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Association between where men who have sex with men (MSM) meet sexual partners and chlamydia/gonorrhea infection before and during the COVID-19 pandemic in San Diego, CA

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King, Colin Michael Baile

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Association between where men who have sex with men (MSM) meet sexual partners and  
chlamydia/gonorrhea infection before and during the COVID-19 pandemic in San Diego, CA

A Thesis submitted in partial satisfaction of the requirements  
for the Master's degree

in

Public Health

by

Colin Michael Baile King

Committee in charge:

Professor Richard Garfein, Chair  
Professor Britt Skaathun, Co-Chair  
Professor Angela Bazzi  
Professor Susan Little

2022

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University of California San Diego

2022

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## LIST OF ABBREVIATIONS

aOR	Adjusted Odds Ratio
CDC	Centers for Disease Control and Prevention
CHBRP	California Health Benefits Review Program
CI	95% Confidence Interval
COVID-19	Coronavirus disease caused by SARS-CoV-2 virus
CT	Chlamydia trachomatis (chlamydia)
GC	Gonorrhea
GHB	Gamma Hydroxybutyrate
GSN	Geosocial Networking
GTG	Good To Go Sexual Health Clinic
HIV	Human Immunodeficiency Virus
IRB	Internal Review Board
MSM	Men who have Sex with Men
OR	Odds Ratio
PCR	Polymerase Chain Reaction
PIRC	Preventative Intervention Research Centers
PrEP	Pre-Exposure Prophylaxis (e.g. Truvada or Descovy)
NAAT	Nucleic Acid Amplification Test
NG	Neisseria gonorrhoeae (gonorrhea)
SD	Standard Deviation
STD	Sexually Transmitted Disease
STI	Sexually Transmitted Infection

## ACKNOWLEDGEMENTS

I would like to acknowledge Dr. Richard Garfein and Dr. Britt Skaathun for their support as the co-chairs of my thesis committee. All chapters are coauthored with Skaathun, Britt; Garfein, Richard S.; Bazzi, Angela R.; Little, Susan J. The thesis author was the primary author for all chapters. Chapters 1, 3, 4, and 5 are currently being prepared for submission for publication.

## ABSTRACT OF THE THESIS

Association between where men who have sex with men (MSM) meet sexual partners and chlamydia/gonorrhea infection before and during the COVID-19 pandemic in San Diego, CA

by

Colin Michael Baile King

Master of Public Health

University of California San Diego, 2022

Professor Richard Garfein, Chair  
Professor Britt Skaathun, Co-Chair

Meeting sex partners online is associated with increased risk of acquiring sexually transmitted infections (STIs). We examined whether different venues where men who have

sex with men (MSM) meet sex partners was associated with prevalent chlamydia and gonorrhea infection, and if prevalence increased during (vs. before) the COVID-19 pandemic.

We conducted a cross-sectional analysis of data from the San Diego “Good To Go” (GTG) sexual health clinic from two enrollment periods: (1) 03/2019-09/2019 (pre-COVID-19), and (2) 03/2021-09/2021 (during COVID-19). Participants completed self-administered intake assessments. This analysis included males  $\geq 18$  years old self-reporting sex with other males within 3 months before enrollment. Participants were categorized as (1) meeting new sex partners in-person only (e.g. bars, clubs, etc.), (2) meeting new sex partners online (e.g. applications, websites, etc.), or (3) having sex only with existing partners. We used multivariable logistic regression, adjusting for year, age, race, ethnicity, number of sex partners, PrEP use, and drug use to examine whether venue or enrollment period were associated with chlamydia and gonorrhea infection (either vs. no STI).

Among 2,546 participants, mean age was 35.5 (range: 18-79); 27.9% were non-white; 37.0% were Hispanic. Overall STI prevalence was 14.8% and was higher (17.8%) during COVID-19 versus pre-COVID-19 (13.3). Participants met sex partners online (56.9%), in-person (16.9%), or only had existing partners (26.2%) in the past 3 months. Compared to having only existing sex partners, meeting partners online was associated with higher STI prevalence (adjusted Odds Ratio [aOR]: 2.32; 95% confidence interval [CI]: 1.51-3.65), while meeting partners in-person was not associated with STI prevalence (aOR: 1.59; CI: 0.87-2.89). Enrollment during COVID-19 was associated with higher STI prevalence compared to pre-COVID-19 (aOR: 1.42; CI: 1.13-1.79).

Meeting sex partners online was associated with increased chlamydia/gonorrhea prevalence among MSM. Prevalence appeared to increase during the COVID-19 pandemic.

## CHAPTER 1: INTRODUCTION

In March 2020, the State of California issued an executive shelter-in-place order to help preserve public health amidst the COVID-19 pandemic, however, the pandemic had many negative consequences for sexual health in the United States.<sup>1,2</sup> The shift in resources to respond to the COVID-19 pandemic caused many healthcare clinics to close or limit in-person visits, thereby reducing screening and testing for asymptomatic sexually transmitted infections (STIs).<sup>2</sup> The pandemic also caused a spike in unemployment rates due to mass layoffs, with California maintaining a 7.7% unemployment rate by June 2021, compared to 4.2% in February 2020.<sup>3</sup> These trends, along with loss of employer-sponsored health insurance, may have reduced clinic visits and screening for STIs.<sup>2</sup> However, at the same time, social distancing measures may have decreased in person interactions, which could have offset potential increases in STIs during the pandemic, including gonorrhea and chlamydia.<sup>2,4</sup>

Currently, there are no studies that specifically assess a relationship between gonorrhea and chlamydia amidst shelter-in-place orders due to the COVID-19 pandemic. Moreover, the relationship between gonorrhea and chlamydia and where MSM meet sex partners, such as meeting in-person or online, is understudied, with no studies assessing this relationship during the COVID-19 pandemic. Therefore, additional research is needed to evaluate changes in sexual behaviors, including where MSM met sex partners, throughout the COVID-19 pandemic.

Men who have sex with men (MSM) are disproportionately impacted by STIs, such as gonorrhea and chlamydia.<sup>5</sup> The prevalence of these infections also varies by the site of infection. Studies in the United States have shown that among MSM, the prevalence of urethral gonorrhea and chlamydia range from 0.4% to 11.1% and 2.2% to 8.4%, respectively, prevalence of rectal gonorrhea and chlamydia range from 2.0% to 11.6% and 7.0% to 17.4%, respectively, and

prevalence of pharyngeal gonorrhea and chlamydia range from 1.7% to 16.5% and 1.0% to 2.9%, respectively.<sup>5-20</sup> Importantly, it is estimated that approximately 70% of gonorrhea and chlamydia infections are asymptomatic, thus posing a concern during the COVID-19 pandemic when asymptomatic screening may have declined due to clinics limiting appointments to only patients experiencing symptoms.<sup>2,5,10</sup>

The COVID-19 pandemic also raised concerns about how MSM meet sex partners. Common ways to meet sex partners include in-person venues, such as bars, clubs, gyms, or other physical locations frequented by MSM; through online venues, such as websites or mobile applications; or by seeking existing sex partners.<sup>21</sup> Shelter-in-place orders, such as the one issued by the California State Public Health Officer, limited the ability to meet sex partners through in-person methods due to closures of these types of spaces.<sup>1,22</sup> At the beginning of the COVID-19 pandemic, MSM increased their use of dating applications to connect with other men online; however, this did not directly translate to an increase in meeting sexual partners through online methods.<sup>23,24</sup> Within one month of the initial stay-at-home order, MSM did not change the frequency of using dating apps to meet people in person.<sup>24</sup> However, there is a gap in research as to whether this changed, as stay-at-home orders were extended while the pandemic progressed. As such, with community venues being closed or operating at reduced capacity for an extended period due to the COVID-19 pandemic, it is plausible that MSM moved toward meeting sexual partners through online venues as the pandemic dragged on.

If this is the case, it is also possible that this contributed to increased chlamydia and gonorrhea prevalence during the pandemic. Research from before the pandemic has shown an increase in odds of gonorrhea and chlamydia for MSM who meet sex partners online.<sup>25,26</sup> Specifically, one study identified increased odds of chlamydia (aOR: 2.18; 95% CI: 1.15-4.15)

and gonorrhea (aOR: 2.00; 95% CI: 1.52-4.65) among those who used both online and in-person means to meet sex partners compared to those who used neither, while adjusting for HIV status, number of male sex partners in the past year, and demographics.<sup>25</sup> Another study found increased odds for both chlamydia (OR: 1.37; 95% CI: 1.13-1.65) and gonorrhea (OR: 1.25; 95% CI: 1.06-1.48) in individuals who met sex partners on geosocial networking applications compared to individuals who met in-person only.<sup>26</sup> Part of the reason for the increased odds of gonorrhea and chlamydia in MSM who meet sex partners online could be due to higher rates of sexual risk behavior often seen in this group, including a higher number of sexual partners and a higher use of drugs.<sup>27-29</sup>

The primary aim of this study was to investigate the association between the venues where MSM meet sex partners with gonorrhea and chlamydia prevalence before and during the COVID-19 pandemic. A secondary aim was to determine whether there were changes in the prevalence of gonorrhea and chlamydia, venues where MSM meet sex partners, and other risk behaviors, such as number of sex partners and drug use before and during the COVID-19 pandemic.

I would like to acknowledge Dr. Richard Garfein and Dr. Britt Skaathun for their support as the co-chairs of my thesis committee. This chapter is coauthored with Skaathun, Britt; Garfein, Richard S.; Bazzi, Angela R.; Little, Susan J. The thesis author was the primary author for this chapter. This chapter is currently being prepared for submission for publication.

## CHAPTER 2: LITERATURE REVIEW

### 2.1: Eligibility Criteria

A literature review was conducted to examine chlamydia and gonorrhea risk and prevalence among MSM in the United States. The review included articles that were English-language, published after 1995, included information on an MSM or sexual minority population within the United States, and included the prevalence of *Neisseria gonorrhoeae* (NG) and *Chlamydia trachomatis* (CT). Articles were excluded if they only compared NG/CT collection modalities or were studies that were exclusively on other STIs (i.e. syphilis or HIV). Studies related to the COVID-19 pandemic were included if they assessed changes in sexual behavior during the COVID-19 pandemic, such as changes in the number of sex partners, regardless of whether they reported the prevalence of gonorrhea or chlamydia.

### 2.2: Search Strategy

A systematic review was conducted in January 2022 by performing four searches in PubMed using the following search fields:

1. ((chlamydia OR chlamydia trachomatis OR gonorrhea OR neisseria gonorrhoeae OR gonorrh\* OR gonococcal)) AND (MSM OR same sex OR sexual minorit\*)
2. ((chlamydia OR chlamydia trachomatis OR gonorrhea OR neisseria gonorrhoeae OR gonorrh\* OR gonococcal)) AND (COVID OR COVID-19 OR coronavirus) AND (MSM OR same sex OR sexual minorit\*)
3. ((chlamydia OR chlamydia trachomatis OR gonorrhea OR neisseria gonorrhoeae OR gonorrh\* OR gonococcal OR chlamydia)) AND (venue) AND (MSM OR same sex OR sexual minorit\*)



4. ((chlamydia OR chlamydia trachomatis OR gonorrhoea OR neisseria gonorrhoeae OR gonorrh\* OR gonococcal)) AND (MSM OR same sex OR sexual minorit\*) AND (application\* OR app\* OR website)

This literature search resulted in 853 studies. Abstracts of articles with relevant titles were reviewed to determine relevance. After elimination of duplicate studies or studies that did not meet the eligibility criteria, 22 studies were included and reviewed in full. These studies were grouped into the following categories: COVID-19 related studies, venue related studies, and studies on general gonorrhoea and chlamydia prevalence among MSM.

### 2.3: Study Characteristics

Most of the included studies were cross-sectional 77% (17/22). Three were prospective cohort studies, which provided incidence of gonorrhoea and chlamydia in addition to prevalence. Of the included studies, 14% (3/22) described changes in STD prevalence and/or sexual behaviors due to the COVID-19 pandemic, 18% (4/22) discussed GC/CT prevalence as it relates to specific venues, such as online applications or community-based venues (e.g. bars, clubs). In addition, 68% (15/22) of studies discussed the general prevalence of gonorrhoea and/or chlamydia in their target population. Sample sizes ranged from n=114 to n=103,000.

### 2.4: Results of Literature Review

Table 2.1 shows the studies that were included in the literature review.

#### 2.4.1: General gonorrhoea and chlamydia prevalence among MSM

Most studies provided measures of the prevalence of chlamydia and gonorrhoea among MSM (n=15/22). Measurements for these studies ranged from reporting overall prevalence of

chlamydia or gonorrhea, to identifying the prevalence in each anatomical collection site. In studies that evaluated the prevalence in all anatomical sites for either chlamydia or gonorrhea, the prevalence ranged from 6.4% to 11.0%.<sup>12,19</sup> Studies that evaluated chlamydia and gonorrhea separately identified a prevalence range of 12.2% to 21.9% for chlamydia and 13.2% to 22.8% for gonorrhea.<sup>6,19</sup> Urethral gonorrhea ranged from 0.4% to 11.1%, rectal gonorrhea ranged from 2.0% to 11.6%, pharyngeal gonorrhea ranged from 1.7% to 16.5%, urethral chlamydia ranged from 2.2% to 8.4%, rectal chlamydia ranged from 7.0% to 17.4%, and pharyngeal chlamydia ranged from 1.0% to 2.9%.<sup>6,10,11,13,16</sup> The majority of these studies (14/15) used Nucleic Acid Amplification Testing (NAAT) for detection of *Chlamydia trachomatis* and *Neisseria gonorrhoea* in their samples.

The differences in chlamydia and gonorrhea prevalence between studies are likely due to sample characteristics of those being tested for chlamydia and gonorrhea. Four studies tested chlamydia or gonorrhea in only asymptomatic individuals, likely underestimating the population prevalence by omitting symptomatic individuals from the study population. For example, Marcus et. al studied only asymptomatic individuals and reported some of the lowest prevalence for urethral gonorrhea and urethral chlamydia among the studies, with 0.4% of the sample testing positive for urethral gonorrhea and 2.3% of the sample testing positive for urethral chlamydia.<sup>10</sup> Mimiaga et. al measured both asymptomatic and symptomatic individuals and reported that symptomatic individuals were more likely to test positive for gonorrhea and urethral chlamydia.<sup>13</sup> Further, only one study tested individuals with a history of receptive anal intercourse. In this study, Danby et. al reported that for MSM with a history of receptive anal intercourse, 22.8% tested positive for gonorrhea at any anatomic site and 21.9% tested positive for chlamydia at any anatomic site.<sup>6</sup> Further, Danby et. al reported a prevalence of 16.5% for

pharyngeal gonorrhea, 17.4% for rectal gonorrhea, 2.2% for pharyngeal chlamydia, and 17.4% for rectal chlamydia, which are all on the higher end of prevalence of infections.<sup>6</sup> These results may also overestimate the prevalence of gonorrhea and chlamydia since this study only included those with a history of receptive anal intercourse. Further, the high prevalence of pharyngeal gonorrhea and chlamydia in this sample could be due to receptive partners being more likely to provide oral intercourse, causing this sample to have a higher prevalence than the general population.

#### 2.4.2: Venue-related studies for gonorrhea and chlamydia prevalence among MSM

Four studies identified gonorrhea and chlamydia prevalence specific to venues, with one study evaluating a community venue sample of MSM, defined as physical locations frequented by MSM (e.g. bars, clubs, fitness centers, etc.), and three studies evaluating online venues. The study that sampled a community venue found a 12.5% prevalence of extragenital (rectal or pharyngeal) chlamydia or gonorrhea infection in MSM.<sup>21</sup> Two of the studies of online venues compared the prevalence of meeting sex partners online and meeting sex partners in-person, and both found that there were increased odds of reporting an STI if individuals met sex partners online. Beymer et. al found an increased odds for both chlamydia (OR: 1.37; 95% CI: 1.13-1.65) and gonorrhea (OR: 1.25; 95% CI: 1.06-1.48) in individuals who met sex partners on geosocial networking (GSN) applications, such as Grindr and Scruff, compared to individuals who met in-person only.<sup>26</sup> Allen et. al found an increased odds of chlamydia (aOR: 2.18; 95% CI: 1.15-4.15) and gonorrhea (aOR: 2.00; 95% CI: 1.52-4.65) among those who used both online and in-person means to meet sex partners compared to those who used neither, while adjusting for HIV status, number of male sex partners in the past year, and demographics.<sup>25</sup> One study compared

the different types of applications for meeting sex partners online and found that the Scruff phone application was significantly associated with testing positive for an STI (OR: 2.28; 95% CI: 1.09-4.94).<sup>26</sup>

#### 2.4.3: COVID-19-related studies of sexual behavior changes among MSM

Two studies examined behavior changes during the COVID-19 pandemic. One study found that there was increased use of mobile applications to connect with other men among MSM (PR: 1.52; 95% CI: 1.14, 2.03), however, there was not an increase in meeting in-person (PR: 0.91; 95% CI: 0.50-1.65) and the number of sex partners remained the same (PR: 0.86; 95% CI: 0.73-1.00).<sup>24</sup> Another study found that there was a decrease in sexual behaviors (e.g. kissing, anal sex, number of sex partners) among MSM at the start of the pandemic between February to April 2020, however, these sexual behaviors began to see an increase between April to June 2020.<sup>30</sup> There are currently no studies that evaluate the long-term impact of continued social distancing measures and clinical closures.

#### 2.5: Acknowledgement

I would like to acknowledge Dr. Richard Garfein and Dr. Britt Skaathun for their support as the co-chairs of my thesis committee. This chapter is coauthored with Skaathun, Britt; Garfein, Richard S.; Bazzi, Angela R.; Little, Susan J. The thesis author was the primary author for this chapter.

Table 2.1: Current literature for the prevalence of chlamydia and gonorrhea in different settings

First Author (Publication Year)	Title	Aim(s)	Study Design	Study period	Population	Total Participants	Main Findings
<b>Community Venue related studies:</b>							
Johnson Jones (2019)	Extragenital Chlamydia and Gonorrhea Among Community Venue--Attending Men Who Have Sex with Men -- Five Cities, United States, 2017	To find the prevalence of extragenital chlamydia and gonorrhea in a community venue setting	Descriptive, cross-sectional study	2017	MSM who participated in National HIV Behavioral Surveillance	2,371	Approximately one in eight participants had extragenital chlamydia or gonorrhea.
<b>Online Venue related studies:</b>							
Allen (2017)	Mobile Phone and Internet Use Mostly for Sex-Seeking and Associations with Sexually Transmitted Infections and Sample Characteristics among Black/African American and Hispanic/Latino Men who have Sex with Men in Three U.S. Cities	To determine the association of STI prevalence and use of mobile phones and/or Internet to meet sexual partners	Descriptive and analytic cross-sectional study	June - October 2014	Black and Hispanic/Latino MSM in U.S.	1,759	Men who reported use of both mobile phones and computer-based Internet for sex-seeking had increased odds of reporting an STI (AOR=2.59, 95% CI=1.75-3.83).
Beymer (2014)	Sex On-Demand: Geosocial Networking Phone Apps and Risk of Sexually Transmitted Infections among a Cross-Sectional Sample of Men who have Sex with Men in Los Angeles County	To determine whether there was an increased incidence of STIs for MSM who use geosocial networking apps to meet sex partners compared to those who only meet in person	Analytic, cross-sectional study	August 2011 - January 2013	HIV-negative MSM	7,184	Individuals who used GSN apps to meet sexual partners had greater odds of testing positive for gonorrhea (OR: 1.25; 95% CI: 1.06-1.48) and for chlamydia (OR: 1.37; 95% CI: 1.13-1.65) compared to individuals who met partners through in-person methods only.

Table 2.1: Current literature for the prevalence of chlamydia and gonorrhea in different settings (continued)

First Author (Publication Year)	Title	Aim(s)	Study Design	Study period	Population	Total Participants	Main Findings
Chan (2018)	A network analysis of sexually transmitted diseases and online hookup sites among men who have sex with men	To determine whether there was an association between STDs and using online hookup sites	Descriptive and analytic cross-sectional study	October 2014 - January 2017	MSM in Rhode Island	415	75% of MSM who met partners online and were diagnosed with an STD had met a partner on Grindr. Scruff was significantly associated with testing positive for an STD. Alcohol consumption and crystal meth use were behaviors associated with testing positive for an STD.
COVID-19 related studies:							
Pampati (2021)	Changes in Sexual Behavior, PrEP Adherence, and Access to Sexual Health Services Because of the COVID-19 Pandemic Among a Cohort of PrEP-Using MSM in the South	To assess how sexual behaviors and PrEP use changed during the COVID-19 pandemic.	Prospective Cohort	October 2019 to July 2020	PrEP-using MSM in Southern United States	56	82% reported a decrease in sexual activity with casual sex partners. Longitudinal trends in sexual behaviors (e.g. kissing, anal sex) showed a decline from Feb-April 2020 and an increase from April-June 2020.
Sanchez (2020)	Characterizing the Impact of COVID-19 on Men Who Have Sex with Men Across the United States in April, 2020	To identify COVID-19 impacts on sexual health and behavior	Descriptive study, cross-sectional	April 2 - April 13, 2020	MSM in U.S.	1,051	Increased use of dating apps to connect with other men, although no change in the use of dating apps to meet men in person. Increased use of recreational drugs and alcohol consumption. Decreased access to STI testing/treatment and condoms.

Table 2.1: Current literature for the prevalence of chlamydia and gonorrhea in different settings (continued)

First Author (Publication Year)	Title	Aim(s)	Study Design	Study period	Population	Total Participants	Main Findings
<b>General Gonorrhea and Chlamydia Prevalence in MSM:</b>							
Danby (2016)	Patterns of Extragenital Chlamydia and Gonorrhea in Women and Men Who Have Sex with Men Reporting a History of Receptive Anal Intercourse	To assess the prevalence of GC and CT at all collection sites.	Cross-sectional	March 2014 to March 2015	MSM	224	In MSM, 22.8% had GC and 21.9% had CT. GC was detected in 16.5% of pharyngeal swabs, 11.6% of rectal swabs, and 5.4% for urogenital sites. CT was detected in 2.2% of pharyngeal, 17.4% for rectal, and 4.5% for urogenital.
Gunn (2008)	Gonorrhea screening among men who have sex with men: value of multiple anatomic site testing, San Diego, California, 1997-2003	To estimate the proportion of GC infections in MSM at all collection sites	Cross-sectional	1997-2003	MSM	7,733	Prevalence of GC at any site was 15.8%. The individual prevalence was 10.8% for urethral, 9.8% for rectal, and 4.0% for pharyngeal.
Kent (2005)	Prevalence of Rectal, Urethral, and Pharyngeal Chlamydia and Gonorrhea Detected in 2 Clinical Settings among Men Who Have Sex with Men: San Francisco, California, 2003	To determine the prevalence of rectal, urethral, and pharyngeal chlamydia and gonorrhea infections among MSM	Descriptive, cross-sectional study	July - December 2003	MSM in San Francisco, CA	6,434	The prevalence of chlamydia infection was 7.9% for rectal, 5.2% for urethral, and 1.4% for pharyngeal. The prevalence of gonorrhea was 6.9% for rectal, 6.0% for urethral, and 9.2% for pharyngeal.

Table 2.1: Current literature for the prevalence of chlamydia and gonorrhea in different settings (continued)

First Author (Publication Year)	Title	Aim(s)	Study Design	Study period	Population	Total Participants	Main Findings
Kim (2003)	Risk Factors for Rectal Gonococcal Infection Amidst Resurgence in HIV Transmission	Determine behavioral risk factors associated with rectal gonorrhea among MSM by HIV serostatus.	Cross-sectional	February 2000 to October 2000	Men reporting receptive anal sex	564	Rectal GC was 7.1%
Marcus (2011)	Infections missed by urethral-only screening for chlamydia or gonorrhea detection among men who have sex with men	To estimate the prevalence of GC and CT infections in MSM at all collection sites	Cross-sectional	2008-2009	MSM	3,398	0.4% had urethral gonorrhea, 3.6% had rectal gonorrhea, 5.0% had pharyngeal gonorrhea. 2.3% had urethral chlamydia, 7.8% had rectal chlamydia, 1.9% had pharyngeal chlamydia In MSM, rectal gonorrhea had 2% prevalence at baseline and 2% incidence; pharyngeal gonorrhea had 3% prevalence and 1% incidence; rectal chlamydia had 7% prevalence and 5% incidence; pharyngeal chlamydia had 1% prevalence at baseline and 2% incidence.
Mayer (2012)	Ongoing Sexually Transmitted Disease Acquisition And Risk Taking Behavior Among U.S. HIV-Infected Patients In Primary Care: Implications For Prevention Interventions	To determine incidence and prevalence of STDs among HIV-positive persons	Prospective cohort	March 1, 2004 and June 30, 2006	HIV-infected persons	557	



Table 2.1: Current literature for the prevalence of chlamydia and gonorrhea in different settings (continued)

First Author (Publication Year)	Title	Aim(s)	Study Design	Study period	Population	Total Participants	Main Findings
Mimiaga (2008)	Asymptomatic gonorrhea and chlamydial infections detected by nucleic acid amplification tests among Boston area men who have sex with men	To determine the prevalence of asymptomatic STDs in MSM	Cross-sectional	March 2007	MSM	114	11% tested positive for either gonorrhea or chlamydia
Mimiaga (2009)	Gonococcal, chlamydia, and syphilis infection positivity among MSM attending a large primary care clinic, Boston, 2003 to 2004	To identify the prevalence of STDs in asymptomatic MSM	Cross-sectional	2003-2004	MSM	21,927	Among all asymptomatic MSM tested, 1.0% had urethral gonorrhea, 1.7% had pharyngeal gonorrhea, 5.6% had rectal gonorrhea, and 2.2% had urethral chlamydia. Among all MSM, 13.4% had rectal gonorrhea, 1.9% had pharyngeal gonorrhea, 3.4% had rectal gonorrhea, and 5.8% had urethral chlamydia.
Morris (2006)	Prevalence and incidence of pharyngeal gonorrhea in a longitudinal sample of men who have sex with men: the EXPLORE study	To examine the prevalence and incidence of pharyngeal GC among HIV-negative MSM.	Prospective cohort	March 2001 through July 2003	MSM enrolled in Project EXPLORE	603	Prevalence of pharyngeal gonorrhea was 5.5%. The incidence rate was 11.2 cases per 100 person-years.

Table 2.1: Current literature for the prevalence of chlamydia and gonorrhea in different settings (continued)

First Author (Publication Year)	Title	Aim(s)	Study Design	Study period	Population	Total Participants	Main Findings
Park (2012)	Sentinel surveillance for pharyngeal chlamydia and gonorrhea among men who have sex with men--San Francisco, 2010	To determine the positivity rate of pharyngeal CT and GC specimens	Cross-sectional	2010	MSM	12,454	Pharyngeal CT positivity rate was 1.69% and pharyngeal GC positivity rate was 5.76%
Patton (2014)	Extragenital Gonorrhea and Chlamydia Testing and Infection Among Men Who Have Sex With Men—STD Surveillance Network, United States, 2010–2012	To assess the number of MSM attending STD clinics who tested positive for GC/CT	Cross-sectional	July 2011–June 2012	MSM	21,994	Of MSM tested, 11.1% tested positive for urogenital GC, 7.9% for pharyngeal GC, 10.2% for rectal GC, 8.4% for urogenital CT, 2.9% for pharyngeal CT, and 14.1% for rectal CT
Rieg (2008)	Asymptomatic sexually transmitted infections in HIV-infected men who have sex with men: prevalence, incidence, predictors, and screening strategies	To determine the prevalence and incidence of STIs among MSM	Cohort	April 2004 to September 2006	HIV-infected MSM	212	Baseline prevalence of STIs was 14%. Incidence of new STIs was 20.8 cases per 100 person years.
Tabet (1998)	Incidence of HIV and sexually transmitted diseases (STD) in a cohort of HIV-negative men who have sex with men (MSM)	To determine the prevalence of sexually transmitted diseases (STD) and incidence among a cohort of MSM	Prospective cohort	1995	HIV-negative MSM	578	Of 31 participants with a symptomatic bacterial STD syndrome, 5 participants reported CT and 11 reported GC.

Table 2.1: Current literature for the prevalence of chlamydia and gonorrhoea in different settings (continued)

First Author (Publication Year)	Title	Aim(s)	Study Design	Study period	Population	Total Participants	Main Findings
Taylor (2015)	HIV status and viral loads among men testing positive for rectal gonorrhoea and chlamydia, Maricopa County, Arizona, USA, 2011–2013	To determine the prevalence of rectal GC and CT	Cross-sectional	October 2011 through September 2013	Men tested for rectal GC and CT	1,591	13.2% tested positive for GC, 12.2% tested positive for CT, and 6.4% tested positive for both.
Turner (2013)	HIV, rectal chlamydia and rectal gonorrhoea in men who have sex with men attending an STD clinic in a midwestern US city	To determine the prevalence of rectal GC and CT	Cross-sectional	November 2010 to December 2011	MSM who report receptive anal intercourse	326	Prevalence of rectal GC, rectal CT and either rectal infection was 9%, 9% and 15% by culture and 24%, 23% and 38% by NAAT, respectively.

## CHAPTER 3: METHODS AND PROCEDURES

### 3.1: Study Design and Sample

Research participants for this cross-sectional analysis were recruited through the “Good To Go” (GTG) sexual health clinic in San Diego, CA during two enrollment periods: (1) pre-COVID-19 (between 03/2019-09/2019) and (2) during COVID-19 (03/2021-09/2021). GTG was initially founded in 2007 as the Early Test Program, a HIV-testing research initiative funded through the National Institutes of Health Primary Infection Resource Consortium grant, which aimed to reduce HIV incidence in the region.<sup>31,32,33</sup> The Early Test was part of an outreach program known as “Lead the Way,” which was rebranded as GTG in 2018 to broaden its scope to more services, including STI testing and treatment.<sup>31</sup> Individuals who visited GTG for STI testing received the “Total Test,” a community-based, confidential acute and early HIV infection and STI screening program. The staff at each site, after protocol training by University of California, San Diego (UCSD) personnel, obtained consent and performed procedures.<sup>33</sup> To receive the Total Test, participants were required to be 18 years of age or older and HIV-negative or with an unknown HIV status. Demographic and sexual risk information were collected at intake via a self-administered risk-assessment. Data from participants who self-identified as a male and reported having sexual intercourse with other males in the 3 months prior to their visit were included in the analysis. The study was approved by the University of California, San Diego Institutional Review Board (IRB).

### 3.2: Measures

Gonorrhea and chlamydia infection, hereafter referred to as STIs, were detected using the Cepheid CT/NG Xpert Rapid PCR Test through urine samples and swabs taken from the rectum and oropharynx.<sup>34</sup> The Cepheid CT/NG Xpert Rapid PCR Test is a validated, NAAT-based point-of-care, test to detect bacterial STIs in urogenital samples, as well as extragenital sites, such as the rectum and pharynx.<sup>35,36</sup> Participants were given the opportunity to receive testing from all anatomical sites, but had the option to decline one or more tests. If a test produced an invalid result, the test was repeated on the original sample. Test results from either STI (gonorrhea or chlamydia) and any collection site (urethral, rectal, or pharyngeal) were combined into one variable to align with the study aims. This also served as an advantage to increase the power in the multivariable analysis. Therefore, if participants tested positive for gonorrhea or chlamydia at any collection site, they were categorized as positive, while participants who tested negative at all collection sites were categorized as negative.

Participants self-reported the venues where they met sex partners in the past 3 months through the risk-assessment provided at intake. We categorized venue type in the past 3 months into three groups: (1) only in-person venues (i.e., bars, clubs, gyms, outdoors, bathhouses, sex clubs, school, work, through friends/family); (2) any online venue (mobile apps, websites, both online/in-person); and (3) only existing sex partners.

### 3.3: Covariates

Studies have shown that number of sexual partners and use of drugs other than marijuana are associated with where people meet sex partners and STI transmission,<sup>26-28</sup> therefore, these variables were included in the analysis as possible covariates. Drug use was coded to include

barbiturates/tranquilizers, crack, cocaine, ecstasy, erectile dysfunction medications, gamma hydroxybutyrate (GHB), heroin, ketamine, methamphetamine, nitrates/nitrites, prescription pain medications, and steroids. Alcohol and marijuana were not evaluated for this study. The referent time period for these variables was past 3 months. Other covariates included were age at enrollment, race, and ethnicity due to their previously identified associations with STI transmission.<sup>37-40</sup> PrEP was also included as a covariate due to the high prevalence of STIs among PrEP users.<sup>41</sup>

### 3.4: Statistical Analyses

Descriptive statistics were calculated for the study sample overall and then stratified by enrollment period. Chi-squared tests, Welch's t-tests, and Wilcoxon Ranked Sum tests were used to assess whether the prevalence of demographic variables (age, race, ethnicity, sex at birth, gender identity, sexual orientation, homeless status, and health insurance) and sexual risk behaviors (number of sex partners in the past 3 months, PrEP use in the past 2 weeks, drug use in the past 3 months) differed between participants recruited pre-COVID-19 and during COVID-19. A p-value of less than 0.05 was considered statistically significant.

Multivariable logistic regression was used to identify associations between the venues where MSM met sex partners and the prevalence of gonorrhea or chlamydia. Having only had sex with existing partners in the past 3 months was considered the reference category for venue. All models were adjusted for enrollment period, age, race, ethnicity, number of sex partners, drug use, and PrEP use. These variables were determined a priori based on previous literature. Additional analyses examined whether year, number of sex partners, or age acted as effect modifiers on the association between venue and STI status. ANOVA likelihood ratio tests were

used to assess whether each interaction term was statistically significant in separate models. P-values of less than 0.05 were considered statistically significant for all models. All analyses were performed using R version 4.0.2.<sup>42</sup>

### 3.5: Acknowledgement

I would like to acknowledge Dr. Richard Garfein and Dr. Britt Skaathun for their support as the co-chairs of my thesis committee. This chapter is coauthored with Skaathun, Britt; Garfein, Richard S.; Bazzi, Angela R.; Little, Susan J. The thesis author was the primary author for this chapter. This chapter is currently being prepared for submission for publication.

## CHAPTER 4: RESULTS

### 4.1: Demographics and Behaviors

Among the 2,546 participants included in this study, 59.0% were under the age of 35 (range: 18-79), 27.9% were non-white, 37.0% were Hispanic/Latino, and 80.6% identified as gay (Table 4.1). In addition, 18.2% of participants had used PrEP in the past 3 months, 15.3% reported recreational drug use in the past 3 months, and the median number of sex partners in the past 3 months was 3 unique sex partners (range: 1-120).

Further, 1,554 and 992 of these participants were enrolled pre-COVID-19 and during COVID-19, respectively (Table 4.1). The two groups of participants differed by age, race, ethnicity, sexual orientation, use of PrEP, and number of sex partners (all  $p < 0.05$ ); therefore, these variables were included in the multivariable analyses. Participants recruited in 2021 were more diverse, particularly with more Latino/Hispanic participants, slightly younger participants, and participants reporting fewer sex partners, on average.



Table 4.1: Characteristics of participants, stratified by year.

<b>Characteristic</b>	<b>Total n=2,546</b>	<b>March-Sept 2019 n=1,554</b>	<b>March-Sept 2021 n=992</b>	<b>p-value<sup>3</sup></b>
	<b>n (%)</b>	<b>n (%)</b>	<b>n (%)</b>	
<b>Age</b>				
<25	317 (12.45)	188 (12.10)	129 (13.00)	0.02*
25-34	1,186 (46.58)	711 (45.75)	475 (47.88)	
35-44	538 (21.13)	312 (20.08)	226 (22.78)	
44-54	273 (10.72)	184 (11.84)	89 (8.97)	
≥55	232 (9.11)	159 (10.23)	73 (7.36)	
<b>Race</b>				
White	1,835 (72.07)	1,092 (70.27)	743 (74.90)	<0.001*
American Indian/ Alaskan Native	33 (1.30)	22 (1.42)	11 (1.11)	
Asian	246 (9.66)	161 (10.36)	85 (8.57)	
Pacific Islander/Native Hawaiian	30 (1.18)	22 (1.42)	8 (0.81)	
Black/African American	183 (7.19)	101 (6.50)	82 (8.27)	
Other	84 (3.30)	51 (3.28)	33 (3.33)	
Multiracial	88 (3.46)	59 (3.80)	29 (2.92)	
Does not want to report	47 (1.85)	46 (2.96)	1 (0.10)	
<b>Ethnicity</b>				
Hispanic/Latino	943 (37.04)	545 (35.07)	398 (40.12)	0.02*
Not Hispanic/Latino	1,596 (62.69)	1,003 (64.54)	593 (59.78)	
Did not report	7 (0.27)	6 (0.39)	1 (0.10)	
<b>Sex at birth</b>				
Male	2,543 (99.88)	1,552 (99.87)	991 (99.90)	1.00
Did not report	3 (0.12)	2 (0.13)	1 (0.10)	
<b>Gender Identity</b>				
Male	2,515 (98.78)	1,534 (98.71)	981 (98.89)	0.54
Do not identify as female, male, or transgender	1 (0.04)	1 (0.06)	0 (0.00)	
Non-binary/Genderqueer/ Gender Fluid/ Agender	25 (0.98)	14 (0.90)	11 (1.11)	
Another identity not listed	2 (0.08)	2 (0.13)	0 (0.00)	
Did not report	3 (0.12)	3 (0.19)	0 (0.00)	
<b>Sexual Orientation</b>				
Gay	2,053 (80.64)	1,286 (82.75)	767 (77.32)	0.001*
Bisexual	390 (15.32)	201 (12.93)	189 (19.05)	
Straight (heterosexual)	32 (1.26)	22 (1.42)	10 (1.01)	
Queer	41 (1.61)	26 (1.67)	15 (1.51)	
Another orientation not listed	27 (1.06)	18 (1.16)	9 (0.91)	
Did not report	3 (0.12)	1 (0.06)	2 (0.20)	
<b>Homeless status (current)</b>				
Homeless	31 (1.22)	20 (1.29)	11 (1.11)	0.83
Not homeless	2,509 (98.55)	1,530 (98.45)	979 (98.69)	
Did not report	6 (0.24)	4 (0.26)	2 (0.20)	

Table 4.1: Characteristics of participants, stratified by year. (continued)

Characteristic	Total	March-Sept 2019	March-Sept 2021	p-value <sup>3</sup>
	n=2,546	n=1,554	n=992	
	n (%)	n (%)	n (%)	
<b>Insurance</b>				
None	567 (22.27)	356 (22.91)	211 (21.27)	0.29
Private	1,477 (58.01)	888 (57.14)	589 (59.37)	
Medicaid / Medi-Cal	252 (9.90)	151 (9.72)	101 (10.18)	
Medicare	39 (1.53)	30 (1.93)	9 (0.91)	
Military	135 (5.30)	79 (5.08)	56 (5.65)	
Other	21 (0.82)	12 (0.77)	9 (0.91)	
Multiple Insurances	24 (0.94)	14 (0.90)	10 (1.01)	
Don't know	31 (1.22)	24 (1.54)	7 (0.71)	
<b>Sexual Behaviors</b>				
	n (%)	n (%)	n (%)	
<b>Venue where MSM met sex partners</b>				
No New Sex Partners in the past 3 months (only existing partners)	668 (26.24)	342 (22.01)	326 (32.86)	<0.001*
In-person venues <sup>1</sup>	430 (16.89)	297 (19.11)	133 (13.41)	
Online Venues <sup>2</sup>	1,448 (56.87)	915 (58.88)	533 (53.73)	
<b>PrEP Use in the past 2 weeks</b>				
Yes	462 (18.15)	308 (19.82)	154 (15.52)	0.01*
No	2,082 (81.78)	1,244 (80.05)	838 (84.48)	
Did not report	2 (0.08)	2 (0.13)	0 (0.00)	
<b>Drug Use in the past 3 months<sup>4</sup></b>				
Yes	389 (15.28)	239 (15.38)	150 (15.12)	0.90
No	2,157 (84.72)	1315 (84.62)	842 (84.88)	
	Median (IQR)	Median (IQR)	Median (IQR)	
<b>Number of Sex Partners in past 3 months</b>	3 (2,5)	3 (2,5)	3 (2,5)	<0.001*

<sup>1</sup>Includes only in-person venues (community venues and social network)

<sup>2</sup>Includes only online venues and online or in-person venues

<sup>3</sup>p-values were calculated using Chi-Squared test for age, Wilcoxon ranked sum test for sex partners, and Welch's t-tests for continuous variables

<sup>4</sup>Excludes alcohol and marijuana

\*statistically significant at the 0.05 level

#### 4.2: Prevalence of Gonorrhea and Chlamydia

Of the participants who received the Total Test, 78.5% completed the rectal CT/NG test, 94.3% completed the pharyngeal CT/NG test, and 94.0% completed the urine CT/NG test. Failure to submit samples for a particular collection site was likely attributed to absence of perceived risk. The prevalence of gonorrhea was highest in extragenital sites, with rectal and pharyngeal gonorrhea at 4.6% each (Table 4.2). Similarly, the prevalence of chlamydia was highest from rectal swabs (6.2%). Further, the prevalence of gonorrhea and chlamydia from in any anatomical site was 7.6% and 8.7%, respectively; the prevalence of chlamydia or gonorrhea from any site overall was 14.8%. The prevalence of gonorrhea and chlamydia regardless of collection sites was higher among participants enrolled during COVID-19 compared to pre-COVID-19, apart from pharyngeal chlamydia, which decreased from 1.2% to 1.0%. Similarly, there was an increase in the prevalence of either STI among participants recruited during COVID-19 compared to those recruited pre-COVID-19 (13.3% vs. 17.0%,  $p=0.01$ ).

Table 4.2: Gonorrhoea and Chlamydia prevalence by anatomical site and year

	Total n=2,546			March-Sept 2019 n=1,554			March-Sept 2021 n=992		
	Gonorrhoea	Chlamydia	Coinfection	Gonorrhoea	Chlamydia	Coinfection	Gonorrhoea	Chlamydia	Coinfection
<b>Rectal</b>	117 (4.60)	157 (6.17)	27 (1.06)	56 (3.60)	93 (5.98)	17 (1.09)	61 (6.15)	64 (6.45)	10 (1.01)
<b>Pharyngeal</b>	116 (4.56)	29 (1.14)	4 (0.16)	67 (4.31)	19 (1.22)	3 (0.19)	49 (4.94)	10 (1.01)	1 (0.10)
<b>Urethral</b>	27 (1.06)	63 (2.47)	5 (0.20)	9 (0.58)	31 (1.99)	1 (0.06)	18 (1.81)	32 (3.23)	4 (0.40)
<b>Total Unique</b>	194 (7.62)	221 (8.68)	39 (1.53)	102 (6.56)	128 (8.24)	23 (1.48)	92 (9.27)	93 (9.38)	16 (1.61)
<b>Total with CT or GC</b>	376 (14.77)			207 (13.32)			169 (17.04)		

### 4.3: Venues where MSM met Sex Partners

Overall, 56.9% of all participants reported using online venues to meet sex partners over the past 3 months, while 16.9% reported only meeting sex partners at in-person venues and 26.2% reported not having any new sex partners (only existing sex partners) (Figure 4.1).

Among participants enrolled pre-COVID-19, 58.9% reported using online venues to meet sex partners over the past 3 months, while 19.1% reported only meeting sex partners in in-person venues, and 22.0% reported only having existing sex partners. During the COVID-19 pandemic, there was an increase in only having existing sex partners in the past 3 months (32.9%), while there was a decrease in meeting sex partners online (53.7%) and at in-person venues (13.4%).

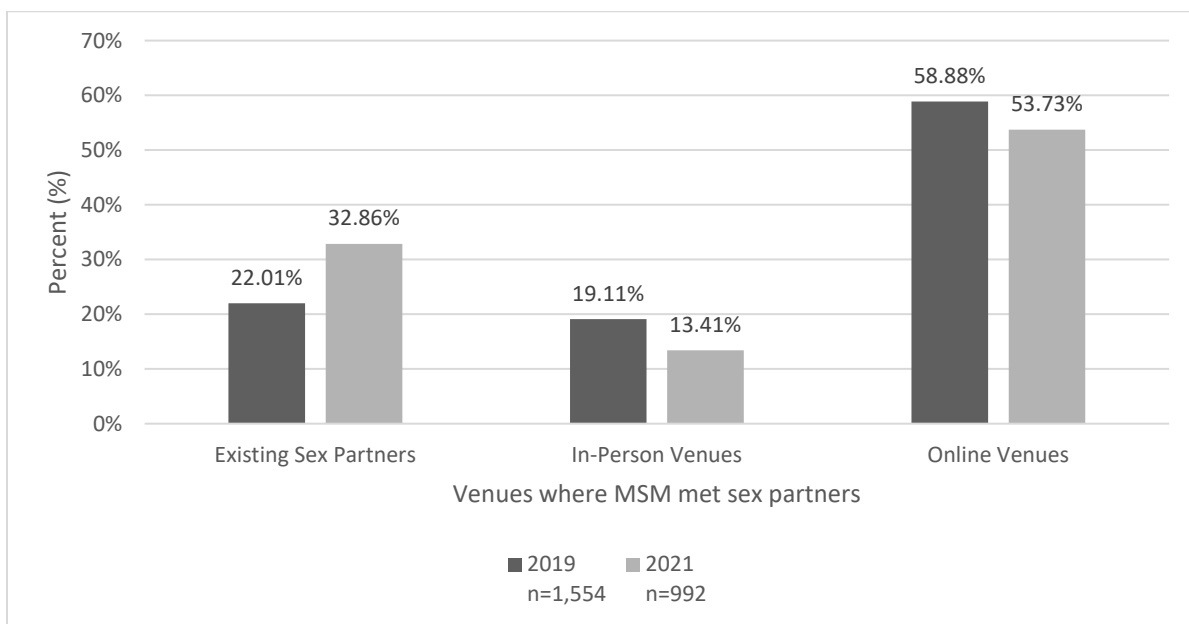


Figure 4.1: Venues where MSM met sex partners in the past 3 months, by year

#### 4.4: STI Prevalence by Venues where MSM met sex partners

STI prevalence was higher in the participants enrolled during COVID-19 compared to pre-COVID-19 for each venue (Figure 4.2). For participants who reported meeting sex partners at in-person venues, the prevalence of gonorrhea and chlamydia increased from 10.8% to 19.6%, while the prevalence increased from 15.4% to 19.7% for participants who reported meeting sex partners online. For participants who only had existing sex partners over the past 3 months, the prevalence of chlamydia and gonorrhea increased slightly from 9.9% to 11.7%. In 2019, the prevalence of gonorrhea and chlamydia for in-person venues was similar to the prevalence for existing partners. However, in 2021, the prevalence for in-person venues increased significantly to nearly the same prevalence as online venues.

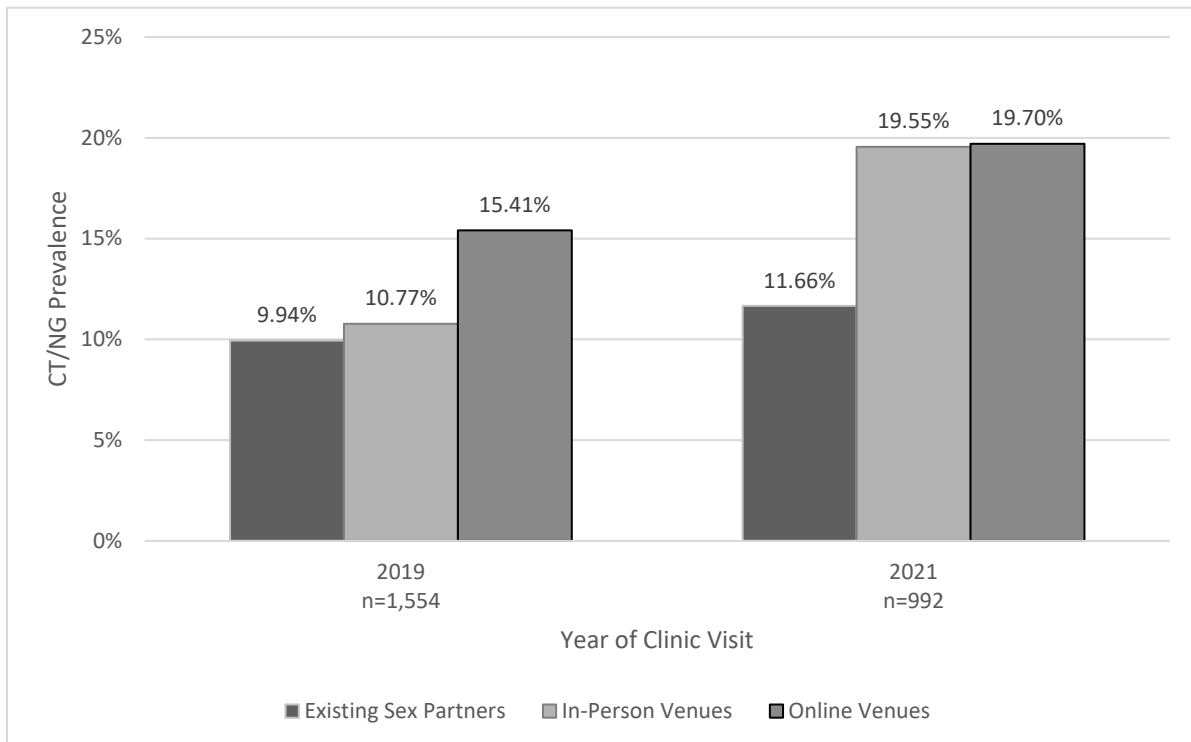


Figure 4.2: CT/NG Prevalence by venue where MSM met sex partners, stratified by year

#### 4.5: Multivariable Logistic Regression

Using multivariable logistic regression analysis to determine the association between gonorrhea and chlamydia with venue, we adjusted for year, age, race, ethnicity, drug use, PrEP use, and number of sex partners and found that meeting new sex partners online was associated with a higher prevalence of gonorrhea or chlamydia (adjusted Odds Ratio [aOR]: 2.32; 95% confidence interval [CI]: 1.51-3.65) compared to having only existing sex partners in the past 3 months (Table 4.5). Meeting new sex partners in-person was not associated with the prevalence of gonorrhea or chlamydia infection compared to having only existing sex partners (aOR: 1.59; CI: 0.87-2.89). Further, the odds of having gonorrhea or chlamydia were higher among those enrolled during COVID-19 versus pre-COVID-19 (aOR: 1.42; CI: 1.13-1.79). The odds of STI infection was also higher among those with younger age (aOR: 0.97; CI: 0.96-0.98), greater number of sex partners over the past 3 months (aOR: 1.33; CI: 1.16-1.55), and PrEP use over the past 2 weeks (aOR: 1.77; CI: 1.35-2.30). Although not statistically significant, those who reported drug use in the past 3 months also had a higher odds of gonorrhea or chlamydia infection (aOR: 1.25; CI: 0.93-2.29). Race and ethnicity were not associated with STI prevalence.

#### 4.6: Effect Modification

Effect modification between the association between venues where participants met sex partners in the past 3 months and gonorrhea or chlamydia infection was investigated independently with potential confounding factors, including enrollment year, age, drug use, and number of sex partners, which are all factors that could be related to both gonorrhea or chlamydia transmission and the venues in which MSM meet sex partners. Of these variables, the

interaction between the number of sex partners and venue was the only interaction statistically associated ( $p=0.001$ ), providing a better model fit. In particular, we found no significant interaction between year and venue ( $p>0.1$ ). Each model with an interaction term was checked for statistical significance using ANOVA likelihood ratio tests. The interaction between venue and number of sex partners was included in the final multivariable logistic regression. Among participants who met sex partners at in-person venues, the odds of gonorrhea and chlamydia increased by 8.58% per increase of 1 sex partner. Among participants who met sex partners online, the odds of gonorrhea and chlamydia increased by 2.63% per increase of 1 sex partner.



Table 4.3: Multivariable analysis of factors associated with Chlamydia and/or Gonorrhea infection among MSM

Covariate	CT/NG+ (n=376)	CT/NG- (n=2,170)	Unadjusted OR (95% CI)	Adjusted OR <sup>1</sup> (95% CI)	Adjusted p-value
<b>Year, n (%)</b>					
2019	207 (13.32)	1,347 (86.68)	1.00 (Reference)	1.00 (Reference)	
2021	169 (17.04)	823 (82.96)	1.34 (1.07, 1.67)	1.42 (1.13, 1.79)	0.003*
<b>Venue, n (%)</b>					
No new sex partners in the past 3 months	72 (10.78)	596 (89.22)	1.00 (Reference)	1.00 (Reference)	
In-person venues <sup>2</sup>	58 (13.49)	372 (86.51)	1.29 (0.89, 1.87)	1.59 (0.87, 2.89)	0.13
Online Venues <sup>3</sup>	246 (16.99)	1,202 (83.01)	1.69 (1.29, 2.26)	2.32 (1.51, 3.65)	<0.001*
<b>Age, Mean (SD)</b>	32.66 (10.19)	35.94 (11.74)	0.97 (0.96, 0.98)	0.97 (0.96, 0.98)	<0.001*
<b>Race</b>					
White	256 (13.95)	1,579 (86.05)	1.00 (Reference)	1.00 (Reference)	
American Indian/ Alaskan Native	6 (18.18)	27 (81.82)	1.37 (0.51, 3.14)	1.01 (0.36, 2.42)	0.99
Asian	37 (15.04)	209 (84.96)	1.09 (0.74, 1.57)	1.13 (0.75, 1.66)	0.56
Pacific Islander/Native Hawaiian	3 (10.00)	27 (90.00)	0.69 (0.16, 1.96)	0.79 (0.18, 2.31)	0.70
Black/African American	33 (18.03)	150 (81.97)	1.36 (0.90, 2.00)	1.32 (0.86, 1.99)	0.19
Other	14 (16.67)	70 (83.33)	1.08 (0.44, 2.29)	1.08 (0.56, 1.93)	0.81
Multiracial	20 (22.73)	68 (77.27)	1.81 (1.06, 2.98)	1.80 (1.03, 3.02)	0.03*
Did not report	7 (14.89)	40 (85.11)	1.23 (0.66, 2.16)	1.21 (0.48, 2.65)	0.66
<b>Ethnicity</b>					
Not Latino/Hispanic	226 (14.16)	1,370 (85.84)	1.00 (Reference)	1.00 (Reference)	
Latino/Hispanic	150 (15.91)	793 (84.09)	1.15 (0.92, 1.43)	1.16 (0.90, 1.50)	0.25
<b>Sex Partners, Mean (SD)</b>	6.09 (6.67)	4.38 (5.53)	1.04 (1.02, 1.06)	1.33 (1.16, 1.55)	<0.001*
<b>Drug Use, n (%)</b>					
No	298 (13.82)	1,859 (86.18)	1.00 (Reference)	1.00 (Reference)	
Yes	78 (20.05)	311 (79.95)	1.56 (1.18, 2.05)	1.26 (0.94, 1.68)	0.12
<b>PrEP Use, n (%)</b>					
No	272 (13.82)	1,810 (86.18)	1.00 (Reference)	1.00 (Reference)	
Yes	104 (20.05)	358 (79.95)	1.93 (1.50, 2.48)	1.77 (1.35, 2.30)	<0.001*
<b>Interaction between venue and number of sex partners, n (%)</b>					
No new sex partners in the past 3 months	-	-	-	1.00 (Reference)	
In-person venues <sup>2</sup>	-	-	-	0.82 (0.69, 0.97)	0.02*
Online venues <sup>3</sup>	-	-	-	0.77 (0.66, 0.89)	<0.001*

\*Statistically significant at the 0.05 level

<sup>1</sup>Adjusted for year of clinic visit, venue, age, race, ethnicity, number of sex partners, PrEP use, and drug use

<sup>2</sup>Includes only in-person venues (community venues and social network)

<sup>3</sup>Includes only online venues and online or in-person venues

#### 4.7: Acknowledgement

I would like to acknowledge Dr. Richard Garfein and Dr. Britt Skaathun for their support as the co-chairs of my thesis committee. This chapter is coauthored with Skaathun, Britt; Garfein, Richard S.; Bazzi, Angela R.; Little, Susan J. The thesis author was the primary author for this chapter. This chapter is currently being prepared for submission for publication.

## CHAPTER 5: DISCUSSION

### 5.1: Discussion of Findings

In this large sample of MSM enrolled before and during the COVID-19 pandemic, we identified independent associations between gonorrhea and chlamydia infection with both venue where participants met new sex partners and enrollment period (pre-COVID-19 and during COVID-19). Specifically, when compared to only having existing sex partners, there were increased odds of gonorrhea and chlamydia infection among participants who met sex partners online. This finding is consistent with other literature showing an increase in odds for gonorrhea and chlamydia for MSM who meet sex partners online.<sup>25,26</sup> Likewise, the prevalence of gonorrhea and chlamydia among participants during COVID-19 was higher compared to pre-COVID-19. However, our study did not find that the year of clinic visit (pre-COVID-19 compared to during COVID-19) modified the relationship between gonorrhea and chlamydia prevalence and the venue where participants met sex partners. This is consistent with research conducted early in the pandemic, showing that although MSM were using online applications more to connect with others, these connections were not leading to increased use of online applications to meet sex partners in-person.<sup>23,24</sup>

Although the interaction term between venue and year was not statistically significant, we did observe a significant increase in gonorrhea and chlamydia prevalence for MSM who met sex partners in-person between pre-COVID-19 in 2019 and during COVID-19 in 2021. Interestingly, the prevalence of gonorrhea and chlamydia for this group was similar to those with only existing sex partners in 2019. However, the prevalence in this group shifted in 2021 to be more similar to online venues. This could suggest that those who met sex partners in-person during the COVID-19 pandemic had engaged in more risky sexual behaviors that were

previously found to be associated with online venues. At the same time, we noted an increase in the percent of MSM who only had existing sex partners in 2021 compared to 2019. This could demonstrate an increase in people having sexual intercourse with trusted partners and a decrease in having sexual intercourse with strangers or anonymous partners in an attempt to decrease the risk of COVID-19 transmission or fewer opportunities to meet in person due to the shelter-in-place orders. Regardless, over 50% of participants reported using online methods to meet sex partners in both study time periods. This provides an opportunity to utilize online methods to educate users on STI transmission, testing, and treatment. For example, an organization called Building Healthy Online Communities (BHOC) has developed initiatives for online health education to promote testing and treatment of STIs, such as messaging on common online venues (i.e. Grindr, Scruff, etc.) to promote testing and condom use and developing online methods to inform partners of potential STD exposure.<sup>43</sup> One study that surveyed state health department HIV and STD programs and online application users noted that these types of interventions could prove effective, among others.<sup>44</sup>

We also found that while the prevalence of gonorrhea and chlamydia increased between pre-COVID-19 and during COVID-19, many of the risk factors declined during this period. For example, there was an increase in MSM having sexual intercourse with existing partners and a decrease in the number of sex partners reported in the previous 3 months. This leads us to speculate that a potential reason for the increase in gonorrhea and chlamydia prevalence in 2021 was due to barriers to clinical care, including a reduction of testing and treating STI infections during the pandemic, resulting in an increased per act risk of acquiring a bacterial STI during COVID, despite similar risk behaviors to the pre-COVID period. A recent study predicted an increase in gonorrhea and chlamydia transmission due to clinic closures while sexual risk

behaviors remained constant.<sup>4</sup> Future research should identify which barriers exist for MSM seeking testing and treatment, and interventions should be put into place to alleviate these barriers. The State of California, for example, recently passed legislation to allow those with state-regulated private insurance plans to reimburse at-home STD collection kits.<sup>45</sup> An objective report by the California Health Benefits Review Program (CHBRP) noted that these types of laws could not only be beneficial for clinical closures, but could increase testing due to privacy, stigma, and financial resource concerns, among others.<sup>46</sup>

It is also important to note that in-person venues had the largest increase in the prevalence of gonorrhea and chlamydia. Factors that enhance sexual risk, such as alcohol and drug use, as well as environmental and interpersonal factors, are commonly associated with sexual risk.<sup>47</sup> Therefore, it could be possible that seeking sex partners at in-person venues, such as bars and clubs, during a pandemic is a non-sexual risk associated with testing positive for STIs.

The majority of our results for the prevalence of gonorrhea and chlamydia in MSM at each collection site are supported by current literature on MSM in the United States, apart from rectal chlamydia.<sup>5-20</sup> For our combined variable of either gonorrhea or chlamydia at any collection site, our study indicated a higher prevalence than current literature. This could be due to clinic closures, as mentioned previously.

Our study also supports prior studies showing that the number of sex partners is directly associated with STI risk.<sup>5,48,49</sup> Interestingly, the added risk of STIs due to increasing numbers of sex partners appeared to be greater among MSM who met new sex partners at in-person venues compared to online venues, which contrasts with prior studies showing that meeting partners online is riskier than meeting partners in other venues.<sup>25,26</sup> More research is needed to investigate

why increased sex partners in community venues has a higher increase in STI prevalence than for those who meet online. Again, this could be that MSM who met sex partners in-person during the pandemic were less risk averse than those who were maintaining social distancing measures throughout the pandemic. Particularly, it could be that individuals who met partners online were more risk averse due to a perception of decreased risk for meeting individuals online, rather than going to in-person venues during the pandemic to meet new partners.

## 5.2: Limitations and Strengths

There were specific limitations to this study. Notably, this study was cross-sectional and cannot determine causality or temporality between the identified associations. We used two cross-sectional samples from different time periods, therefore, differences could be due to differing samples rather than changes over time. Similar to other studies that recruited through sexual health clinics, our findings may overestimate gonorrhea and chlamydia prevalence, since participants may have been seeking testing and treatment due to possible exposure, rather than routine screening.<sup>6,7,16</sup> Last, participants could decline testing in one or more anatomical site. However, the most likely reason for refusing was because participants didn't have exposures that would lead to infection in certain site, so we don't believe this significantly impacted the prevalence estimates. Our study also had several strengths. Given that the study period overlapped with the start of the COVID-19 pandemic, we were able to examine the potential impact that COVID-19 mitigation strategies, such as shelter-in-place orders, had on STI transmission among MSM. Further, STI results were collected through NAAT at a clinic using samples from 3 anatomic sites, thus providing objective and comprehensive STI prevalence estimates. These results were reported individually by collection site and total unique infections,

allowing for this study to expand the current literature for all reporting methods. Although the majority of participants were White, our study included a higher percentage of Black/African American, American Indian/Alaskan Native, Native Hawaiian/other Pacific Islander, and Latino/Hispanic than the general San Diego region.<sup>50</sup>

### 5.3 Conclusion

We hypothesized that MSM would be more likely to meet sex partners through online methods due to the closure of in-person venues, such as bars and clubs, as a result of the COVID-19 shelter-in-place orders. We found that meeting sex partners online was associated with increased gonorrhea and chlamydia prevalence among MSM. Further, our study found that the prevalence of gonorrhea and chlamydia appeared to increase during the COVID-19 pandemic, since those who were enrolled during COVID-19 had higher odds for STIs. However, we did not find that there was a significant interaction between venues and enrollment year, demonstrating that changes in gonorrhea and chlamydia prevalence likely weren't a result of participants using online venues more during the pandemic.

Future studies should continue to assess the relationship between STI transmission and where MSM meet sex partners, including prospective studies to better evaluate individual behavior change during the ongoing COVID-19 pandemic and help determine a causal pathway between behavior change and STI transmission. Qualitative studies are also needed to help determine barriers to STI testing and treatment. These types of studies would also help evaluate possible protective measures that could be occurring for MSM who meet sex partners online and in-person, compared to those who only have existing sex partners. As noted, online venues provide an avenue for essential STI prevention education, however, these programs can be

expensive. Further interventions, such as healthcare coverage for at-home STI testing, could be a method to reduce barriers to testing when there is low access to clinical facilities during as well as after the pandemic. Since STI rates are expected to continue increasing post-COVID-19 pandemic, interventions are needed to address these barriers in the long-term.<sup>51</sup>

#### 5.4: Acknowledgement

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