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A Latent Class Analysis of Risk Factors for Acquiring HIV Among Men Who Have Sex with Men: Implications for Implementing Pre-Exposure Prophylaxis Programs

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Abstract

Current Centers for Disease Control and Prevention (CDC) guidelines for prescribing pre-exposure prophylaxis (PrEP) to prevent HIV transmission are broad. In order to better characterize groups who may benefit most from PrEP, we reviewed demographics, behaviors, and clinical outcomes for individuals presenting to a publicly-funded sexually transmitted diseases (STD) clinic in Providence, Rhode Island, from 2012 to 2014. Latent class analysis (LCA) was used to identify subgroups of men who have sex with men (MSM) at highest risk for contracting HIV. A total of 1723 individuals presented for testing (75% male; 31% MSM). MSM were more likely to test HIV positive than heterosexual men or women. Among 538 MSM, we identified four latent classes. Class 1 had the highest rates of incarceration (33%), forced sex (24%), but had no HIV infections. Class 2 had <5 anal sex partners in the previous 12 months, the lowest rates of drug/alcohol use during sex and lower HIV prevalence (3%). Class 3 had the highest prevalence of HIV (7%) and other STDs (16%), > 10 anal sex partners in the previous 12 months (69%), anonymous partners (100%), drug/alcohol use during sex (76%), and prior STDs (40%). Class 4 had similar characteristics and HIV prevalence as Class 2. In this population, MSM who may benefit most from PrEP include those who have >10 sexual partners per year, anonymous partners, drug/alcohol use during sex and prior STDs. LCA is a useful tool for identifying clusters of characteristics that may place individuals at higher risk for HIV infection and who may benefit most from PrEP in clinical practice.

Introduction

Approximately 50,000 individuals are newly infected with HIV each year in the United States (US).[1] HIV continues to impact gay, bisexual, and other men who have sex with men (MSM) disproportionately. In 2011, more than 78% of all new HIV diagnoses in the US were among MSM, with a disproportionate number of infections among males age 13–24 years old.[1] MSM of color are also disproportionately impacted by HIV. Of all MSM diagnosed with HIV in 2011, 38% were African American and 24% were Hispanic. Other populations at high risk for acquiring HIV include men and women in serodiscordant partnerships, commercial sex workers, individuals with multiple sexual partners, and individuals diagnosed with other sexually transmitted diseases (STDs).[2–5]

Pre-exposure prophylaxis (PrEP) is a once-daily antiretroviral medication (emtricitabine/tenofovir) that is used to prevent HIV infection. Approved by the US Food and Drug Administration in July 2012, PrEP has been demonstrated to be safe and effective in multiple at-risk populations.[6] Among MSM, PrEP was associated with a greater than 90% efficacy

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in those with detectable levels of medication in their blood.[7] PrEP is also efficacious in other populations, including high-risk heterosexuals and people who inject drugs (PWID).[7–10] The success of PrEP in clinical trials now gives way to questions regarding how implementation and dissemination of PrEP will be executed in real-world settings.[11] Given that STD clinics routinely provide care to those at highest-risk for HIV infection, they may be an ideal place to implement PrEP programs.[12]

Commonly cited concerns about PrEP implementation include side-effects, cost of medications, increased risk behaviors while taking PrEP, and the potential for drug resistance during seroconversion.[11] Current Centers for Disease Control and Prevention (CDC) guidelines recommend reserving PrEP for individuals at highest risk for acquiring HIV.[13] The guidelines suggest that populations who may benefit most from PrEP include: MSM who have had at least one act of condomless anal sex in the last year; MSM who have been recently diagnosed with an STD; and MSM in a serodiscordant relationship with an HIV-positive partner. These broad criteria may be less than optimal for identifying men who are at highest risk for acquiring HIV. Factors including medication cost, available clinical resources, and potential for long-term side-effects may limit broad PrEP implementation to the general population of MSM. Effective use of resources requires identification of the highest-risk subgroups of MSM to help inform PrEP implementation programs.

In this study, we use latent class analysis (LCA) to characterize risk factors for HIV infection among individuals presenting to an urban STD clinic. We build upon previous studies on individual risk behaviors[14–17] to identify groups of individuals who are at highest risk for HIV infection and candidates for PrEP. The results of this study will help guide individual clinicians on PrEP use and, importantly, policy-level PrEP planning as programs are implemented in the US.

LCA is a statistical analysis that uncovers subgroups, or ''classes'' defined by distinct response patterns on multiple HIV risk factors. LCA has been used to evaluate substance use,[18–23] HIV risk factors,[24–26] medication adherence,[27] and other HIV behaviors,[28–30] but has not been widely used to elucidate classes of MSM who may benefit most from PrEP.

Unlike traditional regression approaches that evaluate the average effects of risk factors on HIV risk and can add only a few interaction terms before becoming too difficult to interpret, LCA assesses the differential effects of multiple risk factors simultaneously. In essence, LCA evaluates the interaction and patterns of multiple risk factors to identify individuals at greatest risk for HIV.[31] This methodology allows for the identification of specific subgroups of MSM with distinct patterns of high-risk behaviors, which can then inform targeting of HIV preventions interventions such as PrEP.

The objective of this study was to evaluate the behavioral risk profiles of individuals presenting to an urban STD clinic in order to identify distinct subgroups of individuals at highest risk for acquiring HIV infection, and who may benefit most from PrEP.

Methods

Participants

The Miriam Hospital STD Clinic is the only publicly-funded STD clinic in the state of Rhode Island. All individuals presenting for HIV or STD testing complete a one-page intake form, which includes demographics, behavioral risk factors, and other conventional HIV surveillance information. We collected de-identified patient data for all individuals presenting for testing between January 2012 and May 2014. We reviewed the following surveillance data: age, gender, race, ethnicity, risk behaviors, state of residence, insurance status, prior HIV and STD testing, injection drug use, and number of sex partners in the last 12 months (oral, vaginal, and/or anal). Other behavioral data included sex with anonymous partner(s), alcohol or drug use during sex, sex with someone of unknown HIV status, sex with someone who exchanges sex for drugs or money, history of exchanging drugs or money for sex, having ever been forced to have sex, and prior history of incarceration.

Sexual behavior categories included: MSM (exclusively), men who have sex exclusively with women (MSW), men who have sex with men and women (MSMW), women who have sex exclusively with men (WSM), women who have sex exclusively with women (WSW), and women who have sex with men and women (WSWM). HIV (antibody testing), syphilis (treponemal and non-treponemal), gonorrhea (urine nucleic acid amplification testing, NAAT), and chlamydia (urine NAAT) results were reviewed for all individuals. Rectal and pharyngeal NAAT testing for gonorrhea and chlamydia was performed in a small subset of MSM with symptoms, but otherwise not routinely performed.

Bivariate analyses including the chi-square test were used to compare demographics and behaviors between groups. Significance was defined as alpha less than 0.05 and all reported p-values were two-sided. This study was approved by The Miriam Hospital's Institutional Review Board.

Latent class analysis

LCA was used to identify groups of individuals at highest risk for HIV based on specific variables. The purpose of this analysis was to identify groups of individuals who had a higher prevalence of HIV in order to better understand how to implement PrEP. LCA[32,33] is a statistical approach that generates latent classes based on patterns of data, with the goal of grouping similar individuals. A series of LCA models with between one and five classes was tested using the Mplus software package Version 7.1 (Muthén and Muthén, 1998–2013). To avoid the likelihood of converging on a local maximum, 500 start values were generated for each model.

Indices used to determine the best model fit and thus the optimal LCA solution included the Akaike Information Criterion (AIC), sample size adjusted Bayesian Information Criterion (BIC), which are measures of the relative fit of a statistical model to a set of data compared to other models and used for model selection (lower AIC and BIC values indicate better model fit), and the bootstrapped likelihood ratio test (BLRT) for model fit,[34] which tests the null hypothesis of no improvement in fit for the model under consideration compared to a model with one less class.

Entropy, which measures the extent to which classes are distinct from each other, the average posterior probability of class membership, and interpretability of the classes were also considered. Entropy values above 0.8 indicate better distinction of classes.[35]

Variables used in the LCA included: date of last HIV test, number of oral sex partners in the last 12 months, number of anal sex partners in the last 12 months, any anonymous

partner(s) in the last 12 months, alcohol or drug use during sex in the last 12 months, sex with a partner of unknown HIV status in the last 12 months, prior STD diagnosis in the last 12 months, exchanging sex for money/drugs or sex with someone who exchanges sex for money/drugs, prior injection drug use, having been ever forced to have sex, and prior history of incarceration.

Demographic covariates included age, race, and ethnicity. Outcomes of primary interest included testing positive for HIV or other STDs (i.e., syphilis, gonorrhea, and/or chlamydia) at the clinic visit. After identifying the LCA model with the optimal number of classes based on these criteria, multinomial logistic regression was used to compare classes on demographic covariates, including age, race, and ethnicity, and on outcomes including testing positive for HIV or another STD.

Results

A total of 1723 individuals presented for HIV and/or STD testing during the study period (Table 1). Among these, 75% were male, 52% were less than 30 years old, 70% were Caucasian/white, 18% African American/black, and 23% Hispanic. Sexual preference included MSM (26%), MSMW (5%), MSW (43%), WSM (22%), WSWM (2%), and WSW (1%). Of the whole cohort, 29% reported a prior STD diagnosis in their lifetime. Seventy-six percent of individuals had been previously tested for HIV. Among those tested, 1.5% were found to be positive for HIV, 4.4% for syphilis, 2.6% for gonorrhea and 8.9% for chlamydia. In total, 11.7% of individuals tested positive for at least one STD.

Compared to non-MSM, MSM were more likely to test positive for HIV (96%, 22/23 of cases in MSM vs. 4%, 1/23 cases in non-MSM, $p < 0.01$); syphilis (86%, 59/69 vs. 14%, 10/69, $p < 0.01$); and gonorrhea (59%, 24/41 vs. 41%, 17/41, $p < 0.01$, Table 1). Non-MSM were more likely to test positive for chlamydia than MSM (81%, 113/139 of cases in non-MSM vs. 19%, 26/139 cases in MSM, $p < 0.01$).

Of the 538 MSM presenting for testing, 4.1% were positive for HIV. In the bivariate analyses, MSM who tested positive for HIV were much more likely to have a history of prior IDU (14% vs. 3%, $p < 0.01$) and of being forced to have sex (27% vs. 5%, $p < 0.01$, Table 2). There was no difference between MSM who tested positive for HIV compared to those who were HIV negative and age group, race, ethnicity, prior HIV testing, number of sex partners in the preceding 12 months (anal or oral or both), anonymous partners, prior STD diagnosis ever or in the preceding 12 months, exchanging sex for money/drugs, sex with someone who exchanges sex for money/drugs, or history of incarceration. There was no difference between MSM who did and did not test positive for any STD and any of the variables tested.

In the LCA, a total of 449 MSM were included who had complete demographic, behavioral, and clinical data available. A comparison of model fit indices demonstrated that a four-class solution was preferable (Table 3). Compared to models that contained one to three classes, the four-class solution provided the lowest BIC and AIC values, indicating the best model fit, and good entropy (0.81), suggesting adequate distinction of classes, with a significant improvement in model fit over other models by the BLRT. Although entropy was higher for the five-class model (0.84), the decrease in the AIC and BIC between the four- and five-class model was minimal, and the BLRT suggested no improvement in fit for the five-class model over the four-class model ($p = 0.20$). The average probability of latent class membership was 0.87 for Class 1, 0.89 for Class 2, 0.90 for Class 3, and 0.92 for class 4 (Table 3).

As shown in Table 4, Class 1 ($N = 33$) was evenly distributed across age and over one-fifth were Hispanic (21%). This class had the lowest percent of individuals who had never had an HIV test (28%), as well as lowest number of reported oral and anal sex partners (82% and 85% with <1 oral and anal sex partners in the past 12 months, respectively). This class also had the highest proportion of past incarceration (33%), history of having been forced to have sex (24%), and sex with a partner of unknown status (67%). A prior STD in the last 12 months was lowest in this group. Class 1 did not contain any HIV positive individuals and had a low proportion (6%) of members testing positive for any STD (Tables 4 and 5).

Class 2 ($N = 142$) had a similar distribution of age and race/ethnicity as Class 1. Approximately half (56%) reported never HIV testing. Class 2 had the highest proportion reporting one or two oral and anal sex partners, and no members reporting five or more sexual partners in the past year. Class 2 had the lowest proportion reporting anonymous partners, alcohol and/or drug use during sex, sex with partners of unknown HIV serostatus, or exchanging sex. This class had the second-lowest HIV prevalence at 3%, and 13% of members of this class were positive for at least one STD (Tables 4 and 5).

Class 3 ($N = 55$) was evenly distributed across age groups, but had the largest number of Caucasian members (85%). Sixty-eight percent had never had an HIV test and no one in the class had been tested for HIV in the preceding year. Individuals in Class 3 also had the largest number of oral sex partners in the past 12 months; 100% reported >3 partners and 69% >10 partners. These individuals also reported the largest number of anal sex partners in the past 12 months; all had had anal sex and 60% had >10 partners. One-hundred percent of individuals in this class reported having had anonymous sex partners.

This class also had the largest number of individuals who had used alcohol or other drugs during sex (76%), exchanged sex for drugs/money or had sex with someone who exchanges sex for drugs/money (38%), had a STD in the preceding 12 months (40%), or had previously injected drugs (22%). Class 3 had the highest prevalence of HIV (7%) and the highest prevalence of any STD (16%).

Class 4 ($N = 219$) was evenly distributed across age groups, and had the lowest percent of Hispanic individuals (14%). Similar to Class 2, slightly more than half reported that they had never had an HIV test. Individuals in Class 4 more frequently reported having 5–10 oral and anal sex partners than any other category, the second highest number of partners second to Class 3. A larger percent of Class 4 reported sex with an anonymous partner (74%) and a history of an STD in the last 12 months (19%) than any class except Class 4. No members of Class 4 reported a history of injection drug use or incarceration. Class 4 has the second-highest HIV prevalence at 4% and second-highest STD prevalence at 15% testing positive for any STD (Tables 4 and 5).

Table 1. Demographic and Behavioral Characteristics of Patients Presenting for Care at an Urban Sexually Transmitted Diseases (STD) Clinic in Providence, Rhode Island (2012–2014)

	Total (N = *1,723*)		*MSM* (N = *538*)		*Other* (N = *1185*)		
	%	N	%	N	%	N	p *Value*
Gender							
Male	75%	(1291/1723)	99%	(534/538)	64%	(757/1185)	<0.01
Female	25%	(428/1723)	-		36%	(428/1185)	
Transgender	0.2%	(4/1723)	1%	(4/538)	0%	(0/1185)	
Age							
15–19	4%	(68/1723)	1%	(8/538)	5%	(60/1185)	<0.01
20–24	25%	(432/1723)	20%	(107/538)	27%	(325/1185)	
25–29	23%	(393/1723)	21%	(113/538)	24%	(280/1185)	
30–34	15%	(251/1723)	15%	(80/538)	14%	(171/1185)	
35–39	9%	(154/1723)	8%	(42/538)	9%	(112/1185)	
40+	25%	(423/1723)	35%	(187/538)	20%	(236/1185)	
Unknown	0%	(2/1723)	0%	(1/538)	0%	(1/1185)	
Race							
Caucasian/white	70%	(1206/1723)	78%	(418/538)	66%	(788/1185)	<0.01
African American/black	18%	(316/1723)	11%	(60/538)	22%	(256/1185)	
Asian	3%	(57/1723)	4%	(24/538)	3%	(33/1185)	
Cape Verdean	1%	(22/1723)	1%	(7/538)	1%	(15/1185)	
Other/mixed	7%	(122/1723)	5%	(29/538)	8%	(93/1185)	
Ethnicity							
Hispanic/Latino	23%	(396/1723)	16%	(86/538)	26%	(310/1185)	<0.01
Risk							
MSM	26%	(449/1723)	83%	(449/538)	-		
MSMW	5%	(89/1723)	17%	(89/538)	-		
MSW	43%	(744/1723)	-		63%	(744/1185)	
WSM	22%	(372/1723)	-		31%	(372/1185)	
WSMW	2%	(35/1723)	-		3%	(35/1185)	
WSW	1%	(13/1723)	-		1%	(13/1185)	
N/A	1%	(21/1723)	-		2%	(21/1185)	
Prior HIV test	76%	(1305/1723)	89%	(477/538)	70%	(828/1185)	<0.01
Last HIV test							
<1 year	50%	(592/1179)	62%	(267/428)	43%	(325/751)	<0.01
1–2 years	30%	(358/1179)	26%	(110/428)	33%	(248/751)	
2–5 years	12%	(139/1179)	5%	(22/428)	16%	(117/751)	
>5 years	8%	(90/1179)	7%	(29/428)	8%	(61/751)	
Sex with anonymous partner	35%	(551/1560)	55%	(251/457)	27%	(300/1103)	<0.01
Alcohol/drugs and sex	34%	(523/1560)	34%	(154/457)	33%	(369/1103)	0.93
Partner with unknown HIV status	37%	(582/1559)	45%	(205/457)	34%	(377/1102)	<0.01
Exchanged sex for money/drugs	2%	(34/1561)	4%	(20/457)	1%	(14/1104)	<0.01
Sex with exchanger	7%	(103/1561)	7%	(33/457)	6%	(70/1104)	0.52
Forced sex	5%	(81/1561)	7%	(32/457)	4%	(49/1104)	0.04
Prior STD ever	29%	(506/1720)	37%	(200/538)	26%	(306/1182)	<0.01
STD last 12 months	13%	(208/1561)	18%	(82/457)	11%	(126/1104)	<0.01
Prior IDU	3%	(57/1718)	4%	(21/536)	3%	(36/1182)	0.35
Incarcerated	10%	(160/1561)	4%	(19/457)	13%	(141/1104)	<0.01
HIV	2%	(23/1519)	5%	(22/451)	0%	(1/1091)	<0.01
Syphilis	4%	(69/1582)	12%	(59/498)	1%	(10/1084)	<0.01
Gonorrhea	3%	(41/1567)	5%	(24/463)	2%	(17/1104)	<0.01
Chlamydia	9%	(139/1565)	6%	(26/461)	10%	(113/1104)	<0.01
Any STD	12%	(201/1723)	14%	(78/538)	10%	(123/1185)	0.01

IDU, injection drug use; MSM, men who have sex with men; MSW, men who have sex exclusively with women (MSW); MSMW, men who have sex with men and women (MSMW); STD, sexually transmitted disease; WSM, women who have sex exclusively with men (FSM); WSW, women who have sex exclusively with women (WSW); WSWM, women who have sex with men and women (WSWM).

Discussion

This LCA of MSM presenting for testing at the only publicly-funded STD clinic in Rhode Island helped identify patients who may benefit most from PrEP by identifying groups of patients with differential HIV prevalence. Overall, 4.1% of MSM presenting to the publicly funded STD clinic in Rhode Island tested positive for HIV. MSM were also more likely to test positive for syphilis and gonorrhea compared to non-MSM.

Table 2. Demographics and Behaviors of Men Who Have Sex with Men (MSM) Presenting for Care at an Urban Sexually Transmitted Diseases (STD) Clinic in Providence, Rhode Island (2012–2014)

			HIV					*Any STD*				
	Total (N = 538)		*Positive (N = 22)*		*Negative (N = 429)*			*Positive (N = 78)*		*Negative (N = 460)*		
	%	N	%	N	%	N	p	%	N	%	N	p
Age												
15–19	1%	(8/537)	0%	(0/22)	2%	(7/428)	0.55	0%	(0/78)	2%	(8/459)	0.28
20–24	20%	(107/537)	23%	(5/22)	20%	(87/428)		22%	(17/78)	20%	(90/459)	
25–29	21%	(113/537)	27%	(6/22)	21%	(88/428)		26%	(20/78)	20%	(93/459)	
30–34	15%	(80/537)	5%	(1/22)	16%	(70/428)		15%	(12/78)	15%	(68/459)	
35–39	8%	(42/537)	14%	(3/22)	7%	(30/428)		12%	(9/78)	7%	(33/459)	
40+	35%	(187/537)	32%	(7/22)	34%	(146/428)		26%	(20/78)	36%	(167/459)	
Race												
Caucasian/white	79%	(418/530)	77%	(17/22)	80%	(336/422)	0.10	74%	(56/76)	80%	(362/454)	0.13
African American	11%	(60/530)	14%	(3/22)	10%	(44/422)		17%	(13/76)	10%	(47/454)	
Asian	5%	(24/530)	0%	(0/22)	5%	(21/422)		3%	(2/76)	5%	(22/454)	
Cape Verdean	1%	(7/530)	0%	(0/22)	2%	(7/422)		3%	(2/76)	1%	(5/454)	
Pacific Islander	0%	(2/530)	0%	(0/22)	0%	(1/422)		1%	(1/76)	0%	(1/454)	
Mixed	0%	(2/530)	5%	(1/22)	0%	(1/422)		1%	(1/76)	0%	(1/454)	
Other	3%	(17/530)	5%	(1/22)	3%	(12/422)		1%	(1/76)	4%	(16/454)	
Ethnicity												
Hispanic/Latino	16%	(86/531)	18%	(4/22)	17%	(70/422)	0.85	18%	(14/76)	16%	(72/455)	0.57
Prior HIV test (yes/no)	89%	(477/537)	95%	(21/22)	87%	(371/428)	0.23	92%	(72/78)	88%	(405/459)	0.29
Last HIV test												
<1 year	62%	(267/428)	48%	(10/21)	65%	(227/351)	0.02	64%	(45/70)	62%	(222/358)	0.68
1–2 years	26%	(110/428)	24%	(5/21)	26%	(93/351)		24%	(17/70)	26%	(93/358)	
2–5 years	5%	(22/428)	19%	(4/21)	5%	(16/351)		7%	(5/70)	5%	(17/358)	
>5 years	7%	(29/428)	10%	(2/21)	4%	(15/351)		4%	(3/70)	7%	(26/358)	
Sex partners last 12 months (anal or oral)												
0	1%	(4/524)	0%	(0/20)	0%	(2/421)	0.37	1%	(1/73)	1%	(3/451)	0.17
1	14%	(75/524)	15%	(3/20)	13%	(55/421)		11%	(8/73)	15%	(67/451)	
2	16%	(84/524)	10%	(2/20)	18%	(74/421)		15%	(11/73)	16%	(73/451)	
3–4	19%	(97/524)	10%	(2/20)	18%	(75/421)		10%	(7/73)	20%	(90/451)	
5–10	34%	(176/524)	30%	(6/20)	35%	(146/421)		40%	(29/73)	33%	(147/451)	
10+	17%	(88/524)	35%	(7/20)	16%	(69/421)		23%	(17/73)	16%	(71/451)	
Sex partners last 12 months (oral only)												
0	5%	(21/454)	13%	(2/15)	4%	(15/368)	0.33	6%	(4/64)	4%	(17/390)	0.17
1	16%	(73/454)	20%	(3/15)	15%	(57/368)		13%	(8/64)	17%	(65/390)	
2	17%	(79/454)	0%	(0/15)	18%	(68/368)		11%	(7/64)	18%	(72/390)	
3–4	20%	(90/454)	20%	(3/15)	20%	(72/368)		14%	(9/64)	21%	(81/390)	
5–10	31%	(139/454)	33%	(5/15)	30%	(112/368)		42%	(27/64)	29%	(112/390)	
10+	11%	(52/454)	13%	(2/15)	12%	(44/368)		14%	(9/64)	11%	(43/390)	
Sex partners last 12 months (anal only)												
0	8%	(38/454)	7%	(1/15)	8%	(28/369)	0.34	6%	(4/64)	9%	(34/390)	0.12
1	24%	(111/454)	27%	(4/15)	25%	(92/369)		19%	(12/64)	25%	(99/390)	
2	16%	(74/454)	13%	(2/15)	18%	(66/369)		17%	(11/64)	16%	(63/390)	
3–4	18%	(80/454)	0%	(0/15)	17%	(64/369)		11%	(7/64)	19%	(73/390)	
5–10	25%	(115/454)	47%	(7/15)	24%	(90/369)		39%	(25/64)	23%	(90/390)	
10+	8%	(36/454)	7%	(1/15)	8%	(29/369)		8%	(5/64)	8%	(31/390)	
Anonymous partner	55%	(251/457)	60%	(9/15)	55%	(205/370)	0.73	61%	(39/64)	54%	(212/393)	0.30
Alcohol/drugs and sex	34%	(154/457)	47%	(7/15)	33%	(122/370)	0.27	42%	(27/64)	32%	(127/393)	0.12
Partner with unknown HIV status	45%	(205/457)	67%	(10/15)	45%	(168/370)	0.11	48%	(31/64)	44%	(174/393)	0.54
Exchanged sex for money/drugs	4%	(20/457)	0%	(0/15)	5%	(17/370)	0.40	3%	(2/64)	5%	(18/393)	0.60
Sex with exchanger	7%	(33/457)	7%	(1/15)	7%	(25/370)	0.99	6%	(4/64)	7%	(29/393)	0.75
Forced sex	7%	(32/457)	27%	(4/15)	5%	(20/370)	<0.01	9%	(6/64)	7%	(26/393)	0.42
Prior STD ever	37%	(200/538)	41%	(9/22)	31%	(131/429)	0.31	44%	(34/78)	36%	(166/460)	0.21
STD last 12 months	18%	(82/457)	13%	(2/15)	15%	(57/370)	0.83	20%	(13/64)	18%	(69/393)	0.59
Prior IDU	4%	(21/536)	14%	(3/22)	3%	(13/428)	<0.01	6%	(5/78)	3%	(16/458)	0.22
Incarcerated	4%	(19/457)	7%	(1/15)	4%	(15/370)	0.62	3%	(2/64)	4%	(17/393)	0.66
PEP												
Heard of	56%	(302/538)	59%	(13/22)	55%	(234/429)	0.68	50%	(39/78)	57%	(263/459)	0.23
Taken	5%	(29/538)	9%	(2/13)	6%	(24/234)	0.56	6%	(5/39)	5%	(24/263)	0.47
PrEP												
Heard of	47%	(254/538)	55%	(12/22)	45%	(194/429)	0.39	40%	(31/78)	49%	(223/459)	0.15
Taken	2%	(10/538)	9%	(2/12)	2%	(8/194)	0.05	3%	(2/31)	2%	(8/223)	0.44

IDU, injection drug use; PEP, post-exposure prophylaxis; PrEP, pre-exposure prophylaxis; STD, sexually transmitted disease.

Table 3. (A) Latent Class Analysis Fit Indices for 1–5 Class Model and (B) Average Class Membership Probabilities for the Final 4 Class Model

A.

Model	*Log likelihood (# parameters)*	*AIC*	*Sample size adjusted BIC*	*BLRT p value*	*Entropy*
1 Class	−3405 (20)	6851	6869	0.000	NA
2 Classes	−3178 (41)	6437	6475	0.000	0.81
3 Classes	−3145 (62)	6415	6473	0.000	0.82
4 Classes	−3080 (83)	6326	6404	0.000	0.81
5 Classes	−3041 (104)	6290	6387	0.200	0.84

B.

	Class 1	*Class 2*	*Class 3*	*Class 4*
Class 1	**0.87**	0.11	0.00	0.02
Class 2	0.04	**0.89**	0.00	0.07
Class 3	0.01	0.00	**0.90**	0.07
Class 4	0.02	0.05	0.03	**0.92**

LCA revealed four distinct classes of MSM demonstrating different characteristics and risk profiles. Among these, Class 1 had no HIV-positive individuals and the lowest rates of STDs (6%). Individuals in Class 1 tended to have been previously tested for HIV and had fewer sex partners compared to other classes. Class 1 also had the highest rate of incarceration (33%) and of having been forced to have sex (24%). Class 3 included MSM with the highest rate of HIV (7%) and other STDs (16%). A significant number (68%) of MSM in Class 3 had never had an HIV test and over 60% had >10 anal sex partners in the preceding year; 100% of this class reported having had anonymous sex partners. Class 3 had the largest number of MSM who were reported using alcohol or drugs during sex (76%), exchanging sex for drugs/money or having sex with someone who exchanges sex for drugs/money (38%), having a prior STD in the preceding 12 months (40%), or using injection drugs (22%). Interestingly, 55% (12/22) of newly diagnosed MSM had heard of PrEP, including 100% of those in the highest-risk class who tested positive.

These analyses helped identify groups of MSM who are at highest risk of HIV and may be ideal candidates for PrEP in the setting of an urban STD clinic. Previous evidence has demonstrated significant HIV risk behavior immediately preceding a new HIV diagnosis.[36] In our STD clinic, when individuals are identified as having behaviors associated with the highest risk class (i.e., a large number of partners, anonymous partners, alcohol and/or drug use during sex, etc.), they receive more intensive counseling and education related to PrEP. In addition, identification of these classes has guided practice by indicating that HIV prevention outreach should focus on areas where individuals meet partners (i.e., venues for meeting anonymous partners) rather than in prisons or jails.

The HIV seropositivity rate at the STD clinic of 1.3% overall and 4.1% among MSM is several magnitudes higher than the general US population of 0.3%,[1] but lower than

Table 4. Latent Class Prevalence Rates for Classification Variables

Classification variable	*Class 1 (N = 33; 7.3%)* N *(%)*	*Class 2 (N = 142, 31.6%)* N *(%)*	*Class 3 (N = 55; 12.2%)* N *(%)*	*Class 4 (N = 219; 48.8%)* N *(%)*
Last HIV test				
Never	9 (28.1)	70 (56.4)	**34 (68.0)**	55.0
Less than 1 year	**13 (40.6)**	16 (12.9)	0 (0.0)	10.6
1 year or more ago	10 (31.2)	38 (30.6)	16 (32.0)	34.3
# Oral sex partners last 12 months				
0 partners	**9 (27.3)**	9 (6.4)	0 (0.0)	1 (0.5)
1 partner	**18 (54.5)**	55 (39.3)	0 (0.0)	0 (0.0)
2 partners	0 (0.0)	**58 (41.4)**	0 (0.0)	20 (9.3)
3–4 partners	0 (0.0)	18 (12.9)	8 (14.8)	62 (28.7)
5–10 partners	6 (18.2)	0 (0.0)	9 (16.7)	**120 (55.6)**
10+ partners	0 (0.0)	0 (0.0)	**37 (68.5)**	13 (6.0)
# Anal sex partners last 12 months				
0 partners	**10 (30.3)**	12 (8.6)	0 (0.0)	15 (6.9)
1 partner	**18 (54.5)**	66 (47.1)	2 (3.8)	24 (11.1)
2 partners	1 (3.0)	**49 (35.0)**	0 (0.0)	24 (11.1)
3–4 partners	1 (3.0)	13 (9.3)	3 (5.7)	59 (27.2)
5–10 partners	3 (9.1)	0 (0.0)	16 (30.2)	**92 (42.4)**
10+ partners	0 (0.0)	0 (0.0)	**32 (60.4)**	3 (1.4)
Anonymous partner	12 (36.4)	**16 (11.4)**	**55 (100)**	161 (73.8)
Alcohol/drugs and sex	16 (48.5)	**17 (12.1)**	**42 (76.4)**	75 (34.4)
Sex with unknown HIV status	22 (66.7)	**12 (8.6)**	36 (65.4)	130 (59.6)
Prior STD last 12 months	**1 (3.0)**	16 (11.4)	**22 (40.0)**	41 (18.8)
Prior injection drug use	2 (6.1)	1 (0.7)	**12 (22.2)**	**0 (0.0)**
Ever exchanged sex	11 (33.3)	**0 (0.0)**	**21 (38.2)**	9 (4.1)
Forced sex	**8 (24.2)**	5 (3.6)	7 (12.7)	12 (5.5)
Ever incarcerated	**11 (33.3)**	**0 (0.0)**	8 (14.5)	**0 (0.0)**

STD, sexually transmitted disease.

Table 5. Latent Class Prevalence Rates for Demographics and HIV/STD Outcomes and Odds Ratios for Differences Between Classes

Variable	Class 1 N (%)	Class 2 N (%)	Class 3 N (%)	Class 4 N (%)	Class 2 compared to Class 1 OR (95%CI)	Class 3 compared to Class 1 OR (95%CI)	Class 4 compared to Class 1 OR (95%CI)	Class 3 compared to Class 2 OR (95%CI)	Class 4 compared to Class 2 OR (95%CI)	Class 4 compared to Class 3 OR (95%CI)
Demographics covariates										
Age (years)										
15–24	7 (21.1)	24 (17.1)	12 (21.8)	51 (23.4)	REF	REF	REF	REF	REF	REF
25–29	7 (21.1)	35 (25.0)	7 (12.7)	47 (21.6)	1.5 (0.4, 4.7)	0.6 (0.1, 2.4)	0.9 (0.3, 2.8)	0.4 (0.1, 1.2)	0.6 (0.3, 1.2)	1.6 (0.6, 4.3)
30–34	7 (21.1)	19 (13.6)	11 (20.0)	34 (15.6)	0.8 (0.2, 2.6)	0.9 (0.2, 3.5)	0.7 (0.2, 2.1)	1.1 (0.4, 3.2)	0.8 (0.4, 1.8)	0.7 (0.3, 1.8)
35–39	2 (6.1)	13 (9.3)	8 (14.5)	15 (6.9)	1.9 (0.2, 10.5)	2.3 (0.4, 14.2)	1.0 (0.2, 5.5)	1.2 (0.4, 1.8)	0.5 (0.2, 1.3)	0.4 (0.1, 1.3)
40+	10 (30.3)	49 (35.0)	17 (30.9)	71 (32.6)	1.4 (0.5, 4.2)	1.0 (0.3, 3.5)	1.0 (0.3, 2.7)	0.7 (0.3, 1.7)	0.7 (0.4, 1.2)	1.0 (0.4, 2.2)
Ethnicity										
Hispanic	7 (21.2)	29 (20.7)	9 (16.4)	30 (13.8)	1.0 (0.4, 2.4)	0.7 (0.2, 2.2)	0.6 (0.2, 1.5)	0.7 (0.3, 1.7)	0.6 (0.3, 1.1)	0.8 (0.4, 1.8)
Race										
White	25 (75.7)	110 (78.6)	47 (85.4)	172 (78.9)	REF	REF	REF	REF	REF	REF
Black	3 (9.1)	17 (12.1)	5 (9.1)	25 (11.5)	1.3 (0.3, 4.7)	0.9 (0.2, 4.0)	1.2 (0.3, 4.3)	0.7 (0.2, 2.0)	0.9 (0.5, 1.8)	1.4 (0.5, 3.8)
Asian	1 (3.0)	7 (5.0)	1 (1.8)	13 (6.0)	1.6 (0.2, 13.5)	0.5 (0.03, 8.9)	1.9 (0.2, 15.1)	0.3 (0.04, 2.8)	1.2 (0.5, 3.1)	3.5 (0.4, 27.8)
Other	4 (12.1)	6 (4.3)	2 (3.6)	8 (3.7)	0.3 (0.1, 1.3)	0.3 (0.04, 1.5)	0.3 (0.1, 1.0)	0.8 (0.1, 4.0)	0.8 (0.3, 2.5)	1.1 (0.2, 5.3)
STD outcomes										
HIV positive	0 (0.0)	4 (3.4)	3 (6.8)	8 (4.3)	—	—	—	2.1 (0.4, 9.6)	1.3 (0.4, 4.3)	0.6 (0.1, 2.4)
Any STD positive[a]	2 (6.1)	18 (12.9)	9 (16.4)	33 (15.1)	2.3 (0.5, 10.4)	3.0 (0.6, 15.0)	2.8 (0.6, 12.1)	1.3 (0.5, 3.2)	1.2 (0.6, 2.2)	0.9 (0.5, 2.0)

[a]Testing positive for at least one of the following: HIV, syphilis, gonorrhea, chlamydia.
OR, odds ratio; STD, sexually transmitted disease; REF, reference.

previous estimates of HIV prevalence among MSM in the US with higher prevalence among MSM of color and significant geographic variation.[37] These trends in HIV prevalence, however, mask more complex latent classes, particularly among MSM. Using latent class analysis, we were able to identify a subgroup of MSM (Class 3) who may most benefit from PrEP. Classes 2 and 4 reflected risk factors and HIV prevalence that placed them in the second highest tier for HIV infection risk. MSM from Class 1 had lower HIV prevalence overall and may be less ideal candidates for PrEP.

Interestingly, incarceration and having been forced to have sex were most common among Class 1, which had no HIV infections in the group. The reasons behind a lack of association between incarceration and forced sex with HIV, which are traditionally considered to be risk factors for HIV,[38–41] are likely reflective of the current HIV epidemic in Rhode Island. Robust HIV screening and treatment programs in the Rhode Island prison system and community-based needle exchange programs have contributed to a decrease in HIV transmission among incarcerated individuals and PWID in Rhode Island;[42,43] these programs may have had positive spillover effects on patients in Class 1. Individuals in this class reported fewer sexual partners, which may reflect an overall lower HIV risk in this population. LCA identifies clusters of characteristics that may identify individuals who are at higher or lower risk of HIV; in this population, individuals with a history of incarceration and forced sex appear to have lower risk for sexual acquisition of HIV, which may explain this result.

The main characteristics among MSM in the highest risk class included having more than 10 oral and anal sex partners in the past year, history of prior STD(s), having anonymous sex partners, and using drugs or alcohol use before or during sex. These findings are consistent with prior studies focused on individual risk behaviors impact on HIV infection[14,44–46] and suggests that the combination of these risk factors culminates in elevated HIV risk. Our results suggest that individuals in this latent class may benefit most from PrEP and other HIV prevention interventions.

Previous reports among MSM suggest that prior STDs, drug use, and having more than 10 sexual partners in the last year are among the most robust predictors of HIV acquisition.[17,46] More recent data suggest that social and sexual network phenomena may also play an important role in elevating HIV acquisition risks, particularly among MSM of color.[47,48] Although we did not have network-level data, the LCA results suggest that individuals with similar demographic and behavioral patterns may, based on similar characteristics, be in the same social or sexual networks that facilitate HIV transmission.

Our findings suggest that focusing PrEP interventions on MSM in the highest risk groups is important: MSM who reported concurrent and anonymous partners and who reported drug and alcohol use during sex had the highest prevalence of HIV in our study. HIV-negative individuals in those high-risk groups may benefit most from PrEP. Educational efforts targeting the highest risk networks may be important for expanding PrEP uptake among those populations. Future work should also consider whether identification of the highest risk group via a method such as LCA leads to better uptake of PrEP and engagement in PrEP care compared to identification of higher risk groups via

traditional routes, and if this method may ultimately lead to a reduced incidence of HIV.

Our study is subject to several limitations. Some behavioral variables used in the LCA were not routinely collected during the first year of the study but were added later. Therefore, complete demographic and behavioral data were available for most, but not all, patients who presented for testing. There was also a relatively low number of newly diagnosed HIV-positive individuals. This may have limited the power of the study to identify significant risk factors for infection. The results of this study arise from patients presenting for care at a STD clinic, which may differs from individuals receiving care at primary care or other clinics.

While the results of this study may not be generalizable to other populations of MSM, the method for identification of subpopulations that may benefit from PrEP could be replicated in other populations. Nevertheless, our findings suggest that LCA helped identify a group of MSM at highest risk for acquiring HIV infection and most suitable for PrEP. Despite its ability to discern interactions and patterns among multiple HIV risk factors, LCA is largely a descriptive method. Future replication of the analysis in larger, independent samples would be useful to determine whether the same profiles emerge reliably.

Furthermore, it may be important to conduct LCA using additional risk factors, as more informative profiles with greater predictive value may emerge. Future work should also consider using LCA to evaluate incident HIV infection in a prospective setting to determine risk factors in a more rigorous manner.

Although CDC guidelines recommend that PrEP should be considered for all MSM who have had any condomless anal sex in the past 6 months or any STD diagnosed or reported in the past 6 months,[13] results from our analysis suggest that a more nuanced public health approach may be useful for identifying ideal candidates for PrEP. We found that combinations of behaviors in MSM, such as having anonymous sexual partners, having more than 10 sexual partners, and using drugs or alcohol during sex, are among the most useful proxies for identifying those who are at highest risk for contracting HIV. These patients may be the most ideal candidates for PrEP.

The findings from this analysis have informed clinical practice in our own PrEP implementation program; this method and our related findings have important implications for clinical practice and for scaling up PrEP interventions around the country.

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