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# Evaluating the Connection between Gender Based Violence and HIV/AIDS

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By

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## ABSTRACT

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Mathematical models are essential for mapping the future spread of HIV/AIDS and for evaluating the impact of prevention efforts. These models are often relied on by policymakers to make decisions about where to target resources and it is crucial that the model predictions are as accurate as possible. One model that is relied on to predict HIV Incidence is the UNAIDS Modes of Transmission model (MOT.) A major limitation of this model is that it does not incorporate different heterosexual sex risk factors, such as the presence of violence. In this thesis I created a revised MoT model in South Africa, which incorporates a concerning sexual risk factor: the presence of violence. South Africa was chosen because of its high rates of HIV prevalence and gender based violence. The results of the revised MoT model in South Africa indicate that gender based violence is a significant contributor to the HIV/AIDS epidemic. With our current parameter estimates for violence, the model demonstrates that the violence sub groups both relatively account for a greater proportion of new infections than the non-violence groups and on an absolute level, the violence sub groups have a significantly higher HIV incidence rate than the non-violence groups. For example, the violence sub group of individuals engaging in casual heterosexual sex is predicted to account for 7.18% of the total new infections in South Africa, where as the non-violence group is estimated to account for 2.82% of the new infections. In absolute terms, the violence group is expected to have an HIV incidence rate of 2.097% whereas the non-violence group is predicted to have an HIV incidence rate of .498%. In the case that

violence was entirely eliminated, the model predicts that overall HIV incidence in South Africa would drop from 1.9% to 1.22%. The designed experiment sensitivity analysis similarly demonstrates that sexual risk behaviors associated with violence are significant drivers of HIV incidence. Based on these results, I suggest that addressing gender based violence be an important goal of the HIV/AIDS response.

## ABBREVIATIONS

AIDS: Acquired Immune Deficiency Syndrome

ART: Antiretroviral therapy

CHS: Casual Heterosexual Sex

FSW: Female Sex Worker

HIV: Human Immunodeficiency Virus

HIV incidence: the number of new infections that occur during a specific time frame (usually a year)

HIV prevalence: the number of people currently living with HIV

GBV: gender based violence-inclusive of both physical and/0r sexual violence

MoT: modes of transmission model

# CHAPTER 1: BACKGROUND ON HIV/AIDS

## 1.1 IMPORTANCE OF STUDYING HIV/AIDS

The statistics on HIV/AIDS, one of the world's most extensive global pandemics, are astonishing. Globally, an estimated 35.3 million people were living with HIV in 2012 and there were an estimated 2.3 million new HIV infections in 2012.[1] According to the World Health Organization, an estimated 36 million people have died since the first cases of HIV/AIDS were reported in 1981. It is estimated that in 2012 alone, 1.6 million people died of HIV/AIDS.[2] HIV/AIDS remains the leading cause of death for adults in sub-Saharan Africa.[3] Life expectancy in many African countries has dropped below forty years, leaving many child-headed households. Entire villages exist with practically no living adults between twenty-one and fifty.[4] With over six thousand new infections and more than four thousand deaths per day, it is clear that HIV/AIDS is not disappearing.[5]

While Sub-Saharan Africa is still disproportionately affected by the disease, having 70% of all new HIV infections in 2012[6], the epidemic is global, and there are millions infected in countries around the world including China, India, Russia, and the United States. Regional distribution of HIV prevalence is represented in the World Health Organization (WHO) map below (graph 1). Note that HIV prevalence is defined as the number of people living with HIV

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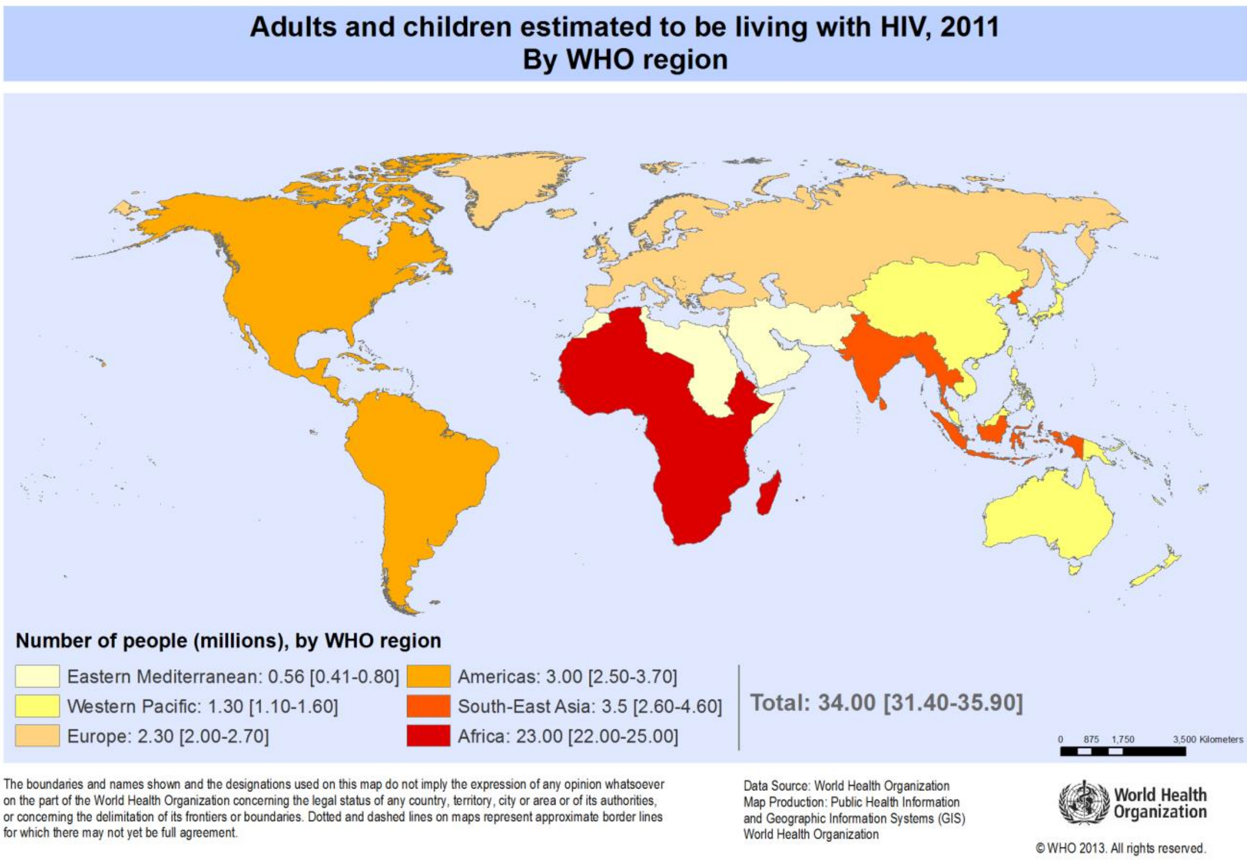
[1] UNAIDS, ""2013 Global Report"," *UNAIDS Publications* 2013: 1. Available from: http://www.unaids.org/en/media/unaids/contentassets /documents/ epidemiology/2013/gr2013/UNAIDS_Global_Report_2013_en.pdf.
[2] "Global Aids Overview," last modified December 18, 2013, http://aids.gov/federal-resources/around-the-world/global-aids-overview/
[3] "The African Regional Health Report," World Health Organization, accessed January 12, 2014. http://www.who.int/bulletin/africanhealth/en/
[4] Roger W. Hoerl and Presha E. Neidermeyer, *Use What You Have: Resolving the HIV/AIDS Pandemic* (Xilibris Corporation, 2009), 18.
[5] Hoerl and Neidermeyer, *Use What You Have: Resolving the HIV/AIDS Pandemic, 19.*
[6] UNAIDS, *"2013 Global Report"*, 4.

infection at a given time. HIV incidence is defined as the number of new infections that occur during a specific time frame (usually a year.)[7]

Graph 1: Adult and Children HIV Prevalence by WHO (http://www.who.int/gho/hiv/en/)




HIV/AIDS has a particularly large impact on women and children. Globally, women comprise 52% of all people living with HIV in low- and middle-income countries, however in

[7] Center for Disease Control and Prevention, "HIV/AIDS Statistics Overview," 2011, http://www.cdc.gov/hiv/statistics/basics/.

sub-Saharan Africa, women still account for approximately 57% of all people living with HIV.[8] HIV is still driven by gender inequalities and harmful gender norms that promote forced and unsafe sex as well as reduced access to HIV and sexual/reproductive health services. This epidemic places a particular burden on women and girls as they are more physiologically susceptible to HIV acquisition and also face social, legal and economic disadvantages which reduce their ability to protect themselves from HIV acquisition as well as diminish their access to essential health services. Women are more likely to acquire HIV at an early age. Global HIV prevalence among girls and young women is double or greater than among males of the same age.[9] For women aged fifteen to forty-four years, HIV/AIDS is the leading cause of death worldwide, with unsafe sex being a main risk factor.[10] Even in the United States, AIDS is still the leading cause of death among African-American women between the ages of twenty-five and thirty-four.[11]

It is estimated by WHO that 3.34 million children worldwide are living with HIV and over 700 children are newly infected each day.[12] Most of these children received the virus from their mothers at birth or through breast-feeding. Unfortunately many of these children account for a portion of the 15 million orphans HIV/AIDS left behind, 12 million of which reside in sub-Saharan Africa alone. Regrettably there is a synergistic relationship between AIDS and orphans. Children are orphaned after their parents die from AIDS, but then often become vulnerable to sexual exploitation and drug use, which results in more AIDS cases.[13]

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[8] UNAIDS, *"2013 Global Report"*, 78.
[9] UNAIDS, *"2013 Global Report"*, 78.
[10] World Health Organization, "Women's Health Fact Sheet," 2013, http://www.who.int/mediacentre/factsheets/fs334/en/.
[11] Hoerl and Neidermeyer, *Use What You Have: Resolving the HIV/AIDS Pandemic,* 18.
[12] "Global Aids Overview"
[13] Hoerl and Neidermeyer, *Use What You Have: Resolving the HIV/AIDS Pandemic,* 19.

Key populations are also disproportionately affected by HIV/AIDS. For instance, globally female sex workers are 13.5 times more likely to be living with HIV than other women.[14] People who inject drugs are also disproportionately affected by HIV/AIDS. Although they account for an estimated 0.2-0.5% of the world's population, they make up an approximately 5-10% of all people living with HIV.[15] Men who have sex with men also have an elevated risk of acquiring HIV. For instance, in the United States although men who have sex with men only represent approximately 2% of the population, in 2010 they accounted for 63% of new HIV infections and from 2008 to 2010; new HIV infections increased 22% among young (aged 13-24) men who have sex with men and 12% among men who have sex with men overall.[16]

AIDS is only one of many global heath crises and while other crises certainly need attention as well, there are unique challenges when combatting HIV/AIDS that make it a priority disease to address. First, people tend to die from AIDS in the prime of their lives, which means they often leave behind orphans and widowed spouses who are then vulnerable to exploitation and HIV infection themselves. Secondly, there is no cure for HIV infection today. People who are infected will need medication for the rest of their lives. Getting medication to the 35 million people currently living with HIV is a major challenge, as the cost of the medicine is high and many people who are infected already live in impoverished countries. There are also logistical challenges in reaching those that are infected with the medication they need every day, both ensuring that they know how to take the medication and have access to health care. While there is hope in the decline of HIV/AIDS and evidence to suggest that prevalence, incidence, and

[14] UNAIDS, *"2013 Global Report"*, 20.
[15] UNAIDS, *"2013 Global Report"*, 30.
[16] "HIV Among Gay and Bisexual Men," Center for Disease Control and Prevention, accessed January 12, 2014, http://www.cdc.gov/hiv/risk/gender/msm/facts/index.html.

access to care have greatly improved in the last few decades, AIDS continues to be the greatest crisis facing the human race in this century and needs to be addressed in every sector of our society, including academic study.[17]

## 1.2 WHAT IS HIV/AIDS?

Human Immunodeficiency Virus (HIV) is a virus that attacks key parts of the human immune system, namely the T-cells or CD4 cells. HIV invades these cells, uses them to make copies of itself, and then destroys them. The human body cannot get rid of HIV, so once an individual is infected he/she will have HIV for life. Over time, HIV will destroy so many of these immune cells that the body can no longer fight off diseases or infections. When this happens, HIV leads to Acquired Immunity Deficiency Syndrome (AIDS). [18] HIV is a slow-progressing infection and often takes ten to fifteen years to reach the final stage of AIDS. This is part of the reason why HIV has become so endemic: while it is good that individuals can live longer, it means that they are likely to spread the disease in their lifetime.[19]

The path from HIV infection to AIDS is usually described as a series of phases. The first phase is an incubation phase that transpires two to four weeks after exposure to the virus and usually lasts between seven and twenty-eight days. Most people experience flulike symptoms during this phase which often leads many people not to recognize these initial symptoms as HIV related. During this first phase, the individual is the most contagious because the virus is

[17] Hoerl and Neidermeyer, *Use What You Have: Resolving the HIV/AIDS Pandemic*, 20-21.
[18] U.S. AIDS, “What is HIV AIDS?”, last modified April 29, 2014, http://aids.gov/hiv-aids-basics/hiv-aids-101/what-is-hiv-aids/.
[19] Hoerl and Neidermeyer, *Use What You Have: Resolving the HIV/AIDS Pandemic*, 32-33.

replicating within the cells. Because of this, detection of HIV infection is critical at this point to safeguard against further spread of the virus by the individual.[20]

After the initial acute phase of the infection, the individual moves into the latency phase; this typically lasts around ten years, depending on the individual's general health. People can still pass on the virus at this point, although they are less infectious than in the first phase because HIV may lay moderately dormant in the body.[21]

Gradually, the individual will become increasingly more at risk of infection and disease as the immune system is compromised and CD4 counts drop. Symptoms will become more severe and when an individual develops life-threatening infections because of a debilitated immune system as well as experiences very low CD4 counts, they are considered to have full-blown AIDS.[22] People with AIDS contract a variety of diseases, but as of 2013 the most common cause of death for AIDS patients globally is tuberculosis.[23]

To clarify, AIDS then is not actually a disease, but is rather a health condition that involves a compromised immune system and typically several diseases. People do not die from AIDS, but rather die because their weakened immune system (caused by HIV) can no longer fight off various diseases that in most cases would not have been deadly.[24]

### 1.2.1 Where did HIV come from?

Scientists believe that HIV originated with a certain type of chimpanzee in West Africa. They think that the chimpanzee version of the virus (simian immunodeficiency virus, or SIV) most

[20] Hoerl and Neidermeyer, *Use What You Have: Resolving the HIV/AIDS Pandemic*, 33.
[21] Hoerl and Neidermeyer, *Use What You Have: Resolving the HIV/AIDS Pandemic*, 34.
[22] Hoerl and Neidermeyer, *Use What You Have: Resolving the HIV/AIDS Pandemic*, 34.
[23] UNAIDS, *"2013 Global Report"*, 60.
[24] Hoerl and Neidermeyer, *Use What You Have: Resolving the HIV/AIDS Pandemic*, 32.

likely spread to humans and mutated into HIV when humans hunted chimpanzees and came in contact with their blood. HIV may have transferred from chimpanzees to humans as early as the late 1800s. Over decades, the virus spread across Africa and to many parts of the world.[25]

### 1.2.2 How is HIV spread?

HIV lives and reproduces in certain types of bodily fluids including: blood, semen, pre-seminal fluid, breast milk, vaginal fluids, and rectal mucous. One of the most common ways HIV is spread is during sexual contact. During sexual contact the virus can be spread through the bodily fluids by entering the blood stream through microscopic breaks in the linings of the sexual organs. HIV can also enter through open sores, which is why those with sexually transmitted infections (STI's) are particularly susceptible to HIV.[26]

HIV can also be spread from mothers to their children during pregnancy, childbirth, or breastfeeding. Babies can be infected by their mother's body fluids such as their amniotic fluid and blood throughout pregnancy and child birth. After birth, infants can also acquire HIV from drinking infected milk. Another way HIV can be spread is through injected drug use, particularly through the practice of sharing needles. Needles or drugs that are HIV infected can deliver the virus directly into the bloodstream. A less common way HIV is spread is through occupational exposure. Healthcare workers can be at risk of this type of HIV transmission, for instance if a health care worker comes into contact with infected fluids by way of an open cut. Finally, HIV

[25] "About HIV/AIDS," Center for Disease Control and Prevention, accessed January 12, 2014, http://www.cdc.gov/hiv/basics/whatishiv.html.
[26] "How do you get HIV or AIDS," US AIDS, accessed January 12, 2014. http://aids.gov/hiv-aids-basics/hiv-aids-101/how-you-get-hiv-aids/index.html

can be transmitted through a blood transfusion with infected blood or an organ transplant from an infected donor. Screenings of donations can minimize this risk.[27]

### 1.2.3 Antiretroviral Therapy

While no effective cure currently exists, HIV can be controlled through antiretroviral therapy (ART). Antiretroviral medications have been highly effective in improving the life expectancy of people who have HIV/AIDS. These drugs can help those who have HIV from progressing to AIDS and in most cases can enable those who have AIDS to recover their health. There are different types of antiretroviral drugs, but each of them blocks a crucial step in the reproduction of HIV. For example, the drug may block the binding of the virus to the host cell wall, stop the virus from modifying the host cell's DNA, or block the cell from reproducing additional viruses. Each blocked step helps control the HIV disease and thus increases the life span of the infected individual.[28]

As of 2012, 9.7 million people in low-and middle-income countries were receiving antiretroviral therapy, an increase of 1.6 million over 2011. However, the 9.7 million people receiving ART in low and middle income countries only represents 34% of the 28.6 million people eligible in 2013.Approaches that have been effective in accelerating HIV treatment scale-up have been: i) decentralization of treatment, thus bringing services closer to those in need, ii) establishing and updating clinical protocols to enhance quality of treatment and, iii) task shifting- i.e. having nurses implement ART (since there is a lack of human health care resources in many countries.)[29]

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[27] "How do you get HIV or AIDS?"
[28] Hoerl and Neidermeyer, *Use What You Have: Resolving the HIV/AIDS Pandemic*, 38-39.
[29] UNAIDS, *"2013 Global Report"*, 46-47.

While progress has been made, it has not been evenly spread. There are still deficits in care in the following areas: i) access to ART for children, ii) HIV treatment coverage tends to be lower for men than for women, iii) key populations (such as men who have sex with men, prostitutes, drug users) have less access to ART coverage, iv) those affected by humanitarian crises (i.e. refugees) tend to have less access to coverage, and v) adolescents—the 10-19 year age group, is the only age group in which AIDS deaths have risen between 2001 and 2012.[30]

## 1.3 WHAT HAS BEEN DONE SO FAR IN THE FIGHT AGAINST HIV/AIDS?

The UNAIDS 2013 Global Report describes progress that has been made on multiple international goals set for 2015 in the fight against AIDS. Much progress has been made in the international response and as of 2012, an estimated $18.9 billion was available for HIV programs in low and middle income countries, the highest level yet. The first goal is to reduce sexual transmission of HIV by fifty percent by 2015. The number of new HIV infections among adults in low and middle income countries decreased by thirty percent from 2001 to 2012 and was 1.9 million (1.6-2.3) in 2012.[31] In twenty six countries adult HIV incidence declined by more than fifty percent between 2001 and 2012.[32] While decline in transmission is in part due to the nature of the epidemic, part of the progress made is due to the HIV prevention response in which many regional programs have been developed and funded to monitor risky sexual behavior. Behavioral intervention programs have included condom programming, efforts to educate young people about the risk of HIV, voluntary medical male circumcision services, and HIV prevention services targeted at sex workers and men who have sex with men. While much progress has been

[30] UNAIDS, "2013 Global Report", 47.
[31] UNAIDS, "2013 Global Report", 12-13.
[32] UNAIDS, "2013 Global Report", 12-13.

made in HIV prevention efforts, further emphasis on prevention is needed to meet the 2015 goal of reducing sexual transmission of HIV by fifty percent.[33]

A second UNAIDS goal is to eliminate HIV infections among children and reduce maternal deaths. Progress has been made in this area and the number of newly infected children in low and middle income countries is now thirty five percent lower in 2012 than in 2009. The major prevention efforts required to eliminate new HIV infections among children and their mothers are: prevention of new HIV infections among women of reproductive age, helping women living with HIV avoid unintended pregnancies, ensuring that pregnant women have access to testing and counseling as well as access to antiretroviral medicines and that proper HIV care, treatment, and support is provided for women, children, and their families. In many cases the resources allocated to mothers and their children have been impactful and access to antiretroviral medicines for pregnant women has improved, reaching sixty-two percent of women as of 2012. While access to ART and other HIV services has improved at the global level, it is estimated that in 2012, forty-two percent of HIV-positive women needed ART, but could not access treatment. Access to ART was particularly low in some countries including Angola, Chad, D.R. Congo, Ethiopia, and Nigeria. Expansion of the programming for mothers and their children needs to be expanded in order to reach the 2015 goal.[34]

Another UNAIDS goal is to reach 15 million people living with HIV with Antiretroviral Treatment by 2015. Antiretroviral therapy is important because it can reduce virus circulation within a population and can thus reduce the number of new infections. Progress towards this goal has been made and as of 2012, 9.7 million people in low-and middle-income countries were

[33] UNAIDS, *"2013 Global Report"*, 14-28.
[34] UNAIDS, *"2013 Global Report"*, 38-43.

receiving antiretroviral therapy, an increase of 1.6 million over 2011. Globally, the number of people receiving ART has tripled in the last 5 years. Approaches that have been effective in accelerating HIV treatment scale-up have been: decentralization of treatment in order to bring services closer to those in need, establishing and updating clinical protocols to enhance quality of treatment and, iii) training more health care staff workers on how to implement ART. While the progress made in the expansion of ART is impressive, there is still much work to do as the 9.7 million people receiving ART in low and middle income countries only represents 34% of the 28.6 million people eligible in 2013. It will be important to expand accessible HIV testing services (such as home based testing) so that everyone knows their status. Efforts will also have to increase the accessibility to key populations such as sex workers and men who have sex with men.[35]

UNAIDS also has a goal to halve tuberculosis deaths among people living with HIV by 2015. While tuberculosis (TB) remains the number one cause of death among those living with HIV, since 2004 tuberculosis-related deaths among people living with HIV have declined by 36% worldwide. However, progress has not been even among countries with a high HIV/TB burden and in some cases, mortality has decreased less, or even risen. Antiretroviral therapy remains the most effective treatment from preventing tuberculosis-related deaths among people living with HIV. ART reduces by sixty-five percent the risk that a person living with HIV will develop TB and lowers the risk of death among people living with HIV who have TB by approximately fifty percent. Among those who have HIV and TB, ART can repair immune systems damaged by HIV, to prevent development of active TB and can boost the body's capability to respond to the disease.

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[35] UNAIDS, "2013 Global Report", 46-55.

In some countries there has been success in scaling up ART, but globally, ART coverage for people living with HIV and TB remains inadequate, with only 57% of people diagnosed with HIV and TB co-infection receiving ART in 2012. A critical component in preventing TB death is prompt diagnosis of HIV infection among TB patients. The proportion of people with TB who received HIV testing in 2012 increased by fourteen percent from 2011, however globally rates of coverage remain insufficient, particularly in Asia. Effective tuberculosis prevention will involve increasing access to preventative therapy and tuberculosis screening as well as improving the spread and quality of tuberculosis treatment clinics.[36]

Another UNAIDS goals is to eliminate gender inequalities and gender based abuse and violence and increase the capacity of women and girls to protect themselves from HIV.[37] While numerically, there is not yet measurable progress in this area, it is significant that UNAIDS acknowledges that violence against women is an important factor in global HIV incidence. Because awareness of the connection between gender based violence and HIV infection is spreading, more international funding is going towards programs to support women, which is the first step of progress. There is still much more work to be done, but much progress has been made in the realm of awareness.

Similarly, another UNAIDS goal is to eliminate HIV-related stigma, discrimination, punitive laws and practices and, restrictions on entry, stay, and residence. Numerous studies have linked HIVrelated stigma with delayed testing, inability for an individual to tell his/her spouse of HIV status, inability to get HIV services, and involuntary sterilization. HIV related stigma can also contribute to an individual's loss of income, isolation from his/her community and the inability to participate as productive member of society, because of their HIV status. Legal protection

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[36] UNAIDS, "2013 Global Report", 60-66.
[37] UNAIDS, *"2013 Global Report"*, 78-82.

against HIV discrimination has improved and as of 2012, sixty-one percent of countries reported the existence of anti-discrimination laws that protect people with HIV. However, measures need to be taken to ensure that legal services are accessible to the people that need them. Some countries also have restrictions in place on entry, stay, and residence for those with HIV. This is not justified by public health considerations and in many countries progress has been made as they have rejected restrictions on travel for those with HIV. However, forty-three countries still have restrictions in place, which creates many legal barriers for those with HIV.[38]

Finally, UNAIDS has a goal to integrate HIV in health systems and bigger development efforts. Many countries have taken large steps in aligning HIV with broader health and development plans. Forty-five percent of countries have aligned HIV services with other disease specific planning or integrated HIV into national health and development plans, which is a major step in the sustainability of the HIV response.[39]

## 1.4 WHY MATHEMATICAL MODELING?

Mathematical modeling has been an important part of the HIV/AIDS response. Many models have focused on projecting the future spread of HIV in certain regions or subpopulations based on current prevalence rates. These models are often used by policy makers to decide which regions and populations to focus on when allocating resources. It is particularly important in the current global financial climate to use informed, strategic decision-making when allocating resources for the control of HIV. A strategic HIV prevention program requires up-to-date information on the most probable sources of new infections and mathematical modelling provides a "framework for understanding epidemic patterns and for highlighting priority areas

[38] UNAIDS, *"2013 Global Report"*, 86-88, 92.
[39] UNAIDS, *"2013 Global Report"*, 98.

for prevention."[40] These projection models are crucial in targeting the HIV/AIDS response are often published by UNAIDS, a common one being their Excel based Modes of Transmission Model which is the model I will use in my thesis.

Models are also often developed to evaluate the impact of potential interventions that could slow the spread of HIV/AIDS. For instance, a very important 2011 model demonstrated that early antiretroviral therapy (ART) for infected individuals could reduce the likelihood of spreading HIV to their partners by ninety-six percent.[41] This model was named the 'Breakthrough of 2011' by *Science.*[42] Because this model was well-designed and had such strong results, many new international HIV prevention responses are currently being developed with a focus on providing early ART treatment. HIV prevention efforts are typically very costly and having a strong mathematical model supporting the potential impact of that effort can be very important for policy making decisions.

Mathematical models are particularly helpful for modeling the HIV/AIDS epidemic, because there are so many factors that contribute to the spread of HIV. The broad geographical range of the HIV/AIDS pandemic makes modeling much more feasible than trying to perform multiple surveys to study the effects of various HIV/AIDS interventions on people over years in regions all around the world. Also, the outcome of an HIV study can mean life or death for many people, so we do not want to spend years testing out different types of strategies to figure out which ones work or do not work. Using mathematical models to quickly estimate which types of prevention strategies will be the most effective and to decide which areas/populations to focus on

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[40] Jessica Wapner, "Mathematics and HIV," *Work in Progress PLOS Blogs,* July 12, 2012, http://blogs.plos.org/workinprogress/2012/07/12/mathematics-and-hiv/.
[41] Myron S. Cohen et al, "Prevention of HIV-1 with Early Antiretroviral Therapy," *The New England Journal of Medicine* 365 (2011): 493-505.
[42] Wapner, "Mathematics and HIV."

can literally save lives. Also, modeling is a lot less costly than large scale surveying, meaning that more funds can go towards the resources needed for the HIV/AIDS response.[43]

## 1.5 CONNECTION BETWEEN GENDER BASED VIOLENCE AND HIV

Gender inequality plays an important role in the nature of the HIV epidemic, which is why one of the main 2015 goals of UNAIDS is to "eliminate gender inequalities and gender-based abuse and violence and increase the capacity of women and girls to protect themselves from HIV."[44] Women are particularly affected by gender inequality and face a disproportionate risk of HIV acquisition. For instance in sub-Saharan Africa, where 76% of all HIV-positive women are located, HIV prevalence among young women aged 15-24 is two to three times higher than among young men.[45] In order to develop an effective HIV response, particularly in countries in sub-Saharan Africa, policy makers and health care workers need to understand why HIV is significantly higher among young women than among young men. The disproportionate levels of HIV in sub-Saharan Africa can in part be explained by the following gender inequalities as women: are more physiologically vulnerable to HIV, often have unequal access to education, economic opportunities and healthcare, statistically have lower levels of accurate HIV knowledge than young men, often face pressure to have sex with older men (which statistically increases their risk of HIV acquisition), and are less likely to report having used a condom the last time they had sex (implying that men may report having used protection even when that was not the case.)[46] In addition to these gender inequalities, one other important factor that has been significantly linked to risk of HIV acquisition is gender based violence. Gender based violence

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[43] Wapner, "Mathematics and HIV."
[44] UNAIDS, *"2013 Global Report"*, 6.
[45] Klot J, "The Physiology of Sexual Violence, Genito-anal Injury and HIV: Opportunities for Improving Risk Estimation," *American Journal of Reproductive Immunology* 2013;69: 82.
[46] UNAIDS, *"2013 Global Report"*, 78.

affects 30-60% of women worldwide and has substantial mental, physical, and sexual health consequences.[47] Additionally a growing body of research demonstrates that women who have experienced violence are more likely to acquire sexually transmitted infections, including HIV. As my thesis is focused on modeling the relationship between gender based violence (GBV) and HIV, I will use this section to provide the necessary background information including establishing a working definition of gender based violence and explaining the current research's explanations of the pathways between gender based violence and HIV.

Before exploring the connection between gender based violence and HIV further, we must consider what exactly constitutes gender based violence across socio-cultural settings. For the scope of this thesis, I will primarily focus on gender based violence against women, although violence against men and other individuals such as those from the LGBTQ community is certainly a concern that is important to explore in other research. According to the UN, gender based violence against women is any act "that results in, or is likely to result in, physical, sexual or psychological harm or suffering to women, including threats of such acts, coercion or arbitrary deprivation of liberty, whether occurring in public or in private life."[48] I use the term gender based violence because it incorporates physical and sexual violence both of which increase women's susceptibility to HIV/AIDS. According to the World Health Organization, physical violence is "defined as: being slapped or having something thrown at you that could hurt you being pushed or shoved, being hit with a fist or something else that could hurt, being kicked, dragged or beaten up, being choked or burnt on purpose, and/or being threatened with, or

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[47] Dunkle K and Decker M: Gender-Based Violence and HIV: Reviewing the Evidence for Links and Causal Pathways in the General Population and High-risk Groups. *American Journal of Reproductive Immunology* 2013; 69: 20.

[48] United Nations Population Fund: Addressing Gender Based Violence. *UNFPA Publications* 2013: 1-7. Available from: http://www.unfpa.org/webdav/site/global/shared/documents/publications/2013/final%20sexual%20violence%20CSW%20piece.pdf.

actually, having a gun, knife or other weapon used on you."[49] Also according to the WHO, sexual violence is defined as "being physically forced to have sexual intercourse when you did not want to, having sexual intercourse because you were afraid of what your partner might do, and/or being forced to do something sexual that you found humiliating or degrading."[50]

It is important to note that gender based violence does not directly cause HIV, however there are multiple pathways between gender based violence and HIV which explain the heightened association between violence and HIV incidence. The most direct pathway from GBV to HIV is direct infection through sexual assault, with assault or rape causing a heightened risk of HIV transmission because of the genital or anal trauma that can accompany unwanted or forced sex.[51] It is easier for HIV to enter the bloodstream of an individual when there is genital or anal trauma (i.e. tearing or abrasions.) While HIV transmission via rape no doubt occurs, "a growing body of evidence suggests that increased HIV risk caused by violence is not limited to, or even primarily driven by, sexual assault."[52] In fact research is consistently showing that women who report physical violence without accompanying sexual violence still have an increased risk of HIV. The most plausible pathway in this case is that men who are violent are more likely to engage in risky sexual behaviors. In fact evidence from around the world suggests that men who perpetrate violence are more likely to have riskier sexual behaviors including multiple sexual partnerships, transactional sex and prostitution, substance use, and less frequent condom use.[53] This makes

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[49] World Health Organization, "Global and Regional Estimates of Violence Against Women," *WHO Publications* 2013: 5.
[50] World Health Organization, "Global and Regional Estimates of Violence Against Women," 5.
[51] Dunkle K and Decker M. "Gender-Based Violence and HIV: Reviewing the Evidence for Links and Causal Pathways in the General Population and High-risk Groups." *American Journal of Reproductive Immunology* (2013); 69: 21.
[52] Dunkle and Decker, "Gender-Based Violence and HIV: Reviewing the Evidence for Links and Causal Pathways in the General Population and High-risk Groups," 21.
[53] Dunkle and Decker, "Gender-Based Violence and HIV: Reviewing the Evidence for Links and Causal Pathways in the General Population and High-risk Groups," 21.

sense because violence is a product of 'gender power inequities', which are often based on patriarchal ideals of masculinity that are focused on control of women and that celebrate male strength. These masculine ideals often translate into risky sexual behaviors and also discourage men from seeking health and HIV services.[54] This increases the risk of HIV transmission for men who perpetrate violence to their partners even if they have not been violent with a specific partner or if every sexual act in the relationship is not violent.

Violence can also increase HIV risk in indirect pathways. First, the fear of violence often undermines the capacity of women and girls to negotiate safer sex. Also, forced or coerced sex is more often unprotected than consensual sex, which heightens risk of HIV transmission. For example, studies found that women in South Africa who experienced violence were six times more likely to use condoms inconsistently than those who did not experience violence.[55] Secondly, past experience of violence is consistently associated with higher rates of risky sexual behavior in the future including multiple sexual partnerships, lower levels of condom use, increased substance use and sex while intoxicated, and increased participation in transactional sex or commercial sex work.[56] This means that women who have experienced violence in the past, may engage in higher rates of risky behavior in the future, increasing their risk of HIV acquisition in the future higher. Thirdly, concerns regarding the possibility of discrimination, stigma, abuse, and violence may deter women from seeking HIV testing or other health services.[57]

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[54] Dunkle and Decker, "Gender-Based Violence and HIV: Reviewing the Evidence for Links and Causal Pathways in the General Population and High-risk Groups," 22.
[55] Ying Li, Caitlin M. Marshall, Hilary C. Rees, Annabelle Nunez, Echezona E. Ezeanolue, and Jhn E Ehiri, "Intimate partner violence and HIV infection among women: a systematic review and meta-analysis," *Journal of the International AIDS Society* (2014); 7: 2.
[56] Dunkle and Decker, "Gender-Based Violence and HIV: Reviewing the Evidence for Links and Causal Pathways in the General Population and High-risk Groups," 21.
[57] UNAIDS, *"2013 Global Report",* 79.

While considering the pathways between violence and HIV, it is important to consider how these dynamics are magnified in high risk groups such as female sex workers. Female sex workers already carry a much higher burden of HIV prevalence, typically having prevalence rates 14 times greater than the general population.[58] Growing evidence also suggests that female sex workers experience alarmingly high levels of physical and sexual violence. There are similar pathways between violence and HIV infection for female sex workers as there are for the general population, however there are unique risks to be considered. For example, female sex workers may experience severe sexual violence at the initiation of sex work. This is particularly true for those who have been forced or coerced into sex work. Also, like the general population, female sex workers exposed to violence are more likely to face client pressure for unprotected sex, which increases the likelihood of HIV transmission. Finally, qualitative research suggests that violence is associated with higher risk sex for female sex workers such as forced anal sex or coercion into situations with multiple sex partners which in turn poses a heightened HIV risk.[59]

## 1.6 INCORPORATING VIOLENCE INTO THE MOT MODEL

According to UNAIDS, the majority of new infections in sub-Saharan Africa are expected to occur in the general population through heterosexual transmissions. Although model estimates of HIV incidence are certainly improving, little progress has been made in their ability to estimate the risk associated with different forms of heterosexual transmission or to explain the disproportionate rates of infection among young women as compared to young men.[60] One major

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[58] Baral S, Beyrer C, Muessig K, Poteat T, Wirtz AL, Decker MR, Sherman SG, Kerrigan D, "Burden of HIV among female sex workers in low-income and middle-income countries: a systematic review and meta-analysis," *Lancet Infectious Diseases* 2012; 12: 538-549.

[59] Dunkle and Decker, "Gender-Based Violence and HIV: Reviewing the Evidence for Links and Causal Pathways in the General Population and High-risk Groups," 23.

[60] Klot J: The Physiology of Sexual Violence, Genito-anal Injury and HIV: Opportunities for Improving Risk Estimation. *American Journal of Reproductive Immunology* 2013;69: 82.

limitations of the model I have chosen to work with, the UNAIDS Incidence by Modes of Transmission Model (MoT), is the conceptualization of heterosexual transmission as a sexual orientation rather than a range of sexual behaviors as is done with homosexual transmission. Epidemic modelling continues to use a single value to estimate the probability of heterosexual transmission per act even though there are great variations of risks linked with different male-female sexual practices. According to Jennifer Klot, these risks are most likely to vary based on (i) the type of sexual intercourse (vaginal or anal); (ii) the use of force; (iii) sex and age related physiological characteristics; and (iv) the type of relationship (i.e. multiple concurrent sexual partnerships, transactional sex [sex motivated by economic exchange, but which would typically not be self-identified as prostitution]).[61] Based on Klot's findings on the limitation of the MoT model and other evidence from current research supporting the link between violence and HIV, I have chosen to treat perpetrators and survivors of sexual violence as a 'risk group' and sexual violence as a 'risk behavior.'

## 1.7 THE HIV/AIDS EPIDEMIC IN SOUTH AFRICA

I have chosen to study the connection between gender based violence and HIV in South Africa, because as a country it currently has the highest HIV prevalence rate in the world and has one of the highest rates of intimate partner violence in the world.[62] The HIV prevalence rate is approximately 18.8% as of 2012 among adults aged 15-49.[63] It is estimated that HIV incidence among adults in South Africa aged 15-49 is 1.72% with an approximately 396,000 new

[61] Klot J, "The Physiology of Sexual Violence, Genito-anal Injury and HIV: Opportunities for Improving Risk Estimation," 82.
[62] Gass J, Stein D, Williams D, Seedat S, "Intimate partner violence, health behaviours, and chronic physical illness among South African women," *NIH Public Access* (2011); 9: 583-585.
[63] Shisana O, Rehle T, Simbayi LC, Zuma K, Jooste S, Zungu N, Labadarios D, Onoya D et al., "South African National HIV Prevalence, Incidence and Behaviour Survey," *HSRC Press* (2014): 35.

infections occurring in 2012.[64] The HIV epidemic in South Africa is generalized, meaning that "HIV has spread beyond initial subpopulations engaged in high risk sex sexual behavior to the general population as evidenced by prevalence rates of five percent or more in urban areas."[65] So, unlike some countries where the majority of HIV infections are solely attributed to high risk groups (such as female sex workers or recreational drug users) the HIV epidemic has spread to the general population. While the HIV epidemic in South Africa is generalized, there are risk populations within the general population that carry higher HIV burdens by having a HIV prevalence greater than the total population. According to Human Sciences Research Council's (HSRC's) recently published "South African National HIV Prevalence, Incidence, and Behavioral Survey" the most at risk populations based on HIV prevalence are black African females aged 20-34 (31.6%), co-habitating, but not married individuals (30.9%), black African males aged 25-49 years (25.7%), disabled persons aged 15 and over (16.7%), high risk alcohol drinkers over 15 years (14.3%), and recreational drug users (12.7%). In order to better understand the nature of the HIV epidemic in South Africa, I will briefly address how different region, race, gender, and age groups are affected by HIV in South Africa.

First, HIV prevalence varies greatly by region. Overall, geographically speaking, rural informal residents (individuals in rural areas that do not live in formal housing) had significantly higher HIV prevalence than urban formal HIV residents (individuals in urban areas who live in formal housing), which speaks to a lack of health care and other resources in rural regions.[66] More than urban/rural divide, HIV prevalence varies greatly by specific regions. Among all ages,

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[64] Shisana et al. "South African National HIV Prevalence, Incidence and Behaviour Survey," 35.
[65] Goliber T, "The Status of the HIV/AIDS Epidemic in Sub-Saharan Africa, " *Population Reference Bureau* (2002). Available from http://www.prb.org/Publications/Articles/2002/TheStatusoftheHIVAIDSEpidemicinSubSaharanAfrica.aspx
[66] Shisana et al. "South African National HIV Prevalence, Incidence and Behaviour Survey," 36.

the national HIV prevalence is 12.2%.[67] KwaZulu-Natal has the highest HIV prevalence (16.9%), followed by Mpumalanga (14.1%), the Free State (14.0%), and North West (13.3%). The region with the lowest HIV prevalence is the Western Cape (5.0%), followed by the Northern Cape (7.4%) and Limpopo (9.2%). There is also variation in the presence of HIV in regards to 2012 HIV incidence in urban informal settlements(individuals in urban areas who do not live in formal housing) (2.5%) versus urban formal areas (1.1%).[68]

Secondly, race is also an important factor in the HIV epidemic in South Africa. The black population has the highest prevalence, 15% (for all ages), followed by the colored population (refers to people of mixed ethnic origins) 3.1%, Indian .8%, and White .3%.[69] One reason blacks may have substantially higher HIV prevalence is that they were less likely to live in urban formal areas. Urban informal areas tend to be under-resourced and lack basic amenities such as formal housing, water, sanitation, and access to preventive health care. Also, black Africans are less likely to report being married than whites, Indians, or Asians. This may contribute to the higher HIV prevalence among black Africans as nationally HIV prevalence was found to be higher in the un-married and cohabitating population than in the married population.[70]

Thirdly, gender and age are also key determinants of the nature of the HIV epidemic in South Africa. By gender, females have a higher HIV prevalence than males. In the adult population (aged 15-49 years), HIV prevalence is 23.3% among females and 13.3% among males, demonstrating a disproportionate HIV burden for women in the general adult population.[71] HIV

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[67] Shisana et al. "South African National HIV Prevalence, Incidence and Behaviour Survey," 37.
[68] Shisana et al. "South African National HIV Prevalence, Incidence and Behaviour Survey," 36.
[69] Shisana et al. "South African National HIV Prevalence, Incidence and Behaviour Survey," 42.
[70] Shisana et al. "South African National HIV Prevalence, Incidence and Behaviour Survey," 42.
[71] Ina van der Linde, "HIV/AIDS in South Africa: At last the glass is half full," *HSRC Media* (2013). Available from http://www.hsrc.ac.za/en/media-briefs/hiv-aids-stis-and-tb/plenary-session-3-20-june-2013-hiv-aids-in-south-africa-at-last-the-glass-is-half-full.

incidence in the adult population (aged 15-49) years is 1.7 times higher in females than in males. Even more drastic, in the young adult population (15-24) female prevalence of HIV was 8 times higher than their male peers. Female youth aged 15-24 also had an HIV incidence rate over 4 times higher than found among their male peers in 2012. Approximately 24.1% of all new HIV infections in South Africa occurred among the young female population. Encouragingly, HIV incidence has declined among young females from 5.3% in 2002-2005 to 2.1% in 2008-2012. This is a statistically significant reduction by 60% in HIV incidence. However, a 2.1% incidence rate is still a value that the public health community should not be complacent with.[72]

In addition to analyzing how different region, race, age, and gender groups are affected by HIV, it is important to recognize prominent behavioral determinants of HIV in South Africa. It is especially important to understand the nature of risky sexual behaviors in South Africa, because there is a strong association between risky sexual behavior and gender based violence. The first behavioral determinant of HIV is sexual debut before the age of 15. In the HSRC survey, 10.7% of respondents reported having had sex for the first time prior to age 15. There were significant differences in sexual debut based on race/age with 16.7% of males and 11.1% of black Africans having had sex prior to age 15. A second important sexual risk behavior is engaging in age-disparate relationships. In 2012, 19.9% of all respondents aged 15-49 years were in a sexual relationship with a partner five or more years older than them. Gender also figures strongly in this risk behavior, with 33% of females aged 15-19 having reported age-disparate relationships in comparison to 4.1% of their male counterparts. Data also shows that there has been a steady increase in age-disparate relationships for young females from 2005 to 2012. A third behavioral determinant of HIV is having multiple sexual partners. In the HSRC survey, 12.6% of

[72] Ina van der Linde, "HIV/AIDS in South Africa: At last the glass is half full."

respondents aged 15 and older had more than one sexual partner in the past year. Of reporting males, 20.1% had multiple sexual partners which was five times higher than females. Similarly, many more young adults aged 15-24 adults reported having had multiple sexual partners in comparison to other age groups. From 2002-2012 there was a significant increase in respondents who had more than one sexual partner in the past year, from 11.5% in 2002 to 18.3% in 2012. Even more dramatically, among males aged 15-24, the percentage having multiple sexual partners increased from 23% in 2002 to 37.5% in 2012. Finally, another important sexual risk behavior is inconsistent use of condoms. In 2012, 36.2% of respondents in the HSRC survey who were sexually active in the past year reported using a condom in their last sexual act. There was also a gender divide here, with 38.6% of males reporting they had used a condom in last sex in comparison to 33.6% among females. This may suggest that males over-report their use of condoms. Interestingly, overall condom use at last sex in South Africa increased from 2002 to 2008 and then decreased significantly from 2008 to 2012. Also notably, while 24.7% of sexually active respondents reported consistent condom usage, 52.9% indicated they had never used a condom.[73]

From these numbers, it is clear that there is still a relatively large presence of sexual risk behaviors in South Africa even among the general population. These sexual risk behaviors are particularly relevant to our work as they are closely tied to gender based violence.

### 1.7.1 Connection between gender based violence and HIV in South Africa

In addition to HIV, gender based violence is a growing public health concern in South Africa. It is estimated that approximately 31% of women in South Africa have experienced

[73] Shisana et al.,"South African National HIV Prevalence, Incidence and Behaviour Survey," 65-66.

gender based violence at some point in their lifetime.[74] Other reports of lifetime violence range from 43.3% among young rural women[75], to 55.5% among women attending antenatal clinics.[76] The research generally agrees that odds of women in South Africa who experience violence contracting HIV increases by a ratio of 1.5, based on the indirect linkages between violence and HIV described above. Similarly for men, research done on a random sample of men aged 18-49 found that 42.4% had perpetrated physical or sexual violence in their lifetimes and that men who perpetrated violence were 48% more likely to have HIV than those who had not.[77] There is not a consensus on why the prevalence of gender based violence is so high in South Africa. However it is often believed to be a product of unequal gender power distribution which is a product of ideals of male superiority such as heterosexual success and control of women. There is a clear consensus however that men who perpetrate violence and women who experience violence are more likely to engage in riskier sexual behaviors.

### 1.7.2 What has been done/needs to be done in the fight against HIV/AIDS in South Africa

South Africa has certainly made progress in the fight against HIV/AIDS. As a country, South Africa has increased its domestic spending HIV/AIDS by five times from 2006-2009. Many interventions focused on HIV prevention, treatment, care and support have been implemented. Although HIV prevalence remains high, it has been stable over the last decade. Access to ART has increased which has decreased deaths due to AIDS and increased life expectancy. By 2012,

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[74] Gass J et al., “Intimate partner violence, health behaviours, and chronic physical illness among South African women,” *NIH Public Access,* 583-585.
[75] Jewkes R, Dunkle K, Nduna M, et al, “Factors associated withHIV sero-status in young rural South African women: connectionsbetween intimate partner violence and HIV,” *International Journal of Epidemiology* 2006;35:1461–8.
[76] Dunkle KL, Jewkes RK, Brown HC, et al, “Prevalence and patterns of gender-based violence and revictimization among women attending antenatal clinics,” *American Journal of Epidemiology* 2004; 160: 230-239.
[77] Townsend, Loraine et al., “HIV Risk Behaviours and their Relationship to Intimate Partner Violence (IPV) Among Men Who Have Multiple Female Sexual Partners in Cape Town, South Africa,” *AIDS and Behavior* 15 (Jan 2011): 132-41.

of an estimated 6,422,000 people living with HIV (PLHIV), 2,002,200 (31.2%) were exposed to ART. A significantly greater proportion of females (34.7%) than males (25.7%) had accessed treatment, however ART exposure among people living with HIV almost doubled from 16.6% in 2008 to 31.2% in 2012. There is still much work to do in addressing HIV/AIDS in South Africa, but it has come a far ways in the fight so far.

In order to effectively combat HIV in South Africa, the public health community will need to invest in campaigns that target the risky sexual behaviors of early sexual debut, age-disparate relationships, multiple sexual partnerships, and inconsistent condom usage. This is particularly important in an era where ART has become more accessible as there is a tendency for populations to increase engagement in risky sexual behavior in response to a wider availability of ART.  Part of combating this ‘risk compensation’ will involve encouraging more people, particularly men, to be tested for HIV and continuing to educate the population about HIV. From the HSRC report, 92.3% of respondents knew where they could be tested for HIV and 65.6% had been tested. Among females, 55% HIV-positive women and 45% of HIV-negative women were aware of their status. Among males, 37.8% HIV-positive men and 35.6% of HIV-negative men were aware of their status. This suggests that more programs need to be developed to encourage more men to get tested for HIV. Additionally, only 26.8% of South Africans in the HSRC survey had accurate knowledge about the sexual transmission and prevention of HIV, and there was surprisingly a significant decrease in knowledge between 2008 and 2012. This suggests that HIV awareness campaigns need to be continued to be implemented. To address the high prevalence of age-disparate relationships, efforts are needed to empower and educate young women about the risks of such relationships and to break the cycle of poverty which is particularly relevant for young women who have sex with older men for financial gain. Additionally, resources need to

be targeted towards rural and urban informal areas alongside poverty reduction efforts in order to improve access to basic resources like adequate healthcare.[78] Finally, in addition to targeting the above risk behaviors, I believe that it will be important to address gender based violence in South Africa as violence is a significant driver of HIV incidence as will be demonstrated through my mathematical model.

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[78] Shisana et al., "South African National HIV Prevalence, Incidence and Behaviour Survey," 112-113.

# CHAPTER 2: METHODS

## 2.1 THE UNAIDS MODES OF TRANMISSION MODEL

The Modes of Transmission (MoT) model was first developed in 2002 by the UNAIDS Reference Group on Estimates, Modelling and Projections to help countries estimate the distribution of HIV incidence among different risk groups using basic epidemiological and behavioral input data. Application of the model is encouraged through UNAID's "Know your Epidemic/Know your Response" initiative with the goal of helping countries develop strategic approaches to HIV prevention by making evidence-informed decisions when allocating resources to the HIV epidemic. The goal of the MoT Model is to "help countries calculate the expected number of new HIV infections over the coming year on the basis of a description of the current distribution of prevalent infections and patterns of risk within different populations." [79] After inputting country specific data, countries are encouraged to use the output of the MoT model to analyze which subpopulations are most at risk of HIV infection as well as which risk behaviors may facilitate transmission and to subsequently review their current prevention responses in light of the results of the model. A major benefit of the UNAIDS MoT model is that it is designed to be used by a variety of countries as the model is an excel template that can be downloaded from the UNAIDS website and filled in with relevant country parameters. Hence the structure of the model, with the equations and assumptions of how risk groups are related, stays the same, but can be adapted to fit any country which has data on the necessary parameters. It is also relatively simple to implement and allows users to estimate HIV incidence even with fairly elementary

[79] UNAIDS Reference Group on Estimates, Modelling, and Projections, "Modeling the Expected Short –Term Distribution of New HIV Infections by Modes of Transmission," *UNAIDS Publications* 2012: 2. Available from http://www.unaids.org/en/media/unaids/contentassets/documents/document/2012/guidelines/JC2427_ModelingNewHIVInfectionsbyModesofTransmission_en.pdf.

estimates on current HIV parameters As of 2012, over 40 countries will have completed or begun an MoT analysis.[80]

The UNAIDS MoT model is an Excel sheet, downloadable from www.unaids.org, which has numerous biological and epidemiological parameters that the user inputs based on country level estimates. The model then has pre-calculated formulas which take the user's inputs and estimates projected distribution of new HIV infections for the following year based on the mode of exposure.[81] I will briefly explain the inputs that the model uses.

First, the user has to estimate basic population and epidemiological estimates. These parameters include: the size of the adult (15-49) population, the overall estimated HIV prevalence rate, the transmission probability per act of exposure (male to female, female to male, male to male, and by drug use), the percentage of men circumcised, the total number of people receiving ART, and the likelihood of ART to reduce HIV transmission.

Secondly, the user specifies the size of the different risk populations. Adults aged 15-49 are divided into different risk groups depending on their sexual or drug use behavior. These risk groups include: injecting drug users, partners of injecting drug users, female sex workers, male clients of female sex workers, female partners of male clients (of female sex workers), men who have sex with men, casual heterosexual sex (more than one partner in past year), stable heterosexual couples, no risk (did not engage in sex or drug use in past year), medical injections, and blood transfusions.

Thirdly, the user estimates current HIV prevalence by risk population. Individuals that engage in riskier sexual or drug use behavior are more likely to have HIV/AIDS, and so HIV

[80] To see the list of countries, visit: http://www.who.int/bulletin/volumes/90/11/12-102574.

[81] Case K et al., "Understanding the Modes of Transmission Model of New HIV Infection and its Use in Prevention Planning," *Bulletin of the World Health Organization* 2012; 90:831-838.

prevalence rates are higher for certain risk groups. However, the model sums and averages these different HIV prevalence rates into an average population HIV prevalence rate, which the user can make sure matches other published reports.

Fourthly, the model requires the prevalence of sexually-transmitted infections (STI) for each risk group. It is well known in research on HIV/AIDS that individuals who have STIs are more susceptible to receive and spread HIV, as STIs cause tears and abrasions to the genital areas which increases the likelihood of HIV entering the bloodstream. Thus, the model attributes a higher probability of transmission to the individuals in each risk group that have an STI.

Fifthly, the user estimates the average number of partners per year in each risk population. This number is typically highest for female sex workers and their male clients and followed by individuals who engage in casual heterosexual sex, and lowest for individuals in the stable heterosexual population who are assumed to have one partner in the past year. The model also requires an estimate of the average number of acts of potential HIV risk exposures per partner per year. Here, the number of acts per person per year is typically higher for long term couples and lower for higher risk groups like female sex workers who have fewer acts with one person, but multiple partners per year.

Next, the user estimates the percentage of acts of exposure that are protected for each risk group. It is assumed that sexual acts are protected through condom use and drug acts are protected through the use of sterile needles. Finally, the user estimates the percentage of HIV infected individuals who are receiving ART. It is assumed that individuals who are on ART are less likely to transmit HIV (based on the epidemiological parameters provided above.)

Once the user has inputted all of the necessary data, the model calculates incidence by the following equation:

$$I = S[1 - \{p(B(1 - \beta'(1 - u))^a + (1 - B)(1 - \beta)^{a(1-u)}) + (1 - p)\}^n]$$

This equation is evaluated for each risk group in the model and an estimate of the total number of new infections for that risk group in the next year (I), the main output variable, is calculated. (I) is calculated for each risk group by multiplying a series of variables relating either to the risk group or their partner risk group. For example, consider how this model functions in the case of the female sex worker. The total number of new HIV cases in the next year among female sex workers (I) is calculated as a function of the number of susceptible female sex workers (S), the current HIV prevalence of their clients (their partner population) (p), the prevalence of STIs in the client population (a factor which increases risk of HIV spread) (B), the proportion of sexual acts that are protected (as reported by female sex workers) (u), the number of sexual partners the female sex worker has per year (with more clients she is more likely to get HIV) (n), and the number of sexual acts per partner (having more acts with an infected client makes a female sex worker to get HIV) (a). $\beta$ and $\beta'$ represent the probability of HIV transmission from the male client to the female sex worker with the presence or absence of an STI, respectively, (with the presence of an STI leading to a higher rate of HIV transmission) and are factored into the equation as a conditional statement. If the client has an STI, then the second half of the equation using $\beta$ is applied, and if the client does not have an STI then the first half of the equation using $\beta'$ is applied. The goal of the model output is not to derive a perfect estimate of HIV incidence for the following year, but rather for the user to be able to analyze the percentage of new HIV infections which are attributed to each risk group. Additionally, the model has a built in uncertainty analysis tool in which the user can allow specific model inputs to vary randomly for several runs (typically 500-1000), with each run resulting in a different estimate of the number of

cases of HIV incidence for each population as well as total incidence.[82] This tool allows the user to account for and identify some of the uncertainty that is inherent within the structure and parameter values of the model.

## 2.2 THE MOT MODEL IN SOUTH AFRICA

After reviewing multiple published reports on the MoT for different countries, I chose to focus on evaluating the MoT model in South Africa. I strategically chose South Africa, because it is located in sub-Saharan Africa which is the current center of the HIV epidemic and because South Africa is the country with the current highest HIV prevalence rate. Additionally, South Africa has high levels of gender based violence, making it particularly relevant for my research. Also, South Africa has good data on estimates of HIV and violence parameters as a large amount of research has been done and continues to be updated. The data for the South Africa MoT model comes from three main sources: the *National HIV and Syphilis Prevalence Survey* conducted annually by the National Department of Health (includes surveillance data from women attending antenatal clinics), the *Demographic and Health Survey* (DHS) a national survey conducted in 1998 and 2003, and the *National HIV Prevalence, Incidence, Behaviour and Communication Survey* conducted by the Human Sciences Research Council (HSRC) (and others) in 2005, 2008, and 2012. I used the published South Africa MoT report (2009) to fill in the basic parameter values in my model, although I did update the population size and national HIV prevalence rate to 2012 estimates.[83] The output of the original model shows that the majority of new infections were projected to occur in the low risk heterosexual sex group,

[82] UNAIDS Reference Group on Estimates, Modelling, and Projections, “Modeling the Expected Short –Term Distribution of New HIV Infections by Modes of Transmission,” 21.
[83] Kassanjee R, et al, “The Modes of Transmission of HIV in South Africa,” *SACEMA* (2009): 1-36.

demonstrating the generalized nature of the HIV epidemic in South Africa. The model estimated that low risk individuals make up 47% of the susceptible population and account for 57% of new infections in the upcoming year. Although the incidence of HIV is relatively low for these individuals, they still account for a large percentage of new HIV infections because the group is so large. On the other hand, sex workers, clients of sex workers, and injecting drug users had relatively high levels of HIV incidence, collectively accounting for 25% of the new infections, although they only account for 5% of the total susceptible population. Although these high risk groups did not account for a majority of new infections, their relatively high rates of HIV incidence suggest that these risk groups need to also be targeted in the HIV/AIDS response.

## 2.3 ADAPTING THE MOT MODEL TO ACCOUNT FOR VIOLENCE[84]

As mentioned above in the section on gender based violence (GBV) and HIV, a major limitation of the MoT model is that it treats heterosexual sex as a single risk value rather than accounting for variation of risk inherent in the terms of the heterosexual act. One such risk that is not included is the presence of violence. To incorporate violence as a risk factor into my model, I chose to break each of my risk groups into two sub-risk groups, one incorporating violence, the other not. For example, the original MoT model had female sex workers as a risk group. In my model, I broke this down into two separate groups: female sex workers who have experienced violence in the past year and female sex workers who have not. I did this for each risk group, minus injecting drug users and men who have sex with men, due to a lack of data available particularly on the rates of violence that men experience from male partners. Similarly, I

[84] Many thanks to Holly J. Prudden for her helpful explanations on how she adapted and improved the MoT model for her own research: Prudden, Holly J. et al., "Can the UNAIDS modes of transmission model be improved?: a comparison of the original and revised model projections using data from a setting in west Africa."

assumed that male risk groups perpetrated violence against women, and women experienced violence from their partner male groups. Of course, it is likely that some women perpetrate violence and some men experience violence, but I did not have enough data to account for these possibilities.

After I broke each risk group down into sub-risk groups, I researched the new parameter values I needed to fill in the model to account for violence. First, this involved researching and estimating the percentage of men who perpetrated violence in the past year and the percentage of women who experienced violence in the past year. These estimates were somewhat difficult to obtain as many of the studies in South Africa I found were either focused on a specific region or key population in South Africa (making it difficult to generalize the results to the entire country) or provided estimates for the rates of perpetration/experience of violence for individual's whole life time, rather than the past year which is what is required by the model. Ultimately, I used values from studies that seemed to best fit the risk groups in my model, realizing that there is a degree of uncertainty in my estimates.

For men, I estimated that 41.5% of males who engaged in higher risk sex (clients of female sex workers, men engaging in casual heterosexual sex (CHS), and male partners of females in CHS) had perpetrated violence in the past year. This percentage is based on the findings by Townsend et al. (2005) in which they interviewed men who had multiple female sexual partners in Cape Town in 2011 and found that 41.5% had perpetrated violence.[85] For the most part, the men interviewed in Townsend's study came from most-at-risk populations based on their sexual activity, which is why I applied this number to men in higher risk groups in the MoT model. For men in lower risk groups (men in stable heterosexual couples), I estimated that

[85] Townsend, Loraine et al. "HIV Risk Behaviours and their Relationship to Intimate Partner Violence (IPV) Among Men Who Have Multiple Female Sexual Partners in Cape Town, South Africa," 132-41.

26.6% had perpetrated violence in the past year. I based this value off of the percentage of women in low risk groups who experience violence from Jewkes et al (2010), described in further depth below.[86] Although it would have been ideal to calculate a separate population estimate of low risk men who perpetrate violence, I made this assumption because I could not find another report with accurate numbers of perpetration of violence for low risk men in South Africa.

For women, I estimated that 64% of female sex workers experienced violence in the past year, based on the findings by Wechsberg et al. (2005) which included a study of 93 sex workers in Pretoria. Of the women interviewed, 64% said that one or more out of their clients had been violent, 51% reported sexual abuse, and 63% reported partner violence in the past year (by a boyfriend or other long term partner.)[87] For other women engaging in higher risk sex (female partners of male clients (of female sex workers), women who engage in in CHS, female partners of men who engage in CHS), I estimated that 41.5% had experienced violence in the past year. This is based on my estimate for the percentage of high risk men who perpetrate violence. It would have also been ideal to find separate population estimates for high risk females; however I could not find a study in South Africa which had reliable estimates for women engaging in high risk sex. Finally, for women in lower risk groups (stable heterosexual couples), I estimated that 26.6% had experienced violence in the past year. This comes from Jewkes' et al. (2010) report, which found that of the women aged 15-26 interviewed coming from 70 locations in the Eastern Cape province of South Africa, about 12.4% of women had HIV and 26.6% had experienced

[86] Rachel Jewkes, "Intimate Partner Violence, Relationship Power Inequity, and Incidence of HIV Infection in Young Women in South Africa, a Cohort Stuy," *The Lancet* 376 (2010): 41-48.

[87] Wechsberg et al., "Violence against substance-abusing South African sex workers: intersection with culture and HIV risk," *AIDS Care* 17 (2005): S55-S64.

more than one episode of physical or sexual IPV in the past year.[88] Because this study focused on young women aged 15-16, this is an admittedly higher risk group, however this is the only study in South Africa that reported violence for women within the last year, rather than a lifetime estimate and so was the best estimate available.

Secondly, I updated the estimate of HIV prevalence for the risk groups that incorporated violence. I estimated that men who had perpetrated violence were 1.5 times more likely to have HIV, based on Jewkes' et al. (2011) findings.[89] Jewkes' findings are based on a cross-sectional household study of 1220 South African men aged 18-49 in which she found that men who had been physically violent towards a partner in the past year were more likely to be HIV infected with an adjusted odds ratio of 1.5 (95% CI 1.0, 2.17, p=0.03). While 85% of men in the study were black African, which slightly biases the results, this odds ratio was congruent with other findings in the literature. To apply this odds ratio to the risk groups including violence in my model, I took my original HIV prevalence probability, converted it to an odds ratio, multiplied it by 1.5 and then converted it back to a probability. For example, the original HIV prevalence rate for male partners of clients was 32.229%. To calculate the new HIV prevalence rate for male clients who perpetrate violence, I converted this to an odds ratio, which was .47599, multiplied this by 1.5, in order to get my new odds ratio of .71399. I then converted this back to a probability, obtaining a new HIV prevalence rate of 41.657% for male partners of clients. To find the prevalence rate for my sub-risk group of male clients who do not perpetrate, I took a weighted average based on the size of the sub-risk populations and the HIV prevalence rate of

[88] Rachel Jewkes. "Intimate Partner Violence, Relationship Power Inequity, and Incidence of HIV Infection in Young Women in South Africa, a Cohort Stuy," *The Lancet* 376 (2010): 41-48.

[89] Rachel Jewkes et al. "The Relationship between Intimate Partner Violence, Rape and HIV amongst South African Men: A Cross-Sectional Study." *PLoS One* 6 (2011): 1-6.

the original group, in order to obtain a new HIV prevalence rate of 25.541% for male clients who do not perpetrate violence.

Similarly, I updated HIV prevalence rates in the female populations to account for violence. From Dunkle's et al. (2004) findings I estimated that women who experienced violence in the past year were 1.48 times more likely to have HIV. Dunkle interviewed women who attended antenatal clinics and found that 55% had a history of physical or sexual assault. For those women who experienced physical and sexual violence, 40.2% were HIV positive as compared to a 28.6% HIV prevalence rate for those who had not experienced violence . They found that any type of intimate partner violence in the past year was significantly associated with a positive HIV status with an adjusted odds ratio of 1.48 (95% CI: 1.15, 1.89).[90] I applied this odds ratio to each female risk group which incorporated violence, using the same methods as described for the male risk groups. For example, the original HIV prevalence rate for female sex workers is 53.57%. After converting this to an odds ratio and multiplying by 1.5, I found that the prevalence rate for female sex workers who have experienced violence is 63.203%. After calculating a weighted average, I found that the prevalence rate for female sex workers who did not experience violence was 36.849%.

Thirdly, I chose to update the parameter value of percentage of acts protected (by condom use) for risk groups incorporating violence. Based on the Pettifor's et al. (2004) findings, I estimated that men who perpetrated violence and women who experienced violence were 2.1 times less likely to use condoms consistently.[91] Pettifor et al. conducted their research among sexually experienced, women aged 15-24 in South Africa, an admittedly higher risk

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[90] Kristin L. Dunkle et al, "Gender-based violence, relationship power, and risk of HIV infection in women attending antenatal clinics in South Africa," *The Lancet* 363 (2004): 1415-1421.
[91] Pettifor A, Measham DM, Rees HV, Padian NS, "Sexual Power and HIV Risk, South Africa," *Emerging Infectious Diseases* 10 (2004): 1994-2004.

population. They found that women with low relationship control, a score based on partner's power in decision making specifically in regards to timing of sex, were 2.10 times more likely to use condoms inconsistently (95% CI: 1.17–3.78). Additionally, they found that women who reported forced sex were 5.77 times more likely to use condoms inconsistently (95% CI: 1.86-19.71).[92] While it would be ideal to have estimates based on a more general population study, the results of Pettifor's work do coincide with findings of other published reports, so I decided to use Pettifor's results as it is the best information about violence and condom non-use in South Africa currently available. Just as I did when updating HIV prevalence rates to account for violence, I used the odds ratio of 2.1 to estimate the decreased use of condom use among risk groups incorporating violence. For example, originally the model estimates that for clients of female sex workers, 52.4% of sexual acts in the past year were protected. After incorporating the odds ratio of 2.1, I found that 34.39% of sexual acts in the past year were protected for clients who have perpetrated violence. By calculating a weighted average, this meant that 84.83% of sexual acts were protected for clients who did not perpetrate violence.

There were a number of other parameters that I could have chosen to update, however based on limited available data, I chose to experiment with varying these parameters in my uncertainty analysis instead. For example, the research suggests that women who have experienced violence and men who perpetrated violence are likely to have had more sexual partners in the past year than those who did not experience or perpetrate violence. While I did not have concrete estimates of how many more partners individuals who have experienced or perpetrated violence are likely to have, this is an important variable that I considered when conducting my sensitivity analysis. Another variable I chose not to vary was the probability of

[92] Pettifor A et al, "Sexual Power and HIV Risk, South Africa," 1994-2004.

transmission of HIV from males to females and females to males. This is the parameter that would account for the direct pathway between gender based violence and HIV: acts of sexual violence increase the probability of HIV transmission due to trauma of the genital tissue. This is clearly an important variable, however I chose not to alter this value in the model, because based on the model structure, increasing the probability of HIV transmission to account for violence would assume that every single sexual act was violent for individuals in risk groups which incorporate violence. This however is not the case, as it is likely that some sexual acts are violent between two partners, while others are not. Since there was no way to account for a certain proportion of sexual acts being violent, I chose not to vary the probability of HIV transmission to account for violence and will instead highlight this variable in my uncertainty analysis.

After determining which parameter values to use based on my review of the literature, I updated the MoT model by plugging in my new parameters and reformulating the equations in cells where necessary. At this stage I evaluated the incidence outputs of the revised model based on the point estimates I had entered from the parameter values and performed a designed experiment sensitivity analysis, both of which will be discussed in the results section. Before evaluating my results, however, it is important to consider some limitations of the model.

## 2.4 LIMITATIONS

By definition, any mathematical model is a simplified representation of reality and will have limitations that affect the ways the results of the model can be interpreted in the real world. It is important to discuss and understand the limitations of the model so that the numbers outputted by the model are not taken at face value, but can be understand within the context of the data available for the inputs. This is particularly true for mathematical models of the HIV epidemic,

as any mathematical model will oversimplify the ways in which HIV is transmitted through individual and drug use behaviors within large, diverse populations. It is also particularly essential to evaluate the limitations of the MoT model itself as it is well-recognized by the UNAIDS authors to be a fairly simplistic model in comparison to other incidence models. Adding in estimates of violence certainly adds more limitations to the MoT model in South Africa, making this topic of special importance in my thesis. In this section I will discuss the limitations inherit within the MoT model itself as well as within my assumptions and estimations when incorporating violence as an HIV risk factor into the South Africa MoT model.

### 2.4.1 Limitations of the Original MOT Model

As discussed in previous sections, the UNAIDS Modes of Transmission model is a useful tool for estimating the distribution of HIV incidence among risk groups in part because it is a static model with a simple structure that requires relatively few population parameter estimates. While the nature of the MoT model makes it accessible for a number of countries, it also means there are important limitations inherent to the model which need to be discussed. As described by Case et al. (2012) the limitations of the MoT are based on the model structure, the data used in the model, and the interpretation of the results.[93]

First, there are limitations inherent within the model structure. The MoT model assumes that the risk of infection is uniform within each risk group. This means, for example, that all individuals engaging in casual heterosexual sex (having more than one sexual partner in the past year) are assumed to have the same risk of HIV infection. It also means that the model does not capture certain details, such as clients of sex workers only visiting a particular type of sex

[93] Case K et al., "Understanding the Modes of Transmission Model of New HIV Infection and its Use in Prevention Planning," 833.

worker. The model allows the user to create sub-risk groups, which is what I did in my thesis, however there is often insufficient data available to do this.[94]

Another limitation within the model structure is that individuals are assigned to a single risk group and are assumed to only be at risk of infection from one source. Individuals who may be at risk from multiple sources, such as men who have sex with men who also use drugs, are categorized based on the behavior associated with higher HIV transmission. This assumption implies that eliminating the higher source of risk will prevent the infection for that individual. This could result in overestimating the impact of interventions which target that higher source of risk. On the flipside, this means that less risky behaviors may be underestimated and thus not targeted properly. For example, female sex workers are who also inject drugs are categorized into the drug using risk group because drug use is a higher risk behavior. In this case the model assumes that these individuals would not benefit from a successful intervention among sex workers, which is clearly not the case.[95]

Additionally, the model relies on published data (from systematic reviews and analyses of observational studies) to determine the probabilities of HIV transmission for different exposure acts. These sources typically provide an HIV transmission probability value that is generically used for each country that employs the MoT model. While these probability values represent the best data available, they may not account for potential variation in transmission probability based on geographical setting. Also, the model assumes that there is no variation in transmission probability based on the stage of the HIV infection (which is biologically

[94] Case K et al., "Understanding the Modes of Transmission Model of New HIV Infection and its Use in Prevention Planning," 833.
[95] Case K et al., "Understanding the Modes of Transmission Model of New HIV Infection and its Use in Prevention Planning," 833.

inaccurate) and does not allow sexual patterns such as concurrent sexual partnerships to impact the transmission probability.[96]

Another limitation of the structure of the model is that the size of the stable heterosexual subpopulation and the no-risk population  is often estimated after the other risk groups sizes are summed to make the total size of all groups matches the population size. This establishes a dependency between the sizes of the various risk groups so that if one risk group is overestimated, the others will be underestimated and vice versa. Additionally, the model does not capture secondary HIV transmission arising from new cases of incidence within that year. The model also does not deal with patterns of seroconcordance (both partners have HIV status) or serodiscordance (one partner is HIV positive and the other is not) as an individual's partner is randomly selected from the partner group, not allowing a correlation between the status of an individual and the status of his/her partner. Also, the model assumes that the population is closed within country borders and a defined age range of adults from ages 15-49. Due to these limitations, the MoT model will likely need to be adapted at some point to account for migrant populations as well as older adults, particularly as more people are living with HIV to an older age with the introduction of ART.

Secondly, there are limitations in the MoT model based on the available data that is required for the model. Modeling the HIV/AIDS epidemic is difficult in general, because it can be difficult to create estimates for stigmatized populations (like female sex workers or men who have sex with men) and to find data which describes the entire country, particularly when often studies are concentrated in urban areas or particular regions of a country. Finding data to fill in the MoT model can be particularly difficult because most surveys don't provide numbers on

[96] Case K et al., "Understanding the Modes of Transmission Model of New HIV Infection and its Use in Prevention Planning," 833.

some of the detailed inputs required such as the number of sex acts per partner and the prevalence of HIV/STI in each risk group. Additionally, it is unlikely that all of the inputs required for the MoT model can be found in a single survey and so data is usually grouped from several sources conducted over a number of years, using different study designs. [97] This presented a particular challenge for my research, because I based my sub-risk group sizes off of the original sizes of the risk groups. This means that the uncertainty of my population estimates based on violence has a deeper layer of uncertainty based on the original risk group sizes.

The model is also highly sensitive to the size of subpopulations, which can present challenges when trying to find concrete numbers for hidden populations like men who have sex with men in Africa. There is also increasing evidence that higher-risk behaviors are often underreported in national surveys, which would lead to underestimations of the higher risk groups in the MoT model. It can also be difficult to determine how to place people in risk groups, for instance determining where to place women who sporadically sell sex informally, but would not identify as sex workers. In my research, I noticed this was particularly a problem when trying to define accurate risk groups in South Africa, where there are so many other factors like age, race, and socioeconomic background that strongly factor into individuals' risk behavior as well as a number of sexual behaviors like transactional sex that do not clearly fit into the sexual risk behaviors typified by the MoT model. If I were to do future research on the MoT model in South Africa, I would be interested in trying to adapt and redefine the subgroups to make them more accurate to the real population in South Africa, which would likely greatly improve the accuracy of the model.[98] Finally, while the MoT model certainly has limitations in

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[97] Case K et al., "Understanding the Modes of Transmission Model of New HIV Infection and its Use in Prevention Planning," 834.
[98] Case K et al., "Understanding the Modes of Transmission Model of New HIV Infection and its Use in Prevention Planning," 834.

the input data it uses, it is important to recognize that the model requires much less data than dynamic models, making it accessible to countries even with limited data on the epidemic available.

Finally, users of the MoT model have to be careful when interpreting and communicating the results of the MoT model. Case et al. note that it is particularly important to understand the difference between identifying among whom new infections are projected to occur versus the types of risk behavior that sustain the epidemic. For example, while a majority of the new infections may be predicted to occur in the low-risk, stable heterosexual group, it is possible that one of the HIV-positive partners in the couple may have originally acquired HIV from a sex worker. So, while both partners may have had only had sex with each other in the past year and are thus categorized in the stable heterosexual group, the critical driver of HIV transmission between the partners is previous sexual contact with the commercial sex worker population. Instead of solely using the results of the MoT model to target those individuals who are the most susceptible to HIV, it would also be beneficial to target prevention efforts toward the individuals who contribute most to the forward transmission of HIV.

Overall, there are certainly important limitations about the MoT model that need to be considered when analyzing the results it produces. However, the model is useful for describing the ways in which HIV is distributed amongst populations and there is much potential to address some of the limitations described above, which is best demonstrated by the way I am addressing the limitation of treating heterosexual sex as a single risk factor in my thesis research.

### 2.4.2 Limitations of the Revised MOT Model in South Africa

The majority of the limitations in the revised South Africa MoT model I developed are due to the input data I used to estimate violence. While I tried to make sound judgments on which numbers

to use from the best available data I could find, there were a few places where I knew I was making assumptions which, while providing the best available estimates, did not entirely reflect reality. I do not believe these limitations obscure the results of my model enough to make the outputs unreliable, but it is important to recognize the limitations in many of my assumptions.

First, when filling in the original South Africa MoT model from the published report, I ended up ignoring the medical injection population as the report listed that 100% of the population is a part of the medical injection population, which made my total population add up to 200%. Because I could not get further information from the authors, I decided to leave the medical population group out of my model. In the original model, they accounted for less than 1% of new infections, and my overall HIV incidence estimates matched theirs, so I do not believe this assumption significantly altered my results. Secondly, in my choice of violence parameters, I assumed that the transmission probability per HIV exposure, male to female, for men who perpetrate violence and female to male, for women who experience violence is the same as without violence. This is because I can't increase the transmission probability, without implicitly assuming every sexual act between the individual and his/her partner is violent. It would not be fair to assume that every act between partners in the violence groups is violent, especially since my estimates of violence include both physical and sexual violence and physical violence does not increase the likelihood of HIV transmission in the same way that sexual violence does. However, not increasing HIV transmission at all based on violence is a conservative assumption as it is well established that acts of sexual violence physiologically increase the likelihood of HIV transmission.I did vary HIV transmission probabilities based on violence in my designed experiment as part of my sensitivity analysis, which allowed me to

determine how a slightly increased HIV transmission probability based on violence would affect HIV incidence.

Thirdly, I faced limitations in determining the percentage of different risk groups which have experienced violence, particularly as I had to rely on a variety of different studies from different years, regions, population groups, using different survey methods. First, the estimates for the percentage of FSWs who experience violence might be slightly high since I used a study which looked at substance-abusing sex workers in South Africa, which may constitute a higher risk sex worker population. Next, for some groups I was unable to find accurate numbers on violence prevalence and so I used the same percentage from either their partner group or another group with similar risk behavior. For instance, I assumed that the percentage of male clients of female sex workers who perpetrate violence is 41.5%, which is the same as men who engage in casual heterosexual sex. This is because I could not find a value specific to male clients in the literature. I also assumed that 41.5% of female partners of male clients (of female sex workers) experienced violence because of my assumption that 41.5% of clients perpetrated violence. This is somewhat of an oversimplification as the violence prevalence does not necessarily have to match the partner group, but it was the best estimate I was able to make. I similarly assumed that 41.5% of women in CHS and 41.5% of female partners of men experienced violence based on my assumption that 41.5% of men in CHS perpetrate violence. I also assumed that 26.6% of women in stable heterosexual couples experienced violence in the last year, even though in the published report this value refers to women aged 15-26, because this was the only value I could find for the past year versus a lifetime value which was given by all of the other reports. Again, I assumed that 26.6% of men in stable heterosexual couples experience violence, which is an oversimplification.

Next, I made assumptions about violence which applied to a variety of different risk groups, even though in reality it is likely that violence parameters would be different based on the risk group. For instance, I assumed that men who perpetrate violence are more likely to be HIV positive by an odds ratio of 1.5 and that women who experience violence are likely to be HIV positive by an odds ratio of 1.48. This ratio might be different for men and women in various risk categories, however I chose to use 1.5 and 1.48 for each risk group based on gender because prevalence was already higher/lower in each risk group based on numbers from the original model. I also assumed all risk groups were equally as likely to receive ART treatment, even though higher risk groups often have less access to ART treatment. This is because I could not get concrete numbers on distribution of ART by risk group. Also, more women (35%) than men (25%) receive ART in South Africa, however the model is not set up to assign different ART values to women and men, so I chose to use the value for all people between 15 and 49 (28.9%).[99] Finally, I also assumed that all risk groups (incorporating violence) were 2.1 times less likely to use condoms. This assumption however did not hold for female sex workers as the percentage of FSWs who experience violence is so high, that this made the HIV prevalence for the non-violence group to be 99%, which is not a realistic assumption. So, I assumed that 10% less of acts were protected, because this made the non-violence group have a HIV prevalence of 81.67%, a more reasonable number.

While there are a significant number of limitations in both the original MoT model and revised model for South Africa, there are valuable results to be taken from the model outputs as long as these limitations are kept in mind when interpreting the results.

[99] Shisana et al, “South African National HIV Prevalence, Incidence and Behaviour Survey,” 54.

# CHAPTER 3: RESULTS AND CONCLUSIONS

## 3.1 RESULTS OF REVISED VERSUS ORGINAL SOUTH AFRICA MOT MODEL

My first stage of analysis involved evaluating the point estimates that were calculated in the output of the revised South Africa MoT model. One important output variable is overall HIV incidence in South Africa, which the revised model estimates is 1.896%. This value is consistent with published literature, which estimates HIV incidence for adults aged 15-49 in South Africa from 2008 to 2012 to be approximately 1.9%.[100] It is important that my number matches published literature, as introducing violence should not alter the estimate of the overall country incidence, but rather the distribution of that incidence. There are two other main output variables that are important to consider.

The first variable of interest is relative, and represents the distribution of HIV incidence among the total population: that is the percentage of the total incidence rate each risk group accounts for. Rather than focusing on the absolute values of these point estimates, which are likely to have a degree of uncertainty associated with them (discussed below), we are instead interested in the relative distribution of HIV incidence based on violence. Graph 3.1 displays the

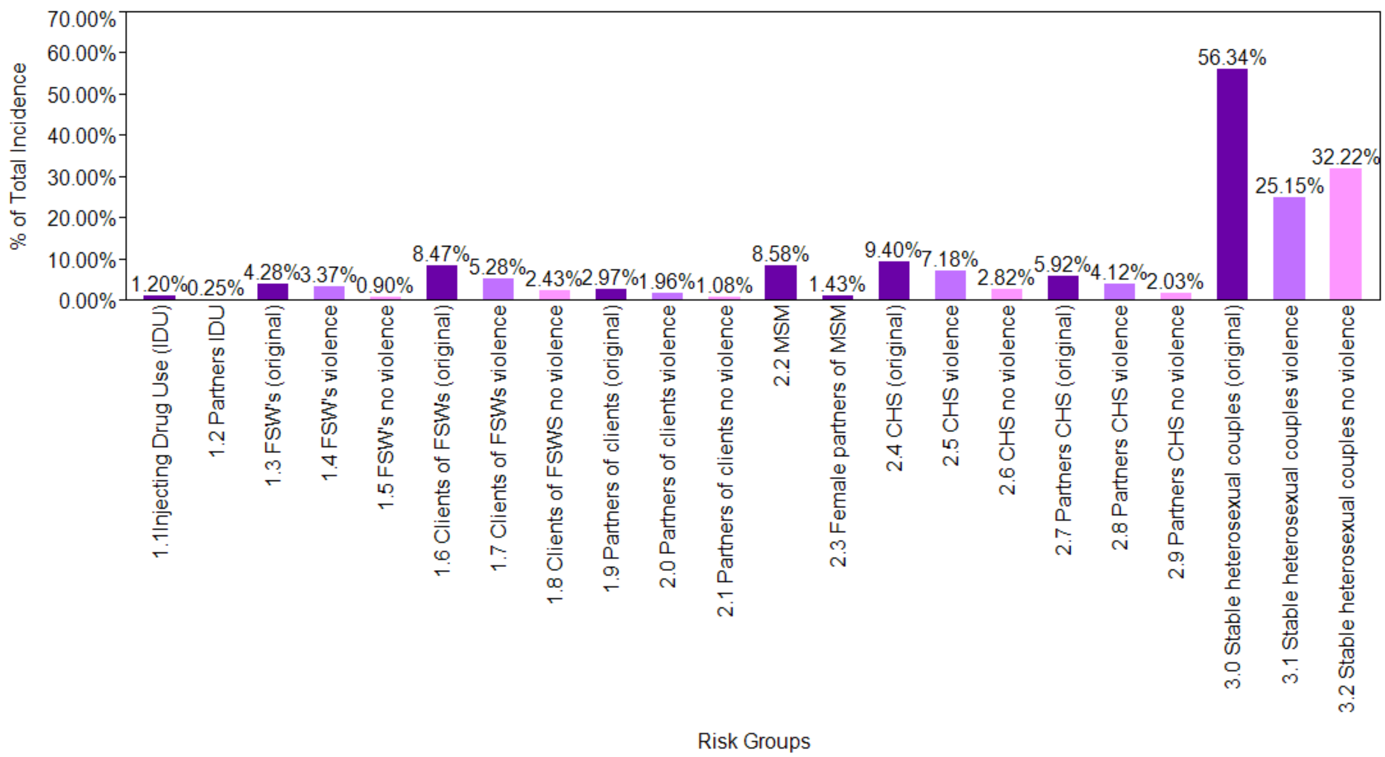
[100] Shisana et al, "South African National HIV Prevalence, Incidence and Behaviour Survey," 60.

distribution of HIV incidence for the original risk group as well as for the sub-risk groups including violence and not including violence. Note that the numbers in Graph 3 are point estimates, but a discussion on the range of plausible values will be discussed in the designed experiment. It is significant that in every group, except for stable heterosexual couples, the violence sub-risk groups account for a larger percentage of incidence than the non-violence sub-risk group. For example, individuals engaging in casual heterosexual sex (CHS) account for 9.4% of the incidence. Within the CHS group, individuals who have perpetrated or experienced violence in the past year account for 7.18% of the incidence where as individuals who have not perpetrated or experienced violence account for 2.82% of the total incidence. Note that these two sub-groups add up to 10% as opposed to 9.4%. This is because of the way incidence is calculated in the model. While the violence and non-violence sub group parameters add up the original CHS parameter values, the overall incidence of the two sub risk groups do not necessarily have to add up to the original risk group incidence because of the way partner risk group values are added in. The partner risk group parameters are not calculated proportionally to the original risk group parameters as the sub-risk group parameters are. For example, those who experience violence in CHS are paired with partners of CHS who perpetrate violence and will have a higher incidence rate based on for instance, the heightened HIV prevalence (because of violence) in their partner population. The violence sub-risk group can then make up a higher enough proportion of the new infections that the total proportion of incidence among the CHS group is actually higher than the original group. So, the model is suggesting that while the original model estimates that the CHS population accounts for 9.4% of new infections, with violence they actually account for 10% of new infections. Note, however that incidence distribution in all of the sub-risk groups adds up to 100% meaning that while the CHS group accounts for a greater

proportion of the new infections, another risk group will account for less, meaning that the model is not altering any of the assumptions about overall incidence in South Africa.

Even in the stable heterosexual group, which accounts for 56.34% of the total incidence, the violence sub-risk group accounts for 25.15% which although less than the non-violence group (32.22%) still accounts for a significant proportion of the new infections. These initial results suggest that violence is a substantial contributor to HIV incidence.

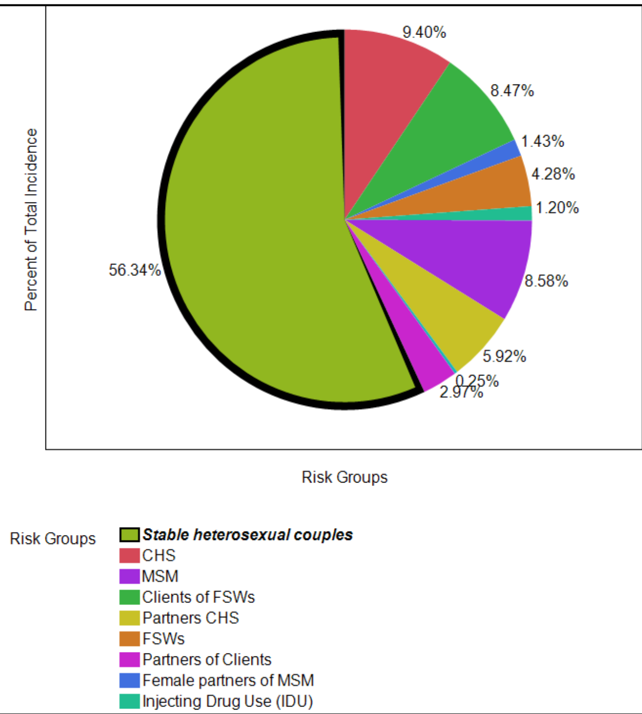
**Graph 3.1.1 Revised MoT Distribution of HIV Incidence**



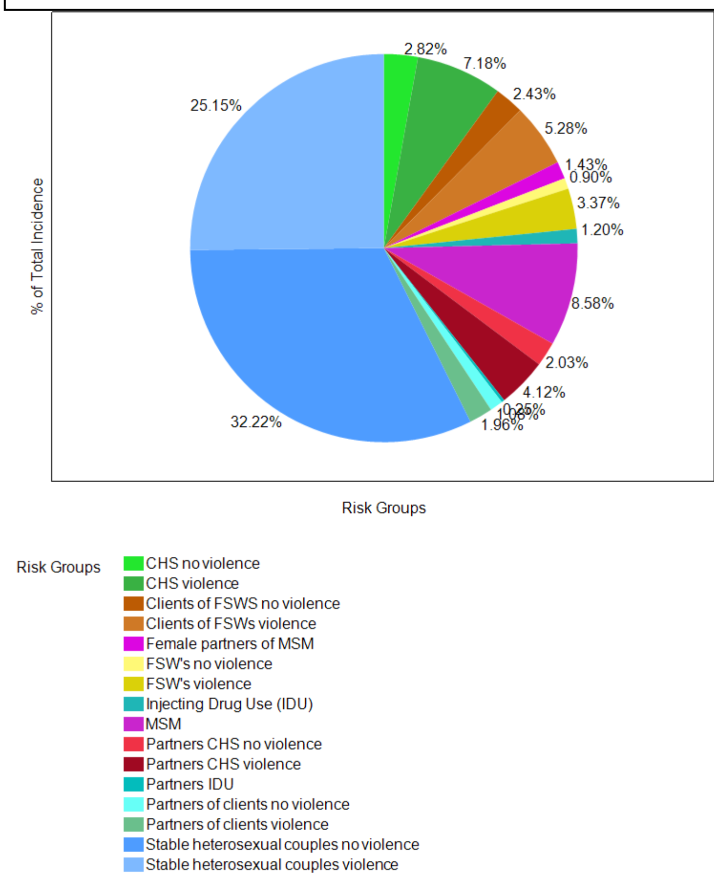

Graphs 3.1.2 and 3.1.3 reinforce these results, with graph 3.1.2 showing the distribution of HIV incidence in the original South Africa MoT model versus graph 3.1.3 which does the same with the revised MoT model. From the pie charts, we can see that the distribution among the original risk groups is the same from graph 3.1.2 to 3.1.3. However, when we separate the original risk

groups into sub-risk groups, it becomes clear that the violence groups account for a significant proportion of new infections.

**Graph 3.1.2 Original South Africa MoT Distribution of Incidence**

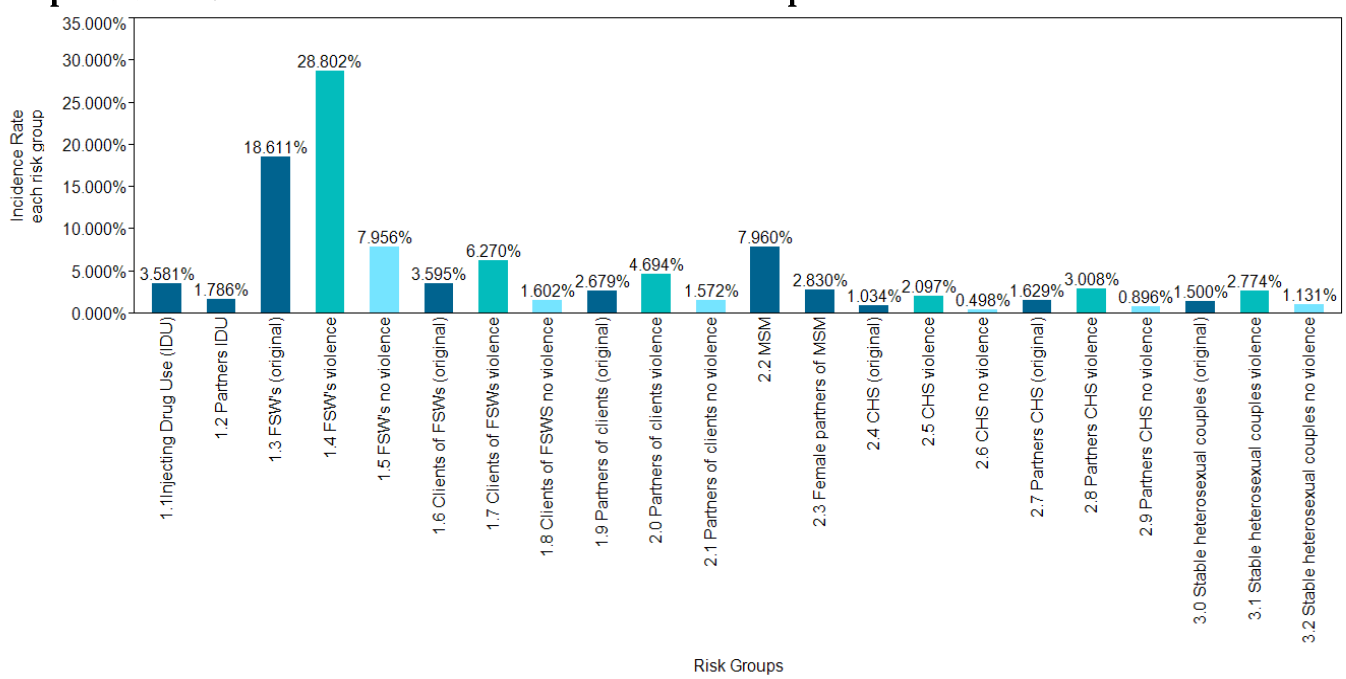



**Graph 3.1.3 Revised South Africa MoT Distribution of Incidence**



Secondly, the other key output variable is an absolute value and represents the HIV incidence rate for each individual risk group: that is the number of uninfected individuals in a specific risk group which are predicted to become infected in the next year. As demonstrated in Graph 3.1.4, in every risk group the violence sub-risk group has a substantially higher HIV incidence rate than the non-violence group. Again, note that the numbers in Graph 3.1.4 are point estimates, however plausible ranges of these values will be discussed in the designed experiment section. For example, the original CHS incidence rate is 1.034%. That is, it is estimated that 1.034% of uninfected individuals in the CHS group will acquire HIV in the next year. However, it is estimated that 2.097% of individuals who have experienced or perpetrated violence will acquire HIV, whereas only .498% of individuals who have not experienced or perpetrated violence will acquire HIV. This again suggests that violence is a significant contributor to HIV incidence.

**Graph 3.1.4 HIV Incidence Rate for Individual Risk Groups**



## 3.2 WHAT IF WE WERE TO ELIMINATE VIOLENCE?

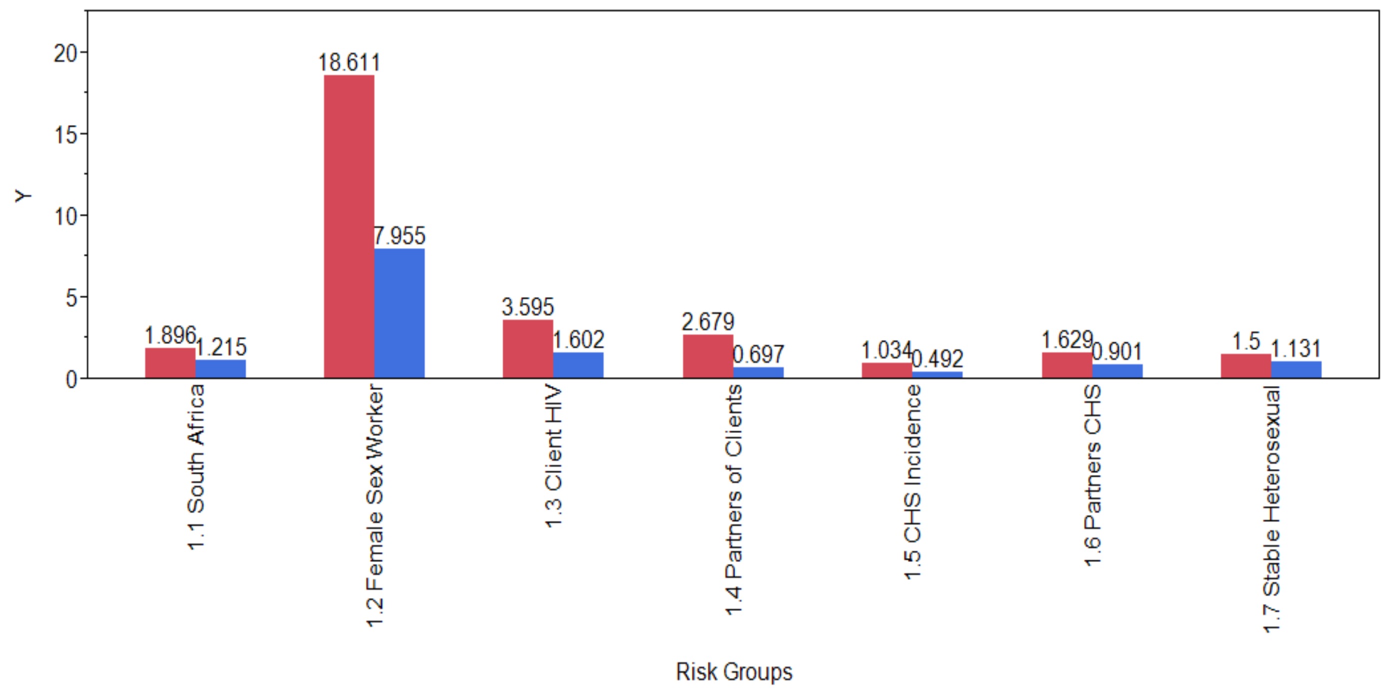
The above initial results indicate that violence is a significant risk factor to consider when estimating HIV incidence. However, the results must be interpreted within the uncertainty that exists in the model and the parameter estimations, which brings us now to the sensitivity analysis. The first step in the analysis is what I am calling the base case, in which I examined the output of the model when the size of the violence group was set to 0. This allows us to consider what happens in the model if we were in theory to entirely eliminate violence. By doing this, the model assumes that the non-violence sub risk groups still have lower parameter estimates, which changes the output of incidence. For example, it is assumed from the original model that female sex workers have an HIV prevalence rate of 53.715%. From my parameter estimates, I assumed that female sex workers who experience violence are 1.48 times more likely to have HIV, giving the violence sub risk group an HIV prevalence rate of 63.202%. Because the non-violence group is calculated as a weighted average in order to maintain the original prevalence rate, their HIV prevalence rate decreases to 36.848%. A similar pattern happens for the other parameter values, and because the non-violence group now accounts for 100% of the original risk group population, but their parameters are lower than the original risk group, they end up with a lower HIV incidence. The results of this zero-violence analysis are presented in Table 3.2.1 and Graph 3.2.2. When violence is non-existent, both country incidence in South Africa and individual risk group incidence decrease by a significant amount. This suggests that if we were able to completely eliminate violence, we could significantly reduce HIV incidence and again indicates that violence is an important risk factor in HIV transmission.

**Table 3.2.1: HIV Incidence Original Estimate vs. No Violence**

| HIV Incidence | South Africa | FSWs | Clients of FSWs | Partners of Clients | CHS | Partners CHS | Stable Heterosexual Couples |
|---|---|---|---|---|---|---|---|
| Original | 1.90% | 18.61% | 3.60% | 2.68% | 1.03% | 1.63% | 1.50% |
| Base Case | 1.22% | 7.96% | 1.60% | 0.70% | 0.49% | 0.90% | 1.13% |

*FSWs=Female Sex Workers, CHS=Casual Heterosexual Sex

**Graph 3.2.2 HIV Incidence (%) Original vs. No Violence**




## 3.3 CREATING THE DESIGNED EXPERIMENT

After doing the base case analysis, I performed a designed experiment in the statistical software package JMP. The goal of the experiment was two-fold. One, to determine a plausible range for the two key outputs on HIV incidence in the model and two, to determine which of the parameter values the revised model is the most sensitive to. In order to do this I chose high and low values for thirteen x-variables including: the population size in regards to violence of female sex

workers, high risk groups, and low risks groups; the odds ratio for increase in HIV prevalence based on violence; the number of partners per year for female sex workers, clients, and individuals in engaging in casual heterosexual sex (based on the assumption that violence is associated with a higher number of partners); the odds ratio decrease for percentage of acts protected (for both females sex workers and other risk groups); the percentage of female sex workers and other risk groups receiving ART; and the transmission probability (male to female and female to male) when including violence. When choosing these values, I most often used the original parameter estimate as my 'low' value. For example, it would not make sense for the male to female HIV transmission rate with violence to be less than the transmission rate without violence (the original value), so I set that as my minimum, but did choose a higher value as it is recognized in the literature that violence is physically associated with higher rates of HIV transmission.

The reason I chose to do a designed experiment as opposed to another type of uncertainty analysis, was largely due to the information on the parameter values I had available to me. Often times the MoT model and other similar models which estimate HIV incidence use a confidence interval approach in their uncertainty analysis, involving Monte-Carlo simulation of parameter values within a plausible range.[101] However, in my case I decided that this would not be the best approach to use as I did not feel that I had sufficient research in order to determine plausible ranges of parameter values, much less a probability distribution. Hence, I felt that I could not develop a confidence interval that would be valid in a probabilistic sense, i.e., a 95% confidence interval would not be accurate with precisely 95% probability. Instead, I decided to develop a designed experiment, which looks at combinations of potential high and low levels of 13 key x-

[101] UNAIDS Reference Group on Estimates, Modelling, and Projections, "Modeling the Expected Short –Term Distribution of New HIV Infections by Modes of Transmission," 14.

variables. This approach I felt I could more easily determine, and does produce a sample distribution of potential outputs of the two main y values: the distribution of total HIV incidence among each risk group and individual risk group HIV incidence. It is important to note however, that this sample distribution should not be interpreted as a confidence interval.

When determining which designed experiment to use, I realized that a standard factorial design for 13 x-variables would require $2^{13}$ runs, or 1,024 in total, which was obviously too many. Instead I selected a Placket-Burman design in 20 runs based on Professor Roger Hoerl's suggestion. This is because I had originally planned to experiment with 16 x-variables, and therefore a 16-run Placket-Burman design, which is a standard fractional factorial, was too small. The next smallest standard fractional factorial would have required 24 runs, hence the 20-run Placket-Burman design was selected. Technically, this is a Resolution III design, meaning that it confounds main effects with two-factor and higher interactions. Therefore, there is some risk that some of the main effects I found could actually be two-factor (or higher) interactions. For further details on fractional factorial designs, see Montgomery.[102]

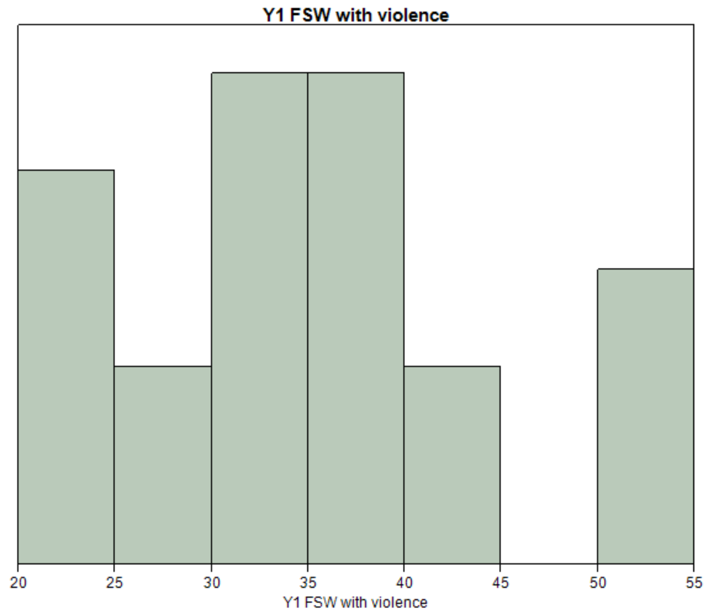
## 3.4 RESULTS OF THE DESIGNED EXPERIMENT

The first goal of the designed experiment was to determine a range of plausible values for the two main output variables from the revised model: the relative output based on distribution of total incidence and the absolute output based on individual risk group incidence. By doing the Placket Burman design in JMP, 20 outputs were calculated for each y variable  depending on a series of high and low values chosen for 13 x-variables. From these 20 outputs, the maximum and minimum were used to determine a range of plausible values for each value. For example,

[102] Douglas C. Montgomery, *Design and Analysis of Experiments*, 8th Ed., (Hoboken, NJ: John Wily and Sons, 2013).

Graph 3.4.1 presents a histogram plot of the 20 outputs from the designed experiment, for the absolute variable of incidence rate for female sex workers with violence.

**Graph 3.4.1 Results of DOE: Absolute incidence rate for FSWs (experiencing violence)**




The graph demonstrates a range of incidence rates for female sex workers who have experienced violence, ranging from 20.809% to 52.515%. The histogram suggests that it is most likely for the 'true' incidence rate to lie in the mid-range values of 30% to 40%, which is slightly higher than the original point estimate: 28.802%. This means that the point estimate 28.802% is a reasonable estimate and may even be a slightly conservative estimate.

This analysis was repeated for each of the y output variables, resulting in Tables 3.4.1 and 3.4.2. Note that the maximum and minimum values are not to be understood in a probabilistic sense or to be representative of a confidence interval, as we did not have enough information to present such results when performing the designed experiment. Instead, they give us a rough estimate of values which are plausible based on the high and low values we chose in our designed experiment. Each point estimate fits within the bounds of the minimum and maximum values and for most of the violence groups lies closer to the minimum than to the

maximum. This suggests that our assumptions were conservative, and yet still gave us significant results about the impact of violence on HIV incidence, offering further validity to our results.

**Table 3.4.1 Plausible Values for Absolute Estimate: Individual Risk Group HIV Incidence**

| Original Risk Groups | **HIV Incidence Estimate from Original South Africa Mot Model** | **Revised Model Risk Groups** | **Absolute Point Estimate: Individual Risk Group HIV Incidence** | **Minimum** | **Maximum** |
|---|---|---|---|---|---|
| South Africa | 1.874% | South Africa | 1.896% | 1.881% | 3.228% |
| FSWs | 18.611% | FSW Violence | 28.802% | 20.809% | 52.515% |
| | | FSW no Violence | 7.956% | 2.711% | 20.809% |
| Clients of FSWs | 3.595% | Client Violence | 6.270% | 3.589% | 16.706% |
| | | Client no Violence | 1.602% | 0.164% | 4.203% |
| Partners of Clients | 2.679% | Partners Clients Violence | 4.694% | 2.679% | 10.719% |
| | | Partners Clients no Violence | 1.572% | 0.445% | 3.018% |
| CHS | 1.034% | CHS Violence | 2.097% | 2.027% | 10.767% |
| | | CHS no Violence | 0.498% | 0.041% | 1.169% |
| Partners of CHS | 1.629% | Partners CHS violence | 3.008% | 1.628% | 5.281% |
| | | Partners CHS no violence | 0.896% | 0.133% | 1.835% |
| Stable Heterosexual Couples | 1.500% | Stable Heterosexual Violence | 2.774% | 1.499% | 6.285% |
| | | Stable Heterosexual no Violence | 1.131% | 0.583% | 1.691% |

***** Note that the original South Africa incidence (1.874%) is slightly different than the revised model South Africa incidence (1.896%). This is because of the issue discussed earlier in which the two sub-risk group incidences do not necessarily add up to the original group incidence. Thus, in the revised model, there ended up being 289,518 total new infections (creating a slightly

higher incidence) than the 286,154 total new infections in the original model. This difference is not ideal, but we decided the original and revised incidence rates were similar enough to not undermine the results.

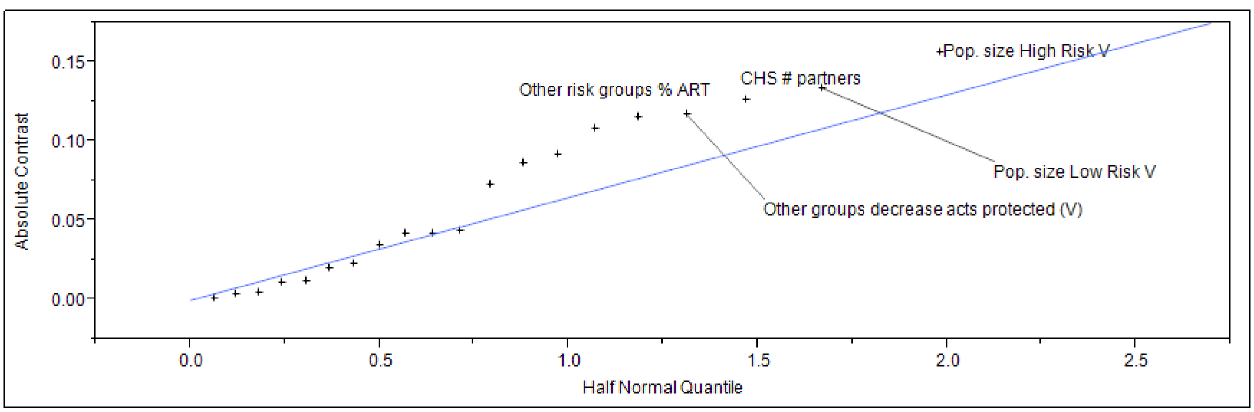
**Table 3.4.2 Plausible Estimates for Relative Estimation: Distribution of HIV Incidence**

| Original Risk Groups | Estimate of Distribution from Original South Africa Mot Model | Revised Risk Groups | Relative Point Estimate: Distribution of total HIV Incidence | Minimum | Maximum |
|---|---|---|---|---|---|
| South Africa | 1.874% | South Africa | 1.896% | 1.881% | 3.228% |
| FSWs | 4.280% | FSW Violence | 3.37% | 0.50% | 4.79% |
| | | FSW no Violence | 0.90% | 0.21% | 3.76% |
| Clients of FSWs | 8.470% | Client Violence | 5.28% | 0.95% | 11.47% |
| | | Client no Violence | 2.43% | 0.14% | 7.69% |
| Partners of Clients | 2.870% | Partners Clients Violence | 1.96% | 0.30% | 2.94% |
| | | Partners Clients no Violence | 1.08% | 0.17% | 2.76% |
| CHS | 9.400% | CHS Violence | 7.18% | 0.95% | 24.77% |
| | | CHS no Violence | 2.82% | 0.13% | 8.59% |
| Partners of CHS | 5.920% | Partners CHS violence | 4.12% | 0.60% | 6.26% |
| | | Partners CHS no violence | 2.03% | 0.17% | 5.39% |
| Stable Heterosexual Couples | 56.340% | Heterosexual Violence | 25.15% | 5.36% | 40.76% |
| | | Stable Heterosexual no Violence | 32.22% | 9.09% | 49.62% |

A second goal of the designed experiment was to determine which x-variables were the key drivers of the y-variables. First, consider the x's that were the most important in determining overall incidence in South Africa. These are: 1) size of the high risk populations experiencing/perpetrating violence in the past year (clients of female sex workers, partners of

clients, individuals engaging in casual heterosexual sex, and partners of casual heterosexual sex), 2) size of the low risk populations experiencing/perpetrating violence in the past year (individuals in stable heterosexual couples), 3) how many partners individuals in the casual heterosexual who experienced/perpetrated violence had in the past year, 4) the percentage of sexual acts protected for individuals who have experienced/perpetrated violence in the past year, and 5) the percentage of individuals in risk groups (other than female sex workers who were considered separately) who received ART treatment. These results are demonstrated in Graph 3.4.3, which is a half normal plot of the effects of each x-variable on overall incidence (y). This plot, produced in JMP, orders the absolute effects (ignoring sing) from smallest to largest, hence the term "half" normal. These effects are then plotted against a normal probability scale. Random variation, i.e. no effect, tends to plot as a straight line in a half normal plot.[103] Conversely, any effect that is too large (in absolute value) to be explained by random variation will tend to fall off of the straight line. These important effects are labeled in Graph 3.4.2.

**Graph 3.4.2 Key Drivers of Overall Incidence in South Africa**




The results of this DOE analysis are significant for two reasons. On the one hand, the model's sensitivity to the size of both high and low risk populations who experience/perpetrate violence, indicates that in future research we need to be careful when estimating this value in

[103] Montgomery, *Design and Analysis of Experiments*.

order to eliminate as much error in the model as possible. It also shows the sensitivity of the model to the number of partners individuals had (who had experienced/perpetrated violence in casual heterosexual sex), as this number was only varied from 2 to 4 partners in the analysis, and even this seemingly small difference had a significant impact on overall incidence. The model is also sensitive to the estimate of the percentage of acts protected for individuals in violence sub-risk groups, which again means we have to be cautious when estimating these parameters. On the other hand, these variables indicate which risks associated with violence are the most important to address in order to decrease HIV incidence. The model indicates that if the size of the high risk or low risk population that experiences/perpetrates violence was to decrease, HIV incidence would also significantly decrease. Also, if individuals in CHS were to have even one less partner per year (a sexual risk behavior associated with violence), this could significantly impact HIV incidence. Finally, these results indicate that addressing the use of protection by addressing violence (particularly addressing situations where women are not able to ask for protection due to fear of violence) could also significantly impact overall HIV incidence. The percent of individuals receiving ART is not directly related to violence, however individuals who face violence may be less likely to have access to treatment. Since these results indicate that the percentage of individuals on ART significantly impacts HIV incidence, it seems that campaigns to increase access to ART for individuals who have experienced/perpetrated violence would be particularly important.

A similar analysis can be done for the other output variables which measure HIV incidence for each risk group. Table 3.4.3 lists the results of the DOE experiment and demonstrates which x-variables were of the most importance in determining the output of the absolute variables. The x-variables that were particularly important for the y output (incidence

for sex workers, clients etc.) are marked by an asterisk. The designed experiment produced 'p-values' and the asterisks mark p-values that were less than .1. However, because our experiment was on a computer model, and not in fact probabilistic in design, we could not interpret these as actual p-values. But, looking at the 'p-values' did allow us to see which x-variables were in fact driving the outputs. Note that the darker grey shading marks x-variables that were drivers for most of the y-variables, whereas the lighter grey shading marks the x-variables that were significant for just a few of the y-variables.

From the table, it is apparent that the percentage of sexual acts protected for individuals who have/experienced violence, HIV prevalence for individuals who have experienced/perpetrated violence, and the population size of high risk groups are of particular importance for driving a majority of the output variables. Again, these results demonstrate that we need to be cautious in estimating these parameters and future research may involve refining these estimates in order to limit error in the model. Just as in overall country incidence, these results indicate that addressing the decrease in use of protection for individuals who have experienced/perpetrated violence and reduce the number of individuals who perpetrate/experience violence will impact HIV incidence for every single risk group. These results also indicate that HIV prevalence in the violence sub-risk groups is an important contributor to HIV incidence. HIV prevalence is estimated to be higher in violence sub-risk groups, because it is assumed that individuals who perpetrate/experience violence are more likely to engage in riskier sexual behaviors. This indicates that addressing the riskier sexual behaviors that are associated with violence will be an important part in reducing HIV incidence.

## Table 3.4.3 Key Drivers of Absolute HIV Incidence

| | South Africa | FSW Violence | FSW no Violence | Client Violence | Client no Violence | Partners Clients Violence | Partners clients no Violence | CHS Violence | CHS No Violence | Partners CHS violence | Partners CHS no violence | Stable Heterosexual Violence | Stable Heterosexual No Violence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pop. Size FSW (V) | | | * | | * | | | | | | | | |
| Pop. Size High Risk Groups (V) | * | | * | | * | | * | | * | | * | | * |
| Pop. Size Low Risk Groups (V) | * | | | | | | | | | | | | * |
| HIV Prevalence (V) | | * | * | * | * | * | * | * | * | * | * | * | * |
| FSWs # Partners | | * | * | | | | | | | | | | |
| Clients # Partners | | | | | | | | | | | | | * |
| CHS # Partners | * | | * | | | | | * | * | | | | |
| FSWs % Sexual Acts Protected (V) | | * | * | | | | | | | | | | * |
| % Sexual Acts Protected (V) | * | * | * | * | * | * | * | * | * | * | * | * | * |
| FSWs: % ART | | | | | * | | | | | | | | |
| Other groups: % ART | * | * | | | | | | | | * | | * | * |
| Male to female transmission (V) | | * | | | | * | | | | * | | * | |
| Female to Male transmission (V) | | | | * | | | | | | | | * | |

The other variables that are also key drivers of HIV incidence for some risk groups, but not necessarily all, are the number of partners in the CHS violence group, percentage of all risk groups on ART, and male to female HIV transmission with violence. The first two of these were also key determinants of overall South Africa incidence and as discussed above, can be targeted as part of anti-violence campaigns.

The x-variable of male to female HIV transmission with violence is particularly interesting, because this is a variable that was not originally factored into the revised model as discussed in the limitations section. However, these results indicate that including this variable is important for the violence sub-risk groups in the female sex worker, partners of clients, partners of individuals engaging in casual heterosexual sex, and stable heterosexual populations. From these results, it seems that it would be useful in future research to incorporate this variable into the model. This also indicates the need for further research on more exact estimations of how much violence increases HIV transmission, as I had difficulty finding accurate estimations when doing my research.

## 3.5 CONCLUSION: WHAT DOES THIS MEAN FOR THE HIV/AIDS RESPONSE?

The results of the revised MoT model in South Africa indicate that gender based violence is a significant contributor to the HIV/AIDS epidemic. With our current parameter estimates for violence, the model demonstrates that the violence sub groups both relatively account for a greater proportion of new infections than the non-violence groups and absolutely, the violence sub groups have a significantly higher HIV incidence rate than the non-violence groups. For example, the violence sub group of individuals engaging in casual heterosexual sex is predicted to account for 7.18% of the total new infections in South Africa, where as the non-violence

group is estimated to account for 2.82% of the new infections. In absolute terms, the violence group is expected to have an HIV incidence rate of 2.097% whereas the non-violence group is predicted to have an HIV incidence rate of .498%. In the case that violence was entirely eliminated, the model predicts that overall HIV incidence in South Africa would drop from 1.9% to 1.22%. The designed experiment sensitivity analysis similarly demonstrates that sexual risk behaviors associated with violence are significant drivers of HIV incidence. Based on these results, I suggest that addressing gender based violence be an important goal of the HIV/AIDS response.

There are many ways to address gender based violence and further innovative approaches need to continue to be developed. A fair amount of research has gone into determining effective ways of addressing violence in South Africa, of which I will share a few methods that seem particularly promising. First, one of the best ways to address gender based violence is to develop community-based participatory learning environments which involve both men and women and encourage more gender-equitable relationships.[104] An example of this is the Stepping Stones program which was designed for young people in the Eastern Cape Province. It was organized around local community structures and involved "participatory learning approaches, including critical reflection, role play, and drama and draws the everyday reality of participants' lives into the sessions."[105] It was carried out over 6-8 weeks and involved discussions of topics regarding relationships, sexual behavior, and gender based violence. In evaluating the program, it was found that Stepping Stones was successful in "reducing sexual risk taking and violence

[104] What Works for Women & Girls, "Addressing Violence Against Women," accessed June 9, 2014, http://www.whatworksforwomen.org/chapters/21-Strengthening-the-Enabling-Environment/sections/59-Addressing-Violence-Against-Women/evidence.

[105] Jewkes R et al, "Impact of Stepping Stones on incidence of HIV and HSV-2 and sexual behaviour in rural South Africa: cluster randomised controlled trial," *BMJ* 2008; 337: 1-11.

perpetuation among young, rural African men."[106] The program did not lead to noticeable decline in HIV incidence as the directors had hoped, however it is significant that it did lead to measurable change in men's perpetuation of violence, which many believe will eventually lead to lower HIV incidence. The success of this program indicates that other programs like this should be implemented in other areas of South Africa.

Another similarly effective campaign for addressing the perpetration of violence among men was One Man Can, by Sonke Gender Justice Network. This program "provided training over the period of one year to engage men in gender awareness, implemented a range of communication strategies to shift social norms about men's roles and responsibility, engaged in advocacy and worked with local government, and resulted in men's positive attitude shifts regarding gender based violence."[107] The results of this campaign indicate that it was highly successful. Through pre- and post-test surveys, it was found that "prior to the workshop, 63% of the men believed that it is acceptable for men to beat their partners; after the workshop, 83% disagreed with the statement; prior to the workshop, 96% of the men believed that they should not interfere in other people's relationships, even if there is violence; after the workshop, all believed they should interfere."[108] The success of this campaign demonstrates the importance of engaging men in solutions to violence.

Secondly, another tested way of addressing gender based violence is to establish microfinance programs which integrate training on HIV/AIDS and violence. For example, the Intervention with Microfinance for AIDS and Gender Equity (IMAGE) intervention "combined a microfinance program with participatory training on understanding HIV infection, gender norms, domestic violence, and sexuality, which resulted in a reduction in experience of physical

[106] What Works for Women & Girls, "Addressing Violence Against Women."
[107] What Works for Women & Girls, "Addressing Violence Against Women."
[108] What Works for Women & Girls, "Addressing Violence Against Women."

or sexual violence by an intimate partner."[109] The results of this program were also significant as after 2 years, the "risk of past-year physical or sexual violence by an intimate partner was reduced by more than half."[110] These findings demonstrate that an important way of reducing gender based violence is to socially and economically empower women. They also indicate that anti-violence programs can be successfully integrated into development campaigns that are already in place.

Additionally, awareness campaigns have proven to be effective in reducing gender based violence in South Africa. For example, a multi-media project in South Africa working with the National Network on Violence Against Women used edutainment to raise awareness about social issues like domestic violence. Surveys conducted before and after the campaign indicated an increased knowledge about domestic violence as well as a shift in norms about the acceptance of gender-based violence.

The success of the above programs reminds us that gender based violence can be addressed, creating real change for men and women that can transform whole communities. Gender based violence should be addressed regardless of its relationship with HIV/AIDS. However, considering the strong association with violence and HIV/AIDS, I recommend that addressing violence should be one of the key goals of the global HIV/AIDS response.

[109] What Works for Women & Girls, "Addressing Violence Against Women."
[110] What Works for Women & Girls, "Addressing Violence Against Women."

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