of ART non-user population in 2009 by back-calculating data to 2006 and excluding prior years. Finally, the natural limitations of NA-ACCORD data for PWH out of care, can potentially affect our estimates of HIV mortality and disengagement in this group.

In conclusion, PEARL projects that the population of MSM in ART care will continue to grow in size and age over the next decade, with persistent heterogeneities by race/

ethnicity. As the population ages with HIV, adopting paradigms that maximize quality of life, minimalize frailty, and increase health span is needed.(37)

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Data availability

A complete description of PEARL's modeling assumptions, parameters' formulation and estimated values can be found at https://pearlhivmodel.org. The model is not yet accessible as open source; however, the source code can be obtained from authors upon request.

The data underlying the results presented in the study are available from NA-ACCORD (https://naaccord.org/). The NA-ACCORD data are available from the NA-ACCORD Steering Committee for researchers who meet the criteria for access to HIPAA-defined "limited data." Ethical restrictions prevent public deposition of data. NA-ACCORD data are made available to any researcher upon completion of a rigorous scientific concept sheet submission, review, and approval process through the NA-ACCORD Steering Committee and Executive Committees, pursuant to agreements with the National Institutes of Health and constituent cohorts. Guidelines for concept sheet submission and approval may be found at https://naaccord.org/

Abbreviations:

ART	Antiretroviral therapy
PWH	People with HIV
MSM	Men who have sex with men
Black	Black/African Americans
NA-ACCORD	North American AIDS Cohort Collaboration on Research and Design
CDC	The US Centers for Disease Control and Prevention

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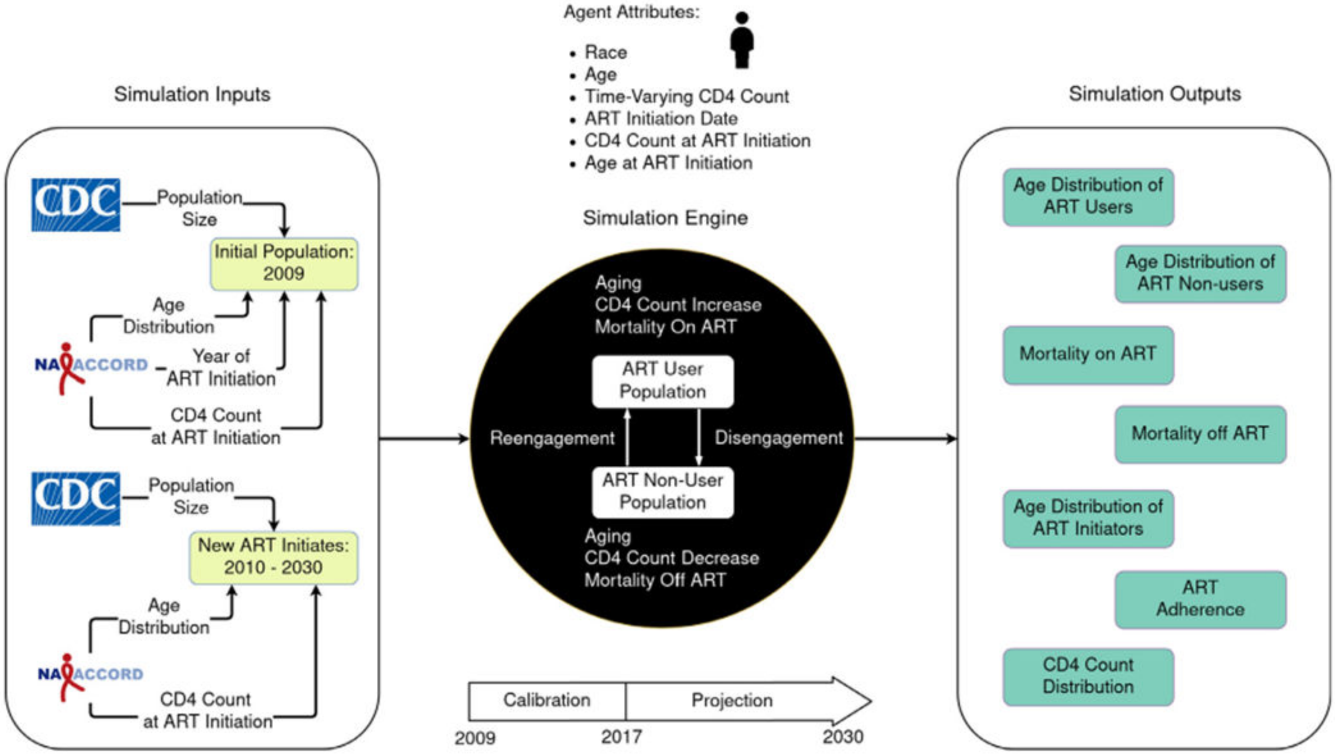

Figure 1.

PEARL simulation logic. Simulated agents are characterized in terms of race/ethnicity, age, CD4 count, and ART initiation status. The simulation engine models the population of MSM between the ages of 15 to 85 who have ever started ART in the US. In each year, a population of new ART initiators enter the model and are followed until death or the end of simulations in 2030. While on ART, individuals experience a gradual increase in CD4 count and are subjected to risk of death and ART disengagement. Upon disengagement, individuals experience gradual reduction in CD4 count, higher risk of death, and a probability of ART reengagement in each consecutive year. Annual processes including aging, CD4 dynamics, and HIV mortality are modeled separately for each group. Main simulation inputs include the size of initial population in 2009 and number of new ART initiators (2010 – 2030) estimated from NA-ACCORD and CDC HIV surveillance data (left panel). Main simulation outcomes are shown in the right panel. The model is calibrated from 2010 – 2017, and outcomes are projected to 2030.

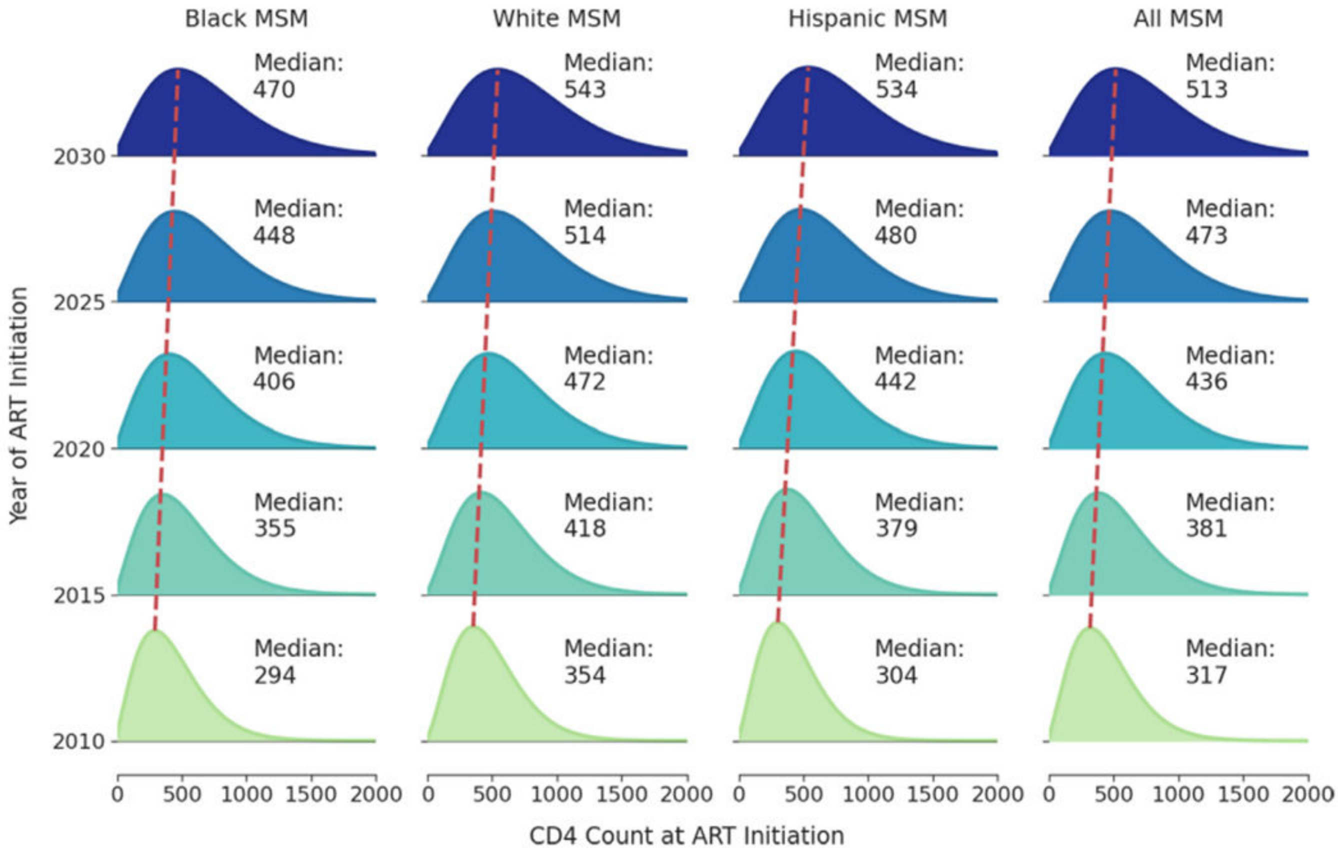

Figure 2.

Projected changes in CD4 count distribution at ART initiation among Black, White, Hispanic, and all MSM in selected years between 2010 and 2030. Each panel shows the projected distribution of CD4 count (x-axis) at ART initiation in selected years (y-axis). The red dashed line mark changes in the median CD4 count over time. Largest improvements are projected among Hispanic MSM with 75.7% increase in median CD4 count (from 304 cells/mm^3 in 2010 to 534 in 2030), followed by Black MSM with 59.9% increase (from 294 cells/mm^3 in 2010 to 470 in 2030), and White MSM with 53.4% increase (from 354 cells/mm^3 in 2010 to 543 in 2030). The overall median CD4 count among all MSM increased from 317 to 513 cells/mm^3 (61.8% increase) from 2010 to 2030.

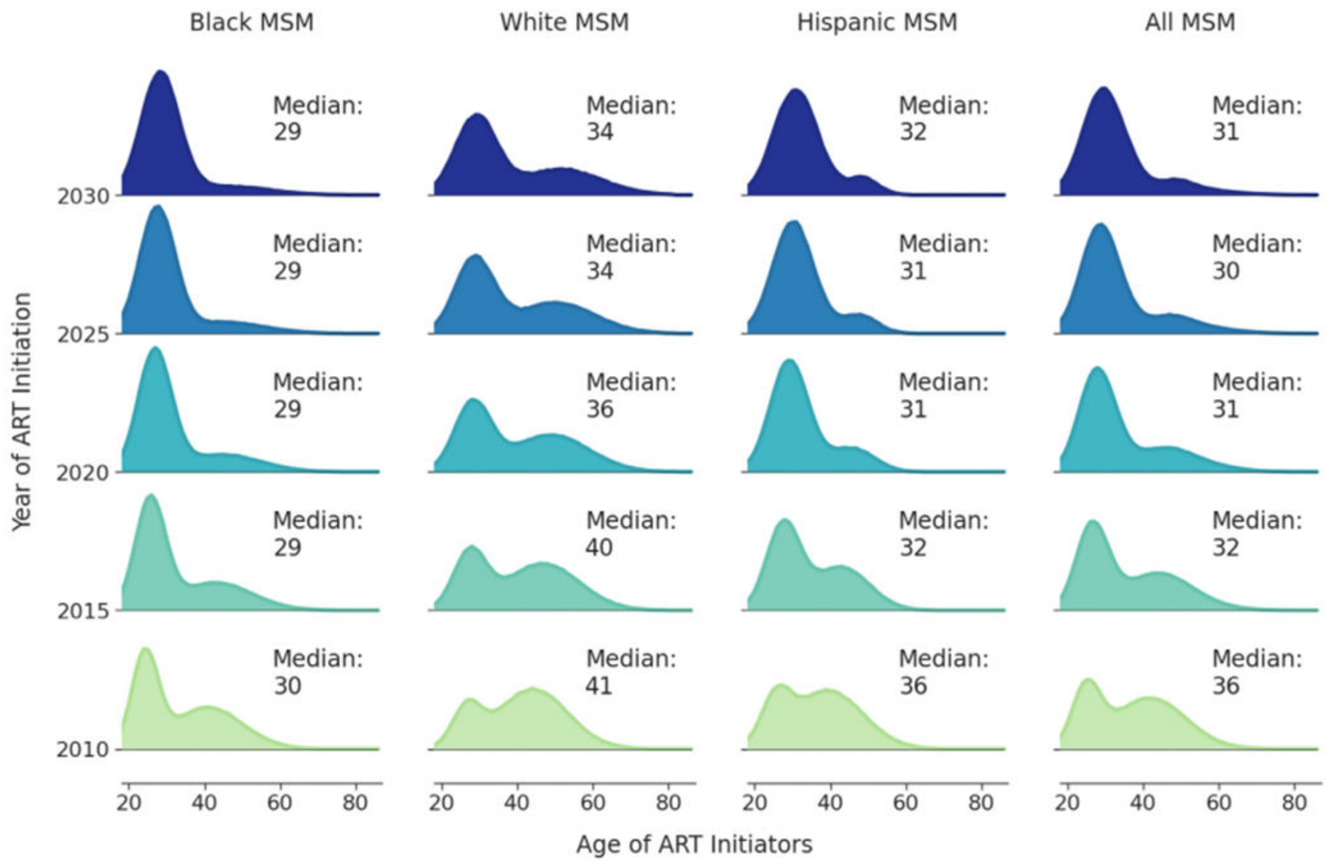

Figure 3.

Projected distribution of age at ART initiation among Black, White, Hispanic, and All MSM in selected years between 2010 and 2030. Each panel shows the projected distribution of age at ART initiation (x-axis) in selected calendar years (y-axis). The distribution of age at ART initiation is modeled using a two-component mixed normal distribution with dynamic parameters as a function of time (Supplement 1.3.2). The distributions are truncated at ages of 18 and 85 years. All race/ethnicity subgroups of MSM reflect a temporal shift in the distribution of age at ART initiation toward younger ages over time (as reflected by reduction in median age). The right column represents the simulated distribution of age among all MSM initiating ART in the model, with a median age of 36y in 2010 and 31y in 2030.

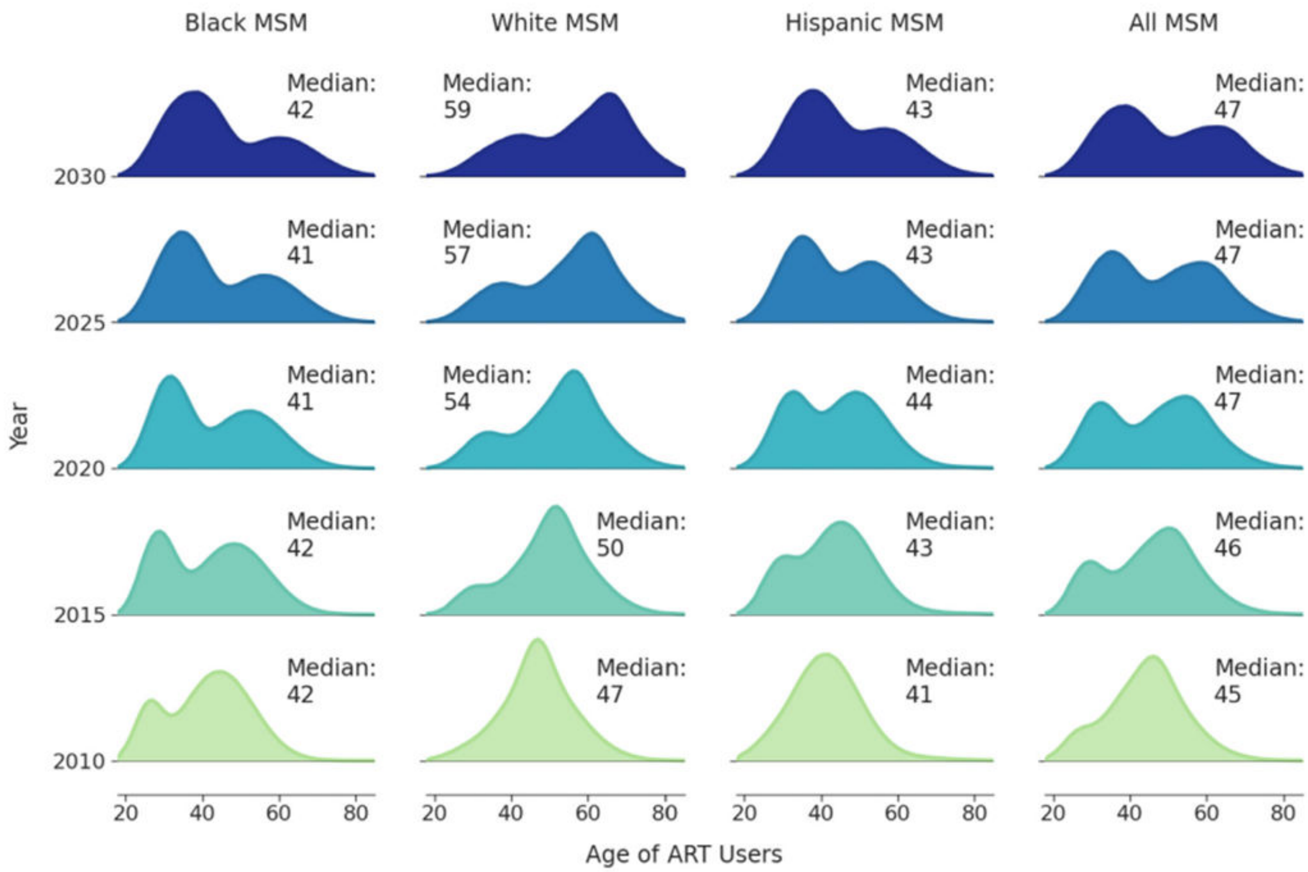

Figure 4.

Projected distribution of age of ART-users among Black, White, Hispanic, and All MSM in selected years between 2010 and 2030. Each panel shows the projected population of ART-users by age (x-axis) and at selected calendar years (y-axis). All race/ethnicity sub-groups of MSM reflect a temporal shift in the age distribution toward older ages over time (as reflected by increase in median age). Furthermore, the projected ages represent a bimodal distribution in later years, with proportion of ART-users age ≥60y in 2010 and 2030 increasing among Black MSM from 3.9% to 19.5%; among White MSM from 9.8% to 49.7%; among Hispanic MSM from 3.5% to 17.2%; and among all MSM from 6.7% to 28.0% (Table S23).

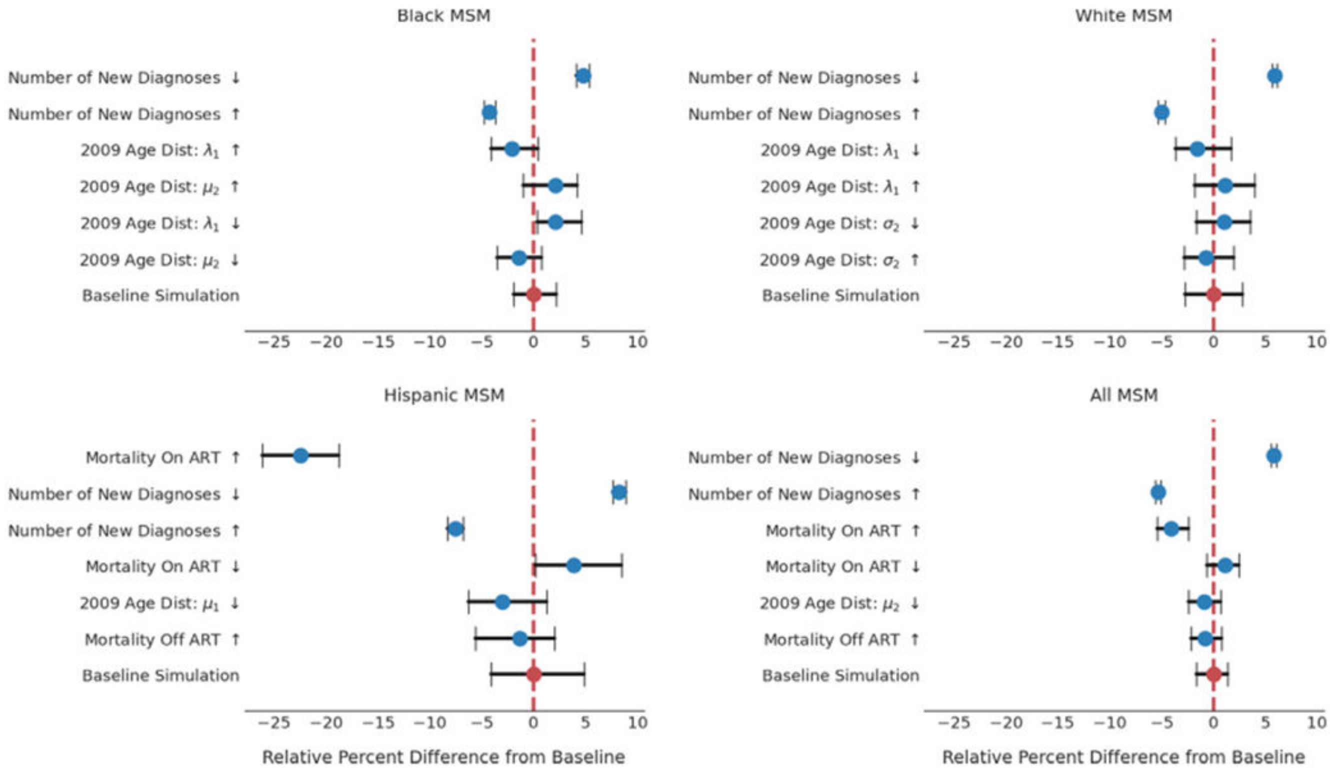

Figure 5.

One-way sensitivity analysis to variation of all parameters. Shown in each panel are the percent changes in the proportion of ART-users age ≥60y in 2030 ‘relative’ to baseline scenario (x-axis) with regard to one-way changes in all model parameters (y-axis). The up/down arrows on the y-axis mark an increase/decrease in value of each parameter to corresponding +/− 95% confidence ranges. Circles mark the median values and black bars represent the 75% interquartile uncertainty range for simulated outcomes. The baseline value is marked in red and shown as a dotted vertical line to compare against other scenarios. Scenarios are ranked in the order of effect and each plot is restricted to the 6 parameters with the larges impact on selected outcome. Using a threshold of 10% relative change to detect significant variations from baseline, the proportion of ART-users age ≥60y remains robust to variation of all model parameters, except for an increase in mortality rate among Hispanic MSM on ART. Further results are presented in Section 4.1 of the Supplement.

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Table 1

Characteristics of the simulated population at selected calendar years between 2009 to 2030. Values represent the median [95%UR] for each simulated outcome across 200 random simulation replications. Simulations begin in 2009 by modeling the initial population of ART-users and ART non-users. New ART initiators enter the model on an annual basis from 2010–2030. The size of ART-users in 2009 is estimated from CDC data directly and, as such, does not reflect any uncertainty. The "ART non-user" population represent HIV-infected MSM previously on treatment who are disengaged from ART in a given calendar year. The age and CD4 distributions for ART-users in 2009 are estimated from NA-ACCORD. The median value of sampled values from these simulations matches the median value of data and, as such, reflect low uncertainty.

	2009	2010	2015	2020	2025	2030
Number of MSM initiating ART:						
All	-	15,168 [14,876, 15,438]	22,211 [21,895, 22,525]	22,108 [21,165, 22,937]	22,037 [19,765, 24,252]	22,226 [18,092, 26,242]
Black	-	5,988 [5,845, 6,133]	8,929 [8,771, 9,087]	8,881 [8,415, 9,347]	8,840 [7,796, 9,881]	8,696 [7,068, 10,328]
White	-	5,455 [5,284, 5,622]	6,892 [6,723, 7,068]	5,753 [5,234, 6,267]	4,366 [3,160, 5,564]	3,032 [1,059, 4,944]
Hispanic	-	3,721 [3,575, 3,877]	6,380 [6,215, 6,560]	7,464 [6,976, 7,984]	8,839 [7,459, 10,282]	10,536 [7,737, 13,553]
Proportion of All MSM initiating ART who are:						
< 30 years old	-	0.335 [0.327, 0.342]	0.405 [0.398, 0.411]	0.440 [0.420, 0.461]	0.438 [0.376, 0.527]	0.412 [0.312, 0.504]
[30, 40) years old	-	0.252 [0.244, 0.258]	0.249 [0.244, 0.255]	0.309 [0.293, 0.321]	0.363 [0.319, 0.423]	0.410 [0.336, 0.503]
[40, 50) years old	-	0.270 [0.263, 0.278]	0.205 [0.200, 0.210]	0.135 [0.122, 0.150]	0.104 [0.061, 0.144]	0.098 [0.054, 0.165]
[50, 60) years old	-	0.122 [0.118, 0.128]	0.114 [0.110, 0.118]	0.088 [0.080, 0.097]	0.067 [0.040, 0.102]	0.058 [0.018, 0.115]
[60, 70) years old	-	0.020 [0.018, 0.022]	0.025 [0.023, 0.027]	0.025 [0.022, 0.028]	0.020 [0.013, 0.029]	0.016 [0.005, 0.029]
70+ years old	-	0.001 [0.001, 0.002]	0.002 [0.002, 0.003]	0.004 [0.003, 0.005]	0.003 [0.002, 0.006]	0.003 [0.001, 0.007]
Median CD4 Count	-	317 [312, 322]	381 [376, 385]	436 [424, 447]	473 [436, 513]	513 [447, 584]
Median Age	-	36 [36, 37]	32 [32, 32]	31 [30, 31]	30 [29, 32]	31 [29, 33]
Number of MSM on ART:						
All	195,465	210,633 [210,341, 210,903]	309,417 [306,807, 312,002]	404,424 [398,966, 409,308]	496,353 [482,837, 508,372]	582,498 [553,259, 610,372]
Black	57,104	63,092 [62,949, 63,237]	104,796 [103,477, 106,200]	143,633 [141,022, 146,189]	181,456 [175,078, 187,884]	216,786 [203,870, 229,839]
White	97,464	102,919 [102,748, 103,086]	131,723 [130,128, 133,316]	156,084 [153,082, 159,185]	172,624 [165,429, 179,859]	179,328 [164,536, 194,056]
Hispanic	40,897	44,618 [44,472, 44,774]	72,781 [71,458, 74,285]	104,457 [101,781, 107,457]	141,928 [134,422, 149,862]	186,308 [168,438, 205,224]
Proportion of All MSM on ART who are:						
< 30 years old	0.093	0.097 [0.096, 0.098]	0.125 [0.124, 0.126]	0.108 [0.106, 0.110]	0.088 [0.083, 0.094]	0.072 [0.063, 0.078]

	2009	2010	2015	2020	2025	2030
[30, 40) years old	0.231	0.215 [0.213, 0.217]	0.191 [0.190, 0.193]	0.236 [0.234, 0.238]	0.264 [0.258, 0.270]	0.250 [0.238, 0.262]
[40, 50) years old	0.404	0.391 [0.389, 0.393]	0.290 [0.289, 0.292]	0.208 [0.206, 0.209]	0.186 [0.183, 0.190]	0.225 [0.221, 0.231]
[50, 60) years old	0.212	0.229 [0.227, 0.232]	0.285 [0.283, 0.286]	0.279 [0.277, 0.281]	0.225 [0.222, 0.229]	0.172 [0.167, 0.178]
[60, 70) years old	0.052	0.058 [0.057, 0.059]	0.092 [0.091, 0.093]	0.137 [0.136, 0.139]	0.181 [0.178, 0.184]	0.189 [0.182, 0.196]
70+ years old	0.007	0.009 [0.008, 0.009]	0.017 [0.016, 0.017]	0.032 [0.031, 0.032]	0.056 [0.054, 0.057]	0.091 [0.088, 0.096]
Median CD4 Count	451	465 [465, 465]	517 [517, 517]	582 [582, 582]	644 [642, 645]	698 [695, 703]
Median Age	44	45 [45, 45]	46 [46, 46]	47 [47, 48]	47 [47, 48]	47 [46, 48]
Mortality among ART users (rate per 100,000 MSM)						
All	-	1,016 [977, 1,063]	817 [783, 845]	791 [768, 814]	895 [868, 925]	1,036 [994, 1,076]
Black	-	1,125 [1,050, 1,202]	835 [790, 886]	796 [757, 845]	895 [855, 938]	1,031 [972, 1,084]
White	-	1,115 [1,048, 1,187]	919 [871, 978]	940 [892, 985]	1,198 [1,148, 1,257]	1,587 [1,488, 1,689]
Hispanic	-	635 [561, 721]	604 [557, 664]	558 [515, 596]	522 [486, 566]	510 [467, 563]
Mortality among all ART non-users (rate per 100,000 MSM) [1]	-	1,501 [1,346, 1,653]	1,314 [1,189, 1,443]	1,161 [1,047, 1,285]	1,075 [948, 1,214]	1,142 [1,030, 1,268]
Disengagement from ART (rate per 100,000 MSM) [1]	-	6,567 [6,451, 6,657]	4,737 [4,665, 4,804]	3,584 [3,524, 3,647]	2,737 [2,692, 2,792]	2,089 [2,045, 2,134]
Reengagement rate in ART (rate per 100,000 MSM) [1]	-	41,546 [40,869, 42,207]	52,738 [52,109, 53,305]	52,922 [52,366, 53,570]	53,128 [52,540, 53,765]	53,251 [52,626, 53,883]
Number of MSM off ART [1] [2]	24,064 [23,055, 24,998]	24,064 [23,055, 24,998]	26,732 [26,388, 27,040]	27,012 [26,609, 27,459]	25,816 [25,051, 26,463]	23,404 [22,165, 24,649]

[1] A complete list of results for all simulated years and racial breakdown for selected categories are provided in Section 3 of the Supplement (Table S23). The model starts with a population of ART non-users at the end of 2009 and while ART engagement/disengagement events occur at the end of 2010, The agent's states are updated in the following year (2011); as such the size of the ART non-user population remains fixed in 2009 and 2010.