**Title:** Modeling State-Level Aging Patterns Among People with HIV in the United States

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**Abstract** (439/250 words)

**Background:** As people living with HIV continue to age in the United States (US), local healthcare systems should prepare to manage the increasing burden of age-related comorbidities. It remains unclear how these demographic trends - and their corresponding impacts on healthcare systems - will continue into the future and how they differ across US states.

**Methods:** The Johns Hopkins Epidemiologic and Economic Model (JHEEM) is a dynamic transmission model of HIV in the US. The model is calibrated to population demographics (by age, race/ethnicity, sex) and key HIV epidemiological targets - including new diagnoses and diagnosed prevalence by age group - in 11 states comprising 63% of diagnosed prevalence in the US (Alabama, California, Florida, Georgia, Illinois, Louisiana, Mississippi, Missouri, New York, Texas, and Wisconsin). We project HIV epidemics from 2025 to 2040, estimating the proportion of people with diagnosed HIV (PWDH) over the ages of 55 as well as the median age of PWDH. We report 95% credible intervals across 1,000 independent simulations per state.

**Results:** The model projected the number of PWDH across all 11 states to rise from 665,000 (95% credible interval: 658,000 to 671,000) in 2025 to 702,000 (673,000 to 726,000) in 2040, with the number age 55+ growing from 308,000 (302,000 to 315,000) in 2025 to 402,000 (379,000 to 326,000) in 2040. This reflects an increase in the proportion of PWDH age 55+ from 46% (45 to 47%) in 2025 to 57% (54 to 60%) in 2040 and a shift in median age of PWDH from 51 years (51 to 52) to 61 years (58 to 63). State-level analysis suggested substantial variations in local outcomes. For example, the proportion of PWDH age 55+ in California was projected to rise from 50% (47 to 53%) to 67% (59 to 75%), with the median age rising from 54 years (52 to 56) to 67 years (63 to 70). By contrast, simulations in Wisconsin projected a stable proportion of PWDH age 55+, 44% (41 to 47%) versus 43% (37 to 53%), accompanied by reductions in projected median age from 49 years (47 to 51) to 41 years (38 to 60) between 2025 and 2040. Projected state-level changes in the proportion of PWDH age 55+ were most strongly correlated with urbanicity (Pearson correlation coefficient = +0.72; p=0.01).

**Conclusions:** The population of persons living with HIV in the US is projected to age significantly by 2040. Aging patterns will vary across states, with more rapid aging projected to occur in urban states. It will be important to allocate resources to help healthcare systems adapt to changing demographic patterns of PWDH in a manner that reflects state-level needs.

**Text** (1655/3000 words)

**Introduction** (364/~500 words; RW: 369)

The United States (US) has made considerable progress in curtailing its HIV epidemic over the past several decades, with new infections seeing a 75% decrease from a peak of approximately 130,000 in 1984 to 31,800 in 2022. With the launch of the national *Ending the HIV Epidemic (EHE)* initiative in 2019, there has been a renewed focus on reducing infections among key risk groups, with new infections declining by 10% among men who have sex with men (MSM) and by 18% among Black or African Americans from 2018 to 2022.

While the EHE initiative focuses primarily on reducing new HIV infections, care must be paid to the estimated 1.2 million people already living with HIV in 2022. The widespread availability of effective antiretroviral therapy (ART) has increased the life expectancy of people with HIV (PWH) in the US. By the end of 2022, over half of individuals with diagnosed HIV in the US were aged 50 years or older.

People aging with HIV are at increased risk for age-related conditions including cardiovascular diseases, chronic obstructive pulmonary disease, diabetes, chronic kidney disease, and certain non-AIDS-defining cancers. They are also at greater risk of acquiring multiple comorbidities as they age. A 2024 modeling analysis of comorbidity among PWH in the US who have initiated ART projected increases in depression, dyslipidemia, diabetes, chronic kidney disease, and myocardial infarction, with multimorbidity (two or more comorbidities other than HIV) projected to increase from 63% in 2020 to 70% in 2030. As the population living with HIV ages, local healthcare systems—as well as the national Medicare program—will need to prepare to manage the increasing burden of age-related comorbidities among this population.

While there have been studies published to date exploring aging among PWH in the US, they have typically been conducted at the national level or focus only on certain risk groups such as MSM. The objective of our study was to explore how aging dynamics of the population with HIV will differ at the state level in the US, using a dynamic, compartmental model of HIV transmission.

**Methods** (434/~700 words; RW: 1185)

*Model structure and calibration*

The Johns Hopkins Epidemiologic and Economic Model (JHEEM) is a dynamic, compartmental model of HIV transmission in the US, stratifying the adult population by age, race/ethnicity, sex, and HIV status. In order to capture the 48 counties highlighted in the EHE initiative, the JHEEM was originally developed to model epidemics at the level of metropolitan statistical area (MSA); the model has been adapted here to represent state-level epidemics. In this analysis, we model HIV epidemics in 11 states comprising 63% of diagnosed prevalence in the US: Alabama, California, Florida, Georgia, Illinois, Louisiana, Mississippi, Missouri, New York, Texas, and Wisconsin. These states were chosen to represent varied geographic regions and prioritization within EHE initiative.

The model calibration process at the state-level followed the same methodology as the previously-published MSA-level models, with analogous targets for population demographics, HIV dynamics (e.g., new diagnoses, diagnosed prevalence, and mortality), and the HIV care cascade (e.g., use of pre-exposure prophylaxis, awareness of HIV status, and viral suppression)—see Supplement.

*Modeled scenario and outcomes*

After calibration, we projected the models forward from 2025 to 2040 across the 11 states. Our projections followed a “status quo” scenario, assuming recent trends in HIV programming continue into the future, allowing for temporary disruptions due to the COVID pandemic.

Our primary outcome was the state-level proportion of people living with diagnosed HIV (PWDH) age 55+ (out of all adults age 13+ with diagnosed HIV in the state), in both 2025 and 2040. Secondary outcomes include the median age of PWDH over age 13, the absolute number of PWDH age 55+, and the proportion and absolute number of PWDH age 65+ (all reported in 2025 and 2040). For all outcomes, we report the mean across 1,000 simulations and the 95% credible interval (2.5th and 97.5th percentiles). We also present results by subgroup, specifically HIV acquisition risk (MSM vs non-MSM) and race (Black, Hispanic, and other).

We chose to include the secondary outcome focused on PWDH age 65+ due to the significance of Medicare eligibility beginning in this age group. However, the oldest age group we explicitly model is age 55+; this was chosen to reflect the age stratifications available in the CDC surveillance data we use as calibration targets. Thus, in order to report estimates for age 65+, we used a smoothing….[GET DETAILS FROM NICK].

*Sensitivity analysis*

We conducted sensitivity analyses to identify the parameters that had the strongest influence on the proportion of PWDH age 55+. We calculated partial rank correlation coefficients (PRCC, a measure of the correlation between each parameter and the outcome) based on this outcome in one state. Furthermore, we inspected how the individual simulations with the highest and lowest values of those parameters compare on the basis of our outcome of interest, the proportion of PWDH age 55+.

**Results** (838/~1000 words; RW: 864)

*Model calibration results and total diagnosed prevalence*

Our model estimates generally fit well to calibration targets. **Figure 1** depicts the calibration fit for [state], showing a comparison between model outputs and reported estimates for both diagnosed prevalence and reported diagnoses by age.

When aggregated across all 11 states, the model projected the total number of PWDH to rise from 665,000 (95% credible interval: 658,000 to 671,000) in 2025 to 702,000 (673,000 to 726,000) in 2040 (**Figure 3**, “Total”). Diagnosed prevalence was projected to increase in all states except for California, New York, and Illinois, where we projected slight decreases in diagnosed prevalence during this period (**Figure 3**).

*Proportion and absolute number age 55+*

The proportion of PWDH age 55+ across all 11 states was projected to increase 11% (8 to 14%), from 46% (45 to 47%) in 2025 to 57% (54 to 60%) in 2040 (**Figure 2**). While New York and Florida had the greatest proportions age 55+ in 2025 (New York: 56% [54 to 58%], Florida: 51% [48 to 54%]), the greatest increases in this proportion occurred in California (17% [11 to 24%]) and Florida (14% [7 to 22%]). As a result, these two states had the highest projected proportion age 55+ by 2040 (California: 67% [59 to 75%], Florida (65% [56 to 75%]).

The states with the lowest proportions age 55+ in 2025 were Alabama (34% [30 to 37%]) and Texas (36% [34 to 38%). While this proportion was projected to grow in Texas, both Alabama and Wisconsin saw decreases of 1% (Alabama interval: 6% decrease to 10% increase; Wisconsin interval: 6% decrease to 7% increase) over this period, resulting in these two states having the lowest 2040 proportions (Alabama: 33% [25% to 47%], Wisconsin: 43% [37% to 53%]).

Across all states, the number of PWDH age 55+ increased from 308,000 (302,000 to 315,000) in 2025 to 402,000 (379,000 to 326,000) in 2040, representing a 31% increase in the total number of diagnosed individuals in this age group (**Supplemental Figure X**). The states with the largest absolute increases in the number of PWDH age 55+ were Florida (growing from 64,700 [61,181 to 68,566] in 2025 to 91,496 [80,767 to 106,063] in 2040, or a 41% increase) and Texas (from 38,685 [35,915 to 41,236] in 2025 to 59,400 [50,022 to 71,931] in 2040, a 32% increase).

Most states showed a persistently bimodal age distribution, with most prevalent cases existing in either the 55+ or 35-44 years age categories (**Figure 3**). Wisconsin was an exception, with 25-34 years becoming the second-largest age category by 2040 with 32% of prevalent cases.

*Proportion and absolute number age 65+*

Compared to the proportion age 55+, the proportion of PWDH age 65+ grew by a smaller amount, 4% (1% decrease to 12% increase), from 22% (19 to 25%) in 2025 to 26% (19 to 37%) in 2040 (**Figure 2**). The total number of PWDH age 65+ rose from 220,000 (214,000 to 226,000) in 2025 to 327,000 (308,000 to 347,000) in 2040, or a 49% increase in the total number in this age group (**Supplemental Figure X**). For the most part, the state-level patterns in proportion and number age 65+ resembled those of the proportion and number age 55+.

*Median age*

From 2025 to 2040, the median age of adults over age 13 with diagnosed HIV was projected to shift 10 years older, from 51 years (51 to 52) to 61 years (58 to 63, **Figure 2**). Again, California and Florida saw the greatest increases, with a 13-year increase in California (from 54 [52 to 56] in 2025 to 67 [63 to 70] in 2040) and a 10-year increase in Florida (from 55 [53 to 57] in 2025 to 65 [60 to 70] in 2040). Three states (Wisconsin, Alabama, and Missouri) had decreasing median ages over this period, with the largest decrease occurring in Wisconsin (a seven-year decrease, from 49 [47 to 51] in 2025 to 41 [38 to 60] in 2040).

*Results by subgroup*

The proportion of MSM age 55+ was projected to increase from 43% (41 to 44%) in 2025 to 53% (49 to 58%) in 2040, while the same proportion for non-MSM individuals began and remained higher, rising from 53% (52 to 55%) in 2025 to 65% (60 to 70%) in 2040.

Among our three modeled racial categories, “Black” and “Hispanic” began younger than “Other”, but all three aged significantly. The proportion of Black individuals who are 55+ was projected to rise from 41% (40 to 43%) in 2025 to 50% (46 to 55%) in 2040, while the similar proportion for Hispanic individuals was projected to rise from 42% (CI: 40 to 45%) in 2025 to 59% (52 to 66%) in 2040, and for Other race individuals, from 59% (CI: 57 to 60%) in 2025 to 66% (CI: 62 to 70%) in 2040.

*Sensitivity analyses – what parameters were most significant*

**[Add in sensitivity analysis results]**

Projected state-level changes in the proportion of PLWDH age 55+ were most strongly correlated with urbanicity (Pearson correlation coefficient = +0.72; p=0.01).

**Discussion** (/ ~800 words; RW: 1077)

**[Fill in discussion]**

*Reprise of main results*

* We used a calibrated model of HIV transmission to project the age distribution of people with diagnosed HIV at the state level in the US.
* By 2040, over half of all diagnosed PWH will be age 55+ and over a quarter will be age 65+

*Context*

* As these proportion shifts, HIV programming will have to consider realignment of priorities
* Health systems will also have to prepare for an increase in the absolute numbers accessing services for age-related comorbidities
* Among the total population eligible for Medicare (age 65+), the proportion with HIV will increase

*Limitations*

* Did not directly model 65+ age group
* Assumptions about no major changes to services
* General limitations of the state model? Such as, HIV epidemics are better modeled at the MSA level in many cases?
  + Yes, you can say that we assumed homogenous mixing within state, whereas there are likely differences by urban/rural areas within states

*Strengths*

* Bayesian calibration approach allows us to represent uncertainty in our model parameters and capture a range of simulation results
* Modeling at the state level captures local dynamics

*Reprise of conclusion*

* Our findings suggest that the United States will face an aging HIV population over the next 15 years
* While policy initiatives such as the EHE plan have historically focused on reducing new HIV infections, we must continue to consider the needs of and provide comprehensive care for individuals living with HIV as they age.

**Figure 1: Model calibration and projected diagnosed prevalence (left panel) and new diagnoses (right panel) by age for [state], overlaid with calibration data.**

[Insert figure – the below panels are what I’m envisioning]

|  |  |
| --- | --- |
| Diagnosed prevalence, 2000-2030 | New diagnoses, 2000-2030 |
| Total | Total |
| 13-24 | 13-24 |
| 25-34 | 25-34 |
| 35-44 | 35-44 |
| 45-54 | 45-54 |
| 55+ | 55+ |

Sample projections by age for [state]. The mean value across 1000 model simulations is shown as a red line, with 95% credible intervals shown as the shaded ribbons. Blue dots indicate calibration target data.

**Figure 2: State-Level Age Distribution Summary** (TO DO: replace num 55+ with prop 65+, move num 55+ and num 65+ to supplemental, unshaded).

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *State* | **Total** | | **Proportion Age 55+** | | | **Number Age 55+** | | | **Median Age** | | | |
| *2025* | | *2025* | *2040* | Δ | *2025* | *2040* | Δ | *2025* | *2040* | Δ | |
| *CA* | 140,514 | | 50% | 67% | 17% | 70,024 | 89,408 | 19,384 | 54 | 67 | 13 | |
|  | | [47 to 53%] | [59 to 75%] | [11 to 24%] | [65,956 to 74,277] | [78,383 to 100,109] | [11,274 to 27,031] | [52 to 56] | [63 to 70] | [11 to 16] | |
| *FL* | 126,261 | | 51% | 65% | 14% | 64,700 | 91,496 | 26,796 | 55 | 65 | 10 | |
|  | | [48 to 54%] | [56 to 75%] | [7 to 22%] | [61,181 to 68,566] | [80,767 to 106,063] | [18,299 to 37,780] | [53 to 57] | [60 to 70] | [6 to 14] | |
| *NY* | 122,642 | | 56% | 65% | 9% | 68,852 | 74,912 | 6,060 | 58 | 67 | 8 | |
|  | | [54 to 58%] | [58 to 72%] | [3 to 16%] | [65,678 to 71,994] | [66,824 to 84,789] | [-676 to 14,310] | [57 to 60] | [63 to 70] | [6 to 11] | |
| *TX* | 107,200 | | 36% | 47% | 11% | 38,685 | 59,400 | 20,715 | 46 | 49 | 3 | |
|  | | [34 to 38%] | [39 to 58%] | [4 to 20%] | [35,915 to 41,236] | [50,022 to 71,931] | [13,258 to 31,171] | [45 to 47] | [42 to 61] | [-3 to 14] | |
| *GA* | 63,841 | | 37% | 45% | 8% | 23,875 | 32,831 | 8,957 | 45 | 47 | 2 | |
|  | | [34 to 41%] | [35 to 58%] | [-1 to 17%] | [21,933 to 26,114] | [25,816 to 39,222] | [3,603 to 14,183] | [44 to 47] | [41 to 64] | [-4 to 17] | |
| *IL* | 35,682 | | 43% | 56% | 14% | 15,209 | 17,807 | 2,598 | 48 | 59 | 11 | |
|  | | [40 to 46%] | [47 to 70%] | [6 to 24%] | [14,206 to 16,345] | [15,471 to 20,933] | [516 to 4,859] | [47 to 50] | [46 to 68] | [-2 to 18] | |
| *LA* | 22,298 | | 39% | 52% | 13% | 8,637 | 12,937 | 4,299 | 47 | 54 | 7 | |
|  | | [36 to 42%] | [40 to 65%] | [4 to 24%] | [7,909 to 9,406] | [10,189 to 16,089] | [2,252 to 6,750] | [45 to 48] | [43 to 65] | [-3 to 17] | |
| *AL* | 15,021 | | 34% | 33% | -1% | 5,045 | 6,150 | 1,105 | 44 | 41 | -3 | |
|  | | [30 to 37%] | [25 to 47%] | [-6 to 10%] | [4,570 to 5,474] | [4,767 to 8,168] | [47 to 2,886] | [43 to 46] | [38 to 46] | [-5 to 1] | |
| *MO* | 13,812 | | 43% | 47% | 3% | 5,964 | 7,366 | 1,402 | 48 | 48 | -1 | |
|  | | [40 to 47%] | [35 to 59%] | [-5 to 14%] | [5,473 to 6,456] | [6,015 to 8,672] | [429 to 2,381] | [46 to 51] | [39 to 64] | [-8 to 14] | |
| *MS* | 10,154 | | 38% | 44% | 6% | 3,853 | 5,292 | 1,439 | 47 | 47 | 0 | |
|  | | [35 to 41%] | [38 to 53%] | [2 to 13%] | [3,532 to 4,172] | [4,325 to 6,461] | [744 to 2,342] | [46 to 48] | [43 to 57] | [-3 to 10] | |
| *WI* | 7,259 | | 44% | 43% | -1% | 3,185 | 4,221 | 1,036 | 49 | 41 | -7 | |
|  | | [41 to 47%] | [37 to 53%] | [-6 to 7%] | [2,976 to 3,409] | [3,700 to 4,774] | [664 to 1,461] | [47 to 51] | [38 to 60] | [-10 to 10] | |
| *Total* | 664,684 | | 46% | 57% | 11% | 308,028 | 401,820 | 93,791 | 51 | 61 | 10 | |
|  | | [45 to 47%] | [54 to 60%] | [8 to 14%] | [301,733 to 314,764] | [379,206 to 425,756] | [75,052 to 113,903] | [51 to 52] | [58 to 63] | [7 to 12] | |
|  | | |  |  |  | | --- | --- | --- | | 0% | A yellow and orange rectangular object  AI-generated content may be incorrect. | 100% | | | | | | | | | | |

Values given are the mean model projections and 95% credible intervals across 1,000 simulations. States are ordered by the 2025 diagnosed prevalence among all adults over age 13. Proportions age 55+ and 65+ indicate the proportion of all diagnosed adults living with HIV who fall into these age categories, with values for 2025, 2040, and the change between these two years. The median age is for all adults with diagnosed HIV, with values for 2025, 2040 and the change between these two years. Cells are shaded according to the relative change in proportion age 55+, with darker orange values indicating states with greater aging and darker blue values indicating states with increasingly younger populations.

**Figure 3: Diagnosed prevalence projections stratified by age group.**

A graph of different colored lines

Description automatically generated

**Figure 4: Diagnosed prevalence projections with estimated populations of PWDH age 65+.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Measure** | **Total** | **Proportion Age 65+** | | | **Number Age 65+** | | |
| *Year* | *2025* | *2025* | *2040* | Δ | *2025* | *2040* | Δ |
| *CA* | 140,514 | 36% | 56% | 20% | 50,003 | 74,207 | 24,204 |
|  | [33 to 38%] | [49 to 63%] | [15 to 26%] | [46,027 to 54,028] | [63,924 to 83,991] | [17,124 to 30,785] |
| *FL* | 126,261 | 37% | 52% | 15% | 47,091 | 73,736 | 26,645 |
|  | [35 to 40%] | [44 to 62%] | [8 to 23%] | [43,714 to 50,652] | [63,766 to 87,506] | [18,524 to 37,366] |
| *NY* | 122,642 | 41% | 55% | 13% | 50,778 | 63,287 | 12,509 |
|  | [39 to 44%] | [49 to 61%] | [9 to 18%] | [47,968 to 53,707] | [56,321 to 71,133] | [7,011 to 19,245] |
| *TX* | 107,200 | 24% | 36% | 12% | 25,725 | 45,913 | 20,187 |
|  | [22 to 26%] | [29 to 46%] | [6 to 20%] | [23,097 to 27,999] | [37,626 to 56,272] | [13,324 to 29,046] |
| *GA* | 63,841 | 26% | 37% | 11% | 16,682 | 27,169 | 10,488 |
|  | [23 to 30%] | [27 to 49%] | [3 to 21%] | [14,880 to 18,898] | [20,075 to 33,550] | [4,976 to 15,575] |
| *IL* | 35,682 | 31% | 45% | 14% | 10,850 | 14,162 | 3,312 |
|  | [28 to 33%] | [37 to 57%] | [7 to 24%] | [9,998 to 11,837] | [12,106 to 17,133] | [1,414 to 5,572] |
| *LA* | 22,298 | 27% | 41% | 14% | 5,966 | 10,200 | 4,234 |
|  | [24 to 30%] | [31 to 52%] | [6 to 23%] | [5,337 to 6,650] | [7,862 to 12,931] | [2,427 to 6,425] |
| *AL* | 15,021 | 22% | 26% | 4% | 3,312 | 4,829 | 1,517 |
|  | [19 to 25%] | [19 to 37%] | [-1 to 12%] | [2,892 to 3,716] | [3,619 to 6,377] | [577 to 2,796] |
| *MO* | 13,812 | 31% | 39% | 8% | 4,310 | 6,206 | 1,895 |
|  | [28 to 35%] | [29 to 50%] | [0 to 17%] | [3,846 to 4,760] | [4,883 to 7,393] | [932 to 2,797] |
| *MS* | 10,154 | 26% | 33% | 8% | 2,586 | 3,966 | 1,381 |
|  | [23 to 28%] | [27 to 43%] | [3 to 15%] | [2,281 to 2,885] | [3,110 to 5,064] | [712 to 2,283] |
| *WI* | 7,259 | 34% | 37% | 4% | 2,381 | 3,587 | 1,207 |
|  | [31 to 37%] | [32 to 46%] | [-1 to 12%] | [2,169 to 2,591] | [3,055 to 4,130] | [771 to 1,609] |
| *Total* | 664,684 | 22% | 26% | 4% | 219,682 | 327,261 | 107,578 |
|  | [19 to 25%] | [19 to 37%] | [-1 to 12%] | [213,946 to 225,702] | [308,039 to 346,827] | [91,172 to 123,728] |

**References**