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Agent-Based HIV Transmission Simulation on Condom Usage among Men Having Sex with Men

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Abstract. This paper describes the simulation model of HIV transmission using an agent-based modeling method with network type to consider the multiple sexual partners of the arbitrary population of 10,0000 MSM. Based on ground data, parameters were identified, such as the transmission risk rate, anal sex activity rate, and unsafe sex practice rate. In 6 months of simulation coverage, the model could simulate the transmission and record the counts of individuals getting infected with the virus. The process flow of the model described herein, and the initial results can be used to strengthen mechanisms how to prevent the spread among MSM.

Keywords. HIV, transmission, safe sex, simulation, modeling

1. Introduction

Human Immunodeficiency Virus (HIV) has been a perennial health issue in the Philippines. In 2019, the Philippines had the fastest-growing HIV epidemic in the Western Pacific, with a 174% increase in HIV cases [1]. In the same year, there was an estimated 97,00 people who were living with HIV in the country - of those, 73% knew their status. The Centers for Disease Control and Prevention defines HIV as a virus that attacks the body's immune system [2] and can be transmitted through blood, semen, rectal fluids, vaginal fluids, and breast milk. If not treated, it can lead to AIDS (acquired immunodeficiency syndrome), which triggers health complications such as acute pneumonia.

Recent reports have shown that men who have sex with men (MSM) have the highest prevalence of HIV transmission, with an estimated 5% rate [3]. Based on the Integrated

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Behavioral & Serological Surveillance [4], the said report revealed that 40.1% of MSM infected with HIV used condoms during sexual intercourse. Still, it is uncertain how consistent the usage was. One of the factors that highly contributed to HIV transmission is the lack of awareness on HIV transmission and prevention and sex education in general [5], since only 19% of those infected have basic concepts on the disease.

Severe HIV epidemics have caused significant mortality increases, which leads to stigma in a community that has reported cases of HIV. Further, a study has shown that acquiring HIV dramatically impacts the population and household structure [6].

Economically, HIV is a marker for high-risk health behaviors. Having infected with the virus has a significant impact on an individual's socioeconomic status, as the treatment for HIV often exceeds the cost of similar chronic conditions. While the government has available support for people with HIV, the psychological impact cannot equate to them.

Only a few studies have been conducted to simulate the HIV epidemic, including the comparison of two individual-based model simulators for HIV epidemiology in a heterosexual population with the Herpes simplex virus [7]. Another study was conducted that described an agent-based epidemic model of a network of individuals who were involved in high and low risks populations. The study used the free links and fixed links concepts to represent tendencies among individuals who either have large numbers of short-term partners or stay in long-term monogamous relationships [8].

This study explores HIV transmission among MSMs using the transmission rate, sexual engagements, and other sexual risk behaviors statistics in the 2018 Integrated HIV Behavioral & Serologic Surveillance [4].

Amidst the COVID-19 pandemic, there is a sustained level of high-risk sexual behavior among MSM in the county [9]. Thus, there is a need to foresight HIV transmission using simulation methods based on available data to guide intervention strategies to control HIV spread.

With these underlying facts, it is upright to increase awareness among the youths on topics related to sex education, particularly on unprotected sex. While sex education is already embedded in the curriculum, sensitive topics such as the use of condoms are mostly filtered due to the religious nature of the Philippines and lack of deep understanding of available prevention mechanisms on acquiring sexually transmitted diseases. Thus, this simulation study aims to visualize and comprehend the HIV transmission with MSM who have knowledge on HIV and those without so that further interventions can be made to stop the stigma and infection of HIV in the country.

2. Modeling Questions

At present, there is no effective cure for HIV. While there are medicines to control HIV, this does not prevent transmission of other sexually transmitted diseases. When medication is not consistent, HIV could potentially harm the immune system of an infected individual. Even with the government's effort to stop its transmission through condom education and access programs, HIV cases continue to rise due to the public stigma on using a condom and sex education in general. This simulation on HIV transmission will try to model the effect of sex education, particularly on using a condom to spread HIV. Notably, it will answer the questions:

- What does the effect of condom use on HIV transmission among MSM?
- What is the effect of having multiple sex partners on HIV transmission?
- What mechanism or strategy is effective in preventing HIV transmission?

3. Methodology

There are four significant steps involved in the conduct of the simulation, including data gathering, development of the prototype model, running of simulation, and model simulation evaluation and analysis (see Figure 1).

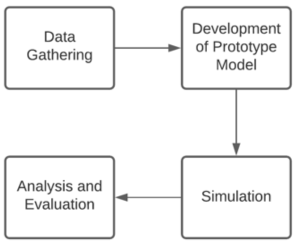

Figure 1. Schematic diagram of the study.

In the first phase of the study, data were gathered as bases for inputs and configuration of the simulation model. Four variables were pre-determined as the model's parameters: a) *hook up rate*, b) *anal sex rate*, c) *unprotected sex rate*, d) *HIV transmission or prevalence rate*. The baseline data were taken from the 2018 HIV Report, which was released in 2019 [4]. As of date, the were no updated reports due to the COVID-19 pandemic.

The hook-up rate was the first important variable in the simulation model. It served as the initial stage of any sexual activity and determined how active sexual activity behaviors of MSMs. Next was the anal sex rate, which was considered a high-risk sexual activity. This parameter determined how often MSMs engaged in anal sex activity. This was followed by how often these MSMs who engaged in anal sex practiced unprotected sex (non-condom usage.) Lastly, the HIV transmission rate defines the percentage of the virus that is most likely to infect.

The next phase was the development of the prototype model, in which the process flow of the HIV infection was designed using the identified parameters, as shown in Figure 2. At the start of the process flow, there were non-HIV MSMs, which population was set to 5,000 since no definite count can be sourced out online as to the exact number of MSMs in the country. The initial population value was taken from the number of MSMs who participated in the 2018 HIV Survey. Afterward, they received a hook-up invitation, and their responses were dependent on the hook-up rate. When they agreed to hook up, the next state was whether they engaged in anal sex activity, which was dependent on the anal sex rate. If they decide to have anal sex, the next state was whether they use a condom during anal sex, which was determined by the unprotected sex rate. If they engage in unprotected sex, the individual becomes susceptible, and based on the HIV transmission rate, they either just stay susceptible or get infected with the virus.

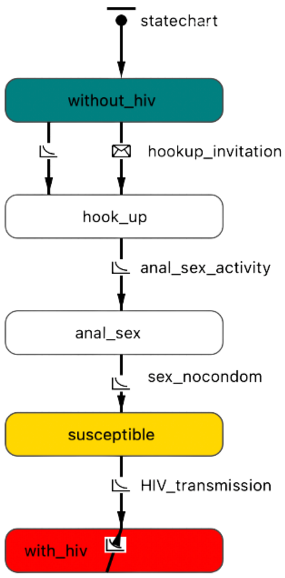

Figure 2. Process flow of the HIV transmission simulation model.

Using the AnyLogic 8 PLE, the simulation model was constructed with a coverage of 1 year. Using the parameter values in Table 1, the count of HIV positive and susceptible were recorded weekly.

Table 1. PARAMETERS AND THEIR VALUES IN THE SIMULATION MODEL.

Parameters	Values
unprotected_sex	From 0 to 1, with .10 steps
hookup_rate	0.05
anal_sex_rate	0.72
HIV_transmission_rate	0.05

During the simulation phase, experiments were conducted using the different parameters of unprotected sex with respect to multiple partners. The model used a network type of environment with three variations of connections: 1, 2, and 3. Each network connection value was simulated given the various values of unprotected sex. The results were analyzed based on HIV positive and susceptible counts in each simulation run, as shown in Figure 3.

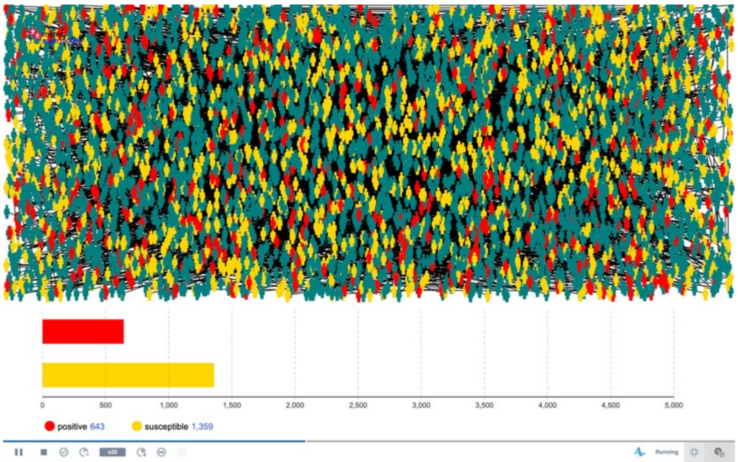

Figure 3. Sample simulation output.

A comparative analysis of the results was conducted using a *two-tailed t-test* measure. The *two-tailed test* aimed to show whether the results of the experiments are significantly greater than or significantly less than the mean of the sample.

4. Results and Discussions

The simulation model aimed to investigate the effect of condom usage and having multiple sex partners in the spread of HIV. Experiments were conducted regarding the number of sex partners and the various rates of unprotected sex per partner value. Results showed that having multiple partners has a shallow effect on the rise of HIV cases, as shown in Figure 4. Further, it can be seen that consistent the use of condom is highly contributory to prevent HIV infection.

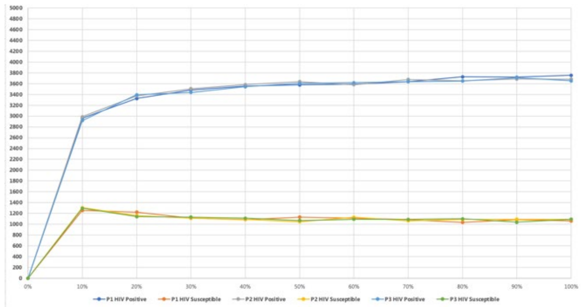

Figure 4. Visualization of HIV cases and HIV susceptible counts based on unprotected sex rate and sex partner counts.

The t-test results confirmed the insignificance of the variance among the HIV positive and HIV susceptible results, as shown in Table 2.

Table 2. T-TEST SCORES OF EXPERIMENTS RESULTS.

HIV Positive	t-value	p-value	HIV Susceptible	t-value	p-value
P1 and P2	-0.00608	0.995212	P1 and P2	0.00062	0.999511
P1 and P3	0.03435	0.972938	P1 and P3	0.01865	0.985305
P2 and P3	0.97385	0.342366	P2 and P3	0.01801	985808

5. Conclusions and Recommendations

This simulation model described the effect of unprotected sex and having sex with multiple partners. Results have shown that consistent use of condoms or practice on safe sex is crucial in preventing HIV infections. Regardless of sexual activity frequency, there is a need to consistently use condoms as protection since the more exposure an individual to an HIV-positive person, the greater the risk.

With this, the government and non-government agencies must strengthen information drive on safe sex and HIV, particularly teenagers. Access to condoms should also be widened, particularly for male sex workers. Testing should also reach in the community level to track and treat those who are infected.

Particularly, the topic on HIV and safe sex must be strengthen in basic education curriculum, and not only on higher education institutions. Raising well-educated individual on safe sex must be nurtured as early as possible and should be even start at home since family influence more on the choices and perspectives of an individual.

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