

Network Influences on the Sexual Risk Behaviors of Gay, Bisexual and Other Men Who Have Sex with Men Using Geosocial Networking Applications

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Abstract Geosocial networking applications (GSN apps) have become increasingly popular among gay, bisexual and other men who have sex with men (MSM). Our study sought to understand whether inclusion of individuals met via GSN apps in participants' social networks was associated with increased HIV risk behaviors among a probability sample of GSN app using MSM ($N = 295$) recruited in Los Angeles, California. Approximately 20 % of participants included a GSN app-met individual as one of their top five closest social network members. Those with a GSN app-met network member had more recent (past 30-day) sexual partners ($B = 1.21$, $p < 0.05$), were nearly twice as likely to have engaged in unprotected anal intercourse (UAI) with their last sexual partner ($AOR = 2.02$, $p < 0.05$), and were nearly four times as likely to have engaged in UAI with their last GSN app-met sexual partner ($AOR = 3.98$, $p < 0.001$). Network-based interventions delivered via GSN apps may be useful in preventing the spread of HIV among MSM.

Keywords MSM · Geosocial networking applications · HIV · STI · Smartphone

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Resumen Las aplicaciones de redes geosociales (apps GSN – por sus siglas en inglés, geosocial networking applications) han aumentado en popularidad entre hombres homosexuales, bisexuales y otros hombres que sostienen relaciones sexuales con otros hombres (MSM – por sus siglas en inglés, men who have sex with men). Nuestra investigación buscaba entender si la inclusión de parejas sexuales conocidas a través de apps GSN en las redes sociales de los participantes estaba asociada con un mayor riesgo de VIH dentro de una muestra de probabilidad de MSM usuarios de apps GSN ($N = 295$) reclutados en Los Ángeles, California. Aproximadamente el 20 % de los participantes incluyó a una pareja conocida en un app GSN dentro de los cinco miembros más cercanos de su red social. Aquellos con parejas sexuales conocidas a través de un app GSN tenían más parejas sexuales recientes (en los últimos 30 días), ($B = 1.21$, $p < 0.05$), era dos veces más probable que hubieran tenido sexo anal sin protección con su última pareja sexual ($AOR = 2.02$, $p < 0.05$), y era cuatro veces más probable que hubieran tenido sexo anal sin protección con la última pareja sexual conocida a través de un app GSN ($AOR = 3.98$, $p < 0.001$). Intervenciones basadas en redes sociales distribuidas a través de apps GSN podrían ser útiles para prevenir el contagio de VIH entre los MSM.

Introduction

HIV remains a pressing public health issue among gay, bisexual, and other men who have sex with men (MSM). In 2011, MSM accounted for nearly two-thirds of all HIV diagnoses in the United States and over 80 % of HIV diagnoses among adult and adolescent males [1]. While

efforts to prevent HIV transmission in this population have typically focused on individual-level behaviors such as consistent condom use and regular HIV testing [2, 3], recent evidence demonstrates the importance that contextual factors, such as where MSM meet sex partners, may have on risk of HIV infection [4]. However, little is known about the extent to which individuals met in various contexts are integrated into social networks of MSM and how that process may influence various HIV risk and protective behaviors.

Geosocial Networking Applications and Sexual Risk Behavior

In recent years, geosocial networking (GSN) applications (“apps”) have emerged as popular technologies for MSM to meet potential sex partners. These apps allow users to create individualized profiles with pictures and demographic information including age, race/ethnicity, height, and weight. Then, using global positioning system (GPS) technology, users can locate other users nearby, exchange pictures and text messages, and establish both virtual and in-person connections. A recent study of 379 MSM recruited using venue-based sampling in Washington, DC found that nearly two-thirds had used a GSN app within the previous year and over one-fifth had sex with an app-met partner during the same time period [5]. In addition to meeting sex partners, MSM report using these apps for a variety of reasons including making new friends, finding someone to date, “killing time,” and connecting to the larger gay community [5–7]. These findings demonstrate the popularity of GSN apps among MSM and the varied use of GSN apps within this population.

Nine empirically published studies to date have examined associations between GSN app use, partner seeking and sexual risk and protective behaviors among MSM [5–13]. In terms of partner seeking, these apps allow MSM to quickly and conveniently locate sex partners nearby, potentially leading to a greater number of sexual partners. Several studies have confirmed this hypothesis, finding that MSM who use GSN apps report greater numbers of sexual partners compared to non-users [5, 7, 13]. Landovitz et al., however, found that only one-fifth of GSN app users reported having more sex partners since beginning to use the app [6], raising questions about whether apps promote proliferation of sexual networks in general or whether this phenomenon is limited to a smaller subset of MSM.

GSN app users generally report high rates of condom use with partners met using these technologies. Rice et al. found that GSN app users reported higher rates of condom use with app-met partners relative to partners met elsewhere [7]. Similarly, Winetrobe et al. found that among MSM who reported having sex with partners met on a

popular GSN app, only one-fifth had unprotected anal intercourse (UAI) with their last GSN app met partner [8]. Participants in this study who reported UAI with their last GSN app-met partner were also more likely to have used the GSN app for at least one year, shown naked chest or abs in their profile photo, and reported more GSN app-met partners in the past month. These findings may suggest that MSM who are more familiar with GSN apps or use GSN apps to portray a sexualized presentation of self may be more likely to engage in sexual risk behaviors with partners met using these technologies.

Despite high rates of reported condom use among MSM using GSN apps, recent evidence points to greater levels of sexual risk behavior among GSN app-using MSM compared to MSM who meet their partners elsewhere. Beymer et al. examined incidence of sexually transmitted infections (STIs) among a sample of 7,184 MSM in Los Angeles, CA and found that participants who used GSN apps to meet sex partners had greater odds of testing positive for gonorrhea and chlamydia compared to those who met partners through in-person or Internet networking methods only [9]. These findings demonstrate the need to better understand the mechanisms by which GSN app-using MSM engage in sexual behaviors that may place them at greater risk for STIs, including HIV.

Geosocial Networking Applications and MSM Social Networks

One possible explanation for higher rates of sexual risk behavior among GSN app users is the integration of individuals who engage in higher risk behaviors into the social networks of MSM, promoting peer norms that are more supportive of risky sexual behaviors. It is well-established that social networks play an important role in the transmission of health risk and protective behaviors [14]. A recent study of MSM in the midwest found the social network to which an individual belonged to be an independent predictor of his number of recent sex partners and whether he traded sex for money or drugs [15]. Similarly, Amirkhanian et al. found that the strongest predictor of sexual risk behavior and STIs among a sample of MSM in Russia was the social network to which an individual belonged [16]. Network characteristics that have been shown to be associated with sexual risk behavior include perceived low peer support of condom use and the presence of an “enabler” who condones risky sex [17, 18]. Studies have also demonstrated the relationship between an individual’s HIV testing behaviors and the testing attitudes and behaviors of his social network [19, 20].

To date, nothing is known about the extent to which MSM who use GSN apps integrate other app users into their social networks and how norms related to sexual

health are similar or different from MSM social network members met elsewhere. The present study sought to answer the following research questions: (1) Do MSM who integrate GSN app users into their social networks engage in higher levels of HIV risk behavior compared to those who do not; and (2) Do social network members met through GSN apps possess attitudes and enact behaviors that put MSM at higher risk for acquiring HIV and other STIs?

Methods

Sampling and Data Collection

Utilizing the geo-location feature of a popular GSN app, research assistants created their own profiles to recruit GSN app users who were within a seven-mile radius of West Hollywood and Long Beach, CA, two neighborhoods with large populations of gay and bisexually identified men. Between August 8, 2011 and October 3, 2011, GSN app users between the ages of 18–24 were recruited (young MSM). Between December 5, 2011 and January 3, 2012, GSN users 25 years of age and over were recruited (older MSM). The recruiters' profiles contained the study institution's name and identified the recruiters as researchers; their profile pictures were of the research assistant or a stock photo. Individuals were eligible to participate if they were GSN app users and had not previously participated in the study.

Potential participants were randomly selected based on their location at the time of recruitment. On the GSN app, profiles are organized by geo-location, with the first profiles being closest in proximity to the user. Users appeared on a grid displaying four profile photos in each row (with a total of five rows) and continued for all users within a seven-mile range. Age filters were used on the GSN-app to isolate the population of interest during the two recruitment periods mentioned above. A random number generator was used by recruiters to randomly select one potential participant from each row. After the fifth potential participant was contacted, the recruiter moved forward in the app interface to the next five rows of potential participants and continued this procedure. The GSN app has a feature, which automatically records all interactions between users; this enabled us to avoid duplication of participants. Therefore, if a user was randomly selected again, the recruiters moved onto the next row of profiles as outlined above. Randomly selected potential participants were sent a text message via the app providing information about the study. Interested participants received a link and unique log-in code to an anonymous, online survey, which took approximately 20–30 minutes to complete. After entering

the unique login code, participants had the opportunity to read an informed consent page, which included the investigator's contact information. Participants who indicated their consent were allowed to proceed; the online survey tool prevented duplicate responses from a single internet protocol (IP) address. Upon completion, participants received a \$25 downloadable gift card to either iCard or Amazon.com. Recruiters were available to answer respondents' questions and to provide minor technical support through the GSN app's chat feature. Due to logistical and safety concerns, recruitment occurred between 9 a.m. and 8 p.m. on weekdays.

Overall, 11.95 % of the men approached via the GSN app text message completed the survey resulting in a total sample of 295 participants. Only eligible participants were randomly selected, so our overall response rate is calculated based on the proportion of those contacted who completed the survey, without any additional inflation of this rate based on excluding non-eligible participants from our calculations. This response rate is comparable and in some cases higher than other studies where MSM were recruited via geosocial networking applications [6]. To determine whether the respondents were representative of the larger GSN app using population, additional data collection capturing user demographics was conducted in June 2012. Research assistants randomly observed profiles of GSN app users in the West Hollywood area and recorded demographic information. Of the young MSM group, 215 men were randomly observed and of the older MSM, 332 men were randomly observed. Research assistants used the same random selection procedures utilized for the study sample and recorded the listed age of the observed individuals. Age frequencies were then calculated to test for age bias in the study sample. In order to account for an age bias towards younger users age weights were created and utilized for descriptive and inferential analysis. Both these groups (older and younger MSM) were included in this study. All study procedures were approved by the Institutional Review Board of the University of Southern California. Secondary data analysis for the present study was approved by the Institutional Review Board of the University of California, Los Angeles.

Measures

Demographics

Participants were asked to identify their age in years, race/ethnicity (1 = African American, 2 = Latino/Hispanic, 3 = White, 4 = Asian, 5 = Native Hawaiian or other Pacific Islander (NHPI), 6 = American Indian or Alaska Native (AIAN), 7 = Mixed race, 8 = Other race). NHPI, AIAN, and "other" race were then collapsed to form one

other race category. Participants also reported highest level of education (1 = less than high school, 2 = high school graduate or GED, 3 = some college, 4 = 4 year college/university degree, master's degree or professional degree, and 6 = doctorate), current employment status (0 = Not currently working, 1 = currently working), sexual identity (1 = gay, 2 = bisexual, 3 = heterosexual, 4 = questioning, 5 = queer, 6 = other), whether they were out (i.e., had "disclosed having sex with other men") to parents, brothers/sisters, other family, co-workers, friends, and no one (0 = No, 1 = Yes), and their relationship status out of nine options (i.e. single, male life partner: monogamous, male life partner: open relationship, female life partner: monogamous, female life partner: open, boyfriend: monogamous, boyfriend: open, girlfriend: monogamous, girlfriend: open). Responses to this question were subsequently dichotomized to reflect a single relationship status (0 = No, 1 = Yes).

GSN App Use

Participants were asked how often they logged on to the GSN app, which was dichotomized (0 = Less than five times per day, 1 = Five or more times per day), how long ago they started using the GSN app, which was dichotomized (0 = Less than one year, 1 = Greater than one year), if their profile picture showed their face (0 = No, 1 = Yes) and what naked body parts were visible in their GSN app profile picture, which was dichotomized to reflect whether they showed their naked chest or abs (0 = No, 1 = Yes), what time of day they usually logged onto the GSN app (1 = Morning, 2 = Afternoon, 3 = Evening, 4 = Night (before midnight), 5 = Late night (after midnight)), and whether they used the GSN app both on weekdays and weekends (0 = No, 1 = Yes).

Sexual Risk and Protective Behaviors

Participants reported on the number of both lifetime and recent (past 30-day) sexual partners, whether they had engaged in unprotected anal intercourse (UAI) with their most recent sexual partner (0 = No, 1 = Yes), and whether they had engaged in UAI with their most recent partner met on the GSN app (0 = No, 1 = Yes). HIV and STI testing was assessed by asking participants whether they had been tested (0 = No, 1 = Yes) and the timing of their last test (1 = Within 3 months, 2 = Greater than 3 months but less than 6 months, 3 = Greater than 6 months but less than 1 year; 4 = Greater than 1 year). These questions were asked separately for each of the variables (HIV and STI). Participants were also asked whether they had ever tested positive for HIV (0 = No, 1 = Yes) or another STI (0 = No, 1 = Yes).

Social Networks

A single-item name generator asked participants to list their top five closest social network members using the following prompt: "The next several questions are about the most important people that you regularly communicate with on a social basis. These are people that you interact with, either through face-to-face contact or via the Internet or cell phone and could be family members, friends, sex-partners, co-workers or anyone else who is important to you. Based on this criteria, we ask that you please list the five people you interact with the most and/or who are most important to you in the space provided below". Next, participants were asked to describe their relationship to that network member (1 = Life partner, husband, or wife, 2 = Boyfriend or girlfriend, 3 = Lover, sex partner, hook-up, 4 = Family, 5 = Friend, 6 = Coworker, 7 = Other) and the age, race/ethnicity, and sexual orientation of that network member. Network members described as husband, wife, boyfriend or girlfriend were grouped to represent main partner (0 = No, 1 = Yes). Lover, sex partner and hook-up were grouped to represent casual partners (0 = No, 1 = Yes). In addition, participants were asked to report whether they had known each network member for more than a year (0 = No, 1 = Yes), the ways in which they communicated with each network member over the past 30 days (1 = Face-to-face, 2 = On the phone, 3 = Via social networking websites (e.g., Facebook), 4 = Through email), whether the network member used the GSN app (0 = No, 1 = Yes), provided the respondent with emotional support (i.e., "anyone who you can go to if you have an important problem to discuss about your personal life," 0 = No, 1 = Yes), provided the respondent with instrumental support (i.e., "anyone who you could borrow \$100 from if you needed it," 0 = No, 1 = Yes), and used condoms regularly (0 = No, 1 = Yes).

Participants' perceived attitudes of social network members towards GSN app use were assessed by asking the participant whether each network member would object to their use of the GSN app (0 = No, 1 = Yes), would object to the participant meeting men on the GSN app (0 = No, 1 = Yes), would object to the participant having sex with men (0 = No, 1 = Yes), would object to the participant having concurrent sex partners (i.e., "anyone on this list who would object to you having more than one recurring sex partner during the same period of time," 0 = No, 1 = Yes), would object to the participant using condoms (0 = No, 1 = Yes), and/or would encourage the participant to use condoms (0 = No, 1 = Yes). Finally, whether or not participants discussed HIV testing and sexual risk behaviors with social network members was assessed by asking participants whether they talked to each network member about condoms or safer sex

(0 = No, 1 = Yes), getting an HIV test (0 = No, 1 = Yes), and/or casual sex or “hooking-up” (0 = No, 1 = Yes).

Data Analysis

Weighted bivariate tests of association (χ^2 , independent sample *t* test) were used to determine correlations between demographic variables, GSN app use, social network member characteristics and each of the three primary behavioral risk outcomes (i.e., number of recent sex partners, UAI at last sex, and UAI with last GSN app-met partner). Statistically significant variables at the bivariate level and theoretically important covariates were included in a multivariate linear regression model for the continuous outcome (i.e., number of recent sex partners) and multivariate logistic regression models for the binary outcomes (i.e., UAI at last sex, and UAI with last GSN app-met partner). All data were analyzed using SPSS (SPSS Software for Windows v. 19.0).

Results

Demographic characteristics of the study sample are presented in Table 1. On average, participants were 30.66 years old (*SD* = 6.68). The majority of participants were white (68.86 %), gay-identified (93.01 %), had graduated high school (99.36 %), were employed (78.75 %) and were single (72.89 %). All participants were sexually active, reporting on average nearly 50 lifetime male anal sex partners (*M* = 46.18, *SD* = 39.83) and nearly three male anal sex partners in the past month (*M* = 2.93, *SD* = 3.75). Nearly all participants had been tested for HIV (95.20 %) and more than half had been tested for HIV within the past three months (51.16 %). Similarly, a substantial proportion of the participants reported having ever been tested for another STI (88.60 %) with less than half reporting testing within the past three months (43.98 %). Approximately seven percent of the sample reported having tested positive for HIV (7.34 %); more than half had tested positive for another STI (51.04 %).

Participants were frequent GSN app users, with more than half logging into the app five or more times per day. Nearly sixty percent had been using the app for more than one year (58.97 %) and approximately thirty percent (28.31 %) displayed their naked chest or abs in their profile picture. Participants used the app throughout the day with high percentages logging-in during the morning (64.84 %), afternoon (65.20 %), evening (80.59 %), night (73.99) and late night (53.48 %). A greater percentage of participants with a GSN app-met partner in their network had used the app for longer than one year (73.24 vs. 53.54 %,

$\chi^2 = 10.818$, $p < 0.05$) and logged-in during the morning (76.06 % vs. 61.11 %, $\chi^2 = 4.466$, $p < 0.05$). MSM with a GSN app-met network member had a statistically significantly higher number of lifetime ($t = 3.298$, $p < 0.01$) and recent ($t = 3.315$, $p < 0.01$) anal sex partners and a greater percentage reported UAI at last sex ($\chi^2 = 15.948$, $p < 0.001$), UAI with their last GSN app-met partner ($\chi^2 = 24.649$, $p < 0.001$) and a previous STI diagnosis ($\chi^2 = 4.521$, $p < 0.05$). A statistically significantly higher percentage of participants with a GSN app-met partner in their network had been tested for HIV ($\chi^2 = 4.156$, $p < 0.05$) (data not presented in tables).

Participants nominated a total of 1,475 social network members, comprised of family (13.44 %), friends (65.05 %), main partners (6.17 %), casual partners (9.10 %), coworkers (2.86 %) and others (3.16 %). Social network members met through GSN apps were younger on average compared to social network members met elsewhere ($t = 4.184$, $p < 0.001$); a greater percentage were gay-identified ($\chi^2 = 68.82$, $p < 0.001$), and main ($\chi^2 = 6.880$, $p < 0.01$) or casual ($\chi^2 = 190.25$, $p < 0.001$) partners compared to those not met on the GSN app. While a greater percentage of GSN app-met network members were seen face-to-face in the past month compared to non-GSN app-met network members ($\chi^2 = 10.33$, $p < 0.001$), participants reported receiving emotional ($\chi^2 = 31.96$, $p < 0.001$) and instrumental ($\chi^2 = 30.65$, $p < 0.001$) support from a greater percentage of network members met elsewhere compared to network members met on the GSN app. A greater percentage of non-GSN app-met network members were perceived to object to GSN app use ($\chi^2 = 13.25$, $p < 0.001$), object to participants meeting men through the GSN app ($\chi^2 = 16.46$, $p < 0.001$) and object to participants having concurrent sex ($\chi^2 = 13.34$, $p < 0.001$) compared to participants met via GSN app. Participants talked to greater percentage of GSN app-met network members about condoms or safer sex ($\chi^2 = 16.59$, $p < 0.001$), getting an HIV test ($\chi^2 = 14.24$, $p < 0.001$) and casual sex or “hooking-up” ($\chi^2 = 22.99$, $p < 0.001$) compared to non-GSN app-met network members. Table 2 contains a complete list of social network member characteristic differences between GSN app-met and non-GSN app met partners.

Bivariate associations between individual variables, GSN app use characteristics and the three main outcomes (i.e., number of recent sex partners, UAI at last sex, and UAI with last GSN app-met partner) are presented in Table 3. Having used the GSN app for more than one year (*B* = 1.00, *t* = 1.42, $p < 0.05$) and after midnight (*B* = 1.10, *t* = 2.44, $p < 0.05$) were both associated with having more recent sexual partners, as was inclusion of a GSN app-met partner in the participant’s social network (*B* = 1.44, *t* = 2.85, $p < 0.005$). Single MSM were two and a half times as likely to have engaged in UAI at last sex

Table 1 Descriptive characteristics of total sample (N = 295)

Variable	N (weighted %) or weighted Mean (SD)
Age	30.66 (6.68)
Race/ethnicity	
Black/African American	13 (3.66)
Latino/Hispanic	69 (10.26)
White	152 (68.86)
Asian	30 (10.26)
Mixed	28 (4.76)
Other	3 (1.83)
Sexual orientation	
Gay/homosexual	265 (93.01)
Bisexual	22 (6.62)
Straight/heterosexual	0 (0.00)
Questioning/unsure	4 (0.37)
Queer	1 (0.00)
Other	2 (0.00)
Education	
Less than high school	5 (0.73)
High school graduate or GED	28 (4.03)
Some college or university	115 (25.00)
4 year college/university degree	112 (45.42)
Master's degree or professional degree	30 (20.15)
Doctorate	5 (4.76)
Employed	209 (78.75)
Who are you "out" to?	
Parents	204 (75.46)
Brothers or sisters	209 (76.56)
Other family	185 (69.60)
Co-workers	226 (87.55)
Friends	280 (96.70)
No one	11 (1.10)
Current relationship status	
Single	240 (72.89)
Male spouse/life partner: monogamous	6 (5.13)
Male spouse/life partner: open	12 (9.89)
Female spouse/life partner: monogamous	1 (0.00)
Boyfriend: monogamous	19 (2.93)
Boyfriend: open	17 (9.16)
Sexual history	
Male anal sex partners: lifetime	46.18 (39.83)
Male anal sex partners: past 30 days	2.93 (3.75)
Sex partners met on GSN: Past 30 days	1.43 (2.31)
Unprotected anal intercourse at last sex	85 (29.04)
Unprotected anal intercourse with last GSN sex partner	50 (17.04)
HIV testing	
Has had HIV test	252 (95.20)
Last HIV test	

Table 1 continued

Variable	N (weighted %) or weighted Mean (SD)
Within 3 months	108 (51.16)
Greater than 3 months and less than 6 months	63 (20.93)
Greater than 6 months and less than 1 year	32 (9.69)
Greater than 1 year	49 (18.22)
Positive HIV test	17 (7.34)
STI testing other than HIV	
Has had STI test	228 (88.60)
Last STI test	
Within 3 months	91 (43.98)
Greater than 3 months and less than 6 months	55 (24.07)
Greater than 6 months and less than 1 year	30 (8.71)
Greater than 1 year	52 (22.82)
Positive STI test	100 (51.04)

compared to MSM who reported being in a relationship (OR = 2.55, $p < 0.05$) and those who used the GSN app five or more times per day were nearly two and a half times as likely to have engaged in UAI at last sex compared to MSM who used the GSN app less than five times a day (OR = 2.36, $p < 0.01$). Participants who had used the app for more than one year were 1.77 times as likely to have engaged in UAI compared to those who had used the app for less time ($p < 0.05$). Including a GSN app-met partner in one's network was associated with nearly two and half times the odds of having engaged in UAI at last sex (OR = 2.34, $p < 0.001$) compared to not including a GSN app-met partner in one's network.

White men were more than twice as likely to have engaged in UAI with their last GSN app-met partner compared to men of other racial/ethnic backgrounds (OR = 2.29, $p < 0.05$); single men were more than three times as likely to have engaged in UAI with a GSN app-met partner compared to men in relationships (OR = 3.10, $p < 0.01$) and those who used the GSN app five or more times per day were more than twice as likely to have engaged in UAI with a GSN app-met partner compared to those who used the app less frequently (OR = 2.37, $p < 0.05$). Those who included a person met on the GSN app in their social networks were nearly 5 times as likely to have engaged in UAI with their last GSN app-met partner compared to those who had not included a person met on the GSN app in their network ($p < 0.001$). In multivariate analyses (Table 4), including a GSN app-met partner in one's network was the strongest predictor of having more recent sex partners and having engaged in UAI at last sex and last sex with a GSN app-met partner after adjusting for all other covariates.

Table 2 Social network alter characteristics of GSN met alters and non-GSN met alters

Variable	All (N = 1,475) N (weighted %) or Weighted Mean (SD)	Non-GSN met alters (N = 1,353)	GSN met alters (N = 87)	χ^2 or T-test	Sig.
Network density ^a	0.72 (0.20)	0.75 (0.19)	0.63 (0.19)	4.493	<0.001***
Age	34.44 (11.32)	34.8 (11.55)	31.3 (7.91)	4.184	<0.001***
Male gender	861 (66.64)	761 (64.16)	82 (100.00)	-25.88	<0.001***
Race/Ethnicity				18.41	0.010*
Black/African American	94 (5.46)	87 (5.43)	6 (6.60)		
Latino/Hispanic	353 (18.66)	322 (17.76)	22 (30.19)		
White	762 (59.22)	701 (59.45)	43 (53.77)		
Asian	154 (10.25)	142 (10.87)	11 (4.72)		
Mixed	52 (3.32)	49 (3.33)	2 (0.94)		
Other	31 (3.17)	25 (3.00)	3 (4.72)		
LGBT sexual orientation	791 (62.71)	687 (59.37)	85 (100.00)	68.82	<0.001***
Relationship with alter					
Intimate	197 (15.27)	148 (11.79)	46 (57.55)	156.87	<0.001***
Life Partner, husband, or wife ^b	22 (3.01)	20 (2.99)	2 (3.77)		0.559
Boyfriend or girlfriend	57 (3.16)	46 (2.83)	10 (7.55)	6.88	0.009**
Lover, sex partner, hook-up	118 (9.10)	82 (5.98)	34 (46.23)	190.25	<0.001***
Family	236 (13.44)	229 (14.70)	0 (0.00)	18.02	<0.001***
Friend	943 (65.05)	880 (66.88)	38 (38.68)	33.99	<0.001***
Coworker ^b	45 (2.86)	44 (3.15)	1 (0.00)		0.068
Other ^b	34 (3.16)	32 (3.15)	2 (3.77)		0.771
Known more than 1 year	1,141 (82.26)	1,098 (87.08)	24 (33.96)	192.09	<0.001***
Communicated with in past 30 days					
Face-to-face	1,111 (78.16)	1,020 (77.14)	70 (90.57)	10.33	0.001**
On the phone	1,346 (94.00)	1,239 (94.13)	77 (93.40)	0.10	0.758
Social networking websites	1,085 (71.15)	999 (71.66)	61 (66.98)	1.35	0.245
Through email	672 (54.50)	622 (55.88)	36 (40.57)	9.22	0.002**
Support provided					
Emotional support	946 (65.49)	884 (67.74)	37 (40.57)	31.96	<0.001***
Instrumental support	812 (61.07)	760 (63.15)	35 (35.85)	30.65	<0.001***
Geosocial networking app related					
Use GSN	361 (34.51)	276 (28.89)	77 (96.23)	191.80	<0.001***
Would object to you using GSN	266 (13.51)	254 (14.48)	8 (1.89)	13.26	<0.001***
Would object to you meeting men on GSN	422 (20.35)	394 (21.45)	12 (4.81)	16.48	<0.001***
Sexual behavior and attitudes of network					
Uses condoms regularly	704 (51.71)	652 (51.14)	45 (60.00)	2.67	0.102
Would object to you having sex with men	92 (2.89)	81 (2.94)	7 (1.89)	0.39	0.533
Would object to you having concurrent sex	372 (19.05)	341 (20.19)	19 (5.66)	13.34	<0.001***
Would object to you using condoms	88 (6.23)	73 (5.94)	12 (9.71)	2.30	0.130
Would encourage you to use condoms	1,163 (78.43)	1,081 (79.43)	59 (67.92)	7.66	0.006**
Talk to about					
Condoms or safe sex	804 (53.89)	727 (52.08)	55 (72.64)	16.59	<0.001***
Getting an HIV test	677 (53.01)	615 (51.70)	47 (70.75)	14.24	<0.001***
Casual sex or hooking-up	862 (63.20)	779 (61.52)	64 (84.91)	22.99	<0.001***

* p < .05, ** p < .01, *** p < .001

^a Age weighted with participant sample (N = 295)^b Fisher's exact test

Table 3 Bivariate associations between individual, GSN use characteristics and HIV risk outcomes

	# Sex partners in last 30 days (N = 295)			UAI at last sex (N = 291)			UAI with last GSN partner (N = 229)		
	B	t	Sig.	OR	95 % CI		OR	95 % CI	
Age	0.05	1.37	0.17	1.00	0.97	1.04	1.01	0.85	1.01
White racial/ethnic group	0.19	0.45	0.65	1.00	0.61	1.66	2.29	1.20	4.37*
Gay/homosexual/queer orientation	0.72	1.01	0.31	1.25	0.51	3.06	1.28	0.42	3.86
Employment status	0.26	0.56	0.58	1.07	0.61	1.87	1.38	0.68	2.78
Single relationship status	0.79	1.14	0.26	2.55	1.17	5.55*	3.10	1.33	7.20**
Use GSN 5+times per day	0.71	1.55	0.12	2.36	1.37	4.06**	2.37	1.21	4.64*
Used GSN more than 1 year	1.00	2.18	0.03*	1.77	1.02	3.08*	1.88	0.93	3.83 [#]
Chest or Abs showing on GSN profile picture	0.72	1.42	0.16	1.59	0.91	2.80	1.14	0.57	2.31
GSN use after midnight	1.10	2.44	0.02*	1.52	0.89	2.59	1.11	0.58	2.13
Included a GSN-met partner in their social network	1.44	2.85	0.01**	2.34	1.30	4.21***	4.67	2.41	9.05***

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 4 Multivariate regressions between individual, GSN use characteristics and HIV risk outcomes

	# Sex partners in last 30 days (N = 295)			UAI at last sex (N = 291)			UAI with last GSN partner (N = 229)		
	B	t	Sig.	OR	95 % CI		OR	95 % CI	
Use GSN 5 + times per day	0.07	0.17	0.87	1.14	0.66	1.98	0.94	0.46	1.94
Used GSN more than 1 year	0.51	1.14	0.26	1.09	0.62	1.91	2.11	1.01	4.43*
Chest or Abs showing on GSN profile picture	0.64	1.37	0.17	1.30	0.73	2.32	1.89	0.91	3.93
GSN use after midnight	0.82	1.84	0.07	0.87	0.50	1.53	1.53	0.73	3.21
Included a GSN-met partner in their social network	1.21	2.33	0.02*	2.02	1.10	3.71*	3.98	1.94	8.15***

Adjusting for age, race/ethnicity, sexual orientation, employment, and relationship status

* $p < .05$, ** $p < .01$, *** $p < .001$

Discussion

This study is the first to examine social network characteristics of GSN app-using MSM and demonstrates the importance of considering network variables in the analysis of risk behaviors among this population. Our descriptive findings are consistent with those of other studies documenting demographic and behavioral health characteristics of GSN app users. For example, participants were predominantly White, gay-identified, educated, single men who were highly sexually active, as has been shown in prior work [5, 9, 10]. The vast majority of our sample had been tested for HIV, and, consistent with CDC-guidelines for sexually active MSM, the majority had been tested within 3- to 6-months [21]. Rendina et al. found that among a sample of GSN app users in New York City, more than two-thirds had received an HIV test within the prior year and more than half tested within the prior 6 months [22]. Additionally, more than twice as many participants had been tested within the prior 3 months as had never tested, suggesting that high frequency testing is more common

among GSN app users than not testing at all. Similarly, Phillips et al. found that GSN app users were more likely than non-users to have been tested for HIV within the past year [5]. High rates of HIV testing appears common among GSN app using MSM, which may be attributed to recent efforts to promote testing via GSN apps or prompted by high-risk sexual encounters that occur among MSM using GSN apps [23].

Approximately seven percent of our sample reported HIV-positive serostatus and more than 50 % had tested positive for another STI in their lifetime. These prevalence rates are higher than those among recent community samples of MSM [9], which may suggest a reservoir of prevalent infection among GSN app using MSM that contributes to greater risk for STI/HIV transmission among MSM who use these apps. As mentioned previously, Beymer and colleagues demonstrated greater chlamydia and gonorrhea (although not syphilis or HIV) infection among MSM who reported using GSN apps for partner seeking in Los Angeles, CA, the same city in which we conducted our research [9]. Further exploration of the

extent to which GSN app using MSM's sexual networks contain GSN-app users versus partners met elsewhere will enable researchers to understand STI/HIV transmission patterns within GSN app-using communities. As has been suggested previously, due to the popularity of GSN apps within MSM communities, these venues are prime targets for sexual health promotion and HIV disease prevention [12]. Previous work by our research team demonstrates willingness of young MSM GSN app users to receive HIV prevention information via smartphone app. Development of innovative, culturally tailored prevention interventions for GSN app-using men should be of primary importance for researchers and practitioners.

A handful of individual GSN app use characteristics were associated with high-risk sexual behaviors. For example, having used the app for greater than one year, logging onto the app multiple times per day, and using the app after midnight were all associated at the bivariate level with at least one of the primary risk behavior outcomes. Winetrobe et al. found similar results using data exclusively from the young MSM subsample included in our analysis. These parallel findings perhaps indicate the utility of understanding the specific ways in which GSN apps are used which could provide critical information on the development and tailoring of HIV prevention interventions for GSN app platforms [8]. For example, more targeted interventions might need to be developed for GSN app users based on their duration, frequency, location, and circumstances of use. Through partnerships with GSN app companies it may be possible to harness back-end user data regarding frequency and timing of GSN app use in order to deliver tailored messaging to users who may be at heightened risk for engagement in HIV risk behaviors. The use of "pop-up" messaging is common within GSN apps and is often utilized for advertising and gathering user feedback. Integrating public health messaging into GSN apps will require deliberate, thoughtful partnerships between GSN app companies and public health researchers so as not to violate the terms of service provided by app companies or alienate users.

Approximately 20 % of the men in our sample reported a GSN app-met individual as part of their closest social network. These findings demonstrate the importance of GSN apps in the lives of MSM and illustrate how these apps are being used in the formation of social network ties. Network members who were met via GSN app were exclusively male, younger, and more likely to be gay or bisexually identified than network members met elsewhere. Previous research has demonstrated that MSM use GSN apps for a variety of reasons, including meeting friends, dating, and seeking connection to the gay community [7]. Our findings show that 10 % of GSN-app met network members were main partners, nearly 50 % were lovers, sex

partners or "hook-ups," and an additional 40 % were friends. Moreover, GSN app met network members were more likely to communicate with participants face-to-face and to talk to participants about condoms and safer sex, getting an HIV test, and casual sex or "hooking up." Those who had integrated a GSN app-met individual into their network also had more recent sexual partners, were twice as likely to have had UAI with their last sexual partner, and were nearly four times as likely to have had UAI with their last GSN app-met partner.

Higher levels of HIV risk behavior among GSN app users who integrate other GSN app users into their closest social networks presents interesting challenges and opportunities for HIV prevention researchers. Extant research shows that perceived network norms are strongly associated with HIV risk behaviors. Participants in our study perceived that their GSN met network members endorsed more risky norms compared to their non-GSN network members; participants perceived that most GSN app-met network members would *not* be encouraging of condom use or discouraging of concurrent sexual partnerships. Introduction of these permissive sexual norms (or perceived norms) into networks may contribute to normalization of sexual risk behavior among men in our study. From our cross-sectional data it is impossible to ascertain whether men who hold values that promote risky sexual behavior themselves are more likely to seek out others who share those values or if values regarding condom use and concurrency held by GSN app-met network members were transmitted to MSM in our study via networks. Longitudinal network research among GSN app-using MSM is needed to understand the mechanisms by which high-risk sexual behavior occurs and possibilities for leveraging network connections to promote safer sexual behaviors among GSN app-using MSM. Other technology platforms, such as Facebook, have been harnessed to disseminate HIV prevention information through networks of users [24]. Similar interventions that are designed for use on GSN app platforms and/or complementary apps for HIV prevention should be explored further.

Limitations

Limitations of our research should be taken into consideration when interpreting findings. As mentioned above, this was a cross-sectional study, making it impossible to determine the direction of our findings or causality. All profile data used for determining eligibility and survey data used for determining behavioral risk was collected via self-report, which may underestimate or overestimate the actual prevalence of HIV risk behaviors. We hope that enabling MSM to take the survey using their private computers, smartphones and/or tablets contributed to veracity in reporting of sexual

behaviors. While duplicate responses were prohibited due to tracking of IP addresses; it is possible that multiple surveys were completed on different devices by the same users. In addition, we gathered data on the composition and attitudes of participants' social network members from the participants themselves, without consulting nominated network members. It is quite possible that participants' perceptions of the attitudes and behaviors of their network members does not mirror actual attitudes or behavior. However, several studies have shown the importance of perception of peer behavior on the actual risk behavior of participants, so this may be less of a concern [17, 25]. In this analysis we do not present data on sexual abuse, trauma, mental health issues or substance use—all factors shown to be important correlates of engagement in sexual risk behavior. Further research should seek to incorporate these variables in order to gain a more nuanced perspective on sexual risk behaviors of GSN app users. Finally, our data are only generalizable to other users of the GSN app used for sampling in the neighborhoods in which our data was collected. While many of our results are similar to those of other studies of GSN app users in other major urban centers, lending to the external validity of our findings, these results may not extend to other GSN apps or other MSM communities throughout the country.

Conclusions

Despite the limitations of the present study, this work provides useful insights for the development and tailoring of future interventions to prevent the spread of HIV and other STIs among GSN app using MSM. Potential areas for further exploration include: (1) partnering with GSN app companies to deliver targeted prevention messaging based on user characteristics that have been associated with greater engagement in HIV risk behaviors; and (2) developing strategies for engagement of sexual networks established and maintained via GSN apps to promote diffusion of norms that encourage safer sex. Longitudinal research is needed to further elucidate the pathways by which MSM engage in sexual behaviors that place them at heightened risk for STIs/HIV. As GSN apps and other technologies become increasingly integrated into the socialization and partner-seeking of MSM, a better understanding of the mechanisms by which technology influences risk taking behaviors will inform the development and tailoring of technology-based interventions to prevent HIV among MSM.

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