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ORIGINAL PAPER

An Integrated Examination of County- and Individual-Level Factors in Relation to HIV Pre-exposure Prophylaxis Awareness, Willingness to Use, and Uptake Among Men Who Have Sex with Men in the US

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Abstract
This study explored the extent to which county- and individual-level factors were associated with awareness, willingness to use, and use of pre-exposure prophylaxis (PrEP) among US men who have sex with men (MSM). We conducted multilevel analyses using a sample of 8338 MSM residing in 1257 US counties drawn from the 2014–2015 American Men's Internet Survey to examine these associations, with focuses on variation in PrEP outcomes across counties and proportion variation explained by county-level factors (HIV prevalence, racial composition, median household income, income inequality, health insurance coverage). Results showed that PrEP awareness varied moderately across counties (intraclass correlation coefficients [ICC] = 7.7%), willingness to use did not vary; however, the actual use varied substantially (ICC = 20.7%). Half of the variation in awareness and use was explained by county-level factors. Higher median household income was associated with greater likelihood of awareness and use. Higher income inequality was associated with greater likelihood of PrEP awareness. Findings can inform the development of multilevel interventions to address PrEP uptake among MSM and identify communities where structural intervention is most needed.

Keywords HIV/AIDS · Pre-exposure prophylaxis · Men who have sex with men · Uptake

Introduction

The uptake of HIV pre-exposure prophylaxis (PrEP) in the US is far from optimal among key populations such as men who have sex with men (MSM). Studies have consistently shown that the prevalence of PrEP use among MSM may be in the single digits [1–3]. Furthermore, there are marked racial and geographical inequities among MSM PrEP users, with MSM who are African American and Latino or who reside in rural or Southern areas reporting much lower PrEP use than White MSM and those living in urban areas and outside the South [1, 4, 5].

Growing numbers of studies have examined MSM uptake of PrEP. The majority of previous research focused on individual-level correlates [1–3, 5, 6]. Only a small number of studies have considered contextual correlates [7–9], and few studies have applied a multilevel framework to understand the key correlates at any given level of PrEP uptake [11]. Thus, to date, little is known regarding the impact of contextual factors on the levels of PrEP use in relation to individual factors. However, improving access to care is best achieved when targeting both contextual and individual determinants in an integrated manner [10]. Moreover, many PrEP studies have been restricted to small sample sizes or certain subgroups of MSM [12–14]. As a result, a lack of consistency or broadness exists in the variables used to assess PrEP uptake.

The current study aims to address the aforementioned gaps in the literature regarding PrEP outcomes. This study is informed by a socioecological perspective and involves a large-scale examination of multilevel factors, specifically those at the county and individual level, in relation to awareness, willingness to use, and use of PrEP. This type of

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research is critical in informing the development of effective structural and/or multilevel interventions to promote PrEP uptake.

To pursue this line of research, this study sought to address two main research questions. The first was to determine how much influence the context may have on PrEP care-seeking behaviors. In other words, we examined the extent to which PrEP awareness, willingness to use PrEP, and actual PrEP use depend on the context (i.e., where a MSM lives). A higher dependency of the context means context has a greater influence on PrEP outcomes, thus implying structural interventions might be more useful in promoting PrEP.

The second aim of this study was to investigate the key correlates of PrEP outcomes at county and individual levels. Our selection of potential county-level covariates was guided by Andersen's Behavioral Model of Health Care Utilization because it is inclusive of all plausible factors that influence the likelihood of utilizing healthcare at both contextual and individual levels. Andersen defines *contextual* as the circumstances and environment where healthcare-seeking behaviors occur. According to Andersen's Model, factors at both contextual and individual levels can be grouped into three components: *predisposing factors, enabling factors, and need factors* [10, 15, 16].

Predisposing factors are existing socio-demographic characteristics that are indicative of the likelihood to seek health care. At the individual level, age, education, region of residence (rural/urban), and race are examples of predisposing factors. Indeed, PrEP research has repeatedly shown that these factors, especially race (i.e., being Black), are associated with PrEP uptake [12, 17, 18]. Contextual-level predisposing factors usually are individual predisposing factors measured at the aggregate. In general, the Black population tend to use preventive health services less than Whites [19]. The composition of the Black population might contribute to the contextual-level variations in PrEP uptake. To our knowledge, no known study has examined the correlation between the proportion of the Blacks in the population and PrEP uptake. However, research regarding diabetes that has applied the Andersen Model found that greater proportion of Black individuals in the community was negatively associated with seeking preventive diabetes care [20]. Thus, we include percentage of Blacks as a potential contextual/county-level covariate.

Enabling factors are the logistical aspects of obtaining care, particularly the financial conditions. At the individual level, research has found income and health insurance are associated with PrEP uptake [3]. Empirically, contextual-level financial aspects including median household income [21], health insurance coverage [20], and income inequality (i.e., GINI coefficient) [22] were found to be correlated with use of preventive care. Therefore, we empirically assess the relationship of median household income, health insurance coverage, and income inequality to PrEP outcomes.

Need factors represent subjective or objective assessments of the need for healthcare. Individual needs are personal health risks. For this study, individual-level need factors were selected based on past research, which included sexually transmitted infections (STIs) and HIV sexual risk behaviors [1, 3, 6, 7, 23, 24]. Epidemiologic contexts, such as HIV prevalence, are contextual-level need factors that may influence individual subjective assessments of HIV risks and subsequent use of HIV preventive service. On the other hand, HIV prevalence determines per-contact transmission probability within the community and influences the actual HIV risks as well as the objectively assessed PrEP needs [25, 26]. As such, we posit that male HIV prevalence rate correlates with MSM awareness of PrEP, willingness to use, and use of PrEP.

Taken together, this study applied multilevel models to analyze a national online sample of MSM collected in the American Men's Internet Survey (AMIS) from November 2014 through April 2015 [27] to examine (1) the variation in PrEP awareness, willingness to use, and use between counties; (2) the proportion of the between-county variation attributable to county- or individual-level factors; and the associations of specific county-level and individual-level factors with PrEP outcomes among US MSM. The overarching goal is to inform the development of coordinated, efficacious multilevel intervention strategies that supplement current PrEP promotion efforts.

Methods

Data Source

Individual data was obtained from the November 2014 to April 2015 cycle of AMIS, an annual web-based behavioral survey of US MSM. Full details of the survey methodology have been published elsewhere [27, 28]. Briefly, men who were 15 years of age or older, considered themselves to be male, resided in the US (residency was assessed based on a valid US ZIP code of residence or an IP address assigned to a location in the US), and reported that they had oral or anal sex with a male at least once in their lifetime were invited to participate in an incentive-free, self-administered behavioral survey through online advertisements. Eligible participants were unduplicated MSM who completed the survey, self-reported as HIV-negative/unknown status, and had oral or anal sex with a male at least once in the past 12 months. For each measure, participants who did not answer the question(s) used for the measure were excluded. For PrEP use outcome, we also excluded MSM who were ineligible for PrEP. PrEP eligibility was assessed using an

approximation criteria we developed (had 1 main partner who is HIV-positive; or had 2 or more partners, and one of the following in the past 12 months: any condomless sex/any STI/any main partner who is HIV-positive) based on the Centers for Disease Control and Prevention (CDC)'s PrEP guideline [32]. These criteria yielded 8338 MSM for analysis in the current study.

Participant county of residence was assigned based on participant reported ZIP code, using the ZIP code to county crosswalk files created by the US Department of Housing and Urban Development (HUD) [29]. For ZIP codes that crossed county lines, participants were assigned to the county with the highest percentage of residential addresses for that ZIP code. The analytic sample of 8338 MSM resided in 1257 counties.

We merged AMIS data with the 2014 county-level male HIV prevalence rate from AIDSVu [30] and the county-level demographic and financial characteristics from 2014 American Community Survey (ACS) estimates [31] using the Federal Information Processing Standard (FIPS) codes for counties.

Measures

Awareness, Willingness to Use, and Use of HIV Pre-exposure Prophylaxis

The dependent measures used in the analyses were PrEP awareness, willingness to use PrEP, and PrEP use. For *PrEP awareness*, AMIS participants were asked whether they had ever heard of PrEP. To determine *PrEP use*, participants were asked if they had taken PrEP in the past 12 months. To determine *willingness to use PrEP*, participants who reported no current PrEP use were given a brief explanation of what PrEP was and were asked if they would be willing to take PrEP. Participants who had missing observations, refused to answer, or answered "Don't know" to PrEP awareness question were not asked about PrEP willingness to use due to an error in the survey skip pattern (also see limitations). The analytical sample sizes for awareness, willingness to use, and use of PrEP were 8338, 4372, and 4013, respectively.

Individual-Level Factors

The predisposing individual-level factors examined in the analyses included demographic characteristics of age, race/ethnicity, college education, and types of county residence (i.e., urban [central], suburban [fringe], medium/small metropolitan, and rural [micropolitan and noncore] based on National Center for Health Statistics Rural–Urban classification) [33].

The enabling individual-level factors examined in the analyses included annual household income, health insurance status, and whether they received an HIV behavioral intervention in the past 12 months. Receipt of HIV behavioral interventions was assessed by an affirmative response to either of the following two questions: "Have you had a one-on-one conversation with an outreach worker, counselor, or prevention program worker about ways to prevent HIV?" and "Have you been a participant in any organized session(s) involving a small group of people to discuss ways to prevent HIV?"

The individual-level need factors examined in the analyses included having had a STI, number of male sex partners, type of male sex partners (main partners only, casual partners only, both main and casual partners), having condomless anal sex with a man, and having condomless anal sex with a male partner of HIV-positive/unknown status in the 12 months.

County-Level Factors

The predisposing county-level factor examined in the analyses included the percentage of the population who were black males.

The enabling county-level factors examined in the analyses included median household income, percent covered by health insurance, and GINI coefficient. The GINI coefficient is a measure of regional income inequality [34], with a value of 0 representing complete income equality and a value of 1 representing an extreme circumstance in which one person has all of the wealth. In this study, we multiply the GINI coefficient by 100 (i.e., GINI × 100) for statistical considerations.

The county-level need factor was the HIV epidemiologic context. HIV prevalence is a commonly used indicator for HIV epidemiologic context. Other indicators of HIV epidemic context with relevance for PrEP, such as new HIV diagnoses or HIV prevalence among MSM, are unavailable for many counties. Therefore, we used 2014 male HIV prevalence rate in the analyses. The original units for the male HIV/AIDS prevalence were calculated per 100,000 population, but for statistical considerations, we scaled the prevalence to cases per 100 persons. Note: 12.6% (1055/8338) of the HIV prevalence data at county-level are not available either due to privacy protection or because data were not released by the state health department.

Analyses

Multilevel analysis can be strategically used to examine sources of variation at different levels. It considers whether the individual probability is statistically dependent on the area of residence. Such dependence indicates the existence

of a contextual effect and needs to be accounted for to obtain accurate regression estimates [35]. Therefore, we applied multilevel logistic models to address our research aims using a sequential modelling approach. Descriptive analyses were used to summarize individual- and county-level factors, as well as the individual characteristics of MSM who were aware of PrEP, willing to use PrEP, and used PrEP in the past 12 months. Collinearity between factors within individual- or county-level was also examined using Condition Index (CI) derived from the inverse of the Information Matrix [36]. No collinearity was found between factors within each level. Bivariate analyses were conducted to explore the relationship of each individual- and county-level factor to PrEP outcomes using bivariate, multilevel logistic regression models. We retained all variables at each level on the basis of theoretical justification and empirical evidence from literature indicating that these variables might be associated with these PrEP outcomes, so all went forward to the multilevel analysis.

We ran a separate multilevel model for each of the three PrEP outcomes. We first constructed an unconditional model (Model 1) to report intraclass correlation coefficients (ICC). The ICC represents the proportion of the total variation in the outcome that is attributable to between-county differences [37]. The higher this proportion, or ICC, the higher the overall contextual effect. In this study, the ICC illustrates the extent to which an MSM's likelihood of using PrEP is determined by his county, and therefore helps quantify the impact of contextual phenomena.

Secondly, we constructed a model with only individual-level factors (Model 2) and a model with only county-level factors (Model 3) to obtain proportional reduction in variance (PRV). PRV quantifies the proportional change in the county-level variance when covariates are added to Model 1. The PRV represents the importance of the added covariates to the explanation of the outcome [35]. Lastly, we built a model with both individual and county-level factors (Model 4) to examine their associations with PrEP outcomes. The fit of the models were assessed using AIC, and deviance (-2 Log Likelihood; -2LL) [35]. SAS 9.4 (SAS Institute, Cary, NC) was used for all statistical analyses.

Results

Among the 8338 MSM in 1257 counties, an average of seven participants (ranging from 1 to 255) lived in each county. The sample was 75.2% White, 41.4% urban, 42.6% with household earnings of more than $75,000/year, 89.9% insured, and 52.5% in receipt HIV behavioral interventions in the past 12 months (Table 1).

Among 8338 participants included in PrEP awareness models, 5281 (63.3%) had heard of PrEP (Table 1). Among 4372 participants included in PrEP willingness models, 2804 (64.1%) reported willingness to use PrEP. Among 4013 participants included in PrEP use models, 301 (7.5%) reported taking PrEP in the past 12 months.

Bivariate results (Tables 2, 3) showed that at the individual level, all covariates, except for race/ethnicity, were associated with the three PrEP outcomes. Individual race/ethnicity was only associated with PrEP willingness. At the county level, percent of population who were Black male, median household income, income inequality, and male HIV prevalence rate were associated with PrEP awareness and use, while median household income and percent covered by health insurance were associated with PrEP willingness.

Below we report results of the multilevel modeling to show sources of variation across levels in each PrEP outcome and the key correlates independently associated with these outcomes.

PrEP Awareness

When considering county of residence alone, 7.7% of the total variance in PrEP awareness could be attributed to differences between counties (Table 4; Model 1). Individual variables accounted for 56% (PRV = 0.56; Model 2) while county-level variables accounted for 65% of the between-county variation (PRV = 0.65; Model 3) in PrEP awareness. When both level's factors were included, 95% CI of the variance bordered on 0 (Model 4), meaning that these factors together likely account for all of the between-county variance in PrEP awareness.

At the county level, median household income and income inequality (i.e., GINI coefficient) were independently associated with PrEP awareness (Table 4; Model 4). A $10,000 increase in county median household income was associated with a 14% increase in the odds of being aware of PrEP (aOR 1.14; 95% CI: 1.06–1.23). A 1-unit increase in income inequality was associated with 6% increase in the odds of being aware of PrEP (aOR 1.06; 95% CI 1.03–1.09). Percent of population who were Black male, percent of population who were insured, and male HIV prevalence rate were not associated with PrEP awareness.

At the individual level, multiple demographic, risk and prevention variables were independently associated with PrEP awareness (Table 4; Model 4). PrEP awareness was higher among those who were younger (vs. aged 55 and above), White (vs. being Black), had a college degree, resided in urban or small/medium metro (vs. rural), or had higher yearly income (vs. lower than $20,000). PrEP awareness was also higher among those who had received HIV behavioral interventions, had an STI, had more than 1 male sex partners (vs. having 1), had both main and casual male sex partners (vs. only having a main sex partner), and had

Table 1 PrEP awareness, willingness, and use among 8338 MSM participants from 1257 counties, American Men's Internet Survey, November 2014–April 2015

	Total N[a] (Column %) or mean ± SD	n (row %) or mean ± SD		
		Aware of PrEP N = 8338[a]	Willing to use PrEP N = 4372[a]	Used PrEP in past 12 M N = 4013[a]
Individual-level				
Predisposing factors				
Age (years)				
15–24	1369 (16.3)	687 (50.7)	561 (72.9)	21 (3.5)
25–34	2071 (24.6)	1468 (71.3)	739 (68.5)	97 (9.4)
35–44	1622 (19.3)	1101 (68.3)	538 (65.7)	72 (9.0)
45–54	1961 (23.3)	1256 (64.6)	627 (60.9)	81 (8.5)
> 55	1383 (16.5)	769 (56.2)	339 (50.2)	30 (4.8)
Race/ethnicity				
Latino/Hispanic[b]	1171 (14.1)	686 (59.1)	496 (74.1)	43 (7.6)
White	6254 (75.2)	3990 (64.3)	850 (70.4)	226 (7.5)
Other[c]	557 (6.7)	345 (62.7)	210 (66.0)	19 (7.0)
Black	333 (4.0)	209 (63.1)	114 (68.3)	11 (7.5)
College or above	7511 (90.2)	4936 (66.1)	2438 (63.3)	289 (8.0)
vs. Less	820 (9.8)	312 (38.8)	339 (70.9)	11 (3.0)
Type of residence				
Urban	3416 (41.4)	2436 (71.9)	1146 (66.1)	196 (11.4)
Suburban	1666 (20.2)	998 (60.5)	534 (62.1)	51 (6.5)
Small/medium metro	2427 (29.4)	1407 (58.4)	797 (61.9)	46 (4.2)
Rural	739 (9.0)	355 (48.3)	262 (66.3)	6 (1.8)
Enabling factors				
Yearly income, US$				
< 20,000	824 (10.8)	435 (53.0)	336 (73.0)	16 (4.3)
20,000–39,999	1466 (19.3)	834 (57.3)	555 (69.8)	50 (7.2)
40,000–74,999	2074 (27.3)	1278 (62.0)	737 (65.1)	72 (7.0)
> 75,000	3238 (42.6)	2260 (70.4)	931 (57.5)	138 (8.8)
Current health insurance	4770 (89.9)	4321 (64.3)	2310 (64.3)	256 (7.8)
vs. No	760 (10.1)	402 (53.7)	241 (62.1)	19 (5.5)
Received HIV behavioral interventions, past 12 months	1263 (15.7)	947 (75.5)	520 (77.7)	117 (17.7)
vs. No	6806 (84.3)	4144 (61.4)	2220 (61.7)	175 (5.4)
Need factors				
Any bacterial STIs, past 12 months[d]	635 (7.6)	508 (80.4)	306 (86.2)	91 (22.6)
vs. No	7771 (92.4)	4773 (61.9)	2498 (62.2)	210 (5.8)
Number of male sex partners, past 12 months				
1	3580 (47.6)	1920 (54.2)	903 (76.7)	20 (1.1)
2–4	2012 (26.8)	1754 (62.6)	1025 (69.2)	43 (3.6)
5–7	589 (7.8)	518 (73.4)	314 (80.3)	31 (8.5)
8 or above	1338 (17.8)	985 (82.1)	564 (85.1)	179 (26.4)
Male partner type, past 12 months				
Main only	2074 (28.4)	1132 (55.1)	507 (44.0)	6 (0.6)
Casual only	2280 (31.2)	1372 (60.6)	801 (68.6)	82 (8.3)
Main and casual	2954 (40.4)	2097 (71.4)	1193 (75.4)	168 (11.2)
Condomless anal sex with male partner, past 12 months	5648 (67.2)	3713 (66.2)	2019 (67.5)	290 (9.4)
vs. No	2758 (32.8)	1568 (57.5)	785 (56.8)	11 (1.2)
Condomless anal sex with male partner of HIV + or unknown status, past 12 months	1594 (19.0)	1147 (72.5)	759 (83.8)	177 (18.3)

Table 1 (continued)

	Total N[a] (Column %) or mean ± SD	n (row %) or mean ± SD		
		Aware of PrEP N = 8338[a]	Willing to use PrEP N = 4372[a]	Used PrEP in past 12 M N = 4013[a]
vs. No	6812 (81.0)	4134 (61.2)	2045 (59.0)	124 (4.1)
County-level				
Predisposing factor				
Percentage of black male	0.15 ± 0.13	0.16 ± 0.13	0.15 ± 0.13	0.17 ± 0.14
Enabling factors				
Median household income[f]	5.51 ± 1.34	5.59 ± 1.35	5.46 ± 1.29	6.05 ± 1.37
Percent of people uninsured	0.17 ± 0.06	0.17 ± 0.06	0.17 ± 0.06	0.16 ± 0.06
Rescaled GINI[g]	46.5 ± 3.8	46.9 ± 3.9	46.5 ± 3.8	48.1 ± 4.4
Need factor				
Male HIV prevalence rate[h]	0.78 ± 0.78	0.86 ± 0.85	0.77 ± 0.78	1.13 ± 1.10

[a]The sample sizes are different in each measure. We excluded missing values and "don't known" or "prefer not to answer" responses among a total of 8406 MSM, resulting a sample size of 8338 in PrEP awareness. Participants who answered "No" to PrEP awareness question were not asked about the PrEP willingness and use. We further excluded MSM who were ineligible for PrEP in PrEP use. Therefore, the sample sizes for PrEP willingness and use are 4372 and 4013, respectively

[b]Latino/Hispanic can be of any race

[c]Include MSM reporting American Indian or Alaska Native, Asian, Native Hawaiian or Pacific Islander, other race, or multiple races

[d]Include syphilis, gonorrhea, or chlamydia

[e]Include a one-on-one conversation with an outreach worker, counselor, or prevention program worker or participation in an organized session involving a small group of people to discuss ways to prevent HIV

[f]1 unit equals 10,000 USD

[g]Initial GINI Coefficient characteristics: 0.46 ± 0.04

[h]Per 100. 0.78 per 100 is equal to 780 per 100, 000

condomless anal sex with an HIV positive/unknown status male partner.

PrEP Willingness

There was no evidence any variance in PrEP willingness could be attributed to differences between counties (Table 5; Models 1–4). No county-level variables were found to be associated with PrEP willingness after controlling for individual-level factors (Model 4). At the individual level, younger age (vs. aged 55 and above), not having a college degree, receipt of HIV behavioral interventions, having an STI, having more than one male sex partner (vs. having 1), having casual only or both main and casual male sex partners (vs. only having a main sex partner), and having condomless anal sex with an HIV-positive/unknown status male partner were independently associated with willingness to use PrEP.

PrEP Use

When considering residence alone, 20.7% of the total variance in PrEP use could be attributed to differences between counties (Table 6; Model 1). Individual-level variables accounted for 54% (PRV = 0.54; Model 2), while county-level variables accounted for 57% (PRV = 0.57; Model 3) of the between-county variation in PrEP use. When both level's factors were included, the 95% CI of the variance bordered on 0 (Model 4), meaning that these factors together likely account for all of the between-county variance in PrEP use.

At the county level, only median household income was independently associated with PrEP use (Table 6; Model 4). A $10,000 increase in county median household income was associated with a 33 percent increase in the odds of using PrEP among MSM (aOR 1.33, 95% CI 1.12, 1.57). Percent of population who were Black male, percent of population who were insured, and male HIV prevalence rate were not associated with PrEP use.

At the individual level, receiving HIV behavioral interventions, having an STI, having more than one male sex partner (vs. having 1), and having condomless anal sex with an HIV-positive/unknown status male partner were independently associated with PrEP use.

Across all three PrEP outcomes, model fit indices (deviance test using -2LL) consistently showed Model 2 and Model 3 were better fitting models than Model 1 (Tables 4, 5, 6; $p < 0.05$). Model 4 was a better model than both Model 2 and Model 3 ($p < 0.05$).

Table 2 Bivariate associations between individual-level covariates and PrEP awareness, willingness to use, and use, American Men's Internet Survey, November 2014–April 2015

Variables	Bivariate OR (95% CI)		
	Aware of PrEP N = 8338	Willing to use PrEP N = 4372	Used PrEP in past 12 M N = 4013
Predisposing factors			
Age (years)			
15–24	**0.81 (0.68, 0.97)**	**2.64 (2.06, 3.38)**	0.83 (0.46, 1.54)
25–34	**1.83 (1.56, 2.15)**	**2.10 (1.70, 2.61)**	**1.94 (1.22, 3.07)**
35–44	**1.55 (1.31, 1.83)**	**1.82 (1.45, 2.28)**	**2.08 (1.29, 3.34)**
45–54	**1.39 (1.18, 1.63)**	**1.45 (1.17, 1.80)**	**1.80 (1.12, 2.89)**
> 55 (Ref)	*1.00*	*1.00*	*1.00*
Race/ethnicity			
Latino/Hispanic	0.94 (0.72, 1.22)	**1.46 (1.01, 2.11)**	0.93 (0.48, 1.79)
White	1.11 (0.88, 1.41)	0.84 (0.60, 1.16)	0.82 (0.45, 1.48)
Other	1.11 (0.82, 1.51)	0.99 (0.66, 1.48)	0.71 (0.33, 1.54)
Black (Ref)	*1.00*	*1.00*	*1.00*
College or above	**2.99 (2.52, 3.55)**	**0.69 (0.54, 0.87)**	**4.06 (1.79, 9.21)**
vs. less (Ref)	*1.00*	*1.00*	*1.00*
Type of residence			
Urban	**2.63 (2.22, 3.11)**	0.89 (0.70, 1.12)	**5.16 (2.51, 10.58)**
Suburban	**1.71 (1.42, 2.05)**	0.81 (0.62, 1.04)	**3.23 (1.51, 6.92)**
Small/medium metro	**1.52 (1.28, 1.80)**	**0.77 (0.61, 0.98)**	1.92 (0.89, 4.14)
Rural (Ref)	*1.00*	*1.00*	*1.00*
Enabling factors			
Yearly income, US$			
< 20,000 (Ref)	*1.00*	*1.00*	*1.00*
20,000–39,999	1.16 (0.97, 1.40)	0.84 (0.65, 1.10)	1.41 (0.79, 2.51)
40,000-74,999	**1.44 (1.21, 1.71)**	**0.67 (0.52, 0.86)**	1.46 (0.84, 2.52)
> 75 000	**2.10 (1.78, 2.48)**	**0.49 (0.38, 0.62)**	**1.94 (1.16, 3.27)**
Current health insurance	**1.55 (1.31, 1.83)**	1.08 (0.85, 1.36)	1.59 (0.93, 2.72)
vs. No (Ref)	*1.00*	*1.00*	*1.00*
Received HIV behavioral interventions, past 12 mos	**1.94 (1.66, 2.26)**	**2.12 (1.71, 2.61)**	**3.67 (2.80, 4.81)**
vs. No (Ref)	*1.00*	*1.00*	*1.00*
Need factors			
Any bacterial STIs, past 12 mos	**2.56 (2.04, 3.22)**	**4.15 (2.93, 5.88)**	**5.61 (4.18, 7.54)**
vs. No (Ref)	*1.00*	*1.00*	*1.00*
# Male sex partners, past 12 mos			
1 (Ref)	*1.00*	*1.00*	*1.00*
2–4	**1.53 (1.37, 1.72)**	**2.74 (2.34, 3.21)**	**8.32 (3.30, 21.02)**
5–7	**2.33 (1.93, 2.82)**	**5.08 (3.84, 6.72)**	**21.43 (8.27, 55.51)**
8 or above	**4.17 (3.50, 4.96)**	**7.09 (5.55, 9.07)**	**79.02 (32.29, 193.40)**
Male partner type, past 12 mos			
Main only (ref)	*1.00*	*1.00*	*1.00*
Casual only	**1.24 (1.10, 1.41)**	**2.89 (2.42, 3.44)**	**13.89 (6.05, 31.91)**
Main and casual	**2.09 (1.85, 2.37)**	**3.89 (3.29, 4.61)**	**18.83 (8.30, 42.71)**
Condomless anal sex, past 12 mos	**1.43 (1.29, 1.59)**	**1.47 (1.28, 1.70)**	**4.88 (3.13, 7.59)**
vs. No (Ref)	*1.00*	*1.00*	*1.00*
Condomless anal sex with HIV+ or unknown partner, past 12 mos	**1.73 (1.52, 1.96)**	**3.81 (3.13, 4.64)**	**7.27 (5.53, 9.55)**
vs. No (Ref)	*1.00*	*1.00*	*1.00*

Bold and italic values indicate the significance level was set at $p = 0.05$

Individual-level bivariate analyses were conducted using bivariate multilevel logistic regression to be consistent with the county-level bivariate analyses. Each regression only include a single individual-level covariate and a dependent variable

Table 3 Bivariate associations between county-level covariates and PrEP awareness, willingness to use, and use, American Men's Internet Survey, November 2014–April 2015

Variables	Bivariate OR (95% CI)		
	Aware of PrEP N = 8338	Willing to use PrEP N = 4372	Used PrEP in past 12 M N = 4013
Predisposing factor			
% of black male	**2.92 (1.76, 4.85)**	1.12 (0.67, 1.87)	**4.23 (1.24, 14.46)**
Enabling factors			
Median household income	**1.14 (1.09, 1.20)**	**0.95 (0.90, 1.00)**	**1.30 (1.16, 1.44)**
% of people uninsured	0.30 (0.09, 1.02)	**9.26 (2.85, 30.07)**	0.55 (0.00, 1.19)
Rescaled GINI	**1.08 (1.06, 1.10)**	1.02 (1.00, 1.03)	**1.08 (1.03, 1.13)**
Need factor			
Male HIV prevalence rate	**1.67 (1.50, 1.87)**	1.06 (0.97, 1.17)	**1.54 (1.24, 1.91)**

Bold and italic values indicate the significance level was set at $p = 0.05$

County-level bivariate analyses were conducted using bivariate multilevel logistic regression to properly model clustering data. Each regression only include a single county-level covariate and a dependent variable. When covariates are continuous, the odds ratio (OR) is calculated for a 1 standard deviation difference in that variable

Discussion

This study is among the first to simultaneously examine county- and individual-level factors in relation to PrEP awareness, willingness, and use among US MSM. By analyzing the county-level variation of PrEP outcomes, we found PrEP awareness varied moderately across counties and willingness to use PrEP did not vary across counties. However, PrEP use varied substantially. Over half of the between-county variation in PrEP awareness and use was attributable to county-level factors, particularly median household income. This finding is evidence for a significant contextual effect on MSM uptake of PrEP.

Median household income, a contextual enabling factor, was the only variable that emerged as a key county-level correlate of PrEP use. Individual-level income was significantly associated with PrEP use in the individual-level only model, which was consistent with prior literature [1–3, 6, 7, 23, 38]. However, once county-level covariates were added, only the effect of household median income remained statistically significant. While few PrEP studies have examined county-level income [9, 39], research on other preventive care has reported a similar association. For example, a recent study found that higher metropolitan statistical area-level median household income was associated with higher odds of past-year HIV testing among persons who inject drugs [40]. Another study examining multilevel correlates of human papillomavirus (HPV) vaccine uptake among US adolescents found that state-level median household income was positively correlated with HPV vaccine initiation among girls [41]. Median household income could represent affordability and demand for healthcare, including PrEP, from county residents' perspectives. It likely also reflects county resources that impact healthcare availability (i.e., amount and distribution of facilities and personnel), accessibility (i.e., hours, location, and transportation of healthcare delivery system, outreach and education program), and quality of care [10, 42, 43]. Future research is needed to disaggregate what median household income might represent and the relative importance of each possible pathway driving the association between county-level income and PrEP use.

We did not find independent association between the contextual need factor of male HIV prevalence rate and PrEP use. No prior work on PrEP use has examined HIV prevalence, but empirical studies looking at other infectious or chronic diseases have found independently significant associations between disease prevalence and healthcare seeking behaviors [20, 44]. According to Andersen's Model, HIV epidemiologic contexts could influence provider's objective assessment of client's contextual risk for HIV acquisition, or MSM's subjective concerns of their risks, and subsequently affect their decision-making regarding PrEP utilization [10]. From the provider's side, it is possible that providers had not incorporated male HIV prevalence when prescribing PrEP, as current CDC guidelines did not specify HIV prevalence should be part of the clinical evaluation [32]. From MSM's perspective, it could be that many MSM, even those residing in HIV high prevalence areas, rarely considered HIV prevalence when assessing their own PrEP needs [4, 12, 13]. These findings are consistent with previous studies which have hypothesized that MSM HIV prevention and care-seeking is likely a highly individualized decision and may be less dependent on epidemiologic context [6, 12, 23, 45].

Although our bivariate models found significant association between the contextual predisposing factor of Black male percentage and PrEP use, this relationship was no longer significant in the multivariable models. Similarly, a recent multilevel study focusing on consistent condom use

Table 4 Relationships between individual- and county-level factors and PrEP awareness among 8338 US MSM participants, American Men's Internet Survey, November 2014–April 2015

Variables	Model 1 (Unconditional model), OR (95% CI)	Model 2 (Individual-level only), OR (95% CI)	Model 3 (County-level only), OR (95% CI)	Model 4 (Both levels), OR (95% CI)
Individual-level				
Predisposing factors				
Age (years)				
15–24		0.91 (0.73, 1.13)		0.99 (0.78, 1.24)
25–34		**1.78 (1.46, 2.16)**		**1.83 (1.49, 2.24)**
35–44		**1.40 (1.15, 1.71)**		**1.47 (1.20, 1.82)**
45–54		1.20 (0.99, 1.45)		**1.32 (1.08, 1.60)**
> 55 (Ref)		*1.00*		*1.00*
Race/ethnicity				
Latino/Hispanic		0.94 (0.69, 1.28)		0.99 (0.72, 1.36)
White		**1.33 (1.01, 1.75)**		**1.43 (1.07, 1.90)**
Other		1.11 (0.78, 1.58)		1.09 (0.76, 1.57)
Black (Ref)		*1.00*		*1.00*
College or above		**2.29 (1.87, 2.80)**		**2.22 (1.79, 2.77)**
vs. less (Ref)		*1.00*		*1.00*
Type of residence				
Urban		**2.11 (1.68, 2.64)**		**1.55 (1.14, 2.11)**
Suburban		**1.48 (1.17, 1.86)**		1.33 (0.95, 1.86)
Small/Medium metro		**1.42 (1.14, 1.75)**		**1.44 (1.08, 1.90)**
Rural (Ref)		*1.00*		*1.00*
Enabling factors				
Yearly income, US$				
< 20,000 (Ref)		*1.00*		*1.00*
20,000–39,999		1.11 (0.89, 1.38)		1.14 (0.90, 1.45)
40,000–74,999		**1.27 (1.03, 1.58)**		**1.32 (1.05, 1.66)**
> 75,000		**2.00 (1.60, 2.47)**		**1.96 (1.56, 2.47)**
Current health insurance		1.09 (0.89, 1.34)		1.07 (0.86, 1.32)
vs. No (Ref)		*1.00*		*1.00*
Received HIV behavioral interventions, past 12 mos		**1.88 (1.57, 2.25)**		**1.83 (1.52, 2.21)**
vs. No (Ref)		*1.00*		*1.00*
Need factors				
Any bacterial STIs, past 12 mos		**1.50 (1.15, 1.96)**		**1.51 (1.13, 2.01)**
vs. No (Ref)		*1.00*		*1.00*
# Male sex partners, past 12 mos				
1 (Ref)		*1.00*		*1.00*
2–4		**1.37 (1.16, 1.62)**		**1.39 (1.16, 1.66)**
5–7		**2.00 (1.55, 2.58)**		**1.89 (1.44, 2.47)**
8 or above		**2.95 (2.30, 3.77)**		**3.08 (2.37, 4.00)**
Male partner type, past 12 mos				
Main only (Ref)		*1.00*		*1.00*
Casual only		1.00 (0.83, 1.20)		1.00 (0.82, 1.21)
Main and casual		**1.29 (1.07, 1.56)**		**1.32 (1.08, 1.61)**
Condomless anal sex, past 12 mos		0.98 (0.85, 1.14)		1.04 (0.89, 1.21)
vs. No (Ref)		*1.00*		*1.00*
Condomless anal sex with HIV+ or unknown partner, past 12 mos		**1.22 (1.03, 1.44)**		1.18 (0.99, 1.42)
vs. No (Ref)		*1.00*		*1.00*

Table 4 (continued)

Variables	Model 1 (Unconditional model), OR (95% CI)	Model 2 (Individual-level only), OR (95% CI)	Model 3 (County-level only), OR (95% CI)	Model 4 (Both levels), OR (95% CI)
County-level				
Predisposing factor				
% of black male			0.89 (0.49, 1.61)	1.28 (0.64, 2.56)
Enabling factors				
Median household income			**1.17 (1.08, 1.27)**	**1.14 (1.06, 1.23)**
% of people uninsured			0.47 (0.13, 1.67)	0.58 (0.15, 2.35)
Rescaled GINI			**1.06 (1.04, 1.09)**	**1.06 (1.03, 1.09)**
Need factor				
Male HIV prevalence rate			**1.41 (1.21, 1.65)**	1.17 (0.98, 1.40)
Variance composition				
County-level variance	0.27 (0.19, 0.35)	0.12 (0.05, 0.19)	0.09 (0.06, 0.12)	0.05 (0, 0.11)[a]
ICC (%)*	7.7	3.4	2.7	1.5[a]
PRV	–	0.56	0.65	0.81[a]
Model fit				
AIC	10546.6	7181.1	9199.9	6274.7
−2 Log Likelihood	10542.6	7129.1**	9208.5**	6218.5**

Bold and italic values indicate the significance level was set at $p = 0.05$

*Pseudo intraclass correlation coefficients (%)

**Likelihood ratio test significant at $p < 0.05$

[a]Lower end of 95% CI of variance equals to 0 in Model 4 means there is no significant variance (vs. 0) at higher-level, or there is no longer evidence for significant between-county variance beyond that explained by variables in model 4. This indicates the inclusion of both individual- and county-level factors in Model 4 jointly accounted for the county-level variance identified in Model 1. The ICC and PRV in Model 4 are insignificant

among MSM found neighborhood-level percent of Black population was only associated with consistent condom use in bivariate analyses, but this relationship was not statistically significant after adjusting for covariates [46]. This finding indicates that the effect of Black population percentage may be compositional rather than contextual. Though we found no influence of living in a Black community on Black MSM uptake of PrEP, close monitoring for racial composition effects is needed to determine if such effects independently and negatively affect PrEP uptake.

Compared to the substantial cross-county variation in PrEP use, PrEP awareness only varied moderately. Research on PrEP awareness among Black MSM also showed small variation in awareness across multiple US cities [1]. This finding might reflect the achievement of current nationwide PrEP awareness campaigns. With the exponential growth of online introductions and discussions of PrEP on MSM-specific social or sexual networking websites in the past few years [47], MSM are frequently exposed to PrEP information and can access needed materials online. As a result, geographic contexts might play a limited role in influencing MSM awareness of PrEP. While individual-level income was an important enabling factor for PrEP awareness, this study also found positive association between median household income and the odds of being aware of PrEP. This finding may reflect the need for PrEP awareness campaigns to reach further to economically disadvantaged individuals and counties.

There was no evidence of geographic variation in PrEP willingness among MSM. Only a few studies have looked at geographic differences in PrEP willingness. For example, one recent study using data from a national sample of MSM (n = 995) also reported no significant geographic variation in PrEP willingness [6]. This finding is in line with the argument of several scholars who suggested that most PrEP willingness questions actually measure hypothetical acceptability and rarely reflect contexts [48]. When PrEP is actually offered, participants might change their minds based on both individual and contextual circumstances.

Table 5 Relationships between individual- and county-level factors and PrEP willingness among 4372 US MSM participants, American Men's Internet Survey, November 2014 - April 2015

Variables	Model 1 (Unconditional model), OR (95% CI)	Model 2 (Individual-level only), OR (95% CI)	Model 3 (County-level only), OR (95% CI)	Model 4 (Both levels), OR (95% CI)
Individual-level				
Predisposing factors				
Age (years)				
15–24		**1.84 (1.36, 2.48)**		**1.82 (1.32, 2.51)**
25–34		**1.54 (1.18, 2.00)**		**1.48 (1.13, 1.95)**
35–44		**1.63 (1.25, 2.13)**		**1.55 (1.17, 2.05)**
45–54		**1.31 (1.02, 1.68)**		1.26 (0.97, 1.64)
> 55 (Ref)		*1.00*		*1.00*
Race/ethnicity				
Latino/Hispanic		1.30 (0.85, 1.99)		1.31 (0.84, 2.04)
White		0.99 (0.68, 1.44)		1.03 (0.70, 1.53)
Other		1.02 (0.64, 1.62)		1.06 (0.65, 1.72)
Black (Ref)		*1.00*		*1.00*
College or above		**0.70 (0.53, 0.92)**		**0.65 (0.48, 0.88)**
vs. Less (Ref)		*1.00*		*1.00*
Residence				
Urban		0.77 (0.58, 1.03)		0.82 (0.54, 1.18)
Suburban		0.91 (0.66, 1.24)		1.00 (0.63, 1.58)
Small/medium metro		0.76 (0.56, 1.01)		0.79 (0.54, 1.18)
Rural (Ref)		*1.00*		*1.00*
Enabling factors				
Yearly income, US$				
< 20,000 (Ref)		*1.00*		*1.00*
20,000–39,999		0.99 (0.72, 1.35)		1.06 (0.75, 1.49)
40,000–74,999		0.91 (0.67, 1.23)		0.98 (0.70, 1.36)
> 75 000		0.80 (0.59, 1.08)		0.86 (0.62, 1.19)
Current health insurance		0.96 (0.72, 1.28)		0.99 (0.73, 1.35)
vs. No (Ref)		*1.00*		*1.00*
Received HIV behavioral interventions, past 12 month		**1.50 (1.18, 1.90)**		**1.46 (1.13, 1.87)**
vs. No (Ref)		*1.00*		*1.00*
Need factors				
Any bacterial STIs, past 12 mos		**2.21 (1.47, 3.32)**		**2.05 (1.36, 3.11)**
vs. No (Ref)		*1.00*		*1.00*
# of male partners, past 12 mos				
1 (Ref)		*1.00*		*1.00*
2–4		**1.72 (1.38, 2.14)**		**1.57 (1.24, 2.00)**
5–7		**2.62 (1.84, 3.73)**		**2.30 (1.57, 3.36)**
8 or above		**2.99 (2.16, 4.14)**		**2.48 (1.75, 3.51)**
Male partner type, past 12 mos				
Main only (Ref)		*1.00*		1.00
Casual only		**1.43 (1.12, 1.82)**		**1.54 (1.19, 1.99)**
Main and casual		**1.74 (1.36, 2.23)**		**1.83 (1.40, 2.38)**
Condomless anal sex, past 12 mos		0.86 (0.71, 1.03)		0.89 (0.73, 1.09)
vs. No (Ref)		*1.00*		*1.00*
Condomless anal sex with HIV+ or unknown partner, past 12 mos		**2.27 (1.78, 2.88)**		**2.30 (1.78, 2.97)**
vs. No (Ref)		*1.00*		*1.00*

Table 5 (continued)

Variables	Model 1 (Unconditional model), OR (95% CI)	Model 2 (Individual-level only), OR (95% CI)	Model 3 (County-level only), OR (95% CI)	Model 4 (Both levels), OR (95% CI)
County-level				
Predisposing factor				
% of black male			0.64 (0.33, 1.26)	1.14 (0.48, 2.70)
Enabling factors				
Median household income			0.97 (0.91, 1.03)	0.98 (0.89, 1.08)
% of people uninsured			**5.14 (1.33, 19.86)**	4.71 (0.85, 26.01)
Rescaled GINI			0.99 (0.97, 1.03)	1.01 (0.98, 1.05)
Need factor				
Male HIV prevalence rate			1.10 (0.95, 1.27)	0.88 (0.73, 1.07)
Variance composition				
County-level variance	0.03 (0, 0.07)[a]	0.002 (0, 0.06)[a]	0.009 (0, 0.22)[a]	0.001 (0, 0.03)[a]
ICC*	0.9[a]	0.06[a]	0.27[a]	0.03[a]
PRV	/	0.93[a]	0.70[a]	0.97[a]
Model fit				
AIC	5600.6	3872.8	4948.0	3424.1
− 2 Log Likelihood	5598.6	3822.8**	4941.8**	3364.1**

Bold and italic values indicate the significance level was set at $p = 0.05$

*Pseudo intraclass correlation coefficients (%)

**Likelihood ratio test significant at $p < 0.05$

[a]In Model 1-4, the lower end of 95% CI of variance equals to 0 indicates there is no significant variance (vs. 0) at higher-level and thus indicates insignificant ICC and PRV in Model 1-4

Limitations

Limitations include the use of an online convenience sample that was mainly comprised of White, well-educated MSM, which might not be representative of all MSM online or all US MSM. The small sample size of Black MSM might limit our ability to obtain precise estimates. For example, the percent of Black population was found to have no impact of PrEP outcomes, while bivariate model showed a significant positive association between percentage of Black population and PrEP awareness and uptake. A more racially-representative sample might produce a more precise estimate or a significant relationship between Black population percentage and PrEP uptake. The present study used data collected through the standard AMIS survey. Factors from the theoretical model of healthcare utilization, such as health belief or the number of PrEP providers in each county in early 2015 was unavailable. We used percentage of people uninsured as a proxy for general county-level access to care. However, data on number of PrEP providers at county-level post-2016 is now available (i.e., PrEP Locator). Our findings support future modeling that could include this variable as a next step. Our findings for county-level factors may be limited by the lack of availability of more specific indicators. For instance, we had to use male HIV prevalence as a proxy of MSM HIV prevalence. Findings related to this variable might need to be interpreted with caution. There was a question logic error that did not show the PrEP willingness question for participants who had missing observations, or refused to answer, or answered "Don't know" to awareness question. This might lead to information bias. The data used in this study was collected/reported from November 2014 to April 2015. The prevalence of PrEP usage among MSM is likely increasing rapidly, and some of the current study findings may change as uptake grows. Future research should be conducted to build on and update our findings using the latest data.

Conclusions

Compared to PrEP awareness and willingness, uptake of PrEP showed a much greater variation across counties. County- and individual-level factors each explained half of the variation in uptake. When considering both county- and individual-level factors, there was no evidence of variance across counties. This study provided evidence for a significant contextual effect on MSM uptake.

Our results support the adoption of a comprehensive, multilevel strategy when planning interventions to improve

Table 6 Relationships between individual- and county-level factors and PrEP use among 4013 US MSM participants, American Men's Internet Survey, November 2014–April 2015

Variables	Model 1 (Unconditional model), OR (95% CI)	Model 2 (Individual-level only), OR (95% CI)	Model 3 (County-level only), OR (95% CI)	Model 4 (Both levels), OR (95% CI)
Individual-level				
Predisposing factors				
Age (years)				
15–24		0.78 (0.37, 1.66)		0.61 (0.28, 1.35)
25–34		1.42 (0.78, 2.57)		1.30 (0.72, 2.37)
35–44		1.66 (0.92, 3.00)		1.63 (0.90, 2.95)
45–54		1.27 (0.71, 2.27)		1.28 (0.72, 2.27)
> 55 (Ref)		*1.00*		*1.00*
Race/ethnicity				
Latino/Hispanic		0.50 (0.23, 1.11)		0.50 (0.23, 1.12)
White		0.88 (0.43, 1.79)		0.81 (0.40, 1.66)
Other		0.68 (0.27, 1.69)		0.64 (0.25, 1.59)
Black (Ref)		*1.00*		1.00
College or above		**2.87 (1.15, 7.17)**		2.20 (0.88, 5.49)
vs. Less (Ref)		*1.00*		*1.00*
Type of residence				
Urban		**4.17 (1.54, 11.28)**		2.04 (0.57, 7.25)
Suburban		**3.88 (1.39, 10.86)**		1.63 (0.42, 6.31)
Small/medium metro		2.55 (0.92, 7.07)		1.58 (0.44, 5.68)
Rural (Ref)		*1.00*		*1.00*
Enabling factors				
Yearly income, US$				
< 20,000 (Ref)		*1.00*		*1.00*
20,000–39,999		1.68 (0.82, 3.42)		1.44 (0.70, 2.99)
40,000–74,999		1.45 (0.73, 2.90)		1.17 (0.57, 2.37)
> 75,000		**2.49 (1.25, 4.95)**		1.94 (0.96, 3.92)
Current health insurance		0.92 (0.47, 1.81)		1.24 (0.61, 2.51)
vs. No (Ref)		*1.00*		*1.00*
Received HIV behavioral interventions, past 12 mos		**3.12 (2.22, 4.39)**		**2.94 (2.08, 4.14)**
vs. No (Ref)		*1.00*		*1.00*
Need factors				
Any bacterial STIs, past 12 mos		**2.14 (1.47, 3.11)**		**1.83 (1.24, 2.69)**
vs. No (Ref)		*1.00*		*1.00*
# of male sex partners, past 12 mos				
1 (Ref)		*1.00*		*1.00*
2–4		**3.90 (1.27, 11.97)**		**3.80 (1.22, 11.85)**
5–7		**6.92 (2.10, 22.84)**		**6.94 (2.06, 23.35)**
8 or above		**20.12 (6.42, 63.06)**		**19.30 (6.06, 61.50)**
Male partner type, past 12 mos				
Main only (Ref)		*1.00*		*1.00*
Casual only		1.89 (0.66, 5.44)		1.75 (0.60, 5.07)
Main and casual		1.85 (0.65, 5.28)		1.70 (0.59, 4.89)
Condomless anal sex, past 12 mos		1.66 (0.93, 2.96)		1.69 (0.92, 3.07)
vs. No (Ref)		*1.00*		*1.00*
Condomless anal sex with HIV+ or unknown partner, past 12 mos		**2.95 (2.06, 4.23)**		**2.92 (2.01, 4.23)**
vs. No (Ref)		*1.00*		*1.00*

Table 6 (continued)

Variables	Model 1 (Unconditional model), OR (95% CI)	Model 2 (Individual-level only), OR (95% CI)	Model 3 (County-level only), OR (95% CI)	Model 4 (Both levels), OR (95% CI)
County-level				
Predisposing factor				
% of black male			1.45 (0.34, 6.22)	2.43 (0.47, 12.53)
Enabling factors				
Median household income			**1.31 (1.15, 1.48)**	**1.33 (1.12, 1.57)**
% of people uninsured			0.82 (0.03, 19.83)	0.13 (0.01, 3.62)
Rescaled GINI			1.03 (0.97, 1.10)	1.05 (0.98, 1.12)
Need factor				
Male HIV prevalence rate			**1.36 (1.00, 1.85)**	0.86 (0.65, 1.16)
Variance composition				
County-level variance	0.86 (0.38, 1.33)	0.34 (0.00, 0.73)	0.32 (0.05, 0.60)	0.0 (0.0, 0.0)[a]
ICC*	20.7	9.4	8.9	0.0[a]
PRV	/	0.54	0.57	1.0[a]
Model fit				
AIC	2189.4	1268.9	1985.5	1150.2
− 2 Log Likelihood	2185.4	1218.9**	1985.7**	1092.2**

Bold and italic values indicate the significance level was set at $p = 0.05$

*Pseudo intraclass correlation coefficients (%)

**likelihood ratio test significant at $p < 0.05$

[a]In Model 4, the lower end of 95% CI of variance equals to 0 means there is no significant variance (vs. 0) at higher-level, or there is no longer evidence for significant between-county variance beyond that explained by variables in model 4. This indicates the inclusion of both individual- and county-level factors in Model 4 jointly accounted for the county-level variance identified in Model 1. The ICC and PRV in Model 4 are insignificant

PrEP uptake among MSM. Our findings echo prior studies that individual-level factors are significant correlates for PrEP uptake. However, focusing only on individual-level obstacles without addressing contextual-level barriers might be a suboptimal strategy. Importantly, the only independently significant correlate at the county-level was the median household income. This finding implies that county-level income might serve as an important identifier for communities where structural intervention is mostly needed.

Using multilevel theory and analyses, we detected contextual effects that might be unnoticeable in single-level analysis. Our study provides a clearer picture of contextual effect in determining PrEP use in relation to individual effect than of the underlying mechanism of these effects, as we were limited by available data for further investigating potential mechanisms involved. However, our study reinforces the need to incorporate ecological components in PrEP intervention that address individual and contextual factors simultaneously. The long-term implication of this study is the expansion of new topics for future PrEP research and the generation of important new insights for contextualizing PrEP information campaigns and PrEP service delivery programs.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed as part of the American Men's Internet Survey study involving human participants were conducted in accordance with the ethical standards of the Emory University Institutional Review Board (IRB) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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