A Predictive Model on the Spread of HIV in Cebu City

Jose D. Velez, Ricky B. Villeta, Roberto N. Padua, Richard Hao and Marielle Colina

Abstract

Human Immunodeficiency Virus (HIV), which can be spread by people's lifestyle, causes Acquired Immune Deficiency Syndrome (AIDS). Social lifestyles such as multiple sexual partnerships, commitment, protected sex practices, and health checkups are lifestyle factors that can impact on the rate at which entry into any of the epidemiologic compartments S, I or D (death) slows or accelerates. Functional relationships between these social parameters and the disease parameters determined the model developed in this study and used predictive agent-based model to simulate the level of spread of HIV cases in Cebu with base data of the risky lifestyle of BPO agents in the region that could make them vulnerable to infections. Simulation results revealed that there is a rise on the incidence of HIV infections every year, which could become an epidemic in the future if no immediate intervention will be done. This high incidence of HIV cases in Cebu as evidenced by simulation results reflect the lack of awareness, prompt action, and policy in Cebu City with regards to mitigating the spread of the virus. Sans any intervention, the incidence of HIV infection can accelerate further in the future.

Keywords: predictive model, Acquired Immune Deficiency Syndrome (AIDS)

1.0 Introduction

Acquired Immune Deficiency Syndrome (AIDS) is caused by Human Immunodeficiency Virus (HIV) (Harvard Center for Communicable Diseases, 2009). This virus is spread by people's lifestyle (De Groot et al, 2010). Consequently, HIV cases could rise globally particularly in developing countries (WHO, 2010). Cebu City, Philippines, for instance, posted a 7% incidence rate (DOH, 2015). Hence, this study models HIV incidence in Cebu for policy purposes. It predicts AIDS cases in the city by 2020.

"The most common epidemiologic model for the spread of communicable diseases uses the compartmentalized "Susceptibles-Infectious-Recovered" (SIR) model (Devaney, 2000; Yamasaki et al, 2007). Such models are useful for controlling the spread of communicable diseases since one can concentrate on any one or two compartments at any given time" (De Groot, 2010; Albert, 2012).

The models that have been reviewed revealed that the main focus of the epidemiologic models is on the relative changes in the sizes of the compartments of the S-I-R. The models have not taken into consideration how these relative sizes are influenced by the social lifestyles of the people under consideration".

Social lifestyles such as multiple sexual partnerships, commitment, protected sex practices, and health checkups are lifestyle factors that can impact on the rate at which entry into any of the epidemiologic compartments S, I or D (death) slows or accelerates. Functional relationships between these social parameters and the disease parameters will be determined in the final model

to be developed in this study. Simulation results will be used to raise awareness on risk impact among Cebuanos, encourage prompt action or intervention on the part of authorities, and help policy makers craft programs.

2.0 Conceptual Framework

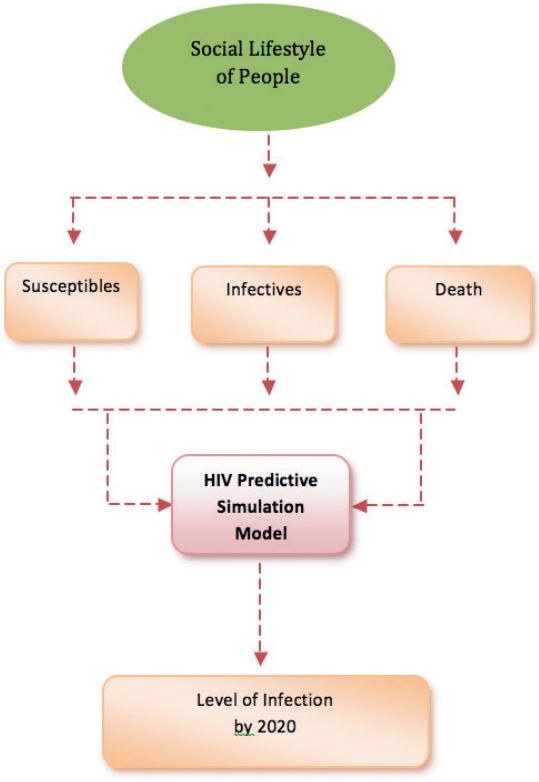
This study modifies Kermack and McKendrick's classic SIR epidemiological model. The Kermack and McKendrick "subdivide the total population N that exists in the community into three separate distinct populations: the population S that is susceptible to the disease, the population I that is infected with the disease and the population R that has recovered from the disease" (Isea et al. 2013).

In the present model, R or the recovery compartment is replaced with D for death, as so far, no cure for HIV/AIDS exists. Additional factor, social characteristic has been considered aside from biological characteristics present in the original model since "this model does not include demographic structure and is suitable for describing those diseases that suddenly develop in a community and then disappear without infecting the entire community" (Isea et al. 2013).

Social lifestyle factors will be used to assess the possible effect on sizes of the different compartments based on the results of the simulation. The result will be further utilized to determine the proportion of HIV infected individuals whose health conditions can affect the rise of the D compartment.

The level of HIV infection as a result of the simulation will then be used to provide awareness on risk impact among Cebuanos, encourage prompt action or intervention on the part of authorities, and help policy makers craft programs. Thus, hopefully, mitigating the rise of HIV cases in Cebu.

Figure 1: Conceptual Framework Diagram



3.0 Design and Methods

This paper uses simulation modeling. Applying the predictive agent-based model, it does a modification of Kermack and McKendrick's classic SIR epidemiological model. In the present model, R or the recovery compartment is replaced with D for death, as so far, no cure for HIV/AIDS exists. Additional factor, social characteristic has been considered aside from biological characteristics present in the original model since "this model does not include demographic structure and is suitable for describing those diseases that suddenly develop in a community and then disappear without infecting the entire community" (Isea et al. 2013). The following outlines the

assumptions being used in predictive agent-based model to simulate results of the present model that determines the level of spread of HIV infection in years to come.

3.1. Delimitation

The study uses secondary data gathered by the UP Population Institute in a 2009 paper titled, "Lifestyle, Health, Status, Behavior of Young Workers in Call Centers and Other Industries: Metro Manila and Metro Cebu."

3.2. Assumptions

Using the paper's Cebu data, several assumptions can be made. Cebu has been chosen due to the significant rise of AIDS cases in the city. Data revealed by the Department of Health as of 2016 revealed "10 full blown AIDS cases and 117 asymptomatic cases … An asymptomatic status means the patient is an HIV carrier without showing any symptom," (The Freeman, 2016).

In June 2015, the Department of Health (DOH) 7 reported that Cebu City has outranked Manila, the Philippine capital in terms of HIV incidence. While cities such as Bangkok, New York, Paris and Vancouver have successfully reduced HIV transmissions (UNAIDS, 2014), Cebu's HIV infection has been accelerating. According to the DOH Report, Cebu City has a prevalence rate of 7.7%, ahead of Manila and Quezon City which recorded 6.7% and 6.6%, respectively (Miasco, 2015). In Central Visayas, Cebu leads the provinces with 67 people confirmed to be with AIDS and 1872 others infected by HIV (Apalisok, 2015).

The following are the assumptions of this study:

On Sexual Behavior

241 persons in Cebu who are less than 35 years old were surveyed in 2009. Of the 241, 160 were asked on their sexual practices the past 12 months prior to the survey. 88 men and 72 women agreed to be made the respondents (UP Population Institute, 2009). Based on the UP study, the following assumptions can be made:

§ Male respondents engage more in risky sexual behavior compared to their female counterparts. The UP study revealed that men have a higher mean number of sexual partners at 3.7 while women only have a 1.2 mean number of sexual partners. Together they have a mean of 2.6 sexual partners i.e. 3 sexual partners.

§ Males too engage more in same-sex sexual experience at 15% as compared to women who merely have a 3.3 % engagement. More males also engage in commercial sex at 17.5% as compared to 0 by females.

§ Since the survey covered 12 months of sexual activity by the respondents, the number of weeks in a 12-month period was divided by the number of sexual partners. The resulting figure constitute the average commitment period of the respondents or the number of weeks the sexual activity would last.

On Protection

In the same study, a survey on use of condoms among respondents during their last casual sex was also conducted. 63 persons, involving 53 males and 10 females responded to the questions.

Based on the UP study, the following assumption can be made:

§ Men since they engage more in sexual activity have higher condom use with 41.5% of the male respondents admitting they

have engaged in protected sex. 40% of the female respondents said they too, engage in the practice. Together they constitute 41.3% of the total number of respondents who engage in safe sex.

AIDS Test

In the same study, a survey of 29 call center agents, involving 20 males and 9 females on whether they have taken an AIDS test was conducted.

Based on the UP study, the following assumptions can be made:

§ 60% of the male respondents said they had undergone an AIDS test. Together they constitute 41.3% of the total number of respondents who engage in safe sex.

3.3 Model Specification

This study uses an agent-based simulation software called Net Logo 5.2.1 (2005) principally authored by Uri Wilensky. The software has various simulation models to choose from. One of them is the AIDS model which simulates the spread of the human immunodeficiency virus (HIV) "via sexual transmission, through a small isolated human population" (Wilensky, 1997).

While HIV is spread in many ways including needle sharing among injecting drug users, blood transfusions, transmission from HIV-infected mothers to their babies, the model focuses only on transmission by sexual contact. The model uses 'couples' which pertain to two people engaged in sexual relations. "Individuals wander around the world when they are not in couples. Upon coming into contact with a suitable partner, there is a chance the two individuals will 'couple' together. When this happens, the two individuals no longer move about, they stand next to each other holding hands as a representation of two people in a sexual relationship" (Wilensky,1997).

Based on the aforementioned parameters the software provides sliders for the following: INITIAL-PEOPLE, how many people the simulation begins with; "AVERAGE-COUPLING-TENDENCY, general likelihood member of population has sex; AVERAGE-COMMITMENT, how many weeks a person remains committed to a sexual partner; AVERAGE-CONDOM-USE, general chance member of population uses a condom; AVERAGE-TEST-FREQUENCY, average frequency member of population will check their HIV status in a 1-year time period," (Wilensky, 1997).

The presence of the virus in the population is represented by the colors of individuals. The red-colored agents in the simulation are those infected with HIV; the green-colored, those who are not infected and the blue agents are those who may or may not have the virus.

3.4. Model Specification and Sensitivity Analysis

Based on the assumptions and data mentioned in the previous chapter, a simulation model was generated using agent-based simulation programming language NETLOGO (2005).

Since the study was made in 2009, an 11-year simulation study involving 143 people (representing the average number of respondents who replied in the UP study) was conducted in order to make the 2020 predictive simulation model.

The level of HIV infection as a result of the simulation will then be used to provide awareness on risk impact among Cebuanos, encourage prompt action or intervention on the part of authorities, and help policy makers craft programs.

Thus, hopefully, mitigating the rise of HIV cases in Cebu.

4.0 Results and Discussion

The following reveals the simulation results using the predictive agent-based model considering a modification of Kermack and McKendrick's classic SIR epidemiological model.

The first simulation model in this study uses an average coupling tendency of 2.6 based on the actual data gathered by the UP Population Institute on the respondents' number of sexual partners the past 12 months prior to the survey. The 20 weeks average commitment is derived by dividing the number of weeks in a year by the average coupling tendency.

4.1. Male and female sexual behavior

Table 1: Simulated results using an average coupling tendency of 2.6

Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	Mean	SD
4.20	4.90	5.59	4.20	4.20	3.50	4.20	4.90	5.59	4.20	4.55	0.68

Given these parameters, the result is combined rate of 4.55% among male and female young workers. This is much lower compared to the 7 percent infection rate reported by DOH as of June 2015. The discrepancy could be due to the fact that the DOH survey does not include only young workers in call centers and other industries.

However, considering it is a predictive model for the next five years (from 2015) using 2009 data, it is still a very conservative estimate. Factor influencing the simulation is the less risky sexual behavior by females that is affecting the overall result.

4.2. More risky behavior by men

Changing the variables by focusing on the data on male sexual practices alters the result dramatically.

Table 2: Simulated results for 10 trials using an average coupling tendency of 3.7

Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial10	Mean	SD
8.39	9.09	6.99	11.19	7.69	6.29	4.20	5.59	9.09	4.90	7.34	2.17

Using data involving males' average coupling tendency only results in higher percentage of infection. Changing the average coupling tendency to 3.7 (the mean number of multiple partners by male young workers according to the UP study) and running the simulation in Net Logo; by 2020, males will have a 7.34% rate of infection. This is higher than the combined infection rate of 4.55% involving male and female young workers.

The result apparently is mitigated by the average test frequency of .60 times per year and a 1.5 average condom use per statistics from the UP Population Institute study.

The result is consistent with the DOH report stating that male to male sex is second highest cause of the spread of the HIV virus in Cebu City.

4.3. More exposure means more chances of infection

From 143 initial people, the figure is raised to 192 to include 50% of the remaining respondents who refused to answer the questions used as parameters of this study. The reason for this is to see what would be the result with more people involved. Simulating the spread of the virus by 2020 with the new data, results in an even higher rate of infection at 13.65%.

Table 3: Simulated results for 10 trials using an average coupling tendency of 3.7 with 192 initial people

Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial10	Mean	SD
13.02	13.02	10.94	15.10	10.94	14.58	16.15	14.58	11.46	16.67	13.65	1.99

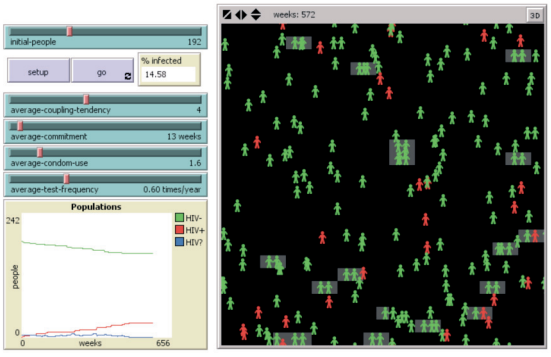
Increasing the initial people in the model also increases the percent of infection. It means the greater the exposure of a probable HIV positive young worker, the greater are the chances of him infecting other people.

4.4. More sexual partners means an exponential rise of infection

Increasing the number of sexual partners by merely rounding off the 3.7 mean number of sexual partners to 4 results in an exponential increase in the percentage of infection. With the change in the data and running a simulation in Net Logo, by 2020 an alarming 16.30% rate of infection is estimated.

Table 4: Simulated results for 10 trials using an average coupling tendency of 4

Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial10	Mean	SD
18.23	10.94	27.08	13.02	12.50	10.42	23.96	13.02	14.58	19.27	16.30	5.38



The simulation shows more and more people infected. As shown by the simulation, by the end of 572 weeks, the infection still has not stabilized.

5.0 Conclusion

Based on the data from UP and the simulation made with Net Logo, male young workers in Cebu with their high risk sexual behavior have more chances of getting infected by the HIV virus. This finding is consistent with the findings of DOH Region 7 identifying male to male sexual practice as the second leading cause of the spread of the HIV virus, next only to injecting drug use. Without any intervention between now and 2020, the number of those infected will reach an alarming level considering that Cebu's infection rate has been rising. Sans any intervention, the incidence of HIV infection can accelerate further in the future.

6.0 Reference

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