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Geosocial-networking App Use Among Men who Have Sex with Men in High HIV Community Viral Load Areas of Baltimore City

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Abstract

Geosocial networking applications (GSN apps) are important tools for HIV/sexually transmitted infection prevention among men who have sex with men (MSM). Strategies for identifying high transmission and acquisition among GSN app users are needed to prioritize public health response. Community viral load (CVL) is associated with HIV transmission and can be used to identify populations with behaviors/environment associated with HIV/STI risk. We sought to determine user profile characteristics and utilization patterns associated with GSN app use in high CVL census tracts (CT). We used routine HIV surveillance data from in-care individuals and their viral loads at the point of diagnosis to estimate CVL in 200 CTs across Baltimore City. CTs were ordered based on CVL and categorized into quantiles from high to low. Among GSN user profiles, multiple imputation methods were used to complete missing profile characteristics. We then used imputed datasets to explore the association between profile characteristics, app utilization times, and app use in high CVL CTs using a Poisson regression model with robust error variances. Data on 606 profiles were collected originally and imputed 50 times to create a complete data set for analysis. GSN app users were aged 18–65 years [mean = 33.9, 95% confidence interval (CI): 33.1–34.7], with 52.2% Black (95% CI: 47.9– 56.5%), 6.8% living with HIV (95% CI: 4.4– 9.2%), 39.1% in high CVL CTs (95% CI: 35.2– 43.0%), 50.6% use at nighttime (95% CI: 46.7– 54.6%) and 51.6% use during the weekend (95% CI: 47.6– 55.6%). Black MSM users [Relative risk (RR) = 1.12, 95% CI: 1.04–1.20] were associated with GSN app use in high CVL CTs. MSM with profiles listing versatile sex position preference (RR = 1.12, 95% CI: 1.02–1.23) and profiles

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Conflict of Interest The authors have no conflicts of interest to disclose.

Declarations

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

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listing top sex position preference (RR = 1.13, 95% CI: 1.03–1.23) were associated with GSN app use in high and medium CVL CTs. GSN app user profiles of people in high and medium CVL CTs, especially Black MSM and those who report top and versatile sexual positions, may benefit from online prevention messages and real-time notification of health resources presently available in their communities to reduce HIV transmission.

Keywords

HIV; Community viral load; Geo-social networking apps; Mobile app; Dating apps; Men who have sex with men; African american

Introduction

Gay, bisexual, and other men who have sex with men (collectively referred to as MSM) continue to be disproportionately affected by HIV, accounting for 67.0% of new diagnoses in 2021 [1]. Black or African American (hereafter referred to as Black) MSM accounted for 37.0% of diagnoses, and young Black MSM (YBMSM) aged 13–24 years were particularly affected, accounting for 53.0% of new HIV diagnoses among MSM in 2021 [1]. Despite the effectiveness of HIV prevention strategies such as routine HIV testing and pre-exposure prophylaxis (PrEP), uptake of and adherence to these strategies remains challenging [2, 3], especially among Black and young MSM [4–6], which tends to exacerbate racial and ethnic HIV disparities among MSM.

In the recent decade, online geosocial networking applications (GSN apps) have become increasingly popular among MSM, especially among young MSM, with over two-thirds of MSM reporting having ever used a GSN app (e.g., *Grindr*, *Jack'd*, *Scruff*) [7]. GSN apps are frequently used to meet sexual partners and engage in sexual behavior [8–12]. Further, recent studies have found that users of GSN apps, compared with non-users, had significantly higher sexually transmitted infection (STI) rates, number of sexual partners [13, 14], and more frequent substance use [15], increasing the chance for STI transmission and acquisition among users who may meet in-person and engage in unprotected sex. Studies among MSM also suggested that the use of GSN apps for public health interventions is both feasible and acceptable [16, 17]. We found that using GSN apps to promote the use of HIV/STI treatment and prevention services among YBMSM [18] was acceptable and feasible. Due to their popularity, feasibility and acceptability *among MSM users* [19], GSN apps continue to be promising tools to reach MSM, specifically young MSM, with effective recruitment and prevention methods [16, 17].

Best practices and strategies for the use of online spaces for public health prevention and control efforts, however, are needed. One challenge for the routine use of online spaces for public health efforts is identifying users in online spaces with behaviors/environment associated with HIV/STI risk, particularly when using GSN apps that only allow targeted messaging via geography rather than other user characteristics. Another challenge for public health efforts is the linkage of online spaces to physical or geographic spaces for in-person interventions, such as where to optimally place an HIV/STI mobile testing van which coordinates with an online space offering the testing. These strategies and methods

are necessary to ensure linkage to services and provide the efficient use of public health resources. This study explored strategies and methods to use online spaces for public health efforts in Baltimore City, MD, where the majority of new HIV diagnoses were found among MSM (61.4%), non-Hispanic Black persons (81.6%), and persons aged 20–39 years (72.8%) [20].

The objectives of this study were to describe one strategy to link GSN users to geographic HIV/STI hotspot transmission areas [21, 22], and to determine the GSN user profile characteristics associated with app utilization in hotspot areas. The authors are not aware of other studies that have considered a similar strategy.

Methods

Data Sources, Study Population & Sampling

This analysis used HIV surveillance data from the Maryland Department of Health (MDH) and GSN app user profiles from two apps: (*Grindr* [www.grindr.com] and *Adam4Adam* [www.adam4adam.com]). The study was conducted from October to December 2017 in Baltimore City, MD. The study was reviewed and approved by the institutional review board at Johns Hopkins School of Medicine.

First, using previously published methods, we calculated community viral load estimates by census tract using MDH surveillance data on viral loads (VL) from in-care individuals (i.e., those retained in care with two or more CD4 or VL measures) and VL measured at the point of diagnosis [16, 22]. We then geocoded the reported primary residential address of individuals at the time of their diagnosis or their most recent in-care VL measure to one of the 200 Baltimore City census tracts. VL measures from individuals were combined and two summary measures were created for each census tract: a geometric mean VL and the percent with an unsuppressed viral load (defined as < 200 copies/mL). Additional methods for constructing the community viral load (CVL) measures are detailed here [22] and based on guidelines from the Centers for Disease Control and Prevention (CDC) [23]. The 200 census tracts were then coded into three ordinal categories of CVL, based on the percentage of unsuppressed VL: high CVL (4th quantile), medium CVL (3rd quantile), and low CVL (1st and 2nd quantile). The two lowest quantiles were combined due to low counts in each.

Next, census tracts were used as the geographic sampling area for collecting data from online GSN app users. Census tracts were ranked ordered by CVL, and we then selected 100% ($n = 100$) of the census tracts in the 4th and 3rd CVL quantiles and a simple random sample of 40% ($n = 40$) of census tracts in the two lowest CVL quantiles for inclusion in the study. For each census tract, we identified the geographic center and the largest radius area within the census tract that did not overlap with neighboring census tracts and used this radius as the search area for collecting GSN app user profiles in each census tract.

Collecting GSN App Use Patterns and User Profile Characteristics

Between October to December 2017, study research assistants used a GPS spoofing app to change the location of their mobile device to the geographic center of each selected census tracts. The GPS spoofing app was a safer and more efficient alternative to physically

traveling to the center of each census tract for data collection. They then logged on to each GSN app for 30 min during eight defined time periods (four hours total) on weekdays (4 am–8 am, 10 am–2 pm, 4 pm–8 pm, 10 pm–2 am) and weekends (4 am–8 am, 10 am–2 pm, 4 pm–8 pm, 10 pm–2 am) to collect app use patterns and self-reported profile characteristics of the GSN app users who met the study inclusion criteria. Active times and days of the week were categorized as: daytime (4 am–8 am or 10 am–2 pm) or nighttime (4 pm–8 pm or 10 pm–2 am) [11]. The active day of the week was categorized as weekdays (4 am Monday–2 pm Friday) or weekends (4 pm Friday–2 am Monday). We developed this approach, based on a similar study of GSN app users [24] and methods our team has used in Baltimore City previously, to identify physical locations where people meet sex partners and to characterize the people who congregate in those spaces [25]. Self-reported profile characteristics collected were defined by the app as follows: age reported in years and then categorized as 18–24, 25–34, or 35 and older, race and ethnicity reported as Black, White, Asian, Latino, Mixed, and Other and then categorized as Black (including Hispanic ethnicity) or non-Black, HIV status (living with HIV or negative), seeking preference as a hookup (or casual sex) (yes or no), friendship (yes or no), or relationship (yes or no) then categorized as hookup or friendship/relationship, and sex position preference (top, bottom, or versatile). We excluded users who self-identified as women.

Statistical Analysis

We first summarized the demographic characteristics of GSN app user profiles by CVL using means and frequencies (Table 1). However, data were missing from multiple profile characteristics. To create a complete data set and to minimize bias due to systematic differences between complete records and those with missing data, the following variables were imputed (the level of missingness ranged from 0.2 to 72.1%): age, race/ethnicity, seeking preference for hookup/friendship/relationship, sex position preference, HIV status, and active time of day and week.

Multiple imputation by fully conditional specification (FCS MI) was performed to impute estimated values in 3 steps [26–27]. First, FCS imputations were generated sequentially for each blank variable by considering the distribution and frequencies of all available variables. Thus, the imputation model was based on information contained in the complete or partially complete records. This process was repeated multiple times (imputation number $n = 50$ was chosen in our case to ensure better performance), finally resulting in the creation of 50 complete imputed data sets. Second, a multinomial logistic regression model was used with each imputed data set to compute conditional proportions and 95% confidence intervals (95% CI) for the key profile characteristics [26, 28]. Further, a modified Poisson regression model with robust error variances for repeated measures [29–30] was applied to explore the association between profile characteristics, app utilization times, and use in high CVL CTs by computing the relative risks (RR) of being in a high or medium CVL census tract compared with low or a high CVL census tract compared with medium or low. Before estimating the parameters based on a fitted regression model, we conducted a thorough multicollinearity investigation. This investigation involved exploring the correlation matrix, examining the variance inflation factor (VIF) and tolerance values, as well as performing collinearity diagnostics such as an eigensystem analysis of covariance comparison. These

steps were taken to ensure that multicollinearity was properly addressed before proceeding with parameter estimation. It revealed that there was no threat of multicollinearity for the models developed in this study. To investigate the potential dependency of one independent variable's effect on another independent variable, a two-way interaction was assessed through the utilization of a general linear model (GLM). A threshold p-value of 0.05 was employed to determine the significance of the interaction term. If the coefficient associated with the interaction term yielded a p-value lower than 0.05, it was retained within the multiple regression model. Third, all 50 sets of estimates obtained were combined, resulting in the statistically valid overall set of estimates that translated the uncertainty caused by the missing data and wide CIs. Outputs from the imputed data set were also compared against similar outputs calculated by excluding records with missing data (See Supplementary Table 1). Variables with p-values less than 0.25 from bivariate analyses were included in the initial multivariate model, with backward selection used to identify the optimal set of predictors (p-values < 0.05 were considered statistically significant) [31]. Variables previously associated with sexual risk behavior in other GSN app studies were also included in the model, regardless of their significance in the bivariate analyses. Two variables, HIV Status and Active Time of Week, were excluded, while Active Time of Day was retained in the final model due to its significance in prior research [32]. All statistical analyses, including multiple imputation methods, were conducted in SAS 9.4 (SAS Institute, Inc., Cary, NC).

Results

Demographic Characteristics

We collected data from 606 online GSN app user profiles from Adam4Adam (321, 53.0%) and Grindr (285, 47.0%) from October 2017 to December 2017 (Table 1). Overall, several profiles had key characteristics missing (Table 1). We present findings using our imputed data in Tables 2 and 3. GSN app users were in high CVL (237, 39.1%, 95% CI: 35.2–43.0%), medium CVL (215, 35.5%, 95% CI: 31.7–39.3%) and low CVL (154, 25.4%, 95% CI: 21.9–28.9%) census tracts throughout Baltimore City (Table 2). User profiles represented MSM aged 18 to 65 years (median = 31.7, 95% CI: 30.5–32.9; Interquartile Range: 27.0–39.6) (not shown in table), and Black race was most frequently reported (316, 52.2%, 95% CI: 47.9–56.5%; White = 177, 29.2%, 95% CI: 25.4–33.1%; Asian = 15, 2.4%, 95% CI: 1.0–3.8%; Latino = 32, 5.3%, 95% CI: 3.4–7.2%; Mixed = 24, 3.9%, 95% CI: 2.2–5.6%; Other = 42, 6.9%, 95% CI: 4.8–9.1%). A small number of user profiles self-reported living with HIV (41, 6.8%, 95% CI: 4.4–9.2%), seeking a friendship/relationship (212, 35.0%, 27.4–42.7%), or preference for a top sex position (93, 21.4%, 95% CI: 11.3–31.5%). Being HIV-negative (565, 93.2%, 95% CI: 90.8–95.6%) was most frequently reported, and app use mainly occurred in the nighttime (307, 50.6%, 95% CI: 46.7–54.6%) and on the weekends between 4 pm Friday–2 am Monday (313, 51.6%, 95% CI: 47.6–55.6%).

App User Characteristics Associated with Community Viral Load Census Tracts

Among all GSN app user profiles in the bivariate model, those reporting Black race (RR = 1.10, 95% CI: 1.03–1.16) as compared with non-Black race, were associated with app use

in high (vs. medium/low) CVL census tracts (Table 3). Users with profiles listing versatile sex position preference (RR = 1.11, 95% CI: 1.01–1.20) or top sex position preference (RR = 1.11, 95% CI: 1.01–1.21), as compared with bottom position preference, were associated with app use in high/medium (vs. low) CVL census tracts.

In the final multivariate model (Table 3), profiles reporting Black race as compared with non-Black race, were associated with app use in high (vs. medium/low) CVL census tracts (RR = 1.10, 95% CI: 1.03–1.18). User profiles listing versatile sex position preference (RR = 1.15, 95% CI: 1.04–1.26) or top sex position preference (RR = 1.14, 95% CI: 1.04–1.25) as compared with bottom position preference, were associated with app use in high/medium (vs. low) CVL census tracts. Age, HIV status, and seeking friendship/relationship were not significantly associated with app use in high (vs. medium/low) or high/medium (vs. low) CVL census tracts.

Discussion

Using routinely collected public health surveillance data and profile characteristics from GSN app users in Baltimore City, we identified profile characteristics associated with app utilization in high and medium CVL census tracts. These characteristics included self-reported Black race and user profiles reporting versatile or top sex position preferences. As prevention messaging is increasingly directed to online spaces, GSN app users in high and medium CVL areas can potentially be used to identify subgroups of MSM who may benefit from enhanced HIV prevention messages or intervention.

The association between Black race and GSN app use in high CVL census tracts found in our study is consistent with prior work demonstrating that Black MSM have greater exposure to sexual networks with high HIV transmission [33–36]. Our finding also extends this prior work by identifying a specific subgroup of Black MSM on GSN apps who may be meeting sex partners in a geographic hotspot with high HIV transmission (i.e., census tracts with high CVL) and how GSN apps may be a potential access point for reaching men disproportionately affected by HIV.

In addition to prioritizing Black MSM users, our results suggest that online prevention could also focus on users who self-report preference for certain sex positions. In our study, GSN app user profiles with a versatile or top sex position preference were associated with app use in high/medium CVL census tracts. This association may reflect the practice of seropositioning among app users to reduce their acquisition of HIV in areas they consider high risk. This rationale presumes users are aware these areas are HIV hotspots, which may or may not be accurate. Alternatively, this association may reflect higher contribution to HIV transmission by users with a top or versatile position preference driven by two critical aspects of HIV transmission dynamics in MSM: (1) during anal sex, HIV is most efficiently transmitted from the insertive partner to the receptive partner [37–38] and (2) HIV is more efficiently transmitted in MSM networks where a significant proportion of men engage in both receptive and insertive anal sex (e.g., versatile position preference) [39]. This study is cross-sectional, so directionality or causality cannot be accurately assessed. Whether either explanation is accurate, our findings suggest users with these position preferences

could benefit from messaging focused on HIV prevention tools to reduce both HIV/STI transmission and acquisition including PrEP, doxycycline post-exposure prophylaxis, anti-retroviral therapy for viral suppression, and condom use. Based on the biology of HIV transmission dynamics in MSM populations, prevention messaging that reduces the risk of HIV transmission among MSM living with HIV with a top position preference may be an especially important implications of our findings. Thus, the association between app user profile characteristics (e.g., sex position preference) and app utilization in high CVL census tracts, which persisted even after adjusting for race, may provide additional context beyond racial identity for tailoring prevention messaging and developing interventions that are inclusive of GSN app users with these preferences.

Notably, most users did not list several profile characteristics, including their HIV status (34.8%), with the majority of these users utilizing the app in high or medium CVL census tracts. This finding could be related to users evading disclosure of living with HIV due to stigma or not being aware of their HIV status. It may also reflect less disclosure of personal characteristics or preferences among GSN app users in high or medium CVL census tracts as compared with those in low CVL census tracts. Given app user profiles without demographic characteristics (age, race), sexual position preference, seeking preference, or HIV status were more frequently used in high and/or medium CVL census tracts, it may be that these types of GSN app users are most susceptible to HIV acquisition or transmission. The information gleaned from GSN app users and their behaviors/environments associated with HIV/STI risk is useful, but is limited when users create profiles to quickly “hook up” with others, thus leaving many profile characteristics blank when not required by the app. For this reason, strategies for tailoring and delivering HIV prevention and treatment messages and interventions to a risk environment (e.g., high and medium CVL census tracts, areas with higher poverty levels and characteristics correlated with higher HIV rates) may be more effective compared to focusing solely on MSM with certain demographic or sexual behavior characteristics. To account for the missing data and better understand the profile characteristics of the GSN app users in our analysis, we used imputation methods. Our study is the first, to our knowledge, to use these techniques with GSN app data in the context of HIV hotspots. Using imputation methods more frequently with dating app data to understand users’ behaviors/environment associated with HIV/STI risk and how to reach this population should be considered when possible. However, imputation methods are just one step to characterizing this population when missing data is abundant, and additional research is needed to further understand the characteristics of the users.

Overall, GSN apps are acceptable tools for outreach to MSM, especially young MSM [18], and they may provide an ideal venue to reach MSM because of the significant amount of time spent on these apps by users [10]. Disseminating effective HIV messaging with images that resonate with GSN app users in high CVL census tracts, especially during peak use hours, can potentially increase the impact and return on funding for geotargeted advertisement and other online outreach [40]. Additional novel uses to reach MSM populations through GSN apps could include sending real-time notifications about mobile vans offering testing, treatment, and/or post-exposure prophylaxis of infections such as HIV, STIs, and mpox to users in the vicinity based on app geolocation data [41–48]. GSN apps could also notify users in geographic hotspots about where to access free HIV self-

testing kits in-person or through the mail and facilitate the delivery of other sexual health tools [47–48]. While many of the proposed strategies are not currently accessible services in GSN apps, prior studies have indicated the acceptability of similar strategies among MSM who use GSN apps [49–50]. Furthermore, public health advocates have successfully partnered with app companies to develop other structural interventions to help users manage their behaviors/environment associated with HIV/STI risk [7]. These findings may warrant additional efforts to increase the services public health programs can use to engage MSM on GSN apps.

This analysis has limitations. First, the results are limited by self-reported data collected from user profiles. Secondly, many users did not list their profile characteristics. Missing data could be related to certain fields not being required as determined by the app or users evading disclosure of certain personal characteristics. We adjusted for missing data using statistical imputation methods; however, our results may be biased, and estimates and standard errors may be over or under-estimated. Third, the utilization of backward elimination, which relies on significant p-values, may have led to the exclusion of crucial confounding factors. This automated method for selecting confounders can potentially introduce bias into effect estimates and underestimate their variance [42]. To address this limitation, variables linked to sexual risk behavior in other GSN app studies were included, regardless of their bivariate significance. HIV Status and Active Time of Week were excluded, while Active Time of Day was kept due to its prior significance [32]. Fourth, an individual may have multiple user profiles across platforms, and deduplication is not feasible (identifiable information was not collected from user profiles). Fifth, it is possible that GSN app users may have used a GPS spoofing app to change the location of their mobile device to the geographic location of the selected census tracts and may not reside in that census tract. Sixth, preferences for condom use, experience with PrEP, or antiretroviral therapy (ART) which are now commonly available and completed by users [7], were not profile characteristic measures at the time of this study; thus, limiting our ability to understand the users' behaviors/environment associated with HIV/STI risk. Lastly, it is possible that incomplete VL data and a lack of timely information on in-care VLs could have led to misclassification of census tracts by CVL category. While CVL use among researchers is not uncommon [21, 43–45], methods on how to measure CVL vary [46], and use of alternate measures of population-level VL burden (e.g., such as geometric mean VL per census tract) could lead to different inferences in the classification of CVL categories.

Despite these caveats, findings from this study describe the profile characteristics from GSN app users that were online in high CVL census tracts that can be used to prioritize and engage with MSM through GSN apps, at optimal times, with effective HIV prevention messaging, intervention, and notification of sexual health tools in their vicinity. User profiles with self-reported Black race, and versatile or top sexual position preference may represent preferred profiles for focused recruitment into HIV prevention and interventions in priority communities. Similarly, user profiles with limited personal characteristics or preferences may also be important to prioritize for HIV prevention and other interventions. Findings from this study lay a groundwork for researchers, health departments, and community-based organizations, and other public health practitioners to identify and reach diverse MSM

populations with vital HIV/STI screening, prevention, treatment and care messaging and intervention.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Profile characteristics of men who have sex with men (MSM) Geo-social networking apps users, Baltimore City, Maryland, October–December 2017, original data analysis with missing values

Profile Characteristic	Overall		High CVL		Medium CVL		Low CVL	
	n	(%)	n	(%)	n	(%)	n	(%)
Total (row %)	606	100	237	39.11	215	35.48	154	25.41
Age, years								
18–24	65	10.7	27	11.3	21	9.7	17	11.0
25–34	257	42.4	96	40.5	97	45.1	64	41.5
35 +	205	33.8	78	32.9	75	34.8	52	33.7
missing	79	13.0	36	15.1	22	10.2	21	13.6
Race								
Non-Black	252	41.5	78	32.9	102	47.4	72	46.7
Black	291	48.0	128	54.0	94	43.7	69	44.8
missing	63	10.3	31	13.0	19	8.8	13	8.4
HIV Status								
HIV Negative	359	59.2	145	61.1	118	54.8	96	62.3
Living with HIV	36	5.9	20	8.4	6	2.7	10	6.4
missing	211	34.8	72	30.3	91	42.3	48	31.1
Seeking								
Hookup	142	23.4	49	20.6	62	28.8	31	20.1
Relationship/Friendship	83	13.6	29	12.2	24	11.1	30	19.4
missing	381	62.8	159	67.0	129	60.0	93	60.3
Sex Position Preference								
Bottom	39	6.4	12	5.0	9	4.1	18	11.6
Versatile	94	15.5	36	15.1	39	18.1	19	12.3
Top	36	5.9	12	5.0	15	6.9	9	5.8
missing	437	72.1	177	74.6	152	70.6	108	70.1
Active Time of Day								
Daytime (4am– 8am or 10am– 2pm)	298	49.2	129	54.4	96	44.6	73	47.4
Nighttime (4pm– 8pm or 10pm– 2am)	306	50.5	108	45.5	117	54.4	81	52.5

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Profile Characteristic	Overall		High CVL		Medium CVL		Low CVL	
	n	(%)	n	(%)	n	(%)	n	(%)
missing	2	0.3	--	--	2	0.9	--	--
Active Day of Week								
Weekdays (4am Monday–2pm Friday)	293	48.4	122	51.4	94	43.7	77	50.0
Weekends (4pm Friday–2am Monday)	312	51.5	115	48.5	120	55.8	77	50.0
missing	1	0.2	--	--	1	0.4	--	--
App Used								
Adam4Adam	321	53.0	137	57.8	109	50.6	75	48.7
Grindr	285	47.0	100	42.1	106	49.3	79	51.2

Abbreviations: CVL, community viral load
Note: Percentages may not total to 100% due to rounding

Table 2

Profile characteristics of men who have sex with men (MSM) Geo-social networking apps users, Baltimore City, Maryland, October– December 2017, imputed data analysis

Profile Characteristic	Overall			High CVL			Medium CVL			Low CVL		
	n	(%)	95% CI	n	(%)	95% CI	n	(%)	95% CI	n	(%)	95% CI
Total	606	100	--	237	39.1	(35.2,43.0)	215	35.5	(31.7,39.3)	154	25.4	(21.9,28.9)
Age, years												
18–24	79	13.0	(10.1,16.0)	34	14.3	(9.4,19.2)	25	11.7	(7.1,16.3)	20	12.9	(7.2,18.5)
25–34	299	49.3	(45.1,53.5)	115	48.7	(42.0,55.4)	109	50.7	(43.6,57.7)	75	48.4	(39.7,57.0)
35 +	228	37.7	(33.6,41.7)	88	37.0	(30.5,43.5)	80	37.6	(30.9,44.4)	60	38.7	(30.5,47.0)
Race												
Non-Black	290	47.8	(43.5,52.1)	94	39.7	(32.8,46.5)	115	53.7	(46.7,60.7)	80	52.1	(43.8,60.4)
Black	316	52.2	(47.9,56.5)	143	60.3	(53.5,67.2)	100	46.3	(39.3,53.3)	74	47.9	(39.6,56.2)
HIV Status												
HIV Negative	565	93.2	(90.8,95.6)	216	91.0	(87.1,94.8)	207	96.3	(93.2,99.3)	142	92.3	(87.4,97.2)
Living with HIV	41	6.8	(4.4,9.2)	21	9.0	(5.2,12.9)	8	3.7	(0.7,6.8)	12	7.7	(2.8,12.6)
Seeking												
Hookup	394	65.0	(57.3,72.6)	156	65.8	(54.3,77.3)	149	69.3	(59.1,79.5)	89	57.6	(43.5,71.7)
Relationship/Friendship	212	35.0	(27.4,42.7)	81	34.2	(22.7,45.7)	66	30.7	(20.5,40.9)	65	42.4	(28.3,56.5)
Sex Position Preference												
Bottom	220	36.4	(27.1,45.7)	79	33.1	(21.0,45.2)	61	28.3	(14.8,41.8)	81	52.3	(39.8,64.7)
Versatile	255	42.2	(30.6,53.7)	104	43.7	(29.1,58.4)	101	47.1	(31.6,62.6)	50	32.3	(20.3,44.3)
Top	131	21.4	(11.3,31.5)	55	23.1	(8.9,37.4)	53	24.6	(10.5,38.7)	24	15.4	(6.8,24.0)
Active Time of Day												
Daytime (4am– 8am or 10am– 2pm)	299	49.4	(45.4,53.3)	129	54.4	(48.1,60.8)	97	45.2	(38.5,51.8)	73	47.4	(39.5,55.4)
Nighttime (4pm– 8pm or 10pm– 2am)	307	50.6	(46.7,54.6)	108	45.6	(39.2,51.9)	118	54.8	(48.2,61.5)	81	52.6	(44.7,60.6)
Active Day of Week												
Weekdays (4am Monday– 2pm Friday)	293	48.4	(44.4,52.4)	122	51.5	(45.1,57.9)	94	43.9	(37.2,50.5)	77	50.0	(42.0,58.0)
Weekends (4pm Friday– 2am Monday)	313	51.6	(47.6,55.6)	115	48.5	(42.1,54.9)	121	56.1	(49.5,62.8)	77	50.0	(42.0,58.0)
App Used												
Adam4Adam	321	53.0	--	137	57.8	--	109	50.7	--	75	48.7	--

Profile Characteristic	Overall			High CVL			Medium CVL			Low CVL		
	n	(%)	95% CI	n	(%)	95% CI	n	(%)	95% CI	n	(%)	95% CI
Grindr	285	47.0	--	100	42.2	--	106	49.3	--	79	51.3	--

Abbreviations: CVL=, community viral load

Table 3

Characteristics of men who have sex with men (MSM) Geo-social networking apps user profiles associated with community viral load categories at the census tract level, Baltimore City, Maryland, October– December 2017 using imputed data

MSM Geo-social Networking App Users Profiles				
Covariate	Bivariate model RR ^a	95% CI	Final multivariate RR ^{a, b}	95% CI
Age, 18–24 years	Reference		Reference	
Age, 25–34 years	1.00 ^c	0.94–1.07	0.96 ^c	0.88–1.04
	0.97 ^d	0.88–1.06	0.91 ^d	0.79–1.03
Age, 35 + years	0.99 ^c	0.93–1.06	0.94 ^c	0.86–1.02
	0.97 ^d	0.87–1.06	0.88 ^d	0.76–0.99
Race, Non-Black	Reference		Reference	
Race, Black	1.03 ^c	0.98–1.07	1.04 ^c	1.01–1.10
	1.10 ^d	1.03–1.16	1.10 ^d	1.03–1.18
HIV Negative	Reference		Reference	
Living with HIV	0.98 ^c	0.89–1.07	1.01 ^c	0.91–1.12
	1.10 ^d	0.97–1.23	1.11 ^d	0.97–1.26
Seeking, Hookup/Casual Sex	Reference		Reference	
Seeking, Friendship/Relationship	0.95 ^c	0.88–1.03	0.91 ^c	0.78–1.04
	0.99 ^d	0.90–1.08	0.90 ^d	0.73–1.09
Sex Position Preference, Bottom	Reference		Reference	
Sex Position Preference, Versatile	1.11 ^c	1.01–1.20	1.15 ^c	1.04–1.26
	1.04 ^d	0.94–1.13	1.10 ^d	0.97–1.23
Sex Position Preference, Top	1.11 ^c	1.01–1.21	1.14 ^c	1.04–1.25
	1.04 ^d	0.92–1.17	1.11 ^d	0.96–1.27
Active Time of the Day, Daytime (4am–8am or 10am–2pm)	Reference		Reference	
Active Time of the Day, Nighttime (4pm–8pm or 10pm–2am)	0.99 ^c	0.95–1.03	1.00 ^c	0.96–1.04
	0.94 ^d	0.89–1.00	1.00 ^d	0.90–1.10
Active Day of the Week, Weekdays (4am Monday– 2pm Friday)	Reference		Reference	

MSM Geo-social Networking App Users Profiles				
Covariate	Bivariate model RR ^a	95% CI	Final multivariate RR ^{a, b}	95% CI
Active Day of the Week, Weekends (4pm Friday– 2am Monday)	1.01 ^c	0.97–1.05	1.01 ^c	0.90–1.12
	0.97 ^d	0.91–1.02	0.96 ^d	0.90–1.01
Adam4Adam	Reference		Reference	
Grindr	0.98 ^c	0.94–1.02	0.94 ^c	0.89–1.00
	0.95 ^d	0.89–1.00	0.95 ^d	0.87–1.01

Abbreviations: RR, relative risk; CI, confidence interval

Note:

^aProc genmode using a robust error variance method was used to estimate the RR

^bVariables with P values greater than 0.25 were excluded from the initial multivariate model through backward selection to develop the final model. Two variables, HIV Status and Active Time of Week, were excluded, with their relative risks (RRs) indicated in grey. However, the variable Active Time of Day was retained in the final model due to its significance in prior research [32]

^cRR of app use in a High and Medium vs. Low Community Viral Load Census Tract

^dRR of app use in High vs. Medium and Low Community Viral Load Census Tract