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The Open AIDS Journal, 2015, *9*, 123-133

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A Matter of Perspective: Comparison of the Characteristics of Persons with HIV Infection in the United States from the HIV Outpatient Study, Medical Monitoring Project, and National HIV Surveillance System

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Abstract: Comparative analyses of the characteristics of persons living with HIV infection (PLWH) in the United States (US) captured in surveillance and other observational databases are few. To explore potential joint data use to guide HIV treatment and prevention in the US, we examined three CDC-funded data sources in 2012: the HIV Outpatient Study (HOPS), a multisite longitudinal cohort; the Medical Monitoring Project (MMP), a probability sample of PLWH receiving medical care; and the National HIV Surveillance System (NHSS), a surveillance system of all PLWH. Overall, data from 1,697 HOPS, 4,901 MMP, and 865,102 NHSS PLWH were analyzed. Compared with the MMP population, HOPS participants were more likely to be older, non-Hispanic/Latino white, not using injection drugs, insured, diagnosed with HIV before 2009, prescribed antiretroviral therapy, and to have most recent CD4+ T-lymphocyte cell count ≥500 cells/mm^3 and most recent viral load test <200 copies/mL. The MMP population was demographically similar to all PLWH in NHSS, except it tended to be slightly older, HIV diagnosed more recently, and to have AIDS. Our comparative results provide an essential first step for combined epidemiologic data analyses to inform HIV care and prevention for PLWH in the US.

Keywords: AIDS, cohort, epidemiology, HIV, observational study, surveillance, United States.

INTRODUCTION

For the estimated 914,000 persons living with diagnosed HIV infection in the United States (US) [1], many of whom are engaged in HIV care to various degrees [1-3], describing the epidemiology of chronic HIV infection and short- and long-term clinical outcomes warrant multifaceted approaches and data sources [4]. Owing to the reductions in morbidity and mortality following the introduction of antiretroviral therapy (ART) [5, 6], HIV infection has become a chronic condition, with individuals living longer, healthier lives and experiencing non-infectious illnesses traditionally associated with aging [7-10]. Innovative uses of cross-sectional and longitudinal data to assess patterns in medical care may guide further improvements in the clinical management of persons living with HIV infection and planning for their care and prevention services [8, 11, 12].

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To this end, the Centers for Disease Control and Prevention (CDC) supports complementary data collection activities for persons living with HIV infection in the US, both research studies and routine surveillance, each with its strengths and limitations. The HIV Outpatient Study (HOPS) is a prospective cohort of HIV-infected persons receiving care at selected HIV specialty clinics in the US [5, 13]. The longitudinal nature of HOPS data enables investigation of associations between HIV disease, ART and other treatments, and a variety of clinical outcomes [5, 14-17]. Since HOPS is a convenience sample of patients at selected HIV clinics, it is unclear how the findings from HOPS reflect those for all patients in HIV care or all persons with diagnosed HIV infection. In contrast, the Medical Monitoring Project (MMP) is an ongoing, multisite, supplemental surveillance system designed to provide nationally representative data about medical care, behaviors, and health status of HIV-infected adults in the US through annual cross-sectional surveys [18]. Each year medical chart abstractions and interviews are collected for a different sample of persons, which precludes multi-year observation of individual patients. Finally, the National HIV Surveillance System (NHSS) collects information on all HIV-diagnosed

1874-6136/15 2015 Bentham Open

persons in the US, for whom longitudinal HIV laboratory assessments, care patterns, and mortality are tracked [1]. However, NHSS has limited clinical information on HIV-related and unrelated conditions and treatments.

The primary objective of this paper was to compare demographic characteristics of HIV-infected persons in HOPS, MMP, and NHSS and to explore potential joint uses of these data to improve treatment and prevention services for persons living with HIV infection in the US. We also sought to address the following two research questions: (1) Do characteristics of a convenience sample of patients consenting to participation in a large longitudinal HOPS cohort approximate those of persons with HIV infection in the population-based MMP and all persons living with diagnosed HIV infection in the United States?; and (2) Are the population-based estimates derived from MMP likely applicable to all patients in HIV care in the United States, despite the fact that MMP sampling frame only includes patients having at least one clinical visit during January - April in the year?

METHODS

Data Sources

HIV Outpatient Study (HOPS)

HOPS is an ongoing, prospective, observational cohort study of HIV-infected adults (age 18 and older) seen at HIV-specialty clinics since 1993 [13]. As an open cohort, HOPS has continued enrollment of new patients, as some patients transfer to care at other locations, are lost to follow-up, or die. The nine clinics participating in HOPS in 2012 and included in this analyses comprise public, private and university-based sites and are located in six US cities: Tampa, FL; Washington, DC; Denver, CO (3 sites); Chicago, IL (2 sites); Stonybrook, NY; and Philadelphia, PA. HOPS clinicians have extensive experience treating patients living with HIV. Information is abstracted from medical records for each visit, entered electronically by trained staff (DISCOVERE®; Cerner Corporation, Kansas City, MO), compiled centrally, and reviewed and edited before being analyzed. Abstracted information includes demographic characteristics, risk factors for HIV infection, diagnoses, prescribed medications, laboratory values (including CD4+ T-lymphocyte cell (CD4) counts and plasma HIV viral loads), mortality, and hospitalization records (primarily from discharge summaries). Participants sign informed consent, and the HOPS protocol has been reviewed and approved annually by the institutional review boards of CDC (Atlanta, GA) and each local site. This analysis uses HOPS dataset available as of March 31, 2015.

Medical Monitoring Project (MMP)

MMP is an on-going HIV surveillance system designed to produce nationally representative estimates of behavioral and clinical characteristics of HIV-infected adults receiving medical care in the US [18-20]. MMP is a complex-sample, cross-sectional survey. For the 2012 data collection cycle, states and territories were sampled first, followed by facilities providing any outpatient HIV care, and then by HIV-infected adults (age 18 years and older) who had at least one medical care visit during January-April 2012 at participating facilities. Data were collected through face-to-face interviews and medical record abstractions from June 2012 through April 2013. Variables from medical records and sociodemographic and behavioral information from structured interviews were ascertained for the 12 months prior to and including the date of a participant's interview. All sampled states and territories participated in MMP: California, Delaware, Florida, Georgia, Illinois, Indiana, Michigan, Mississippi, New Jersey, New York, North Carolina, Oregon, Pennsylvania, Puerto Rico, Texas, Virginia, and Washington.

Of 548 sampled eligible facilities, 467 participated in MMP (facility response rate, 85%). Most of the HIV care facilities sampled were private practices (51%), followed by hospital-based facilities (29%) and community health centers (17%). The remainders were clinical research facilities (8%), state or local health department clinics (8%), other community-based service organizations (5%), and other type of facilities (7%). A facility could belong to multiple categories. Of 9,394 sampled persons, 4,901 completed the interview and had their medical records abstracted (adjusted patient-level response rate, 53%). For nationally representative estimates, data were weighted to adjust for nonresponse by using predictors of response. After weighting the data for probability of selection and non-response, the 4,901 MMP participants were estimated to represent the population of 476,366 adults with HIV infection receiving medical care in the US [18, 19].

National HIV Surveillance System (NHSS)

We used data from CDC-supported NHSS to determine the prevalence of HIV infection among persons 18 years and older in the US in 2012. HIV infection is reportable in all 50 states and the District of Columbia. Cases meeting prerequisite data quality criteria (http://www.cdc.gov/hiv/guidelines/reporting.html) are reported by local health jurisdictions to CDC with demographic information, risk factors, and clinical information, including acquired immunodeficiency syndrome (AIDS) diagnoses, but without personal identifying information. We estimated the number of persons diagnosed through 2011 and alive at year-end 2012 overall, and by age, sex, race/ethnicity, transmission category, year of diagnosis (before 2009, during, or after 2009), and whether their infection had ever been classified as stage 3 (AIDS). Data were reported to CDC through December 2014 and all analyses were adjusted for reporting delays in diagnoses and deaths [1].

Analyses

Primary Analysis: Comparison of HOPS and MMP

For the primary analysis, for closest correspondence with MMP data, we included HOPS participants who met the following inclusion criteria: (A) were actively providing data to HOPS as of January 1, 2012; (B) were 18 years or older by January 1, 2012; (C) had at least one clinic visit between January 1, 2012, and April 30, 2012 (clinic visit defined as routine, initial, return to active status, event triggered, or post-hospital follow up); and (D) were alive in HOPS as of

the weighted mean patient interview date in MMP as described below.

Although the MMP reference population is HIV-infected adults receiving medical care in January-April 2012, MMP participants were interviewed from June 2012 through April 2013. Their sociodemographic, behavioral and clinical characteristics were collected (by interview or medical chart abstraction) for the 12 months prior to the interview. To allow for comparability of MMP and HOPS data, the demographic and clinical variables in HOPS were defined as of the weighted mean (*i.e.*, average) interview date of the MMP participants, which was calculated as November 25, 2012, and spanned the period of the previous 12 months, when appropriate.

Sociodemographic variables were age, sex at birth, race/ethnicity (including non-Hispanic/Latino black or African American [referred to as black], non-Hispanic/Latino white [referred to as white], Hispanic or Latino of any race [referred to as Hispanic], and persons of other race/ethnicity), HIV acquisition risk group (including gay, bisexual and other men who have sex with men [MSM], males and females who inject drugs [IDU], heterosexual males and females, and persons in other risk categories [including hemophilia, perinatal and occupational exposures]) and health insurance coverage. Clinical and HIV-related variables included year of HIV diagnosis, history of AIDS diagnosis by immunologic or clinical criteria, antiretroviral (ARV) exposure status, most recent CD4 count in the 12 months preceding the interview date (weighted mean interview date for HOPS), most recent viral load (defined as most recent HIV viral load undetectable or < 200 copies/mL in the 12 months preceding the interview date, the Department of Health and Human Services (DHHS) recommended threshold [21]), durable viral suppression (defined to include all viral loads in the previous 12 months undetectable or < 200 copies/mL; if no viral loads were measured then the patient was not considered durably suppressed [22]), number of CD4/viral load measurements in the 12 months prior to the interview date, at least one viral load in each 6-month period prior to the interview date, at least one CD4 count measurement in the 12 months prior to the interview date, clinical visit frequency and density, and number of clinic visits in the 12 months preceding the interview date.

Summaries of descriptive data were performed using SAS version 9.3 (SAS Institute Inc., Cary, NC). For the MMP population, we report unweighted frequencies and weighted percentages with 95% confidence intervals (CIs) to characterize all self-reported and clinical characteristics; the weighted estimates are designed to represent the population of adults with HIV infection receiving medical care in the US from January-April 2012. For continuous variables, we report arithmetic means (and geometric means, where indicated) and associated standard errors, and medians and interquartile ranges (IQRs), which were weighted for MMP. For HOPS participants, we estimated standard errors for percentages assuming a binomial distribution and computed 95% CIs. We evaluated differences between means for continuous variables in HOPS *versus* MMP using a z-statistic; similarly, for percentages we calculated the standard error for the difference in percentages using established methods described by Fleiss *et al*. [23] and calculated a standard z-statistic.

Sub-Analysis A: Comparison of HOPS Participants and MMP Population to NHSS

NHSS collects data on all HIV-diagnosed persons living in the US, including persons who are not receiving medical care. We compared percentages among HOPS participants, the MMP population, and persons in NHSS. NHSS percentages are based on a census of all HIV-diagnosed persons (*i.e.*, including those not in care) who have been reported to NHSS. Since NHSS percentages are known population parameters, HOPS or MMP estimates were deemed statistically significantly different from NHSS parameters if the corresponding 95% CI for HOPS or MMP estimates did not include the NHSS value.

Sub-Analysis B: Comparison of HOPS Participants with at Least One Visit in January-April 2012, at Least One Visit in January-December 2012, and Visits Only in May-December 2012

Population-based cross-sectional surveillance systems, such as MMP, need to define a reference population, which for MMP was all HIV-diagnosed persons aged ≥18 years who were receiving medical care between January-April 2012. The 4-month population definition period was adopted for MMP as a compromise based on logistical considerations (*e.g.*, difficulty in enumerating the sampling frame, effort to locate and recruit sampled persons who might have last received care over one year ago, *etc*.) and population representativeness (*e.g.*, prior analyses noted that 88% of all persons who had at least one clinical visit in the calendar year had at least one visit in the first four months of the year) [24]. The rationale for a 4-month population definition period was established using one dataset and has not been re-examined recently.

To assess the potential bias introduced by using a 4-month population definition period in the MMP to approximate the characteristics of persons who had at least one clinical visit in a calendar year, we compared HOPS participants using three different study population definitions: A) persons who had at least one visit between January-April 2012; B) persons who had at least one visit between January-December 2012; and C) persons who had visits only between May-December 2012. Note that populations A and C are mutually exclusive and together sum to population B. The clinic visit types included in this sub-analysis were the same as in the primary analysis. However, for these analyses, clinical and sociodemographic characteristics were assessed for the twelve months of the 2012 calendar year rather than the twelve months prior to the weighted mean interview date (November 25, 2012) described above.

We assessed the statistical differences between HOPS populations A and C using chi-square tests for categorical variables, Cochran-Armitage trend tests for ordinal variables, Student's t-test for comparing means, and Wilcoxon rank sum test for medians of continuous variables. Statistical comparisons with p-values <0.05 were considered significant. To validate the MMP sampling strategy to obtain estimates relevant for all patients in HIV care, we calculated

the differences in percentage estimates from HOPS population A *versus* B.

RESULTS

Primary Analysis

We included 1,697 HOPS and 4,901 MMP participants in the primary analysis. After the MMP data were weighted to derive national estimates, compared with the MMP population, the HOPS participants were older (mean age: 50.2 years *vs* 47.3 years), and a higher percentage were white (47.8% *vs* 35.3%) (Table **1**). In both HOPS and MMP, most persons were MSM (56.2% *vs* 59.9%, inclusive of both MSM and MSM who used injection drugs), but HOPS had fewer participants with IDU as their sole risk factor for HIV acquisition (7.1% *vs* 13.2%). The percentage of non-IDU heterosexual females was similar in HOPS and MMP (20.4% *vs* 19.4%). Compared with the MMP population, a smaller percentage of HOPS participants were diagnosed with HIV

Table 1. Characteristics of HIV Outpatient Study (HOPS) participants, Medical Monitoring Project (MMP) population, and persons living with diagnosed HIV infection in the National HIV Surveillance System (NHSS), United States, 2012.

Characteristic§	HOPS (N=1,697)			MMP (N=4,901)			HOPS *vs* MMP	NHSS (N=865,102)	
	No.	%	(95% CI)	No.	%‡	(95% CI)	P value°	No.	%
Age category, years									
18-24	14	0.8	(0.4 - 1.3)	144	3.1	(2.3 - 3.9)	<0.001	35,381	4.1
25-34	131	7.7	(6.4 - 9.0)	579	12.3	(11.2 - 13.3)	<0.001	122,361	14.1
35-44	324	19.1	(17.2 - 21.0)	1,015	20.7	(19.3 - 22.1)	0.18	215,173	24.9
45-54	696	41.0	(38.7 - 43.4)	1,869	37.4	(35.6 - 39.3)	0.02	309,219	35.7
55-64	410	24.2	(22.2 - 26.3)	1,066	21.8	(20.3 - 23.3)	0.06	145,202	16.8
≥65	121	7.1	(5.9 - 8.4)	228	4.7	(3.8 - 5.6)	0.04	37,766	4.4
Mean age (SE), years	50.2 (0.25)			47.3 (0.20)			<0.001	46.1	
Median age [IQR], years	50.3 [44.1, 57.0]			47.9 [39.8, 54.5]				46.8 [38.6, 53.6]	
Sex at birth*									
Male	1,266	74.6	(72.5 - 76.7)	3,625	74.5	(70.9 - 78.0)	0.96	652,701	75.4
Female	431	25.4	(23.3 - 27.5)	1,274	25.5	(21.9 - 29.0)	0.96	212,401	24.6
Race/Ethnicity									
White, non-Hispanic	811	47.8	(45.4 - 50.2)	1,560	35.3	(27.4 - 43.2)	0.003	281,397	32.5
Black, non-Hispanic	607	35.8	(33.5 - 38.1)	2,072	41.6	(31.9 - 51.3)	0.25	367,503	42.5
Hispanic or Latino	226	13.3	(11.7 - 14.9)	1,060	18.7	(12.7 - 24.6)	0.09	173,311	20.0
Other†	53	3.1	(2.3 - 4.0)	209	4.5	(3.5 - 5.5)	0.04	42,891	5.0
HIV acquisition risk group									
MSM	931	54.9	(52.5 - 57.2)	2,516	53.9	(49.1 - 58.7)	0.71	448,696	51.9
IDU-male	70	4.1	(3.2 - 5.1)	422	7.5	(6.1 - 8.9)	<0.001	80,317	9.3
IDU-female	50	3.0	(2.1 - 3.8)	309	5.7	(4.3 - 7.1)	0.001	51,673	6.0
MSM-IDU	22	1.3	(0.8 - 1.8)	321	6.0	(5.0 - 7.0)	<0.001	49,225	5.7
Heterosexual-male	171	10.1	(8.6 - 11.5)	339	6.5	(5.3 - 7.7)	<0.001	68,590	7.9
Heterosexual-female	347	20.4	(18.5 - 22.4)	944	19.4	(16.9 - 21.9)	0.54	156,114	18.0
Other	106	6.2	(5.1 - 7.4)	51	1.0	(0.6 - 1.4)	<0.001	10,487	1.2
Year of HIV diagnosis¥									
< 2009	1,574	92.8	(91.5 - 94.0)	4153	83.0	(81.5 - 84.5)	<0.001	737,882	85.3
2009 and later	122	7.2	(6.0 - 8.4)	748	17.0	(15.5 - 18.5)	<0.001	127,220	14.7
Ever had AIDS as of end of 2012									
Yes	1,088	64.1	(61.8 - 66.4)	3,380	68.3	(66.1 - 70.5)	0.01	493,497	57.0
No	609	35.9	(33.6 - 38.2)	1,521	31.7	(29.5 - 33.9)	0.01	371,604	43.0

Footnotes to Table **1**.

Abbreviations: CI = confidence interval; IDU = male or female injection drug user; IQR = Interquartile range; MSM = men who have sex with men; SE=Standard error.

° P-values were obtained from z-statistics.

§ Characteristics for HOPS patients and MMP patients were established based on data collected in the twelve months prior to the MMP's weighted interview date which was November 25, 2012.; characteristics for NHSS were established based on data in the entire 2012 calendar year.

* Two people with intersex/ambiguous sex from MMP not shown - these people were included in all the analyses.

‡ MMP data are nationally representative sampling-probability weighted estimates.

† Other race groups include those of multiple race groups and other, unknown or missing race groups.

¥ One person had unknown year of HIV diagnosis from the HOPS.

infection in 2009 or later (7.2% *vs* 17.0%), and a smaller percentage had AIDS (64.1% *vs* 68.3%).

A higher percentage of HOPS participants had any insurance coverage compared to the MMP population (91.8% *vs* 81.5%) and differences by payer type, including utilization of Ryan White HIV/AIDS program, were noted (Table **2**). Compared with the MMP population, a higher percentage of HOPS participants had been prescribed ART in the past year (96.5% for HOPS *vs* 92.7% for MMP, respectively), and specifically had been prescribed the newer classes of ART such as entry or integrase inhibitors (35.6% *vs* 20.4%), had a most recent CD4 count ≥500 cells/mm^3 (58.2% *vs* 50.1%), had a most recent viral load test that was undetectable or <200 copies/mL (84.7% *vs* 77.3%), and had all viral loads in the past 12 months undetectable or <200 copies/mL (77.7% *vs* 66.2%). The mean number of HIV laboratory measurements (viral load and CD4 count tests) was significantly lower for HOPS participants than the MMP population, but HOPS patients were more likely to achieve recommended viral load monitoring (at least once in each 6-month period), and to have at least once CD4 count in the year (Table **2**).

Sub-Analysis A: Comparison of HOPS Participants and MMP Population to NHSS

This analysis included NHSS data on 865,102 persons who were diagnosed with HIV infection by the end of 2011 and were alive at the end of 2012. Compared with HIV-diagnosed persons in NHSS, a lower percentage of HOPS participants were aged 18-24 years (0.8% HOPS *vs* 4.1% NHSS, respectively) and a higher percentage were aged 45-64 years (65.2% *vs* 52.5%, Table **1**). Moreover, a higher percentage of HOPS participants compared with persons in NHSS were white (47.8% *vs* 32.5%) and a lower percentage were black (35.8% *vs* 42.5%) and Hispanic (13.3% *vs* 20.0%). A lower percentage of HOPS participants had HIV acquisition attributed to IDU (7.1% *vs* 15.3%) and a higher percentage were diagnosed before 2009 (92.8% *vs* 85.3%) and ever had AIDS (64.1% *vs* 57.0%). Compared with HIV-diagnosed persons in NHSS, the MMP population had a similar distribution by age (MMP patients were modestly older, by about one year on average), sex at birth, race/ethnicity, HIV acquisition risk group, but it had a greater percentage of persons HIV diagnosed in 2009 or later (17.0% *vs* 14.7%) as well as persons diagnosed with AIDS (68.3% *vs* 57.0%).

Sub-Analysis B: Comparison of HOPS Participants with At Least One Visit January-April 2012, At Least One Visit January-December 2012, and Visits Only May-December 2012

Among the 2,218 HOPS participants who had at least one visit (*i.e.*, were "seen") January-December 2012, 1,697 (76.5%) HOPS participants had at least one visit January-April 2012. As suggested by relatively modest differences in percentage estimates for population A *vs* population C for most categorical factors, HOPS participants who were seen January-April had similar demographic, behavioral, and clinical characteristics to HOPS participants who were seen January-December, except for the percentage with private insurance (49.6% *vs* 53.0%, Table **3**). Of note, both populations had the same percentage of ART prescription (96.5%) and both had similar percentages with most recent viral load undetectable or < 200 copies/mL (84.9% *vs* 83.6%), but HOPS participants who were seen January-April had more visits and CD4 count and viral load tests, and were more likely to have at least one viral load in each 6-month period (Table **3**).

Only 521 (23.5%) of HOPS participants who were seen in January-December had their sole visit in May-December. Persons who were seen only during May-December, and thus may have been somewhat less engaged in care, differed significantly from those seen in January-April in the following ways: they were slightly younger, more likely to be male, white, diagnosed with HIV before 2009, and privately insured, but less likely to have ever had AIDS (Table **3**). Although they had nearly identical level of any health insurance coverage (91.9% *vs* 91.8%), the same frequency of ART prescription in the year (96.5%), used similar classes of ART regimens, and had comparable mean CD4 counts, these patients who were only seen in May-December also had fewer visits and CD4 count and viral load measurements, and fewer had their most recent viral load undetectable or < 200 copies/mL (79.5% *vs* 84.9%) as compared with patients with at least one visit in January-April (Table **3**).

DISCUSSION

In-depth comparative analysis of multiple data sources describing persons living with diagnosed HIV infection is important for evidence-based decision making to guide HIV prevention and care research and programs. We found that participants in the HOPS differed by some demographic and clinical characteristics from the MMP population of persons receiving HIV medical care during January-April 2012, and likewise differed from all persons living with diagnosed HIV infection in NHSS. These findings will inform ongoing patient enrollment in HOPS to focus on under-represented subgroups, including more recently HIV-diagnosed persons, younger individuals, and persons who are black or of Hispanic/Latino race/ethnicity. The MMP and NHSS populations were demographically similar, except a greater percentage of persons in MMP were HIV-diagnosed in 2009 or later and greater percentage have ever been diagnosed with AIDS, suggesting that select findings from MMP may broadly apply to all adults living with diagnosed HIV infection in the US. Since the MMP and NHSS populations were demographically similar also suggests, by extension, that HIV-diagnosed persons who were in care (the majority) were not substantially different by age, sex and race/ethnicity from those HIV-diagnosed but not in care (the minority) captured through the NHSS; although certain differences could be masked in our comparison given that the latter group is smaller than the former [3]. Furthermore, analyses from HOPS revealed that persons seen in the first four months of the calendar year generally resemble in their characteristics persons seen for HIV care throughout the year, thus providing support for the present MMP sampling methodology.

Table 2. HIV care-related characteristics of HIV Outpatient Study (HOPS) participants and Medical Monitoring Project (MMP) population, United States, 2012.

	HOPS (N=1,697)			MMP (N=4,901)			P Value[○]
Characteristic[§]	**No.**	**(%)**	**(95% CI)**	**No.**	**(%[‡])**	**(95% CI)**	
Any health insurance coverage†	1,558	91.8	(90.5 - 93.1)	4,051	81.5	(77.5 - 85.5)	<0.001
Healthcare payer type†							
Any payer or insurance[¥]	1,620	95.5	(94.5 - 96.5)	4,787	97.7	(96.9 - 98.4)	<0.001
Any private	833	49.1	(46.7 - 51.5)	1,422	30.5	(25.7 - 35.4)	<0.001
Any Medicaid	518	30.5	(28.3 - 32.7)	1,909	38.7	(34.0 - 43.4)	0.001
Any Medicare	445	26.2	(24.1 - 28.3)	1,276	26.1	(24.7 - 27.5)	0.94
Any Ryan White	142	8.4	(7.0 - 9.7)	1,992	41.7	(38.9 - 44.5)	<0.001
Any ART prescription in the year	1,637	96.5	(95.6 - 97.3)	4,563	92.7	(91.8 - 93.6)	<0.001
Any ART prescription in a given class in year							
Any NNRTI	734	43.3	(40.9 - 45.6)	2,092	46.7	(44.9 - 48.5)	0.35
Any PI	741	43.7	(41.3 - 46.0)	2,441	52.5	(50.6 - 54.4)	<0.001
Any entry or integrase inhibitor	604	35.6	(33.3 - 37.9)	935	20.4	(18.6 - 22.2)	<0.001
Last CD4 count, cells/mm^3							
Missing/unknown	52	3.1	(2.2 - 3.9)	257	5.9	(4.7 - 7.1)	<0.001
0-199	123	7.2	(6.0 - 8.5)	477	9.4	(8.1 - 10.7)	0.02
200-349	214	12.6	(11.0 - 14.2)	694	13.6	(12.0 - 15.1)	0.38
350-499	321	18.9	(17.1 - 20.8)	1,013	21.0	(19.5 - 22.5)	0.08
≥ 500	987	58.2	(55.8 - 60.5)	2,460	50.1	(48.0 - 52.2)	<0.001
CD4 count, population geometric mean (SE)	598.4 (7.64)			553.4 (6.79)			<0.001
CD4 count, median [IQR]	564.0 [386.5, 776.7]			520.9 [355.3, 714.7]			
Last VL undetectable or <200 copies/mL	1,438	84.7	(83.0 - 86.5)	3,829	77.3	(75.4 - 79.2)	<0.001
All VLs in the year undetectable or <200 copies/mL	1,318	77.7	(75.7 - 79.7)	3,283	66.2	(64.1 - 68.3)	<0.001
Mean number of CD4/VL tests in the year (SE)	2.5 (0.02)			2.9 (0.05)			<0.001
Median number of CD4/VL in the year [IQR]	2.0 [2.0, 3.0]			2.4 [1.4 -3.3]			
% with number of CD4/VL in the year							
0 or none documented	47	2.8	(2.0 - 3.6)	215	4.9	(3.7 - 6.0)	0.003
1	214	12.6	(11.0 - 14.2)	519	10.6	(9.4 - 11.9)	0.05
2	639	37.7	(35.3 - 40.0)	1,131	23.4	(20.9 - 25.8)	<0.001
3	519	30.6	(28.4 - 32.8)	1,471	30.4	(28.5 - 32.2)	0.89
4+	278	16.4	(14.6 - 18.1)	1,565	30.7	(27.7 - 33.7)	<0.001
At least one VL in each 6 month period	1,265	74.5	(72.5 - 76.6)	3,489	70.7	(68.4 - 72.9)	0.01
At least one CD4 in the year	1,645	96.9	(96.1 - 97.8)	4,646	94.1	(92.9 - 95.4)	<0.001

Footnotes to Table **2**.

Abbreviations: ART=Antiretroviral therapy; CD4=CD4+ T-lymphocyte cell; CI = confidence interval; IQR = Interquartile range; MSM = men who have sex with men; NNRTI=non-nucleoside reverse transcriptase inhibitors; PI, protease inhibitors; SE=Standard error; VL=HIV viral load.

§ Characteristics for HOPS patients and MMP patients were established based on data collected in the twelve months prior to the MMP's weighted interview date which was November 25, 2012.

† In MMP, we are relying on self-reported information on any payer(s) that patient may have in the past 12 months. In HOPS, we are relying on chart-abstracted information on any primary and secondary (if available) payers documented during HOPS clinic visits in the past 12 months.

○ P-values were obtained from z-statistics.

¥ Any Health Insurance Coverage was defined as Private, Other, Medicare, Medicaid, Ryan White and Public Insurance (excluding Self Pay and Clinical Study). Ryan White coverage was counted as any payer type but not considered insurance. Please note: Medicaid is a US government insurance program for persons of all ages whose income and resources are insufficient to pay for health care. Medicare is a US government insurance program for Americans aged 65 and older who have worked and paid into the system as well as for younger people with disabilities, end stage renal disease and amyotrophic lateral sclerosis. The Ryan White HIV/AIDS Program provides HIV-related services in the United States for those who do not have sufficient health care coverage or financial resources for coping with HIV disease. The program fills gaps in care not met by other payers.

‡ MMP data are nationally representative sampling-probability weighted estimates.

Table 3. Characteristics of HIV Outpatient Study (HOPS) participants seen in the January-April 2012, compared with those seen January-December 2012, and those seen only in May-December 2012.

	HOPS A (N=1,697) One Visit January-April			HOPS B (N=2,218) One Visit January-December			%	HOPS C (N=521) One Visit May-December But No Visit January-April			P Value°
Characteristic§	**No.**	**%**	**(95% CI)**	**No.**	**%**	**(95% CI)**	**A - B**	**No.**	**%**	**(95% CI)**	**A *vs* C**
Age category, years											
18-24	19	1.1	(0.6-1.6)	26	1.2	(0.7-1.6)	-0.1	7	1.3	(0.4-2.3)	0.07
25-34	142	8.4	(7.0-9.7)	183	8.3	(7.1-9.4)	0.1	41	7.9	(5.5-10.2)	
35-44	359	21.2	(19.2-23.1)	484	21.8	(20.1 -23.5)	-0.6	125	24.0	(20.3-27.7)	
45-54	681	40.1	(37.8-42.5)	902	40.7	(38.6-42.7)	-0.6	221	42.4	(38.2-46.7)	
55-64	404	23.8	(21.8-25.8)	513	23.1	(21.4-24.9)	0.7	109	20.9	(17.4-24.4)	
≥ 65	92	5.4	(4.3-6.5)	110	5.0	(4.1-5.9)	0.4	18	3.5	(1.9-5.0)	
Mean age (SE), years	49.3 (0.25)			49.1 (0.22)				48.4 (0.42)			0.04
Median age [IQR], years	49.4 [43.2, 56.1]			49.3 [43.0, 55.8]				48.8 [42.8, 54.8]			0.07
Sex at birth											
Male	1,266	74.6	(72.5-76.7)	1,681	75.8	(74.0-77.6)	-1.2	415	79.7	(76.2-83.1)	0.02
Female	431	25.4	(23.3-27.5)	537	24.2	(22.4-26.0)	1.2	106	20.3	(16.9-23.8)	
Race/ethnicity											
White, non-Hispanic	811	47.8	(45.4-50.2)	1,112	50.1	(48.1-52.2)	-2.3	301	57.8	(53.5-62.0)	0.001
Black, non-Hispanic	607	35.8	(33.5-38.1)	754	34.0	(32.0-36.0)	1.8	147	28.2	(24.3-32.1)	
Hispanic or Latino	226	13.3	(11.7-14.9)	287	12.9	(11.5-14.3)	0.4	61	11.7	(8.9-14.5)	
Other†	53	3.1	(2.3-4.0)	65	2.9	(2.2-3.6)	0.2	12	2.3	(1.0-3.6)	
HIV acquisition risk group											
MSM	931	54.9	(52.5-57.2)	1,254	56.5	(54.5-58.6)	-1.6	323	62.0	(57.8-66.2)	0.051
IDU-male	70	4.1	(3.2-5.1)	92	4.1	(3.3-5.0)	0.0	22	4.2	(2.5-6.0)	
IDU-female	50	2.9	(2.1-3.8)	62	2.8	(2.1-3.5)	0.1	12	2.3	(1.0-3.6)	
MSM-IDU	22	1.3	(0.8-1.8)	23	1.0	(0.6-1.5)	0.3	1	0.2	(0.0-0.6)	
Heterosexual-male	171	10.1	(8.6-11.5)	219	9.9	(8.6-11.1)	0.2	48	9.2	(6.7-11.7)	
Heterosexual-female	347	20.4	(18.5-22.4)	434	19.6	(17.9-21.2)	0.8	87	16.7	(13.5-19.9)	
Other	106	6.2	(5.1-7.4)	134	6.0	(5.0-7.0)	0.2	28	5.4	(3.4-7.3)	
Year of HIV diagnosis¥											0.04
< 2009	1,574	92.8	(91.5-94.0)	2071	93.4	(92.3-94.4)	-0.6	497	95.4	(93.6-97.2)	
2009 and later	122	7.2	(6.0-8.4)	146	6.6	(5.5-7.6)	0.6	24	4.6	(2.8-6.4)	
Ever had AIDS as of end of 2012	1,088	64.1	(61.8-66.4)	1,397	63.0	(61.0-65.0)	1.1	309	59.3	(55.1-63.5)	0.047
Any health insurance coverage	1,558	91.8	(90.5-93.1)	2,037	91.8	(90.7-93.0)	0.0	479	91.9	(89.6-94.3)	0.92
Healthcare payer type†											
Any payer or insurance‡	1,620	95.5	(94.5-96.5)	2,114	95.3	(94.4-96.2)	0.2	494	94.8	(92.9-96.7)	0.54
Any private	841	49.6	(47.2-51.9)	1,176	53.0	(50.9-55.1)	-3.4	335	64.3	(60.2-68.4)	<0.001
Any Medicaid	504	29.7	(27.5-31.9)	596	26.9	(25.0-28.7)	2.8	92	17.7	(14.4-20.9)	<0.001
Any Medicare	445	26.2	(24.1-28.3)	539	24.3	(22.5-26.1)	1.9	94	18.0	(14.7-21.4)	<0.001
Any Ryan White	143	8.4	(7.1-9.7)	169	7.6	(6.5-8.7)	0.8	26	5.0	(3.1-6.9)	0.01
Any ART prescription in 2012	1,637	96.5	(95.6-97.3)	2,140	96.5	(95.7-97.3)	0.0	503	96.5	(95.0-98.1)	0.93

(Table 3) contd…..

	HOPS A (N=1,697) One Visit January-April			HOPS B (N=2,218) One Visit January-December			%	HOPS C (N=521) One Visit May-December But No Visit January-April			P Value°
Characteristic§	**No.**	**%**	**(95% CI)**	**No.**	**%**	**(95% CI)**	**A - B**	**No.**	**%**	**(95% CI)**	**A *vs* C**
Any ART prescription in a given class in 2012											
Any NNRTI	738	43.5	(41.1-45.8)	977	44.0	(42.0-46.1)	-0.5	239	45.9	(41.6-50.2)	0.34
Any PI	735	43.3	(41.0-45.7)	936	42.2	(40.1-44.3)	1.1	201	38.6	(34.4-42.8)	0.06
Any entry or integrase inhibitor	606	35.7	(33.4-38.0)	783	35.3	(33.3-37.3)	0.4	177	34.0	(29.9-38.1)	0.47
Last CD4 count, cells/mm^3											
Missing/unknown	46	2.7	(1.9-3.5)	72	3.2	(2.5-4.0)	-0.5	26	5.0	(3.1-6.9)	0.69
0-199	123	7.2	(6.0-8.5)	178	8.0	(6.9-9.2)	-0.8	55	10.6	(7.9-13.2)	
200-349	221	13.0	(11.4-14.6)	271	12.2	(10.9-13.6)	0.8	50	9.6	(7.1-12.1)	
350-499	313	18.4	(16.6-20.3)	395	17.8	(16.2-19.4)	0.6	82	15.7	(12.6-18.9)	
≥ 500	994	58.6	(56.2-60.9)	1,302	58.7	(56.7-60.8)	-0.1	308	59.1	(54.9-63.4)	
CD4 count, population geometric mean (SE)	599.5 (7.60)			600.0 (6.73)				601.8 (14.4)			0.89
CD4 count, median [IQR]	567.6 [386.0, 781.5]			568.6 [386.0, 783.0]				570.0 [386.0, 788.0]			0.68
Last VL undetectable or <200 copies/ml	1,440	84.9	(83.1-86.6)	1,854	83.6	(82.0-85.1)	1.3	414	79.5	(76.0-82.9)	0.004
All VLs in the year undetectable or <200 copies/ml	1,330	78.4	(76.4-80.3)	1,713	77.2	(75.5-79.0)	1.2	383	73.5	(69.7-77.3)	0.02
Mean number of CD4/VL tests in the year (SE)	2.6 (0.03)			3.2 (0.04)				1.7 (0.04)			<0.001
Median number of CD4/VL in the year [IQR]	2 [2, 3]			2 [2, 3]				2 [1, 2]			<0.001
Number of CD4/VL in the year											
0 or none documented	40	2.4	(1.6-3.1)	62	2.8	(2.1-3.5)	-0.4	22	4.2	(2.5-6.0)	<0.001
1	207	12.2	(10.6-13.8)	430	19.4	(17.7-21.0)	-7.2	223	42.8	(38.5-47.1)	
2	618	36.4	(34.1-38.7)	815	36.7	(34.7-38.8)	-0.3	197	37.8	(33.6-42.0)	
3	571	33.6	(31.4-35.9)	627	28.3	(26.4-30.1)	5.3	56	10.7	(8.1-13.4)	
4+	261	15.4	(13.7-17.1)	284	12.8	(11.4-14.2)	2.6	23	4.4	(2.6-6.2)	
At least one VL in each 6 month period (%)	1,298	76.5	(74.5-78.5)	1,502	67.7	(65.8-69.7)	8.8	204	39.2	(35.0-43.4)	<0.001
At least one CD4 test in the year (%)	1,651	97.3	(96.5-98.1)	2,146	96.8	(96.0-97.5)	0.5	495	95.0	(93.1-96.9)	0.01
Clinical visit‡ frequency and density											
Mean (SE)	3.6 (0.05)			3.2 (0.04)				1.9 (0.05)			<0.001
Median [IQR]	3 [2, 4]			3 [2, 4]				2 [1, 2]			<0.001
Min-Max	1-16			1-16				1-8			
Number of clinical visits‡ in the year											
1	119	7.0	(5.8-8.2)	348	15.7	(14.2-17.2)	-8.7	229	44.0	(39.7-48.2)	<0.001
2	407	24.0	(22.0-26.0)	598	27.0	(25.1-28.8)	-3.0	191	36.7	(32.5-40.8)	
3	466	27.5	(25.3-29.6)	534	24.1	(22.3-25.9)	3.4	68	13.1	(10.1-16.0)	
4+	705	41.5	(39.2-43.9)	738	33.3	(31.3-35.2)	8.2	33	6.3	(4.2-8.4)	

Footnotes to Table **3**.

Abbreviations: ART= Antiretroviral therapy; CD4=CD4+ T-lymphocyte cell; CI = confidence interval; IDU = male or female injection drug user; IQR = Interquartile range; MSM = men who have sex with men; NNRTI=non-nucleoside reverse transcriptase inhibitors; PI, protease inhibitors; SE=Standard error; VL=HIV viral load.

HOPS A refers to all participant who had at least one outpatient visit during January-April, 2012 (MMP's current population definition period).

HOPS B refers to all participant who had at least one outpatient visit during January-December, 2012

HOPS C refers to all participants who had at least one outpatient visit during May-December, 2012, but had no visit during January-April 2012 (excludes MMP's current population definition period).

§ Characteristics for HOPS patients were established based on data collected in the 2012 calendar year. Note that this time frame differs from that used in the primary analysis.

° P-values for ordinal variables were calculated using Cochran-Armitage trend tests; p-values for categorical variables were calculated using chi-square tests; p-values for distributions were obtained from Wilcoxon rank sum tests; and p-values for means were obtained from Student's t-tests.

† Other race groups include those of multiple race groups and other, unknown or missing race groups.

¥ One participant had unknown year of HIV diagnosis.

† We are relying on chart-abstracted information on any primary and secondary (if available) payers documented during HOPS clinic visits in the past 12 months.

‡ Any Health Insurance Coverage was defined as Private, Other, Medicare, Medicaid, Ryan White and Public Insurance (excluding Self Pay and Clinical Study). Ryan White coverage was counted as any payer type but not considered insurance. Please note: Medicaid is a US government insurance program for persons of all ages whose income and resources are insufficient to pay for health care. Medicare is a US government insurance program for Americans aged 65 and older who have worked and paid into the system as well as for younger people with disabilities, end stage renal disease and amyotrophic lateral sclerosis. The Ryan White HIV/AIDS Program provides HIV-related services in the United States for those who do not have sufficient health care coverage or financial resources for coping with HIV disease. The program fills gaps in care not met by other payers.

ł Eligible types of clinical visits were defined as: routine, initial, return to active status, event triggered, or post-hospital follow up.

The HOPS 2012 data are based on a convenience sample of persons with HIV infection attending nine HOPS-participating clinics in six US cities, while MMP is a probability sample of persons with HIV infection receiving medical care in the US; in 2012 MMP data were collected from 467 facilities in 16 states and Puerto Rico. Although MMP is based on a large, diverse, geographically distributed probability sample of facilities, the data collected reflect only one year of follow-up time. Thus MMP is designed to make accurate estimates of the prevalence of behavioral and clinical characteristics among persons with HIV infection receiving medical care, but is ill-equipped for longitudinal analyses (*e.g.*, estimating incidence rates of conditions and studying risk factors for their onset). The average accrued follow-up time per HOPS participant in 2012 was eight years, making HOPS well poised to assess disease incidence as well as risk factors for disease development. However, as our analyses revealed, HOPS participants enrolled at selected HIV clinics differ in some respects from the overall population of persons with HIV infection receiving medical care in the US. The HOPS cohort is growing in size with an increasing representation of older patients with long-standing HIV infection who are surviving longer due to ART. Because of resource constraints, not all newly HIV-diagnosed persons seen at participating clinics can be enrolled into observational cohorts [8] like the HOPS, posing a challenge with respect to such cohort recruitment strategies to continue to reflect characteristics of all contemporary persons in HIV care in the US.

Moving forward, a data synthesis approach that builds on the relative strengths of MMP (ability to estimate prevalence) and HOPS (ability to estimate incidence) could be developed to improve national epidemiologic data and projections needed for HIV prevention and treatment. HOPS and MMP data can be used jointly to derive population attributable fractions and other estimates for the US population. Specifically, HOPS rates can be standardized to MMP population prevalence to provide estimates that may approximate national rates. For example, HOPS was used to estimate the rates of incident cardiovascular disease (CVD) events according to patients' baseline CD4 count and history of tobacco use [15]. Applying these HOPS rates to the distribution of CD4 count strata and tobacco use history from MMP [18] could be used to project the number of incident CVD events among these subgroups of patients nationally, and inform modeling projections of how many CVD events could be averted by earlier ART initiation to avoid low CD4 counts and by tobacco cessation interventions.

Another key consideration in interpreting data from HOPS and MMP is that both databases only include persons who are receiving medical care. A substantial proportion of HIV-infected persons in the US are not consistently engaged in HIV care [3, 12]. Some of the noted differences between HOPS and NHSS might be due to the nature of the HOPS convenience sample (*e.g.*, types of persons who attended the nine HOPS-participating clinics in 2012, were systematically approached for study participation, and agreed to participate). In addition, differences between MMP and NHSS populations might reflect differences in care seeking; for example persons who have been diagnosed with AIDS are more likely to become enrolled in care than persons without AIDS. To better understand the needs of HIV-diagnosed persons not receiving medical care and thereby better guide HIV prevention and treatment in the US, in 2013, CDC re-designed MMP to directly sample from NHSS; thus, starting with the 2015 data collection cycle, the new MMP reference population will include all HIV-diagnosed persons in the participating jurisdictions regardless of whether they are receiving medical care (see http://www.grants.gov/web/grants/search-grants.html, CDC-RFA-PS15-1503).

Although, MMP uses a probability sample, a methodology to reduce overall bias [25], the 4-month population definition period (*i.e.*, January-April) might skew the overall estimates obtained from MMP. In another multi-site analysis of 12,135 patients in care in 2003, 88% of patients had at least one visit in the first four months of the year [24]. In our analysis using data from 2012, we found that somewhat lower percentage, or 76.5% of HOPS participants who had at least one visit January-December also had at least one visit in January-April. However, persons who had at least one visit January-April and persons who had visits only May-December were equally likely to be prescribed ART in the year with the only notable differences being the percentage with private insurance, the frequency of CD4 count and viral load testing, and the percentage achieving viral suppression. Our results suggest that persons seen in the first four months of the calendar year are a reasonable approximation of all persons engaged in care (*i.e.*, who have at least one visit in the calendar year). However, additional validation studies using other data sources would be beneficial to further explore this issue. The estimates from the HOPS and MMP are in-line with earlier results from the North American AIDS Cohort Collaboration on Research and Design, which found that among 35,324 participants who had ≥1 HIV care visit from January-June 2008, 82% were prescribed ART, and 78% had a suppressed HIV viral load [26].

This analysis has certain limitations. Firstly, although we attempted to define variables similarly across different data sources, estimates may differ to an unknown degree due to different data collection methods for some variables (*e.g.*, documentation of insurance type per structured interview in MMP *versus* medical record abstraction in the HOPS). Secondly, there is no one single gold standard data collection system for care indicators for persons living with HIV infection, and so all comparisons made in this manuscript describe relative differences between data systems, each with its own unique strengths and limitations. Thirdly, due to a higher average number of viral load measurements in the year in the MMP *vs* the HOPS, the difference in the percentage of patients with durable viral suppression across these two populations may have been overestimated.

In conclusion, CDC currently supports complementary data collection systems to describe persons living with diagnosed HIV infection to better inform HIV prevention and treatment efforts. Understanding the comparative strengths and limitations of the individual databases, and contrasting database findings, is key to enhancing data interpretation and utility. The formal comparison presented here is an essential first step to integrating estimates produced *via* the different data systems needed to provide an

overall better understanding of HIV epidemiology in the US. Our findings also provide a reference point for design and interpretation of data from other US-based data collection systems, including other large HIV clinical cohorts in North America [8], and HIV-infected patients receiving care for HIV infection and captured in a variety of health services databases.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

The HIV Outpatient Study (HOPS) Investigators include the following persons and sites: Kate Buchacz, John T. Brooks, Marcus D. Durham, Division of HIV/AIDS Prevention, National Center for HIV, STD, Viral Hepatitis and TB Prevention (NCHHSTP), Centers for Disease Control and Prevention (CDC), Atlanta, GA; Harlen Hays, Kathleen C. Wood, Darlene Hankerson, Rachel L. D. Hart, Thilakavathy Subramanian, Carl Armon, Bonnie Dean, Dana Franklin, Cerner Corporation, Vienna, VA; Frank J. Palella, Joan S. Chmiel, Saira Jahangir, Conor Daniel Flaherty, Jerian Denise Dixon-Evans, Feinberg School of Medicine, Northwestern University, Chicago, IL; Kenneth A. Lichtenstein, Cheryl Stewart, National Jewish Health, Denver, CO; John Hammer, Kenneth S. Greenberg, Barbara Widick, Rosa Franklin, Rose Medical Center, Denver, CO; Bienvenido G. Yangco, Kalliope Chagaris, Infectious Disease Research Institute, Tampa, FL; Doug Ward, Troy Thomas, Matt Starr, Dupont Circle Physicians Group, Washington, DC; Jack Fuhrer, Linda Ording-Bauer, Rita Kelly, Jane Esteves, State University of New York (SUNY), Stony Brook, NY; Ellen M. Tedaldi, Ramona A. Christian, Faye Ruley, Dania Beadle, Princess Graham, Temple University School of Medicine, Philadelphia, PA; Richard M. Novak, Andrea Wendrow, Renata Smith, University of Illinois at Chicago, Chicago, IL; Benjamin Young, Barbara Widick, Mia Scott, APEX Family Medicine, Denver, CO.

MMP Study Group Members - 2012

This report is based, in part, on contributions by MMP participants, facilities, community and provider advisory boards, and interviewers and abstractors. The MMP principal investigators and project coordinators include Karen Mark, MD, Matthew Facer, PhD, Michael Neff, MBA, California Department of Public Health, Sacramento, California; Nanette Benbow, MAS, Alexandra Gagner, MPH, Stephanie Townsell, MPH, Cathy Cortes, Chicago Department of Public Health, Chicago, Illinois; Robert Vella, MPH, James Dowling, MPH, Larry Evans, Myrtle Bergold, Bruce Levan, Angela Crump, Ashley McLean, Delaware Health and Social Services, Dover, Delaware; Rebecca Grigg, PhD, Pam Fillmore, Robert Austin, MPA, Florida Department of Health, Tallahassee, Florida; Natalie Spears, MPH, Jane Kelly, MD, Georgia Department of Public Health, Atlanta, Georgia; Salma Khuwaja, MD, DrPH, Osaro Mgbere, MD, MPH, Houston Department of Health and Human Services, Houston, Texas; Cheryl Ward, MS, Marti Merritt, Illinois Department of Public Health; Daniel Hillman, MPH, Jodi Rhynearson, MPA, Indiana State Department of Health, Indianapolis, Indiana; Amy Rock Wohl, PhD, Judy Tejero, MPH, Los Angeles County Department of Public Health, Los Angeles, California; Kathryn Macomber, MPH, Meosia Lee-Turner, Michigan Department of Community Health, Detroit, Michigan; Leandro Mena, MD, Arti Barnes, MD, Joseph Grice, MPH, Mississippi State Department of Health, Jackson, Mississippi; Barbara Bolden, PhD, Kidane Meshesha, MPH, New Jersey Department of Health and Senior Services, Trenton, New Jersey; Bridget J. Anderson, PhD, Linda Lou Smith, MD, Michael D. Miele, New York State Department of Health, Albany, New York; Alan Neaigus, PhD, Marie Antoinette Bernard, MD, New York City Department of Health and Mental Hygiene, New York City, New York; Delbert Williams, PhD, Mark Turner, PhD, North Carolina Department of Health, Raleigh, North Carolina; Sean Schafer, MD, Oregon Public Health Division, Portland, Oregon; Tyler Smith, MD, Multnomah County Health Department (Oregon); Leequan Ray, PhD, Ronald Skura, MPH, Pennsylvania Department of Health, Harrisburg, Pennsylvania; Kathleen A. Brady, MD, Michael G. Eberhart, MPH, Philadelphia Department of Public Health, Philadelphia, Pennsylvania; Sandra Miranda De León, MPH, Gladys Girona Lozada, MSc, Puerto Rico Department of Health, San Juan, Puerto Rico; Susan Scheer, PhD, Maree Kay Parisi, San Francisco Department of Public Health, San Francisco, California; Sharon K. Melville, MD, Sylvia Odem, MPH, Texas Department of State Health Services, Austin, Texas; Dena Bensen, MPH, Celestine Buyu, MPH, Carmen Roman, Virginia Department of Health, Richmond, Virginia; Tom Jaenicke, MPH, Shawn McBrien, MPH, Jennifer Reuer, MPH, Washington State Department of Health; Elizabeth Barash, MPH, and Susan Buskin, PhD, Public Health Seattle & King County, Seattle, Washington; and members of the MMP team, Division of HIV/AIDS Prevention, Centers for Disease Control and Prevention, Atlanta, GA.

Financial Support

For the HOPS: Centers for Disease Control and Prevention (contract nos. 200-2001-00133, 200-2006-18797, and 200-2011-41872)

For MMP: Centers for Disease Control and Prevention (Cooperative Agreement PS09-937).

For NHSS: Centers for Disease Control and Prevention (Cooperative Agreement PS13-1302).

DISCLAIMER

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention.

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Received: August 26, 2015 Revised: October 7, 2015 Accepted: October 13, 2015