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# Persistent Racial Disparities in HIV Infection in the USA: HIV Prevalence Matters

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**Abstract**
*Objectives* Despite increased funding and efforts to prevent and control HIV infections in the black and Hispanic communities, racial disparities persist in the USA. We used a mathematical model to explain the phenomena.
*Methods* A mathematical model was constructed to project HIV prevalence ratio (PR), incidence rate ratio (IRR), and HIV-specific mortality rate ratio (MRR) among blacks and Hispanics vs. whites in two scenarios: (1) an annual reduction in HIV incidence rate at the 2007–2010 level and (2) an annual reduction in HIV incidence rate at the 2007–2010 level among whites (4.2 %) and twice that of whites among blacks and Hispanics (8.4 %).
*Results* In scenario no. 1, the PR, IRR, and MRR among blacks would decrease from 7.6 to 5.8, 7.9 to 5.9, and 11.3 to 5.3 and among Hispanics from 2.8 to 1.8, 3.1 to 1.9, and 2.3 to 1.0, respectively. In scenario no. 2, the PR, IRR, and MRR among blacks would decrease from 7.6 to 5.1, 7.9 to 2.5, and 11.3 to 4.7 and among Hispanics from 2.8 to 1.6, 3.1 to 0.8, and 2.3 to 0.9, respectively.
*Conclusions* Much of the persistent racial disparities in HIV infection in the USA, as measured by PR, IRR, and MRR, can be explained by higher HIV prevalence among blacks and Hispanics. The public health community should continue its efforts to reduce racial disparities, but also need to set realistic goals and measure progress with sensitive indicators.

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Blacks and Hispanics are disproportionately affected by HIV in the USA [1, 2]. In October 1998, President Clinton declared HIV/AIDS to be a crisis in the black and Hispanic communities, and the Minority AIDS Initiative (MAI) was formed to address HIV/AIDS racial disparities. With a budget that increased from $156 million in fiscal year (FY) 1999 to $426 million in FY 2011, MAI provides funds to a wide range of organizations and institutions to support HIV interventions and research in minority communities [3, 4].

Despite increased HIV prevention funding to black and Hispanic communities, racial disparities for HIV persist in the USA and, especially for blacks, have been essentially unchanged since MAI was introduced. In 1998, blacks represented 13 % of the US population but accounted for an estimated 40 % of persons living with AIDS and 45 % of new AIDS diagnoses; in 2009, blacks represented 12 % of the US population and accounted for 44 % of persons living with HIV/AIDS (PLWHA) and 44 % of new HIV infections. Similarly, Hispanics represented 10 % of the US population in 1998 but accounted for an estimated 20 % of people living with AIDS and 20 % of new AIDS diagnoses; in 2009, Hispanics represented 16 % of the population and accounted for 19 % of PLWHA and 21 % of new HIV infections [1, 2, 5, 6].

Some critics have suggested that the persistent racial disparities in HIV infection in blacks and Hispanics are due to a failure of programs to address infection in these populations [7]. An alternative explanation is that the high prevalence when initiatives first began combined with increasingly long survival has made rapid changes in those proportions reported by the Centers for Disease Control and Prevention (CDC) unlikely.

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To explore this, we use a mathematical model to project changes in HIV prevalence ratio (PR), HIV incidence rate ratio (IRR), and HIV-specific mortality rate ratio (MRR) among blacks and Hispanics vs. whites in the USA to 2030, and model the impact of HIV prevalence on PR and MRR.

## Methods

The prevalence, incidence rate, and cause-specific mortality rate are three important epidemiologic measures to describe the burden of disease in a population [8], and the PR, IRR, and cause-specific MRR are three important measures to quantify differences in disease burden across subpopulations such as racial and ethnic groups [1, 2, 9–12]. HIV prevalence refers to the proportion of persons in a defined population, e.g., youth, pregnant women, and blacks, living with HIV at a specific point in time. HIV incidence rate refers to the rate of new infections, which is the number of new infections in a given time period, e.g., 1 year, divided by the number of persons at risk for HIV infection, i.e., HIV-negative. HIV-specific mortality rate refers to the number of deaths due to HIV in a defined population over a defined period of time.

HIV PR, IRR, and MRR refer to comparison against a reference group to quantify differences in disease burden across subpopulations. For example, to describe racial disparities between blacks and whites, we can calculate HIV PR—HIV prevalence in blacks divided by HIV prevalence in whites, HIV IRR—HIV incidence rate in blacks divided by HIV incidence rate in whites, and HIV MRR—HIV-specific mortality rate in blacks divided by HIV-specific mortality rate in whites.

A mathematical model was constructed using Microsoft Excel. The variables, variable values, and sources are listed in Table 1 [1, 2, 13–16]. The total population in 2010 and the US Census Bureau's projected population in 2030 by race/ethnicity in the USA were used to estimate the annual population growth rate, assuming that the growth rate for the population of all ages was applicable to the population 13 years and older [13, 14]. The population was used as the denominator in the HIV prevalence estimate, and the HIV-negative population (total population minus the number of PLWHA) was used as the denominator in the HIV incidence rate estimate.

All variable values included in the model were limited to persons aged 13 years and older, so the projected numbers and ratios in this paper were also limited to persons aged 13 years and older. For each year between 2010 and 2030, we used the projected population growth rate to estimate the population size, the projected HIV incidence rate to estimate the number of new infections, the projected HIV-specific death rate to estimate the number of persons dying from HIV-specific causes, and the projected HIV-specific and non-HIV-specific death rates to estimate the number of HIV-infected persons dying from HIV-specific and non-HIV-specific causes. The number of PLWHA was the number of PLWHA by the end of the previous year plus the number of new infections minus the number of deaths that year.

HIV PR, IRR, and MRR among blacks and Hispanics vs. whites were projected to 2030 in two scenarios: scenario no. 1, an annual reduction in HIV incidence rate at the 2007–2010 level (blacks: 4.6 %, Hispanics: 4.5 %, and whites: 4.2 %) and, scenario no. 2, an annual reduction in HIV incidence rate at the 2007–2010 level among whites (4.2 %) and twice that of whites among blacks and Hispanics (8.4 %). Blacks and whites were persons who indicated as non-Hispanic and only-one-race groups, and Hispanics were persons who identified as Hispanic of any race.

## Results

Table 2 shows the HIV PR, IRR, and MRR among blacks and Hispanics vs. whites in the USA in 2009 and the data that generated these ratios. Compared to whites, blacks were nearly 8 times as likely to be living with HIV (PR = 7.6) and acquire HIV infection (IRR = 7.9) and 11 times as likely to die of HIV-specific diseases (MRR = 11.3). Hispanics were approximately 3 times as likely to be living with HIV (PR = 2.8) and acquire HIV infection (IRR = 3.1) and more than 2 times as likely to die of HIV-specific diseases (MRR = 2.3).

Table 2 also shows the projected HIV PR, IRR, and MRR among blacks and Hispanics vs. whites in the USA in 2030 in two scenarios, and Fig. 1 shows the trend in the next 20 years. In scenario no. 1, when the annual reduction in HIV incidence rate is at the 2007–2010 level (reduction in blacks 4.6 %, Hispanics 4.5 %, and whites 4.2 %), the PR, IRR, and MRR among blacks would decrease from 7.6 to 5.8, 7.9 to 5.9, and 11.3 to 5.3, respectively, and among Hispanics would decrease from 2.8 to 1.8, 3.1 to 1.9, and 2.3 to 1.0, respectively.

In scenario no. 2, when the annual reduction in HIV incidence rate is at the 2007–2010 level among whites (4.2 %) and twice that of whites among blacks and Hispanics (8.4 %), the PR, IRR, and MRR among blacks would decrease from 7.6 to 5.1, 7.9 to 2.5, and 11.3 to 4.7, respectively, and among Hispanics would decrease from 2.8 to 1.6, 3.1 to 0.8, and 2.3 to 0.9, respectively. In this scenario in 2030, there would be more new infections among whites ($N = 5747$) than blacks ($N = 3121$) and Hispanics ($N = 1457$) combined.

## Discussion

HIV PR, IRR, and MRR have been directly or indirectly used by government agencies and researchers to describe HIV

**Table 1** Input data for the model and sources

| | Black | Hispanic | White | Source |
|---|---|---|---|---|
| Population size in 2009 | 30,297,000 | 35,698,000 | 170,768,000 | [1, 11] |
| Annual net increase in population size, 2010–2030 (%) | 1.1 | 2.2 | 0.1 | [11, 12] |
| Number of PLWHA in 2009 | 510,600 | 220,400 | 380,300 | [1] |
| HIV incidence rate in 2009 (1/100,000) | 66.1 | 25.9 | 8.3 | [2] |
| Annual reduction in HIV incidence rate, 2010–2030 (%) | 4.6 | 4.5 | 4.2 | [2], assumption |
| All-cause death rate among PLWHA in 2009 (1/1000) | 21.1 | 14.7 | 14.7 | [1] |
| HIV-specific death rate among PLWHA in 2009 (1/1000) | 10.4 | 5.7 | 6.9 | [1, 13] |
| Annual reduction in crude HIV-specific death rate, 2010–2030 | Steadily decrease from 7.5 % reduction in 2010 to 2.2 % reduction in 2030 | Steadily decrease from 6.2 % reduction in 2010 to 2.2 % reduction in 2030 | 2.2 % reduction annually between 2010 and 2030 | [1], assumption |
| Annual change in crude non-HIV-related death rate, 2010–2030 (%) | 0.0 | 0.0 | 0.0 | [14] |

*HIV* human immunodeficiency virus, *PLWHA* persons living with HIV/AIDS

racial disparities in the USA [1, 2, 7, 9–12, 17–20]. Many expect successful intervention programs to reduce these ratios. Using a simple mathematical model, we projected the HIV PR, IRR, and MRR among blacks and Hispanics vs. whites in the USA over the next 20 years, and found that successful intervention has a small impact on PR and MRR.

HIV infection has become a manageable chronic disease, and people with HIV infection can live long, relatively healthy lives by taking antiretroviral treatment [21, 22]. In the USA, the number of PLWHA has been increasing since the beginning of the epidemic, reaching 1.1 million by the end of 2009 [23]. Successful intervention programs may reduce the HIV incidence rate, but because of the relatively small number of new infections compared with the number of PLWHA (45,000 vs. 1.1 million in 2009) [2, 23], decades would be needed for the intervention programs to markedly influence HIV prevalence [24].

Therefore, the persistent racial disparities in HIV infection in the USA measured by PR and MRR can be explained in large part by the higher HIV prevalence among blacks and Hispanics and the relatively small number of new infections compared with the number of PLWHA. Significantly reducing racial disparities will require a long period, not just a substantial reduction in HIV incidence rate among blacks and Hispanics. The small impact of successful intervention programs on reduction of HIV PR and MRR was demonstrated by the almost negligible differences in the projected PR and MRR between a very successful program (scenario no. 2) and the current projection (scenario no. 1) in our model.

While it may appear that the longer-term small reduction in HIV PR and MRR is due to a larger reduction of HIV incidence rate in blacks and Hispanics, much of the reduction over time seen in our model is the result of larger population growth rates in blacks and Hispanics than whites [13]. If we assumed an equal annual reduction (4.2 %) in HIV incidence rate in all racial/ethnic groups while having the different population growth rates in the model, we would see the HIV PR and MRR among blacks decrease from 7.6 to 5.9 and 11.3 to 5.4, respectively, and among Hispanics 2.8 to 1.8 and 2.3 to 1.0, respectively, by 2030, results not markedly different from the current projections. Larger relative population growth in blacks and Hispanics would mean a relatively larger increase in the number of HIV-negative individuals, and a larger increase in the denominator, and would lead to a reduction in PR and MRR among blacks and Hispanics compared to whites.

Our mathematical model projects that racial disparities in HIV infection in the USA will persist for decades even with successful efforts to reduce transmission. Trends in racial disparities should thus be interpreted with caution. First, we should avoid automatically interpreting reductions in PR, IRR, and MRR among blacks and Hispanics vs. whites as the results of successful HIV interventions, since they may be mainly the results of larger population growth among blacks and Hispanics. Second, we should avoid automatically interpreting persistently high HIV RR, IRR, and MRR as results of failed HIV interventions, since they may be attributable to higher HIV prevalence among blacks and Hispanics.

Our model has limitations. First, we projected the HIV PR, IRR, and MRR based on assumptions regarding annual reductions in the HIV incidence rate and HIV-specific mortality rate. These assumptions may not hold in the next 20 years because of new intervention options and saturation effects [25, 26]. Therefore, the projected HIV prevalence, incidence

**Table 2** Estimated and projected HIV prevalence, incidence rate, and HIV-related mortality rate ratios among blacks and Hispanics vs. whites in the USA, 2009–2030

| | Population size ($A = B/C$) | Prevalence | | | Incidence | | | HIV-specific mortality | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | PLWHA ($B$) | Prevalence (1/100,000) ($C$) | Prevalence ratio ($D$) | New infections ($E$) | Incidence rate (1/100,000) ($F = E/(A - B)$) | Rate ratio ($G$) | HIV-specific deaths ($H$) | HIV-specific death rate (1/1000 PLWHA) ($I = H/B$) | HIV-specific mortality rate (1/100,000) ($J = H/A$) | Rate ratio ($K$) |
| 2009 (baseline) [1, 2, 14] | | | | | | | | | | | |
| Black | 30,297,000 | 510,600 | 1685.3 | 7.6 | 19,700 | 66.1 | 7.9 | 5307 | 10.4 | 17.5 | 11.3 |
| Hispanic | 35,698,000 | 220,400 | 617.4 | 2.8 | 9200 | 25.9 | 3.1 | 1263 | 5.7 | 3.5 | 2.3 |
| White | 170,768,000 | 380,300 | 222.7 | 1.0 | 14,200 | 8.3 | 1.0 | 2640 | 6.9 | 1.5 | 1.0 |
| 2030 (scenario no. 1)[a] | | | | | | | | | | | |
| Black | 38,122,191 | 572,783 | 1502.5 | 5.8 | 7299 | 19.4 | 5.9 | 2288 | 4.0 | 6.0 | 5.3 |
| Hispanic | 56,378,534 | 266,179 | 472.1 | 1.8 | 3478 | 6.2 | 1.9 | 657 | 2.5 | 1.2 | 1.0 |
| White | 174,390,063 | 452,960 | 259.7 | 1.0 | 5747 | 3.3 | 1.0 | 1969 | 4.3 | 1.1 | 1.0 |
| 2030 (scenario no. 2)[b] | | | | | | | | | | | |
| Black | 38,122,191 | 506,526 | 1328.7 | 5.1 | 3121 | 8.3 | 2.5 | 2036 | 4.0 | 5.3 | 4.7 |
| Hispanic | 56,378,534 | 233,804 | 414.7 | 1.6 | 1457 | 2.6 | 0.8 | 581 | 2.5 | 1.0 | 0.9 |
| White | 174,390,063 | 452,960 | 259.7 | 1.0 | 5747 | 3.3 | 1.0 | 1969 | 4.3 | 1.1 | 1.0 |

*HIV* human immunodeficiency virus, *PLWHA* persons living with HIV/AIDS

[a] Scenario no. 1. Annual reduction in HIV incidence rate at the 2007–2010 level (blacks 4.6 %, Hispanics 4.5 %, and whites 4.2 %)

[b] Scenario no. 2. Annual reduction in HIV incidence rate at the 2007–2010 level among whites (4.2 %) and twice that of whites among blacks and Hispanics (8.4 %)

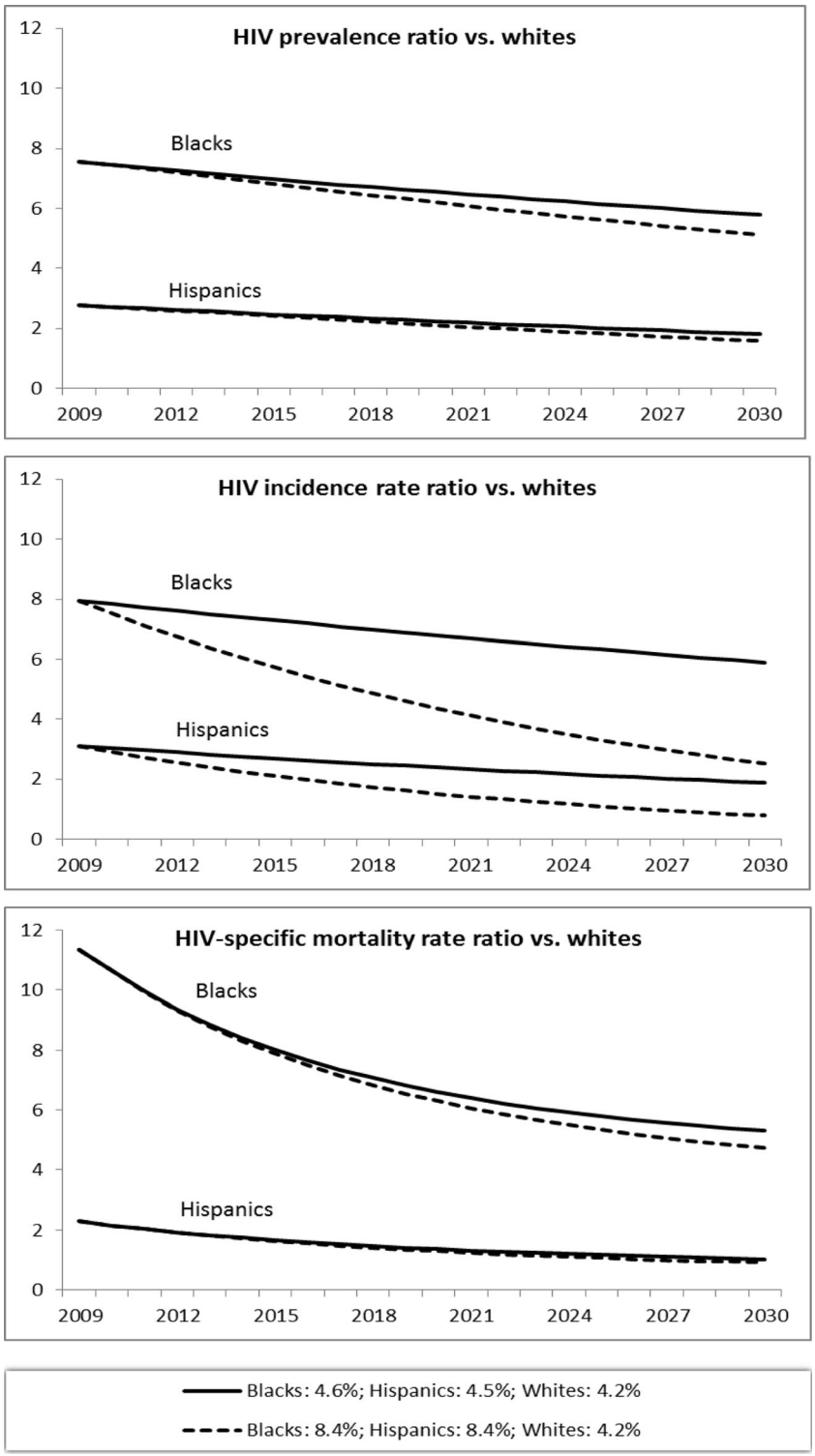


**Fig. 1** Projected HIV prevalence ratio, HIV incidence rate ratio, and HIV-specific mortality ratio among blacks and Hispanics vs. whites in the USA, 2009–2030, by annual reduction in HIV incidence rate

rate, and mortality rate may not be accurate. However, as scenario no.2 in the model demonstrated, these possibly inaccurate HIV prevalence, incidence rate, and mortality rate do not affect the conclusion that HIV PR, IRR, and MRR are heavily influenced by HIV prevalence and that racial disparities in HIV infection in the USA will persist.

Second, scenario no. 2 presented in our model is very optimistic. It assumes that we can achieve double the risk reduction in blacks and Hispanics as we achieve in whites, and HIV IRR will be reduced from 7.9 to 2.5 in blacks and 3.1 to 0.8 in Hispanics, respectively. One recent modeling study shows that such a dramatic reduction in HIV IRR is unlikely to happen

when HIV PR is high [27]. The purpose of showing such an optimistically successful intervention program is to demonstrate the persistence of disparities in HIV PR and MRR in the USA and how small the impact of an intervention would be on these two measures.

Third, we presented the projected HIV PR, IRR, and MRR but only modeled the impact of HIV prevalence on HIV PR and MRR. We did not model the impact of HIV prevalence on IRR because it would require a different model based on HIV transmission risk and racial mixing [28, 29]. The modeling study mentioned above reported that racial disparities in the rates of HIV transmission among men who have sex with men (MSM) could be reduced, but racial disparities in HIV incidence would persist for decades to come because of the higher HIV prevalence among black MSM [27]. The study was done on MSM, but the findings apply to other populations as well. With all other conditions comparable to whites, e.g., sexual risk behaviors and the proportion of HIV-infected individuals with a suppressed viral load, blacks and Hispanics would still have a higher HIV incidence rate because of higher HIV prevalence [30]. Therefore, higher HIV prevalence among blacks and Hispanics will lead to not only persistently high HIV PR and MRR but also persistently high HIV IRR.

Fourth, the crude baseline death rates presented in the model likely are misleading. For example, the HIV-specific death rate among Hispanics was lower than the rate among whites (5.7/1000 vs. 6.9/1000). The lower crude HIV-specific death rate among Hispanics could be that Hispanic PLWHA were younger and more likely to be diagnosed recently, and deaths among Hispanic PLWHA were more likely to be missed during death registry matches due to common names or immigration issues [31]. To truly represent the differences across racial/ethnic groups, age-adjusted rates should be used. However, the purpose of this paper is to demonstrate that the racial disparities in HIV infection in the USA will persist and the persistence is mainly caused by the higher HIV prevalence among blacks and Hispanics. To be consistent with the CDC report on racial disparities [1, 2], we used crude rates in our model and reported crude ratios.

Using a mathematical model, we demonstrated the impact of HIV prevalence on HIV PR, IRR, and MRR among blacks and Hispanics vs. whites in the USA. Besides other structural and social factors [18, 32–36], much of the persistent racial disparities in HIV infection in the USA, as measured by PR, IRR, and MRR, can be explained by higher HIV prevalence among blacks and Hispanics than whites when minority-focused initiatives first began. The public health community should continue its efforts to reduce racial disparities but should set realistic goals and measure progress with sensitive indicators. HIV PR, IRR, and MRR can still be used to describe racial disparities but are not optimal standalone measures for monitoring and evaluation because of the pervasive effect of HIV prevalence. Therefore, preferred measures would include those that are not affected by HIV prevalence and can reflect the current efforts in reducing racial disparities, e.g., risk behaviors, proportion of people ever tested for HIV or tested for HIV in the last year, proportion of new diagnoses with timely linkage to HIV care, proportion of HIV-infected individuals with a suppressed viral load, and HIV transmission rate [28, 37–52].

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**Compliance with Ethical Standards**

**Conflict of Interest** The authors declare that they have no competing interests.

**Informed Consent** No animal or human studies were carried out by the authors for this analysis.

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