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On the Reproductive Number of HIV/AIDS Patients in Nigeria

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Abstract:
This paper presents the basic reproductive number of HIV/AIDS in Nigeria as well as endemic prevalence using the SIR model developed by Mckendric (2001). The Basic reproduction number R_o determines if the disease is transmissible or it will die a natural death, and the endemic prevalence gives a clue on the rate of transmission of the disease. This study obtained both the $R_o$and the endemic prevalence as a tool for controlling the endemic in an SIR model of disease dynamics.

Keywords: *Endemic prevalence, basic reproductive number, disease transmission, disease dynamics*

1. Introduction

HIV/AIDS has become a worldwide known epidemic due to its incurable nature. Government at all levels and non-governmental organizations as well as international organizations like UN, WHO, USAID has made efforts in ensuring the reduction in its spread through the media and other means. Others like the Society for Family Health, National Agency for the Control of Aids and so on have also contributed to the campaign against the spread of the epidemic. In the last one decade the use of internet and communication couriers have been seriously explored. The basic reproductive number is the average number of secondary cases of infection generated by one primary case in a susceptible population. It is a measure of how many other people that infected persons would infect before they either died or ceased to be infected. If $R_o < 1$, it implies that for every new infection, less than one subsequent infection occurs, hence the disease will eventually die out. The R_o can also be obtained if the endemic prevalence is known or vice versa. Hence, for a disease to be transmissible to R_o>1.

2. Materials and Methods

The SIR model labels these three compartments **S** = number susceptible, **I** =number infectious, and **R** =number recovered (immune). This is a good and simple model for many infectious diseases including Ebola Measles, mumps and rubella

A sexually active (15-49yrs) population divided into two groups: Susceptible (i.e. HIV-negative) individuals and infected individuals were considered.

An SIR disease transmission dynamics model was used.

Let X denotes the number of susceptible individuals and Y denotes the number of infected individuals, then the total number of sexually active population will be X+Y=N (the total sexually active population).

It is assumed the sexually active population is constant, i.e. there is always exactly the same number of people entering the population as those that are leaving the population.

If μ is the rate which individuals leave the sexually active population and β is the probability of HIV infection in a single sexual partnership with an HIV positive individual, and C is the rate at which new partnerships are formed.

It is also assumed that once people become infected with the disease, they experience an increase in the rate of mortality equal to α, then the basic reproductive number is obtained as follows:

R_o is the product of the probability of transmission per unit time and the duration or the period of infectiousness. The probability that an infected individual transmits the virus in a given unit of time (Δt) it CβΔt, and the average duration of infectiousness per unit time is measured as

$$\frac{1}{(\mu+\alpha)\Delta t}$$

Hence,

$$R_o = C\beta\Delta t\left(\frac{1}{(\mu+\alpha)\Delta t}\right)$$

$$=\frac{C\beta}{\mu+\alpha} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Suppose that the size of the sexually active population is constant (as assumed earlier), then a constant prevalence can only be maintained if every new infection generates one further infection on the average.
The number of new infections generated by one infection is calculated as R_o, reduced in proportion to the number of sexual contacts who are susceptible to infection. i.e $R_o\left(\frac{X}{N}\right)$
For equilibrium condition to hold, the

$$R_o\left(\frac{X}{N}\right)=1$$

$$R_o\left(1-\frac{Y}{N}\right)=1$$

$$1-\frac{Y}{N}=\frac{1}{R_o}$$

$$\frac{Y}{N}=1-\frac{1}{R_o} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Substituting (1) into (2)

$$\frac{Y}{N}=1-\frac{1}{\left(\frac{C\beta}{\mu+\alpha}\right)}$$

$$\frac{Y}{N}=\frac{C\beta-\mu-\alpha}{C\beta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3$$

Equation (3) provides an avenue to easily calculate the R_o and endemic prevalence if the population of infected individuals is known without taking into consideration the right hand side of the equation.

3. Results and Discussion

The HIV/AIDS data obtained from the epidemiological fact sheet of 2011 was used. From where the sexually active population was obtained as being in the neighborhood of 40,900,000, the total population of infected individuals is 2,714,000.

$$\frac{Y}{N}=1-\frac{1}{R_o}$$

$$\frac{2{,}714{,}000}{40{,}900{,}000}=1-\frac{1}{R_o}$$

$$0.06=1-\frac{1}{R_o}$$

$$R=1.1$$

The endemic prevalence is thus 0.06
The value of R_o=1.1>1 implies that the epidemic will continue to spread within the population and the higher the R_o the more rapidly it continuous to spread and the endemic prevalence also continues to increase.

4. Conclusion

The basic reproductive number R_o and the endemic prevalence play a vital role in the determining the status of a diseases.
When R_o is less than 1, it implies that for every new infection, less than one subsequent infection occurs, hence the disease will eventually extinct. With R=1.1 and the endemic prevalence of 0.06, more than one infection will occur for every new infection.
Therefore, if the basic reproductive number can be brought below 1.0, which can be done through several means like campaign against the disease, awareness on radio and television as well as the internet, the prevalence will be reduced and it can then be brought under control.

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