Social Media Use and STI Incidence in Men Who Have Sex With Men

Thesis

Presented in Partial Fulfillment of the Requirements for the Degree Master of Mathematical Science in the Graduate School of The Ohio State University

By

Niraj Wagh, B.S.

Graduate Program in Mathematical Sciences

The Ohio State University

2015

Thesis Committee:

Adriana Dawes, Advisor

Alison Norris
Abstract

The emergence of social media in the 21st century has led to an increase in the speed of interacting with new individuals on both intimate and non-intimate levels. In this thesis we explore the use of social media applications (apps) on smartphones and its impact on men who have sex with men (MSM). The purpose of this thesis is two-fold: we first examined if social media use led to a higher rate of sexually transmitted infections (STIs) and second, we developed a mathematical model to determine the most effective point of intervention to reduce STI incidence. Our data consisted of 195 men adapted from a prior study conducted by Dr. Cara Rice at the Department of Public Health in Columbus, Ohio. We created and non-dimensionalized a closed susceptible-infected (SI) ordinary differential equation (ODE) model to illustrate how sexually transmitted infections impacted two different MSM populations, one that used social media, and one that did not. The computer software XPP was used to vary the population dynamics in different scenarios to test STI incidence in order to gain insight on efficacy of interventions. Our results showed that those men who use social media apps are more likely to be afflicted with STIs and that the greatest intervention to reduce STI incidence was the use of advertisements on apps and on display in public venues.
Dedication

This paper is dedicated to the many individuals afflicted by sexually transmitted infections.
Acknowledgements

I would like to thank Dr. Adriana Dawes and Dr. Alison Norris for supporting my project. I thank Dr. Adriana Dawes for having the openness in working with me on a project that was new to her area of interest. Her patience, intellect, and flexible attitude have helped me immensely in creating a paper that will help many. I thank Dr. Alison Norris for helping me strengthen myself in understanding epidemiological theory and helping me gain insight on men who have sex with men. Lastly, I would like to thank Dr. Cara Rice for providing me with a data set that was the backbone of this study.
Vita

May 2008………………………………Walled Lake Northern High School

2010 to 2012……………………………..Undergraduate Learning Assistant, Lyman
Briggs College, Michigan State University

2012………………………………..Undergraduate Learning Assistant Teaching
Award, Lyman Briggs College, Michigan State
University

2012……………………………………...B.S. Human Biology, Michigan State University

2012 to 2013…………………………..Graduate Teaching Assistant, Department of
Mathematics, Central Michigan University

2013 to 2015…………………………..Graduate Teaching Associate, Department of
Mathematics, The Ohio State University

2014……………………………………..Distinguished First-Year Graduate Teaching
Associate Teaching Award

2015…………………………………….M.M.S. Mathematics, The Ohio State University

Field of Study

Major Field: Mathematical Sciences

Specialization: Mathematical Biology
Table of Contents

Abstract.........................................................................................................................ii
Dedication.....................................................................................................................iii
Acknowledgements......................................................................................................iv
Vita...............................................................................................................................v
List of Tables................................................................................................................vii
List of Figures...............................................................................................................viii
Chapter 1: Introduction...............................................................................................1
  1.1 Introduction to Men Who Have Sex With Men & Sexually Transmitted Diseases.................................................................1
  1.2 Introduction to Social Media..............................................................................2
  1.3 Data.......................................................................................................................5
Chapter 2: Closed Population....................................................................................9
  2.1 Introduction to Closed Population SI Model.....................................................9
  2.2 SI Model for STI Risk in Closed Population......................................................10
Chapter 3: Parameter Variations..............................................................................18
  3.1 Scenario 1: Advertisements (Ads) on Apps and in Public Venues to Increase Awareness of Safe Sex.................................................18
  3.2 Scenario 2: State Mandate Requires All MSM To Be Tested For STIs...........21
  3.3 Scenario 3: PrEP Becomes Available and Men Engage in Riskier Sex...........24
3.4 Scenario 4: Pride Festivals Increase the Rate of Risky Sex…………………27

Chapter 4: Conclusion………………………………………………………………………..31

4.1 Interventions to Reduce STI Incidence……………………………………………31

4.2 Scenarios to Increase STI Incidence………………………………………………….33

4.3 Final Remarks…………………………………………………………………………35

4.4 Future Research……………………………………………………………………….35

References…………………………………………………………………………………..36
List of Tables

Table 1. Population sizes of each MSM class.........................................................7
Table 2. Risk type of each MSM population out of the general population.................7
Table 3. Risk type of men who were deleted from the study due to HIV+ status..........7
Table 4. Scenario 1 parameter variations based on different cases..........................19
Table 5. Scenario 2 parameter variations based on different cases.........................22
Table 6. Scenario 3 parameter variations based on different cases..........................25
Table 7. Scenario 4 parameter variations based on different cases..........................28
List of Figures

Figure 1. Grindr template…………………….................................................................3

Figure 2. Possible interactions of MSM who access online venues.........................10

Figure 3. Possible transition of states from susceptible to infected class and vice versa after treatment.................................................................11

Figure 4. Case type and population trend as time increases in scenario 1.................20

Figure 5. Case type and population trend as time increases in scenario 2...............23

Figure 6. Case type and population trend as time increases in scenario 3................26

Figure 7. Case type and population trend as time increases in scenario 4..............29
Chapter 1: Introduction

1.1 Introduction to Men Who Have Sex With Men & Sexually Transmitted Diseases

Sexually transmitted infections (STIs) including HIV (human immunodeficiency virus) can have devastating consequences for infected individuals such as reduced lifespan and impaired quality of life. They also represent an economic burden through public health services and reduced productivity. According to the 2013 Centers for Disease Control (CDC) fact sheet, there are 20 million new STIs every year in the United States (CDC, 2013). In addition, the incidence of gonorrhea has decreased by approximately 0.6% since 2012, but chlamydia has increased by 1.5% and primary and secondary syphilis has increased by 10% since 2012 (CDC, 2013). Much theoretical and epidemiological research has been done on transmission risk factors between men who have sex with women, but additional research needs to be conducted on MSM (men who have sex with men).

According to the CDC, MSM account for approximately 4% of men in the U.S. population (CDC, 2011). MSM are classified as a high-risk population in the United States because they are 60 times more likely than other men to contract STIs and 54 more times likely than woman to contract STIs such as gonorrhea, chlamydia, syphilis, and HIV among others (CDC, 2011).

A significant problem of many STIs and HIV is that many men don’t know whether or not they have an infection, as the infections can be asymptomatic in
individuals particularly in the early stages of infection. According to the CDC, nearly 44% of HIV-positive MSM were not aware of their HIV status in 2008 (CDC, 2011). STIs may take as few as two days to show symptoms or as long as five weeks. For example gonorrhea can take approximately 2-3 weeks to detect using the most sensitive diagnostics, and syphilis can take up to 12 weeks (CDC, 2013). In the case of HIV, the CDC recommends testing 3 months after sexual intercourse due to the window period of this disease. A window period is the length of time it takes for a disease to be detected by a clinical test after infection. This lack of awareness about HIV/STI status may pose one reason why transmission rates are high. We speculate that many are unaware of the window period that STIs have and may get tested earlier than needed which results in a false negative. This false negative may lead patients to believe that they are disease-free which potentially leads to future unprotected sexual encounters.

1.2 Introduction to Social Media

Since the late 2000s use of smartphones and applications (apps) has become increasingly prevalent in the United States. One consequence of this technology is the introduction of social media, which may facilitate sexual encounters in the MSM population. According to the Merriam Webster Dictionary, social media is defined as forms of electronic communication (as Web sites for social networking and microblogging) through which users create online communities to share information, ideas, personal messages, and other contact (as videos). Social media is one of the leading ways of connecting to other people in current society and it is often one of the most efficient. Certain networks like Facebook, Instagram, MySpace, and Twitter provide the means of communication to people that may or may not know one another. These
types of networks are used by millions of individuals throughout every day and involve many virtual interactions between people in many communities all throughout the world. In the MSM community, there are ways of connecting on an intimate level through networks on smartphones. Such apps like Grindr, Jack’d, Scruff, VGL, and Hornet, among others, allow MSM to connect on a more intimate basis. Many use these apps to connect for many reasons: friends, dating, networking, and also to arrange sexual encounters. Martin J. Downing (2011) conducted a study to examine whether frequency of Internet usage was associated with risky behavior in the MSM community. He found that men who engaged in high-frequency use of the Internet were more likely to be HIV-positive, to be marginally more likely to engage in unprotected sex, and to have a preference for sex venues that offered the opportunity to have sex with multiple male partners as compared to men who engaged in low-frequency use of the Internet. Due to this finding, we speculate the same behavior in those who use apps.

A sample template of an application used for connecting with other MSM shows multiple thumbnail pictures of men. Some of these pictures involve solely a body picture, a face shot, or simply a picture of genitals.

Figure 1. Grindr template (Grindr, 2015).
Each user on the application posts his preference for making social contacts. For example on the app Grindr, users can view others’ preferences in the section titled “Looking For.” The options are listed as “Chat, Dates, Friends, Networking, Relationship, and Right Now.” When two individuals have the same preference, they can interact and achieve their goal quicker. For example, if one individual states he is looking for “Right Now” he can filter the men he sees to have the same preference as him. In addition, most of the apps have a global positioning system (GPS) that has accelerated the rate that men can find sexual partners (Grindr, 2015). According to a study done by Lewnard and Berrang-Ford (2014), 36% of MSM in the United States use applications for sexual encounters. Due to this finding, we speculate that this leads to higher rate of meet-ups than past traditional methods of interaction like club/bar meetings among other non-virtual methods. Furthermore, the study concluded that nearly 50% of men who use apps engage in unprotected sex and those who use apps were 37% more likely to be diagnosed with chlamydia and 42% more likely to contract gonorrhea than non-app users.

Sexual arousal is an important co-factor in the usage of apps. Some men engage on the app when bored, but the majority engage when they are highly sexually aroused (Harrington, 2015). If all men on an app are sexually aroused, the probability that a sexual encounter will occur may be higher than meeting someone at a club/bar who may or may not be sexually aroused.

In this thesis, we explore how app vs. non-app usage is associated with infection of STIs. There have been many studies done on the correlation between social media use and risky sexual behavior. One meta-analysis study conducted by Lehmiller and Loerger (2014) came to the conclusion that those who use apps typically have a greater number of
sexual partners and tend to be more sexually active than those who do not. In their study, there were many confounders that were controlled such as age, relationship status, gender identity, and race. 80% of the MSM were younger than 40 with the median age of 29.97, 69.6% identified as single, 96.4% identified as male, and 86.2% were white. Our goal is two-fold; to demonstrate whether the use of smartphone apps is associated with prevalent STIs and to develop a mathematical model to find the most effective point of intervention to reduce STIs in the MSM population. To do this we will analyze a data set to demonstrate that social media use correlates to higher STI incidence and we will use a closed susceptible-infected (SI) ordinary differential equation (ODE) to analyze the efficacy of interventions within four different scenarios, two illustrating decreasing STI incidence rates and other two illustrating increasing STI incidence rates within the MSM population. Our results from this thesis show that increasing social media use correlates to a higher incidence of STIs and our model shows that having advertisements on apps and on display in public venues may offer the best intervention to reduce STI incidence.

1.3 Data

Our dataset was obtained from a study done by Dr. Cara Rice at the Department of Public Health in Columbus, Ohio. Men who identified as MSM and met other eligibility criteria when they went for their STI screening were recruited, consented, and participated in the study. Participants completed a self-administered behavioral questionnaire as well as a one-on-one interview to get more insight on their sexual behavior. The sample size that participated consisted of 235 men but for our study we eliminated 40 men who knew they were HIV positive before the STI screening which reduced our sample set to 195 men. These men were eliminated because it is not possible
to analyze their behavior before diagnosis. Within this sample, we divided the men up into four categories: susceptible app users (SH), susceptible non-app users (SL), infected app users (IH), and infected non-app users (IL). Those who were negative for STIs during the visit and answered on the questionnaire that they met a sex partner through an Internet dating site and/or a smartphone app were placed within the SH group while the rest of the STI-negative participants (who did not use the Internet or a smartphone app) were placed within the SL group. Likewise, those who were positive for STIs during the screening and reported that they met a sex partner through an Internet dating site and/or a smartphone app were placed within the IH group, while the remaining STI-positive participants (who did not use the Internet or a smartphone app) were placed in the IL group. Out of the total population of 195 men, 136 used Internet dating sites and/or a smartphone app for sexual pursuits and 59 reported not using Internet dating sites and/or a smartphone app for sexual pursuits. It is important to note that we did not control for confounding. That is, we did not analyze other variables such as age, gender identity, relationship status, amongst others that would give further insight on which group was at most risk in acquiring an STI. We might speculate that the age group of 18-24 would use social media apps the most in contrast to older individuals and thus would be at a higher risk, but this claim was not verified. Future research could be conducted to test these variables.
Table 1. Population sizes of each MSM class.

<table>
<thead>
<tr>
<th>MSM Class</th>
<th>$S_L$</th>
<th>$S_H$</th>
<th>$I_L$</th>
<th>$I_H$</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>App-User</td>
<td>X</td>
<td>88</td>
<td>X</td>
<td>48</td>
<td>136</td>
</tr>
<tr>
<td>Non-App User</td>
<td>43</td>
<td>X</td>
<td>16</td>
<td>X</td>
<td>59</td>
</tr>
</tbody>
</table>

Risk behavior was also analyzed. High-risk behavior (HRB) was defined as individuals who had engaged in group sex or unprotected anal intercourse in any of their sexual encounters, while low-risk behavior (LRB) was defined as those who engaged in less risky behaviors such as using condoms or engaging strictly in oral sex (without engaging in group sex).

Table 2. Risk type of each population out of the general population.

<table>
<thead>
<tr>
<th>Risk Type</th>
<th>$S_L$</th>
<th>$S_H$</th>
<th>$I_L$</th>
<th>$I_H$</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-Risk</td>
<td>60%</td>
<td>75%</td>
<td>56%</td>
<td>79%</td>
</tr>
<tr>
<td>Low-Risk</td>
<td>40%</td>
<td>25%</td>
<td>44%</td>
<td>21%</td>
</tr>
</tbody>
</table>

This table shows that riskier behavior occurs in MSM who used apps as opposed to MSM who did not use apps.

Table 3. Risk type of men who were deleted from the study due to HIV+ status.

<table>
<thead>
<tr>
<th>Risk Type</th>
<th>$I_L$</th>
<th>$I_H$</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-Risk</td>
<td>5%</td>
<td>88%</td>
</tr>
<tr>
<td>Low-Risk</td>
<td>2%</td>
<td>5%</td>
</tr>
</tbody>
</table>
This table shows that riskier behavior occurs in HIV positive MSM who used apps as opposed to MSM who did not use apps. 88% of those infected with HIV used apps engaged in HRB as opposed to the 5% HIV positive MSM who did not use apps. These risk values are not included within our mathematical models that will be presented in chapters 2 and 3 but it is important to note that, as a whole, riskier sexual activity occurs significantly more in individuals who use apps to meet other men as opposed to those who don’t.
Chapter 2: Closed Population Susceptible-Infected (SI) Model

2.1 Introduction to Closed Population SI Model

Our model will represent a closed population based on our data in 1.3. A closed population is one where there isn’t much movement in or out of the MSM population. We assume that Columbus, Ohio is an example of a closed population. In addition, we assume that our closed population model is suitable for small-mid cities.

\[ S \leftrightarrow I \]
\[ S + I = N \]

The total number of susceptible individuals plus the total number of infected equals the total number of people in the population.

In social media apps, there are four different categories of MSM:

\[ S_L : \text{Susceptible, non-app user} \]
\[ S_H : \text{Susceptible, app user} \]
\[ I_L : \text{Infected, non-app user} \]
\[ I_H : \text{Infected, app user} \]

As defined before, susceptible means that the individual is not infected with an STI, and an infected user means that he is infected with some type of STI. A user who engages on online venues is classified as an app user, and a user who does not go on apps is classified as a non-app user. For simplicity, we will assume that the behavior of each individual doesn’t change over the time scale of interest in this model. That is, those who
are app users will always be app users, and those that are non-app users will always be non-app users. In terms of a mathematical model, we first define 2 conservation laws:

\[ S_L + I_L = N_L \]  (1)
\[ S_H + I_H = N_H \]  (2)

(1) Illustrates the total number of non-app users on social media apps that comprise of non-app susceptible and non-app infected users.

(2) Illustrates the total number of app users on social media apps that comprise of app susceptible and app infected users.

2.2 SI Model for STI Risk in Closed Population

We will now introduce the Susceptible-Infected (SI) model for STI risk in a closed population of MSM engaging in online venues:

![SI Model Diagram](image)

Figure 2. Possible interactions of MSM who access online venues.
Figure 3. Possible transition of states from Susceptible to Infected class and vice versa after treatment.

The $\alpha$ parameter illustrates the “growth” or possible infection rate, and the $\beta$ parameter illustrates the recovery rate after an individual is treated. With these four categories of men, we can generate four differential equations using standard SI models (Brauer, 2008) to model the probable interactions:

$$\frac{dS_I}{dt} = -\alpha_{LL} I_L S_L - \alpha_{LH} I_H S_L + \beta I_L$$  \hspace{1cm} (3)

$$\frac{dS_H}{dt} = -\alpha_{HH} I_H S_H - \alpha_{HH} I_H S_H + \beta I_H$$  \hspace{1cm} (4)

$$\frac{dI_L}{dt} = \alpha_{LL} I_L S_L + \alpha_{LH} I_H S_L - \beta I_L$$  \hspace{1cm} (5)

$$\frac{dI_H}{dt} = \alpha_{HH} I_H S_H + \alpha_{HH} I_H S_H - \beta I_H$$  \hspace{1cm} (6)
In this model, $\alpha$ represents the growth term (newly infected individual) and $\beta$ represents the recovery term (individual recovery from population). We assume that no one dies or leaves in our population over the course of our simulation.

Equation (3): The first two terms on the right hand side of the equation illustrate the contact of $S_L$ with $I_L$ and $I_H$. The parameter $\alpha_{LL}$ is dependent on person and time, i.e.

$$\frac{1}{p} \times \frac{1}{t}$$

and measures how often an individual contacts other individuals and the frequency of infection. The frequency of contact $\frac{1}{p}$ is low due to non-app usage, but we assume frequency of infection $\frac{1}{t}$ is the same as app users. This assumption is based off the speculation that a susceptible individual is at greater risk if exposed to more infected individuals who are app-users than infected people who are non-app users because from our data riskier behavior occurs in app-users. Therefore, $I$ infected individuals cause a total number of infections per unit time of $\alpha_{LL}I_LS_L$ and $\alpha_{IH}I_HS_L$ depending on whether an $S_L$ interacts with an app or non-app infected user. The $\beta I_L$ term represents the amount of non-app users who recover and return to the susceptible class.

Equation (4): The first two terms on the right hand side of the equation illustrates the contact of $S_H$ with $I_L$ and $I_H$. The parameter $\alpha_{HH}$ is dependent on person and time, i.e.

$$\frac{1}{p} \times \frac{1}{t}$$

and measures how often an individual contacts other individuals and the frequency of infection. The frequency of contact $\frac{1}{p}$ is high due to app usage, but we assume
frequency of infection $\frac{1}{t}$ is the same as non-app users. Again, this assumption is based off the speculation that a susceptible individual is at greater risk if exposed to more infected individuals who are app-users than infected people who are non-app users because from our data riskier behavior occurs in app-users. Therefore, $I$ infected individuals cause a total number of infections per unit time of $\alpha_{LH} I_H S_L$ or $\alpha_{HH} I_H S_H$ depending on whether an $S_H$ interacts with an app or non-app infected user. The $\beta I_H$ term represents the amount of app users who recover and return to the susceptible class.

Equation (5): Illustrates the same as (3) except we are modeling infected class of non-app users.

Equation (6): Illustrates the same as (4) except we are modeling infected class of app users.

Section 2.3 Process of Non-dimensionalization

Non-dimensionalization is used to reparametrize our model. This technique is used to simplify many real world mathematical problems that involve differential equations by allowing us to rescale the parameters and variables so that all computed quantities are on relatively similar magnitudes. We will also use conservation laws to reduce the number of variables, simplifying the model further.

The general procedure is to define dimensionless variables, choose non-dimensionalizing constants, and to define new dimensionless parameters. The following page exemplifies this procedure in our model.
\[ \frac{dS}{dt} = -\alpha_{1L}I_S S_L - \alpha_{1H}I_H S_L + \beta I, \]

**KNOW:** 
\[ I_L = N_L - S_L \]
\[ I_H = N_H - S_H \]

\[ \frac{dS}{dt} = -\alpha_{1L} (N_L - S_L) S_L - \alpha_{1H} (N_H - S_H) S_L + \beta (N_L - S_L) \]

Let \( S_H = S_H^*, S_L = S_L^* \) & \( t = \tau t' \)

Then,
\[ \left( \frac{dS^*}{dt} \right) = \left( \frac{dS^*_L}{dt} \right) \left( \frac{dS^*_H}{dt} \right) \]
\[ \left( \frac{dS^*_L}{dt} \right) = -\alpha_{1L} \tau \left( N_L - \bar{S}_L S_L^* \right) S_L^* - \alpha_{1H} \tau \left( N_H - \bar{S}_H S_H^* \right) S_L^* + \beta \tau \left( N_L - \bar{S}_L S_L^* \right) \]
\[ \left( \frac{dS^*_H}{dt} \right) = -\alpha_{1L} \tau \left( N_L - \bar{S}_L S_L^* \right) S_L^* - \alpha_{1H} \tau \left( N_H - \bar{S}_H S_H^* \right) S_L^* + \beta \tau \left( N_L - \bar{S}_L S_L^* \right) - \beta \tau S_L^* \]

Let \( \bar{S}_L = N_L \) & \( \bar{S}_H = N_H \) & \( N \) is constant

Then,
\[ \left( \frac{dS^*_L}{dt} \right) = -\alpha_{1L} \tau \left( N_L - \bar{S}_L S_L^* \right) S_L^* - \alpha_{1H} \tau \left( N_H - \bar{S}_H S_H^* \right) S_L^* + \beta \tau - \beta \tau S_L^* \]

Let \( \tau = \frac{1}{\beta} \)

Then,
\[ \left( \frac{dS^*_L}{dt} \right) = -\alpha_{1L} \frac{N_L - \bar{S}_L S_L^*}{\beta} S_L^* - \alpha_{1H} \frac{N_H - \bar{S}_H S_H^*}{\beta} S_L^* + 1 - S_L^* \]
\[ \left( \frac{dS^*_H}{dt} \right) = -\alpha_{1L} N_L \frac{1 - S_L^*}{\beta} S_L^* - \alpha_{1H} N_H \frac{1 - S_H^*}{\beta} S_L^* + S_L^* - 1 \]

Let \( \frac{\alpha_{1L} N_L}{\beta} = \gamma_{1L} \) & \( \frac{\alpha_{1H} N_H}{\beta} = \gamma_{1H} \)

Then,
\[ \left( \frac{dS^*_L}{dt} \right) = -\gamma_{1L} \left( 1 - S_L^* \right) S_L^* - \gamma_{1H} \left( 1 - S_H^* \right) S_L^* + S_L^* + 1 \]
\[
\frac{dS_H}{dt} = -\alpha_{1H}I_L S_H - \alpha_{HH} I_H S_H + \beta I_H
\]

**KNOW:**

\[
I_L = N_L - S_L \\
I_H = N_H - S_H
\]

\[
\frac{dS_H}{dt} = -\alpha_{1H} (N_L - S_L) S_H - \alpha_{HH} (N_H - S_H) S_H + \beta (N_H - S_H)
\]

Let \( S_H = \bar{S}_H S'_H \) & \( S_L = \bar{S}_L S'_L \) & \( t = \tau \) & \( N \) is constant

Then,

\[
\left( \frac{\tau}{\bar{S}_H} \right) \left( \frac{dS_H}{dt} \right) = \left( -\alpha_{1H} (N_L - \bar{S}_L S'_L) \bar{S}_H S'_H - \alpha_{HH} (N_H - \bar{S}_H S'_H) \bar{S}_H S'_H + \beta (N_H - \bar{S}_H S'_H) \right) \left( \frac{\tau}{\bar{S}_H} \right)
\]

\[
\left( \frac{dS'_H}{dt} \right) = -\alpha_{1H} \tau (N_L - \bar{S}_L S'_L) S'_H - \alpha_{HH} \tau (N_H - \bar{S}_H S'_H) S'_H + \beta \tau N_L - \beta \tau S'_L
\]

Let \( \bar{S}_L = N_L \) & \( \bar{S}_H = N_H \)

Then,

\[
\left( \frac{dS'_H}{dt} \right) = -\alpha_{1H} \tau (N_L - \bar{S}_L S'_L) S'_H - \alpha_{HH} \tau (N_H - \bar{S}_H S'_H) S'_H + \beta \tau - \beta \tau S'_H
\]

Let \( \tau = \frac{1}{\beta} \)

Then,

\[
\left( \frac{dS'_H}{dt} \right) = -\frac{\alpha_{1H} (N_L - \bar{S}_L S'_L) S'_H}{\beta} - \frac{\alpha_{HH} (N_H - \bar{S}_H S'_H) S'_H}{\beta} + 1 - S'_H
\]

\[
\left( \frac{dS'_H}{dt} \right) = -\frac{\alpha_{1H} N_L}{\beta} \left( 1 - S'_L \right) S'_H - \frac{\alpha_{HH} N_H}{\beta} \left( 1 - S'_H \right) S'_H + S'_H
\]

Let \( \frac{\alpha_{1H} N_L}{\beta} = \gamma_{1H} \) & \( \frac{\alpha_{HH} N_H}{\beta} = \gamma_{HH} \)

Then,

\[
\left( \frac{dS'_H}{dt} \right) = -\gamma_{1H} \left( 1 - S'_L \right) S'_H - \gamma_{HH} \left( 1 - S'_H \right) S'_H + S'_H + 1
\]
Section 2.4 Steady-States

The steady state is where our system is at the equilibrium. We wish to determine parameter values for our the baseline scenario for our population. Setting our ODEs equal to zero allows us to solve for the parameters.

\[
\frac{dS^*_L}{dt^*} = 0 \quad \frac{dS^*_H}{dt^*} = 0
\]

Using the mathematical software, MAPLE, we find the following relationship between parameters:

\[
\begin{align*}
\gamma_{HH} &= \gamma_{HH} \\
\gamma_{LH} &= 2 - 1.3\gamma_{HH} \\
\gamma_{LL} &= -1.2 + 1.7\gamma_{HH}
\end{align*}
\]

Setting (2) and (3) equal to zero, we obtain our \(\gamma_{HH}\) intercepts.

\[
\begin{align*}
\gamma_{LH} &= 2 - 1.3\gamma_{HH} \\
0 &= 2 - 1.3\gamma_{HH} \\
\gamma_{HH} &= 1.53 \\
\gamma_{LL} &= -1.2 + 1.7\gamma_{HH} \\
0 &= -1.2 + 1.7\gamma_{HH} \\
\gamma_{HH} &= 0.7
\end{align*}
\]

Therefore one set of \(\gamma_{HH}\) values can range between 0.7 and 1.53. We choose \(\gamma_{HH} = 1\) as a minimum condition to ensure that \(\gamma_{LH}\) and \(\gamma_{LL}\) are positive. Substituting this value into our equations above we obtain \(\gamma_{LH} = 0.7\) and \(\gamma_{LL} = 0.5\). Thus the order of our parameters is \(\gamma_{LL} < \gamma_{LH} < \gamma_{HH}\). This pairing is significant because we are assuming that the interaction between an app-user and another app-user poses the most significant risk, and thus the parameter \(\gamma_{HH}\) holds the greatest value. Similarly \(\gamma_{LH}\) is the next largest value since this parameter models the interaction between an app-user and a non-app user, which illustrates moderate risk. Finally, the smallest value is shown by the interaction of those
who are non-app users, $\gamma_{ll}$. It is important to note that other order of parameters are possible with a different model, but all the parameter values need to be positive. If one or more of the parameter values are not positive then we would have either a negative infection rate, recovery rate, or number of people, which is not possible.
Chapter 3: Parameter Variations

In this section we will discuss real-life scenarios that our population could encounter. Some of these scenarios will illustrate how STI incidence can be reduced while others will illustrate how STI incidence can even increase.

3.1 Scenario 1: Advertisements (Ads) on Apps and in Public Venues to Increase Awareness of Safe Sex.

Safe sex includes using condoms and using effective lubricants. The ads also display STI clinics where MSM can be tested and treated for STIs. To avoid redundancy, there will be several different ads.

Case 1: Ads shown per instance of application use and ads shown in public restrooms.

In this case, when a user goes on the app, an advertisement (ad) will flash once informing the user about safe sex matters. The user can close the ad and it will not show up again until the app user closes and re-opens the app. Ads will also be displayed in public restrooms to affect both non-app users and app users.

Case 2: Ads shown in intervals of 10 minutes and ads shown in newspapers.

In this case, when a user goes on the app, an ad will flash every 10 minutes informing the user about safe sex measures. This includes case 1, where an ad is flashed initially when the user accesses the app. Ads will also be displayed in newspapers to affect both non-app users and app users.

Case 3: Ads shown after every new conversation and ads shown clubs/bars.
In this case, when a user goes on the app, an ad will flash after each new conversation is initiated. For example, when a user contacts another user with a message, an ad will appear in which the user has to close the ad in order to continue the conversation. For example, if a user contacts 5 other users then he will view 5 ads. Ads will also be displayed in clubs and bars to affect both non-app users and app users.

Parameter Variations:

<table>
<thead>
<tr>
<th>Case #</th>
<th>$\alpha_{LL}$</th>
<th>$\alpha_{LH}$</th>
<th>$\alpha_{HH}$</th>
<th>$\beta$</th>
<th>$\Delta I$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>↓ 10%</td>
<td>↓ 20%</td>
<td>↓ 30%</td>
<td>↑ 5%</td>
<td>↓ 45%</td>
</tr>
<tr>
<td>2</td>
<td>↓ 20%</td>
<td>↓ 35%</td>
<td>↓ 45%</td>
<td>↑ 15%</td>
<td>↓ 62%</td>
</tr>
<tr>
<td>3</td>
<td>↓ 30%</td>
<td>↓ 60%</td>
<td>↓ 75%</td>
<td>↑ 40%</td>
<td>↓ 64%</td>
</tr>
</tbody>
</table>

Table 4. Parameter variations based on different cases in scenario 1.

This table shows the infection rates based on different parameters. We hypothesize that if men are viewing ads on apps that their participation in risky behavior will decrease. Since this is our prediction, each alpha value decreases in each case. We speculate that Case 1 has a slight effect in minimizing risky behaviors, while case 2 and case 3 have moderate and strong effects respectively. Therefore, greater decreases in percentage values are given to Case 2 and Case 3 since it is speculated that they will have the most effect on the population. The most significant effect in percentage decreases is given to $\alpha_{HH}$ since this parameter is based on both individuals using apps, whereas slight effect is given on the parameter $\alpha_{LL}$ since these individuals do not use apps but can view ads in various public
areas. The last column in the table illustrates the change in the infection rate due to each case. As the case number increases the infection rate decreases. This is what we expect since each subsequent case brings about a more significant change in both the susceptible and infected population. Furthermore, it is important to keep in mind that these values are speculated to provide numerical simulation. Additional research needs to be conducted to find specific values based on the particular population.

In this figure we see the effect of ads on apps in each different MSM population as time goes on. The two top plots from left to right illustrate the susceptible non-app user and app-user population. Similarly the bottom two plots from left to right illustrate the
infected non-app user and app-user population. The baseline curve (red) shows the
dynamic of the population without any ads on apps. The green, red, blue, and black
curves represent case 1, case 2, and case 3 respectively. Examining the susceptible plots,
we note that as each subsequent case is implemented, the susceptible population
increases. Conversely examining the infected plots, the population decreases as each
subsequent case is implemented. These trends are expected because we hypothesize that
the more ads a user sees will correlate to safer sex practices between individuals.

3.2 Scenario 2: State Mandate Requires All MSM To Be Tested For STIs

Suppose every MSM individual is required to be tested for STIs.

Case 1: Men get tested and treated for any potential STI.

In this case, every individual who is within the MSM group is required to be tested for an
STI at a clinic or hospital nearby. Those infected receive treatment.

Case 2: Those who tested positive for any STI are not allowed to have sex for 6 months.

In this case, when a user tests positive for an STI he cannot engage in any type of sex for
at least 6 months.

Case 3: Treatment and testing for all STIs is free.

In this case, treatment and testing for STIs is free for all MSM. This case includes both
cases 1 and 2.
Parameter Variations:

<table>
<thead>
<tr>
<th>Case #</th>
<th>$\alpha_{LL}$</th>
<th>$\alpha_{LH}$</th>
<th>$\alpha_{HH}$</th>
<th>$\beta$</th>
<th>$\Delta I$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stays Same</td>
<td>Stays Same</td>
<td>Stays Same</td>
<td>$\uparrow 10%$</td>
<td>$\downarrow 33%$</td>
</tr>
<tr>
<td>2</td>
<td>$\downarrow 5%$</td>
<td>$\downarrow 15%$</td>
<td>$\downarrow 30%$</td>
<td>$\uparrow 30%$</td>
<td>$\downarrow 60%$</td>
</tr>
<tr>
<td>3</td>
<td>$\downarrow 10%$</td>
<td>$\downarrow 35%$</td>
<td>$\downarrow 50%$</td>
<td>$\uparrow 50%$</td>
<td>$\downarrow 63%$</td>
</tr>
</tbody>
</table>

Table 5. Parameter variations based on different cases in scenario 2.

This table shows the infection rates based on different parameters. We hypothesize that if there is a state mandate requiring MSM to be tested for STIs, their participation in risky behavior will decrease. Since this is our prediction, each alpha value decreases in each case. We speculate that Case 1 has a no effect in minimizing risky behaviors since MSM are just being tested and treated so behavior will not change, while case 2 and case 3 have moderate and strong effects respectively since MSM are not allowed to have sex after 6 months if tested positive for any STI. Therefore, decreases in infection rates are given to Case 2 and Case 3 since it is speculated that they will have the most effect on the population. The most significant effect in percentage decreases is given to $\alpha_{HH}$ since this parameter is based on both individuals using apps. We predict that if MSM using apps know that they cannot have sex after 6 months in case 2 and 3 if tested positive, they will be more apt to engaging in safer sex methods than riskier ones. There is slight effect on decrease in infection rate on the parameter $\alpha_{LL}$ since these individuals generally engage in safe behaviors because they do not use apps. Again, the last column in the table illustrates the change in the infection rate due to each case. As the case number increases
the infection rate decreases. This is what we expect since each subsequent case brings about a more significant change in both the susceptible and infected population.

Figure 5. Case type and population trend as time increases in scenario 2.

In this figure we see the effect of a state mandate on each different MSM population as time goes on. The two top plots from left to right illustrate the susceptible non-app user and app-user population. Similarly the bottom two plots from left to right illustrate the infected non-app user and app-user population. The baseline curve (red) shows the dynamic of the population without any ads on apps. The green, red, blue, and black curves represent case 1, case 2, and case 3 respectively. Examining the susceptible plots, we note that as each subsequent case is implemented, the susceptible population increases.
because more people are getting treated for their STI. Conversely, examining the infected plots, the population decreases as each subsequent case is implemented. These trends are expected because we hypothesize that if more MSM are being treated then the susceptible population will increase.

3.3 Scenario 3: PrEP becomes available and men engage in riskier sex

Pre-Exposure Prophylaxis (PrEP) is a new medication that is taken orally every day that reduces the risk of HIV transmission. According to the CDC, PrEP is 92% effective but takes approximately 20 days to provide the most protection in a user’s bloodstream and approximately 7 days to provide protection in the rectal tissue (CDC, 2014).

While PrEP provides benefit in reducing the risk of acquiring HIV, it provides no benefit to the other sexually transmitted infections. One of the concerns is that users who use PrEP engage in riskier behaviors due to the efficacy of the drug (Bluementhal & Haubrich, 2014).

Case 1: Men have unprotected sex with one other MSM immediately after taking PrEP on only one day of the week.

In this case, after a user takes PrEP for the first time, he engages in unprotected sex with one other man on only one day of the week.

Case 2: Men engage in unprotected sex with a different MSM each day of the week immediately after taking PrEP.

In this case, after a user takes PrEP for the first time, he engages in unprotected sex with a different MSM each day of the week.

Case 3: Men take sex-enhancing drugs and have unprotected sex with a different MSM each day of the week.
Sex-enhancing drugs are drugs that enhance the sexual experience. Some types of these drugs are alkyl nitrates, gamma-Hydroxybutyric acid, and gamma-Butyrolactone. These drugs can relax and dilate the anal sphincter, which can cause a rupture in the anal tissue during penetration. In this case, after a user takes PrEP for the first time, he engages in unprotected sex with a different man each day of the week and engages the use of these drugs.

Parameter Variations:

<table>
<thead>
<tr>
<th>Case #</th>
<th>( \alpha_{LL} )</th>
<th>( \alpha_{LH} )</th>
<th>( \alpha_{HH} )</th>
<th>( \Delta I )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>↑10%</td>
<td>↑20%</td>
<td>↑35%</td>
<td>↑25%</td>
</tr>
<tr>
<td>2</td>
<td>↑15%</td>
<td>↑40%</td>
<td>↑55%</td>
<td>↑38%</td>
</tr>
<tr>
<td>3</td>
<td>↑20%</td>
<td>↑60%</td>
<td>↑70%</td>
<td>↑48%</td>
</tr>
</tbody>
</table>

Table 6. Parameter variations based on different cases in scenario 3.

This table shows the infection rates based on different parameters. We hypothesize that if PrEP causes MSM to engage in riskier sex then more people will be infected. Since this is our prediction, each alpha value increases in each case. We speculate that Case 1 has a slight effect in infection rate since having sex with one other individual on one day of the week is less risky than having sex with a new man every day of the week. However, case 2 and case 3 have moderate and strong effects respectively since MSM are having sex with a new MSM each day of the week and using sex-enhancing drugs which are both considered high-risk behaviors. Again, the most significant effect in percentage increases is given to \( \alpha_{HH} \) since this parameter is based on both individuals using apps. We predict
that there is a faster rate of interacting with other MSM on apps, and thus there will be a faster rate of acquiring an STI. There is slight effect in infection rate on the parameter $\alpha_{LL}$ since these individuals generally engage in safe behaviors because they do not use apps. The last column in the table illustrates the change in the infection rate due to each case. As the case number increases the infection rate increases. This is what we expect since each subsequent case brings about a more significant change in both the susceptible and infected population.

Figure 6. Case type and population trend as time increases in scenario 3.

In this figure we see the effect of risky sexual behavior due to PrEP on each different MSM population as time goes on. The two top plots from left to right illustrate the
susceptible non-app user and app-user population. Similarly the bottom two plots from left to right illustrate the infected non-app user and app-user population. The baseline curve (red) shows the dynamic of the population without use of PrEP. The green, red, blue, and black curves represent case 1, case 2, and case 3 respectively. Examining the susceptible plots, we note that as each subsequent case is implemented, the susceptible population decreases because more people are becoming infected. Conversely, examining the infected plots, the population increases as each subsequent case is implemented. These trends are expected because we hypothesize that if MSM are engaging in riskier sexual behavior then the number of STIs will increase.

3.4 Scenario 4: Increasing Availability of Gay Pornography That Shows Unprotected Sex Increases the Rate of Risky Sex

Recently, many gay pornographic studios have been reducing the rate of using condoms within their productions. Exposure to this type of production could potentially lead to riskier behavior between MSM (Haynes, 2010). This scenario illustrates many risky cases that could stem from the exposure of this type of gay pornography.

Case 1: MSM have unprotected sex with one other individual.

In this case, after viewing unprotected sex on gay pornography, an MSM engages in unprotected sex with one another MSM.

Case 2: MSM attend sex venues to have unprotected sex with other MSM.

In this case, after viewing unprotected sex on gay pornography, MSM attend sex venues to have unprotected sex with other MSM. Sex venues could have a greater density of MSM and thus the rate of engaging in unprotected sexual intercourse could increase.

Case 3: Men engage in unprotected group sex.
In this case, men engage in group sex after viewing unprotected group sex on gay pornography. Group sex is classified as having sex with three or more individuals and is considered a risky measure since one infected individual could infect multiple individuals at one time.

Parameter Variations:

<table>
<thead>
<tr>
<th>Case #</th>
<th>$\alpha_{LL}$</th>
<th>$\alpha_{LH}$</th>
<th>$\alpha_{HH}$</th>
<th>$\Delta I$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>↑5%</td>
<td>↑10%</td>
<td>↑20%</td>
<td>↑15%</td>
</tr>
<tr>
<td>2</td>
<td>↑15%</td>
<td>↑30%</td>
<td>↑40%</td>
<td>↑31%</td>
</tr>
<tr>
<td>3</td>
<td>↑30%</td>
<td>↑60%</td>
<td>↑80%</td>
<td>↑50%</td>
</tr>
</tbody>
</table>

Table 7. Parameter variations based on different cases in scenario 4.

This table shows the infection rates based on different parameters. We hypothesize that if unprotected sex on gay pornography causes MSM to engage in riskier sex then more people will be infected. Since this is our prediction, each alpha value increases in each case. We speculate that Case 1 has a slight effect in infection rate since engaging in unprotected sex with one other MSM could lead to a higher STI incidence rate. Case 2 has a moderate effect since MSM have a greater opportunity at a sex venue to meet more MSM to have unprotected sex with. Case 3 has the strongest effect since group sex is classified as a high-risk behavior because one individual has the potential to infect multiple people at one time. Again, the most significant effect in percentage increases is given to $\alpha_{HH}$ since this parameter is based on both individuals using apps. We predict that there is a faster rate of interacting with other MSM on apps, and thus there will be a faster
rate of acquiring an STI. There is slight effect in infection rate on the parameter $\alpha_{LL}$ since these individuals generally engage in safe behaviors because they do not use apps. Again, the last column in the table illustrates the change in the infection rate due to each case. As the case number increases the infection rate increases. This is what we expect since each subsequent case brings about a more significant change in both the susceptible and infected population.

Figure 7. Case type and population trend as time increases in scenario 4.
In this figure we see the effect of risky sexual behavior due to unprotected sex on gay pornography on each different MSM population as time goes on. The two top plots from left to right illustrate the susceptible non-app user and app-user population. Similarly the bottom two plots from left to right illustrate the infected non-app user and app-user population. The baseline curve (red) shows the dynamic of the population without Pride Festivals. The green, red, blue, and black curves represent case 1, case 2, and case 3 respectively. Examining the susceptible plots, we note that as each subsequent case is implemented, the susceptible population decreases because more people are becoming infected. Conversely, examining the infected plots, the population increases as each subsequent case is implemented. These trends are expected because we hypothesize that if MSM are engaging in riskier sexual behavior due to the exposure of unprotected sex on gay pornography the STI incidence rate will increase.
4.1 Interventions to Reduce STI Incidence

One of the primary goals within this thesis was to develop a mathematical model that would identify the most effective intervention in reducing STI incidence. Scenarios 1 and 2 exemplify situations where STI incidence could be potentially reduced. Before implementing the scenario, users are not seeing any ads on their apps to warn them about safe sex measures or areas where they can get tested. Our baseline trend is modeled on this assumption. However after ads are added to the apps, behaviors are modified based on each different case. Each subsequent case increases the susceptible population and decreases the infected population. This trend occurs because we speculate that advertisements influence safer sex methods between MSM and it allows them to be aware on where they can get tested and treated for STIs. If any MSM individual is worried about his status then he can attend an STI clinic in the area to get tested and treated which would decrease the infected population and increase the susceptible if he tested positive for an STI. As the user views an advertisement more, we speculate that his behavior would change to engage in safer sex methods. Due to more individuals engaging in safe sex, the infected population decreases because fewer people are becoming infected. Examining the infection rate column, we see that infections in both the app-user and non-app user population decrease as we expect. It should also be noted that ads on apps are an easy and cost effective approach in reaching high-risk populations.
Furthermore, implementing this method may prove great benefits to both the users and the companies who created the apps.

Exploring scenario 2, before implementing the state mandate, users may have an STI without knowing it and can then infect another individual. This idea of not knowing whether one is transmitting an STI is our baseline trend. Similar to scenario 1, after each subsequent case, the susceptible population increases. We speculate that if every MSM individual is required to be screened and treated for STIs the number of infected users will decrease. Furthermore, in case 2 and 3, those who are tested positive for an STI are not allowed to engage in sex for at least 6 months. Since there is legal punishment on having sex within the 6-month span if tested positive for an STI a wide majority would likely not engage in sex. This will greatly decrease transmission rates between MSM. It is however important to note that this scenario may not be realistic since it is a violation of human rights, and that many MSM may not get tested or treated if the government didn’t know if a man was MSM. Examining the infection rate column, we see that infections in both the app-user and non-app user population decrease as we expect.

Comparing scenario 1 and scenario 2, there is a greater reduction in the number of infections in scenario 1 than 2. In case 1, scenario 1 has a significant reduction, whereas in cases 2 and 3 the comparison between scenarios is slight with scenario 1 showing greater reduction. We hypothesize that this occurs because in a state mandate, users may or may not decide to get tested. Even though there is a state mandate requiring all MSM to get tested, there is no justifiable way for the government to verify if an individual is an MSM unless an MSM informs the authority his sexual behavior. Furthermore, in case 2, when an MSM who tested positive isn’t allowed to have sex for at least 6 months, he may
decide to still have sex since there is no justifiable way to ensure that he does not. However, in scenario 1, an MSM is deciding on his own, not by any government authority, to engage in safer methods, to get tested, and potentially treated. In summary, since MSM in scenario 1 are responsible for getting treated and tested based off of his own views from ads, we speculate that scenario 1 provides the greatest benefit to reducing STI incidence.

4.2 Scenarios to Increase STI Incidence

While reducing STI incidence is one of primary goals in this thesis, in reality, there will be scenarios that could increase STI incidence. It is important to understand how STI incidence can increase under particular scenarios so that future public health studies and measures can be conducted to target particular populations to ensure that particular behaviors within these individuals can be modified. Scenarios 3 and 4 exemplify circumstances where STI incidence could potentially increase. Examining scenario 3, before PrEP became available, users wore condoms as a means to prevent HIV infection. Condoms and effective lubricants were the sole means to prevent STI transmission. Since the availability of this new medication, many users have engaged in riskier behavior (Bluementhal & Haubrich, 2014). Furthermore, since PrEP takes approximately 20 days to have maximum protection in the bloodstream and 7 days in rectal tissues, those who engage in sex before the period are at a high risk of acquiring an STI. Subsequently, in cases 2 and 3, the transmission rate increases due to the increase in risky behavior. Examining the infection rate column, we see that infections in both the app-user and non-app user population increase as we expect. Therefore, since riskier behavior is being conducted, we speculate that an increase in transmissions of STIs
occurs. Thus, the infected population increases and conversely the susceptible population decreases.

Examining scenario 4, before MSM view unprotected sex on gay pornography, MSM are engaging in their typical sexual behavior (which may be protected or unprotected sex depending on the man). These interactions of individuals are our baseline trend. However, after being exposed to unprotected sex on gay pornography, we speculate that the likelihood of engaging in unprotected sex with other MSM increases. Furthermore, case 2, attending sex venues after exposure to pornography to have unprotected sex, could potentially lead to group sex (case 3), which poses the riskiest behavior. Examining the infection rate column, we see that infections in both the app-user and non-app user population increase as we expect. In all cases, the exposure of watching unprotected sex on gay pornography may influence MSM to engage in these types of risky behaviors. Due to this finding, our susceptible population will decrease and our infected population will increase after each subsequent case.

Comparing scenario 3 and scenario 4, there is a greater increase in the infection rate in scenario 3 than scenario 4 except in case 3. We hypothesize that this trend occurs because PrEP is prescribed to those who are high-risk individuals, that is those who have the highest risk of acquiring HIV. However, in contrast, having an exposure to unprotected sex on gay pornography doesn’t necessarily mean that those who are watching the production are high-risk individuals. In scenario 4, case 3, group sex poses the highest risk out of all cases in both scenarios 3 and 4 since an individual can infect multiple people at one time. In summary, we believe that scenario 3 poses the highest risk in increasing STI incidence.
4.3 Final Remarks

In this thesis, we examined social media use and its effect on men who have sex men. We developed and non-dimensionalized a closed susceptible-infected (SI) ordinary differential equation (ODE) model to illustrate how sexually transmitted infections impacted two different MSM populations, one that used social media, and one that did not. We used XPP, a computer program for solving differential equations, to vary the population dynamics in different scenarios to determine their effects on STI incidence in order to gain insight on efficacy of two interventions. To illustrate our results, MATLAB was used to generate plots of various scenarios that we created to show how STI incidence could increase or decrease. Our results from the data showed that those men who use social media apps are more likely to be afflicted with STIs and our mathematical model that we developed showcased that the greatest point of intervention to reduce STI incidence was the use of advertisements on apps and on display in public venues.

4.4 Future Research

In the future we would like to develop an open population SI ODE to illustrate how MSM population dynamics occur in larger cities like Los Angeles, San Francisco, New York City, among others where migration of individuals is greater. In larger cities like these, there are many more individuals as well as greater likelihood of migration of MSM from other cities. Due to this, we speculate that larger cities have a greater STI incidence rate and that different interventions may prove more effective to reduce STI incidence.
References


