Modeling the effects of peer-education campaign on the dynamics of HIV/AIDS

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UR

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Introduction

- HIV/AIDS dynamics provides a large number of new problems to mathematicians, biologists and epidemiologists since it has many features different from traditional infectious diseases and its study has stimulated the recent development of mathematical epidemiology

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Since HIV/AIDS pandemic first became visible, research on how to prevent transmission has been conducted. Efforts to respond to the disease surfaced early in Uganda. One prevention effort in Uganda was ABC, (Abstinence, Be faithful and Condom use).

Cont'd

- Abstinence has not borne much fruits especially among the young, unmarried people and married couples have failed to be faithful to their often-monogamous wives thus making the use of condom an essental option

Cont'd

- Numerous experimental and classical studies have been conducted to ascertain the effectiveness of condom use as a tool for controlling the spread of HIV. The overall consensus of an estimated condom effectiveness is between 60%–90% with a mean of 87%

Cont'd

- The most conclusive evidence of condom effectiveness in reducing HIV/AIDS transmission has come from studies of serodiscordant couples, and another evidence is the Thailand 100% condom policy, which re-quired commercial sex workers and their clients to use condoms every act of intercourse, which reduced STI's from 410,406 in 1987 to 29,362 in 1994 with 14% → 94% increase in condom use

Cont'd

- HIV/AIDS models to assess the effects of condom use in controlling HIV/AIDS in a community have been studied by many authors we can mention here Moghadas, S. M. et al. (2004) .
- Analysis of the dynamics of a two-group deterministic model for assessing the impact of condom use on the sexual transmission of HIV/AIDS within homosexual population was done by Greenhalgh D. (2001)

Cont'd

Their study show that although condom use reduce (R_0) to values less than one, it does not guarantee eradication of the disease, that is why we introduction a new model that incorporates the peer-education campaign parameters and assess their impact on the basic reproduction number and the model is numerically analyzed using demographic data from Rwanda

The model

The model divides the population into classes which are;

(a) susceptible $S_i(t)$, containing individuals in sex group i who have had no contact with the virus

(b) Infected $I_i(t)$, individuals in sex group i who are infected with the virus but have not yet developed AIDS symptoms

(c) AIDS cases $A_i(t)$, individuals who have developed fully symptomatic AIDs and exhibit specific clinical features. where $i = f, m$ denote female and male respectively

Definition of variables and parameters

- $S_i(t)$, $I_i(t)$, $A_i(t)$, $i = f, m$ Susceptible, Infected and AIDS cases
- Λ is the constant sexual maturity rate
- μ is the natural death rate
- ν is the accelerated death rate due to infection and or AIDS case
- τ is the constant incubation period
- β_i is the per exposure risk of infecting the other pattern when no protection of any kind is used $i = f, m$

Cont'd

- c_i where $i = f, m$ are the constant number of sexual exposures per year
- m is the per capita emigration rate
- ρ is the proportion of children who will mature to be females
- $(1-\rho)$ the complimentary proportion of children who will mature to be males
- η is the sexual contact rate of a susceptible with an AIDS case
- $N_i(t) = S_i(t) + I_i(t) + A_i(t)$ where $i = f, m$ proportion of sexual interacting males and females

Assumptions

- The model assumes that vertical and intravenous transmission of HIV is minimal and can be ignored and only HIV transmission through sexual intercourse is considered
- Susceptible and Infected are removed at a constant natural death rate μ
- Constant emigration rate m is positive for sexually mature susceptible and infective
- The model assumes a constant incubation period $\tau > 0$

Cont'd

- The model assumes homogeneous mixing, thus it assumes standard incidence of the form

$$\lambda_j^n S_i(t-n) := \frac{\beta_j c_i S_i(t-n)\left(I_j(t-n) + \eta A_j(t-n)\right)}{N_j(t-n)}$$

  Where $n = 0, \tau$ and $\beta_j c_i$ $i = f, m$, $i \neq j$ are the average number of adequate contacts of one infective individual per unit time

- AIDS cases are not easily recognized in the population because of the use of ARTs and thus contribute in the spread of the epidemic

Cont'd

$$S_i^{'}(t)=\rho\Lambda-\beta_j c_i\frac{S_i(t)\left(I_j(t)+\eta A_j(t)\right)}{N_j(t)}-(\mu+m)S_i(t),$$

$$I_i^{'}(t)=\beta_j c_i\frac{S_i(t)\left(I_j(t)+\eta A_j(t)\right)}{N_j(t)}-\beta_j c_i k\frac{S_i(t-\tau)\left(I_j(t-\tau)+\eta A_j(t-\tau)\right)}{N_j(t-\tau)}-(\mu+m)I_i(t)$$

$$A_i^{'}(t)=\beta_j c_i k\frac{S_i(t-\tau)\left(I_j(t-\tau)+\eta A_j(t-\tau)\right)}{N_j(t-\tau)}-(\mu+\nu)A_i(t) \qquad (1)$$

Cont'd

where $k = e^{-(\mu+m)\tau}$ is the probability that an infected individual will survive until he or she develops AIDS after time τ (incubation period) and the parameters $\beta_i, c_i, \rho, \Lambda, \mu, m$ and $\tau \in \mathbb{R}_+; i = f, m$. System (1) represents the sexually mature age group between 14 and 49 years and it is this age that is responsible for the spread of HIV/AIDS through sexual intercourse. The model (1) has initial conditions at time $t=0$ given by : $S_i(s) = S_{i,0}(s) \geq 0, \quad I_i(s) = I_{i,0}(s) \geq 0 \quad \forall s \in [-\tau, 0]$

with $S_i(0) > 0, \quad I_i(0) > 0, \quad A_i(0) > 0$ where $i = f, m$

Solvability of the model

Theorem 2.1. (Positivity and boundedness of the solution)

Let the initial data be

$S_i(s) = S_{i,0}(s) \geq 0, \quad I_i(s) = I_{i,0}(s) \geq 0, \quad \forall s \in [-\tau, 0)$ with

$S_{i,0}(0) > 0, \quad I_{i,0}(0) > 0, \quad A_{i,0}(0) > 0$. Then the solutions $S_i(t), I_i(t)$ and $A_i(t)$ of the system (1) are positive for all $t > 0$. For the model system (1), the region is positively invariant and all solutions starting in $_{+0}$ or $_{+}$ approach, enter or stay in $_{+}$

Disease free state and its stability

The disease-free equilibrium is given by

$$E_0 = \left(S_f^0, S_m^0, I_f^0, I_m^0, A_f^0, A_m^0\right) = \left(\frac{\Lambda\rho}{\mu+m}, \frac{\Lambda(1-\rho)}{\mu+m}, 0,0,0,0\right) \qquad (2)$$

We compute the basic reproductive number, following the next generation operator approach by Dickmann et al. (1990), van Deen Driesche and Watmough (2002) approaches in which they define the reproductive number R_0 as the spectral radius of the next generation operator. Using the given approach, the basic reproductive number R_0 is defined by $R_0 = \rho\left(FV^{-1}\right)$ (3)

Basic reproduction number Ro

Considering (3) where F is non-negative matrix, V is a non-singular $M-matrix$ and FV^{-1} is the next-generation matrix of the model and $\rho(A)$ denotes the spectral radius of matrix A. For the model system (1) we obtain

And the basic reproductive number is

$$R_0 = \frac{\sqrt{\beta_f \beta_m c_f c_m}\,(1-k)}{(\mu+m)} = \sqrt{R_{0f} R_{0m}} \qquad (4)$$

where $R_{0f} = \frac{\beta_f c_f (1-k)}{(\mu+m)}$ and $R_{0m} = \frac{\beta_m c_m (1-k)}{(\mu+m)}$ are females and males contribution to the basic reproductive number, R_0 respectively. In this respect, we can define R_0 as the geometric mean of R_{0f} and R_{0m}

Global stability of disease-free equilibrium

Theorem 2.2.

If $R_0 < 1$, the disease-free equilibrium is globally asymptotically stable and if $R_0 > 1$, this equilibrium is unstable

Endemic equilibrium and its stability

The endemic equilibrium for the system (1) $E_e=\left(S_f^e,S_m^e,I_f^e,I_m^e,A_f^e,A_m^e\right)$

is $\left(\frac{\left(\mu+m+\beta_f c_m(1-k)\right)I_f^e}{\left(R_0^2-1\right)(\mu+m)},\frac{\left(\mu+m+\beta_m c_f(1-k)\right)I_m^e}{\left(R_0^2-1\right)(\mu+m)},I_f^e,I_m^e,\frac{(\mu+m)kI_f^e}{(1-k)(\mu+v)},\frac{(\mu+m)kI_m^e}{(1-k)(\mu+v)}\right)$ (5)

where

$$I_f^e=\frac{\Lambda\rho(1-k)(\mu+m)(\mu+m)\left(\left(R_m^2-1\right)\right)}{\left(\left((\mu+m)\beta_m c_f(k-1)\left(\mu+m+\beta_m c_f\right)+k\left(m^2+\mu+\beta_f c_m(1-k)\mu+\beta_m c_f\right)\right)+m\left(2\mu+\beta_f\beta_m c_f c_m(1-k)\right)\right)}$$

$$I_m^e=\frac{\Lambda(1-\rho)(k-1)(\mu+m)(\mu+m)\left(\left(R_m^2-1\right)\right)}{\left(\left((\mu+m)\beta_m c_f(k-1)\left(\mu+m+\beta_f c_m\right)+k\left(m^2+\mu+\beta_m c_f(1-k)\mu+\beta_f c_m\right)\right)+m\left(2\mu+\beta_f\beta_m c_f c_m(1-k)\right)\right)}$$

theorem 2.3. The endemic equilibrium E_e exists and is positive if $R_0>1$

PEER-EDUCATION CAMPAIGN

- We analyze the effects of Peer-educators campaign as a single strategy for HIV/AIDS prevention. We define peer-education campaign as the counseling of individuals to engage in safe sex or low risk sexual behaviours

Cont'd

- High risk behavior includes sex after getting "*high*", having many sexual partners, having unprotected sexual relations, polygamy, having sex with commercial sex-workers just to mention but a few. Low risk behavior includes any non-risk behavior e. g delayed sexual; debut, being faithful with one partner, always using a condom among others

Cont'd

- It is believed that the most effective counseling session is between a trained person and a client of almost the same age. This call for the need to have peer-counselors instead of public health campaign
- In this context, the following additional partners are used and assumptions are made to model the effects of peer-education campaign

The model

Assumptions and parameters

- The model in equation (1) is modified to have high and low risk susceptible, high and low risk infected and high and low risk AIDS cases denoted S_{i1} and S_{i2} ; I_{i1} and I_{i2} and A_{i1} and A_{i2} respectively, where $i = f, m$ and the subscript 1 , 2 denote high-risk and low-risk sexual activities respectively
- Individuals in category S_{i1} are educated and transfer to low-risk susceptible class S_{i2} at a rate ω_i
- Upon becoming infected with HIV, a proportion π_i of educated individuals enter I_{i2} and the complementary proportion $(1-\pi_i)$ enter the high-risk class I_{i1}

Cont'd

- Individuals in A_{i1} move to the low risk AIDS classes A_{i2} at a constant rate of a_i due to peer-educational campaign
- High risk infected individuals progress to AIDS stage at a rate $\lambda_j^{\tau}\pi_i kS_i(t-\tau)$ and low risk infected individuals progress to AIDS stage at a rate $\lambda_j^{\tau}(1-\pi_i)kS_i(t-\tau)$
- With the above additional parameters and assumptions, the model in equation (1) becomes

The model

$$S_{i1}^{'}(t)=\rho\Lambda-\beta_j c_i\frac{S_{i1}(t)\left(I_{j1}(t)+\eta A_{j1}(t)\right)}{N_{j1}(t)}-\left(\omega_f+\mu+m\right)S_{i1}(t),$$

$$S_{i2}^{'}(t)=\rho\Lambda-\beta_j c_i\frac{S_{i2}(t)\left(I_{j2}(t)+\eta A_{j2}(t)\right)}{N_{j2}(t)}-\left(\omega_f+\mu+m\right)S_{i2}(t)$$

$$I_{i1}^{'}(t)=\beta_j c_i\frac{S_{i1}(t)\left(I_{j1}(t)+\eta A_{j1}(t)\right)}{N_{j1}(t)}-\beta_j c_i k\frac{S_{i1}(t-\tau)\left(I_{j1}(t-\tau)+\eta A_{j1}(t-\tau)\right)}{N_{j1}(t-\tau)}-\left(\mu+m\right)I_{i1}(t)$$

$$I_{i2}^{'}(t)=\beta_j c_i\frac{S_{i2}(t)\left(I_{j2}(t)+\eta A_{j2}(t)\right)}{N_{j2}(t)}-\beta_j c_i k\frac{S_{i2}(t-\tau)\left(I_{j2}(t-\tau)+\eta A_{j2}(t-\tau)\right)}{N_{j2}(t-\tau)}-\left(\mu+m\right)I_{i2}(t)$$

$$A_{i1}^{'}(t)=a_f\pi_f\beta_j c_i k\frac{S_{i1}(t-\tau)\left(I_{j1}(t-\tau)+\eta A_{j1}(t-\tau)\right)}{N_{j1}(t-\tau)}-\left(a_f+\mu+v\right)A_{i1}(t)$$

$$A_{i2}^{'}(t)=\beta_j c_i k\frac{S_{i2}(t-\tau)\left(I_{j2}(t-\tau)+\eta A_{j2}(t-\tau)\right)}{N_{j2}(t-\tau)}+a_f A_{f1}(t)-\left(\mu+v\right)A_{i2}(t) \qquad (6)$$

Equilibrium points and stability

System (6) has the disease-free equilibrium

$$E_0=\left(S_{f1}^0,S_{m1}^0,I_{f1}^0,I_{m1}^0,A_{f1}^0,A_{m1}^0\right)=\left(\frac{\Lambda\rho}{\mu+m},\frac{\Lambda(1-\rho)}{\mu+m},0,0,0,0\right) \qquad (7)$$

and the endemic equilibrium point (EEP) of this model will be

$$E_e=\left(S_{f1}^e,S_{m1}^e,I_{f1}^e,I_{m1}^e,A_{f1}^e,A_{m1}^e\right)$$

$$=(\frac{\Lambda\rho}{\mu+v+\omega_f+\lambda_m^e},\frac{\Lambda(1-\rho)}{\mu+v+\omega_f+\lambda_f^e},\frac{(1-k)\pi_f\Lambda\rho\lambda_m^e}{((\mu+m)\mu+v+\omega_f+\lambda_m^e)},\frac{(1-k)\pi_f\Lambda(1-\rho)\lambda_f^e}{((\mu+m)\mu+v+\omega_f+\lambda_f^e)},$$

$$\frac{k\left(b_f(1-\pi_f)+a_f\pi_f\right)\rho\Lambda\lambda_m^e}{(\mu+v+\alpha_f)(\mu+v+\omega_f+\lambda_m^e)},\frac{k\left(b_m(1-\pi_m)+a_m\pi_m\right)(1-\rho)\Lambda\lambda_f^e}{(\mu+v+\alpha_f)(\mu+v+\omega_f+\lambda_f^e)}) \qquad (8)$$

where $\lambda_j^e=\dfrac{\beta_j c_i\left(I_{j1}^e+A_{j1}^e\right)}{N_{j1}^e}$

Basic reproduction number

To get the basic reproductive number R_{f1} for the system (6), we consider a single newly infected high risk male entering the disease-free population at equilibrium. The individual is still present and infectious at $t < \tau$ with probability $\exp\{-(\mu+m)t\}$ and in this case infects females at rate

$$\pi_f \beta_m c_f \frac{S_{f1}^0}{S_{m1}^0}$$

Hence, the expected number of females infected by this high risk male is approximately

$$R_{f1} = \int_0^{\tau} \pi_f \beta_m c_f \frac{S_{f1}^0}{S_{m1}^0} e^{-(\mu+m)t} dt = \frac{\pi_f \beta_m c_f S_{f1}^0}{(\mu+m) S_{m1}^0}(1-k) \qquad (9)$$

Cont'd

in the same ways we get

$$R_{m1} = \int_0^{\tau} \pi_m \beta_f c_m \frac{S_{m1}^0}{S_{f1}^0} e^{-(\mu+m)t} dt = \frac{\pi_m \beta_f c_m S_{m1}^0}{(\mu+m) S_{f1}^0}(1-k)$$

$$R_{f2} = \int_0^{\infty} \left(a_f \pi_m + \beta_f \left(1-\pi_f\right)\right) \beta_m c_f k \frac{S_{f1}^0}{S_{m1}^0} e^{-\left(a_f+\mu+v\right)t} dt = \frac{\left(a_f \pi_m + \beta_f \left(1-\pi_f\right)\right) \beta_m c_f k S_{f1}^0}{\left(\alpha_f + \mu + v\right) S_{m1}^0}$$

$$R_{m2} = \frac{\left(a_m \pi_f + \beta_m \left(1-\pi_m\right)\right) \beta_f c_m k S_{m1}^0}{\left(\alpha_m + \mu + v\right) S_{f1}^0} \qquad (10)$$

Cont'd

The reproduction number R_0 for the model (6) can be written as

$$R_0 = \left(\beta_f \beta_m c_f c_m \left(\frac{\pi_f \pi_m (1-k)^2}{(m+\mu)^2} + \frac{k(1-k)}{(v+\mu)} \left[\frac{\pi_m \left(b_f (1-\pi_f) + a_f \pi_f\right)}{\left(\mu + v + \alpha_f\right)} + \frac{\pi_f \left(b_m (1-\pi_m) + a_m \pi_m\right)}{\left(\mu + v + \alpha_m\right)} \right] + \frac{k^2 \left(b_f (1-\pi_f) + a_f \pi_f\right)\left(b_m (1-\pi_m) + a_m \pi_m\right)}{\left(\mu + v + \alpha_f\right)\left(\mu + v + \alpha_m\right)} \right) \right)^{\frac{1}{2}} \tag{11}$$

Effects of Peer- Educational campaign on

We use the computed R_0 to estimate the effects of peer-educational campaign in controlling HIV/AIDS in a community for the following cases,

(i) **Case 1**: when there is completely no educational campaigns, $\pi_i = a_i = b_i = 1$ and $\alpha_i = 0$, for this case we have

$$\lim_{\pi_i, a_i, b_i \to 1} R_0 = R_1 = \sqrt{\beta_f \beta_m c_f c_m \left(\frac{(1-k)^2}{(m+\mu)^2} + \frac{k(1-k)}{(\nu+\mu)} \left[\frac{1}{\mu+v} + \frac{1}{\mu+v} \right] + \frac{k^2}{(\mu+v)(\mu+v)} \right)} \qquad (12)$$

Where R_1 is the reproductive number when there is no education?

Cont'd

We have that $R_1 > R_0$ suggesting that lack of educational campaigns in communities with HIV/AIDS, results in an increase in the number of secondary infections

(ii) Case 2: When there is effective educational campaigns, $\pi_i = a_i = b_i = 0$ and $\alpha_i > 0$. For this case we shall have

$$\lim_{\pi_i, a_i, b_i \to 0} R_0 = R_1 = 0 \qquad (13)$$

We have the effective peer-group educational campaigns in a community, the number of secondary infections is reduced to zero thus the effective educational campaigns help slow or eradicate the epidemic if properly implemented in communities affected by the epidemic

4. Numerical simulation

4.1. Situation in Rwanda

The first cases of HIV in Rwanda have been reported in 1980. In this year, 4257 cases have been recorded. Since then, the evolution of HIV increased like in other developing countries. The following figure illustrates the evolution of HIV in Rwanda. The highest rate of HIV was reported in 1999.

Cont'd

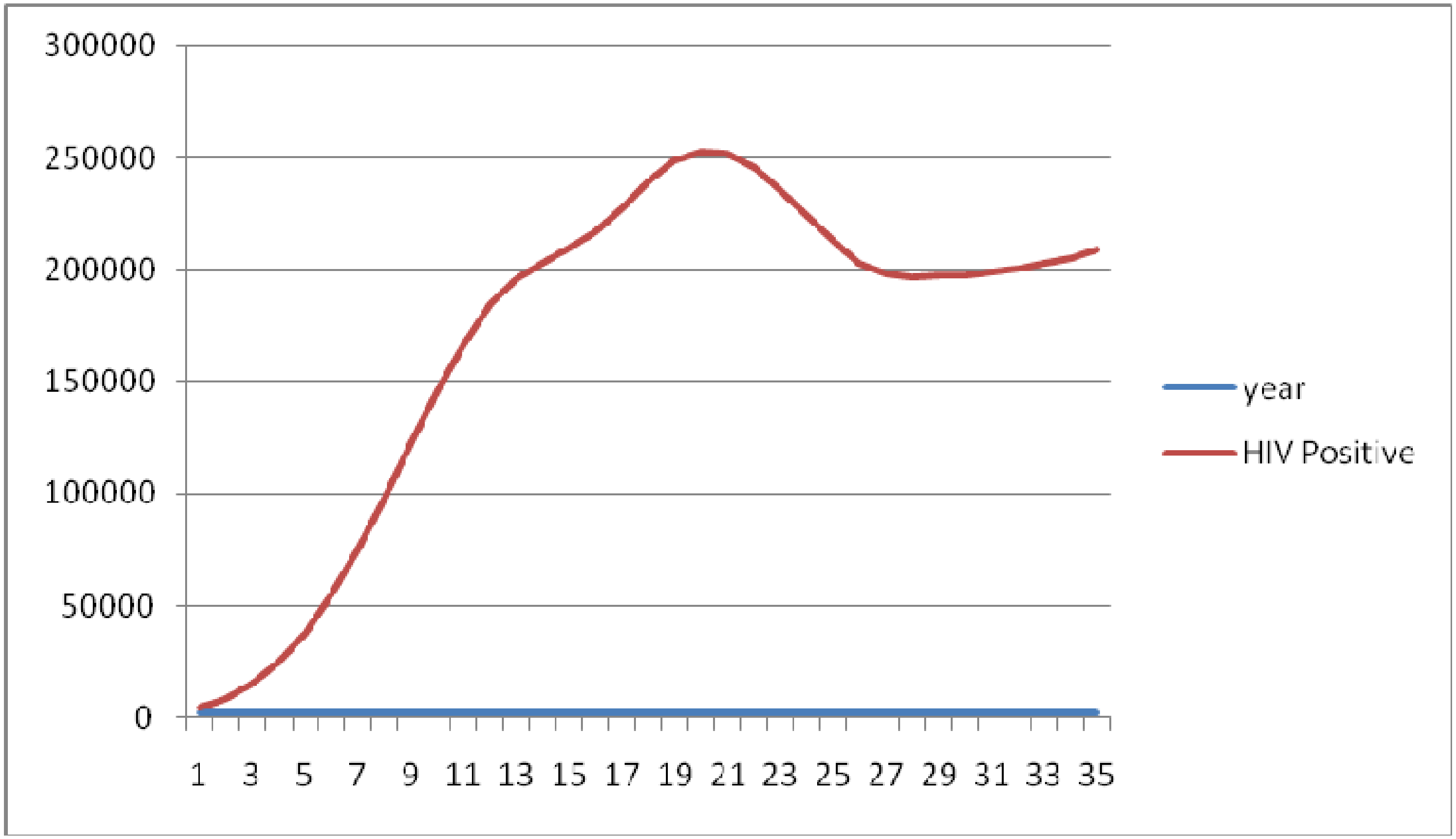


Figure 1: HIV evolution in Rwanda 1980-2014

Cont'd

Considering the number of infectious for each of the mentioned year, and considering the transition matrix for both male and female, the basic reproduction number is estimated to 3.92 and 4.21 for male and 3.65 for female.

In 2010, a random sample of 13,522 individuals were tested for HIV in the whole country; the following table summarizes the information about that survey

Cont'd

Background Characteristics	**Number (%)**	**HIV Status**	
PROVINCE		Positive	Negative
North	2069	66(3.19%)	2003(96.81%)
South	3186	99(3.11%)	3087(96.89%)
East	3273	93(2.84%)	3180(97.16%)
West	2983	110(3.69%)	2873(96.31%)
Kigali City	2011	61(3.03%)	1950(96.97%)
Total	**13522**	**429(3.17%)**	**13093(96.83%)**

Cont'd

AGE GROUP			
15-19 years	3065	90(29.36%)	2975(70.64%)
20-24 years	2463	91(36.95%)	2372(63.05)
25-29 years	2237	59 (2.64%)	2178(97.36%)
30-34 years	1562	48(3.08%)	1514(96.92%)
35-39 years	1041	30(2.88%)	1011(97.12%)
40-44 years	933	29(3.11%)	904(96.89%)
45-49 years	869	35(4.03%)	834(95.97%)
50-54 years	806	31(3.85%)	775(96.15%)
55-59 years	545	16(2.94%)	529(97.06%)
Total	**13522**	**429(3.17)**	**13093(96.83%)**

Cont'd

PLACE OF RESIDENCE			
Urban	2482	357 (14.38%)	2125 (85.62%)
Rural	11040	72 (0.01%)	10968 (99.99%)
Total	**13522**	**429 (3.17%)**	**13093 (96.83%)**
GENDER			
Male	11158	359(3.22%)	10799(96.78%)
Female	2364	70(2.96%)	2294(87.04%)
Total	**13522**	**429(3.17%)**	**13093(96.83%)**

Cont'd

EDUCATION			
No education	1734	47(11.0%)	1687(97.29%)
Primary	8777	303(70.6%)	8474(64.7%)
Secondary	2648	61(14.2%)	2587(19.8%)
Higher	363	18(4.2%)	345(2.6%)
Total	**13522**	**429**	**13093**

Cont'd

According to this study , the seroprevalence (rate of HIV positive) in Rwanda is 3.17% with a 95% confidence of 2.82% and 3.51%

Cont'd

Among these factors, only the education factor was significant. That is why a great attention has been taken to this factor in order to reduce the speed of spreading HIV in Rwanda. First of all "*clubs against HIV*" have been organized both in schools and out of the schools for youth sensitization. 23 Youth-friend centers are operational. The main objective of these clubs is to sensitize the youth and to get low risk sex contact

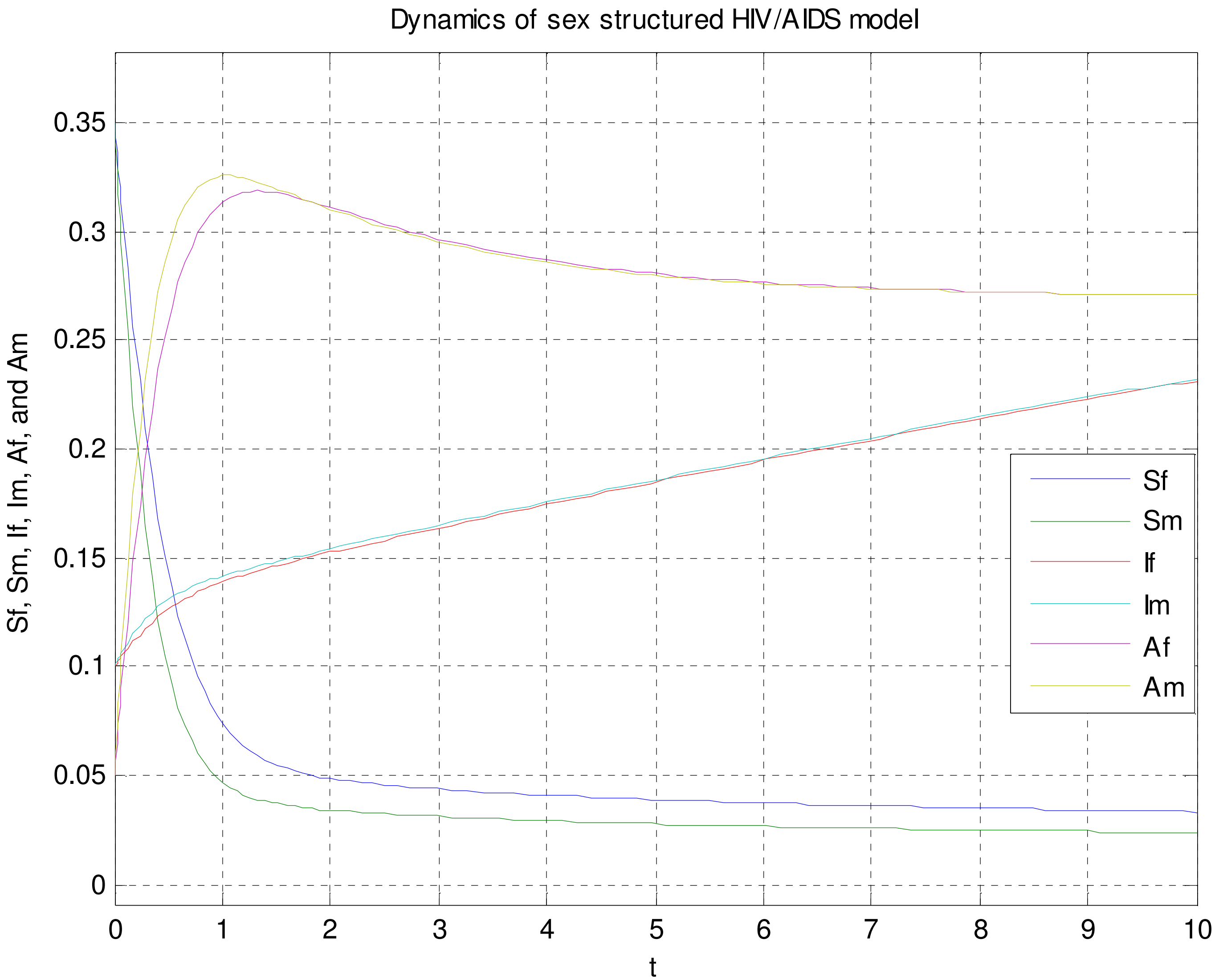
Cont'd

Now, a new method is in experimentation where once a week people in the village are meeting in the so called "*evening of parents*". One of the topics to discuss in these meetings is the transmission of HIV, this will help people especially in rural area and for non educated people to know about this endemic. The achievement of this policy will constitute the basis of peer-education campaign against the transmission of HIV. The big challenge of this policy is that the men don't want to attend these meetings

4.2 Numerical simulations

Some of the parameters used have been estimated others assumed

The following figure represents the sex structured dynamics of HIV/AIDS in a population without any intervention.


Dynamics of sex structured HIV/AIDS model
Sf, Sm, If, Im, Af, and Am
t
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
6
7
8
9
10
Sf
Sm
If
Im
Af
Am

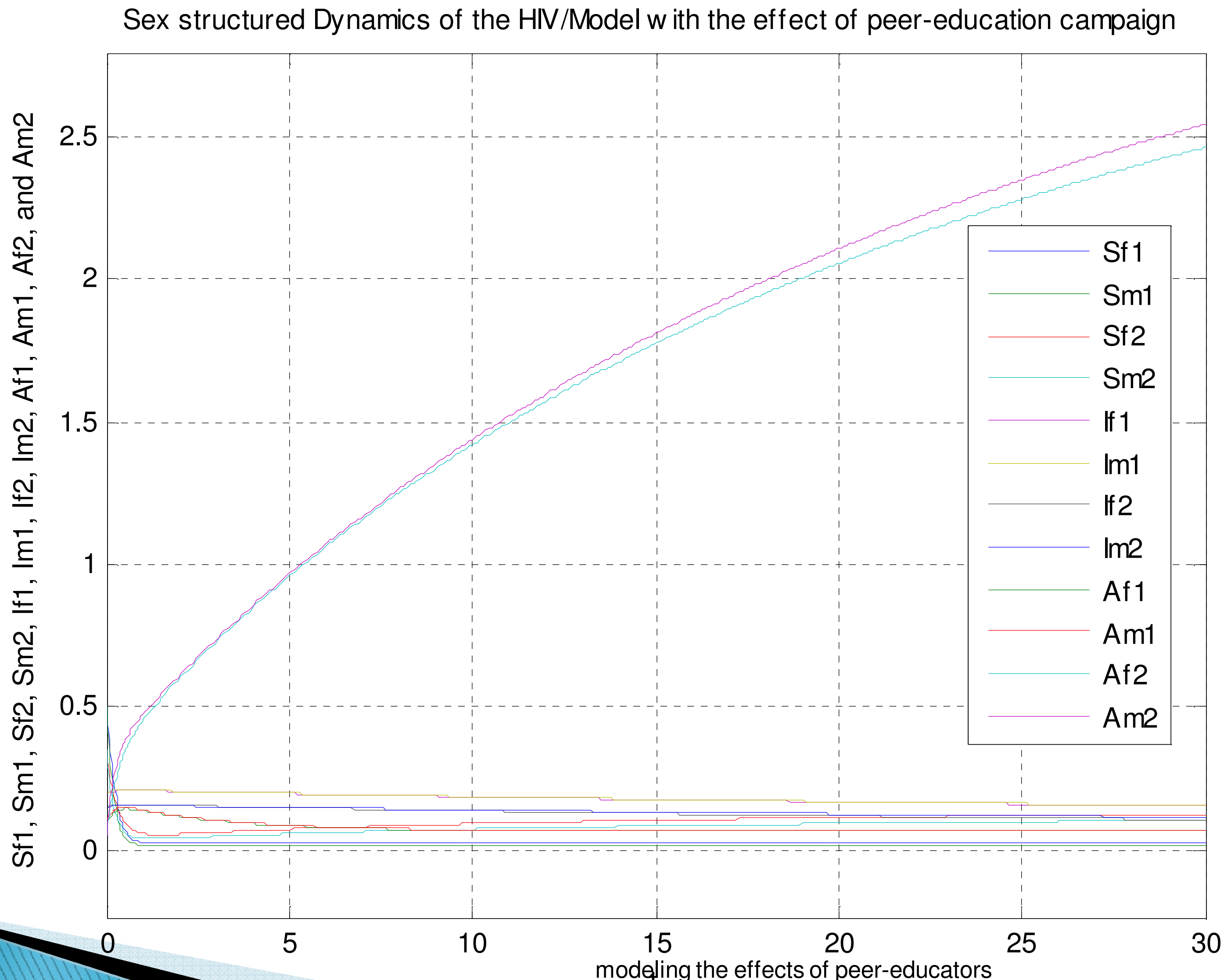
Cont'd

The following figure represents the simulation of the dynamics of HIV/AIDS with the effect of peer-education campaign, assuming the following initial data

$$S_{f1} = S_{m1} = 0.50,\ S_{f2} = S_{m2} = 0.35, I_{f1} = I_{m1} = 0.20$$

$$I_{f2} = I_{m2} = 0.15, A_{f1} = A_{m1} = 0.10, A_{f2} = A_{m2} = 0.05$$

Cont'd



Sex structured Dynamics of the HIV/Model w ith the effect of peer-education campaign
Sf1, Sm1, Sf2, Sm2, If1, Im1, If2, Im2, Af1, Am1, Af2, and Am2
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
t
Sf1
Sm1
Sf2
Sm2
If1
Im1
If2
Im2
Af1
Am1
Af2
Am2

Conclusion

The sex structured model developed for The dynamics of HIV/AIDS incorporating the effects of peer – education campaign shows a big interest in that the The basic reproduction number obtained is a function of the parameters of peer-education campaign and when there is effective educational campaigns, the basic reproduction number tends to zero the number of secondary infections is reduced to zero and the cases of new AIDS cases will also reduce to zero

THANK YOU !!!!

Appendix1. Parametres of the model

Parameter	Symbol	value
Birth rate into sexually mature age group	Λ	0.03
Proportion of mature female	ρ	0.52
Adult natural death	μ	0.02
AIDS- related death	υ	0.33
Emigration rate	m	0.01
Average incubation period	τ	(6-11) 8

Cont’d

Probability of transmission of HIV when there is no protection	(β_f, β_m)	$(0.49, 0.52)$
Number of sexual exposures	(c_f, c_m)	$(20, 30)$
The basic reproduction number	(R_0, R_f, R_m)	$(3.92, 3.65, 4.21)$
the sexual contact rate of a susceptible with an AIDS case	η	0,03
Proportion of educated people	(π_f, π_m)	$(0.5, 0.5)$
Rate of individual in S_{i1} who move to the low risk class S_{i2} due to the peer- education campaign	(ω_f, ω_m)	$(0.4, 0.3)$
Rate of individual in A_{i1} who move to the low risk class A_{i2} due to the peer- education campaign	(a_f, a_m)	$(0.3, 0.2)$

Appendix 2. The Dynamics of HIV in Rwanda 1980-2014 (RBC,2015)

year	Exposed	Infectious	Total HIV positve
1980	3736	521	4257
1981	7482	813	8295
1982	9594	5307	14901
1983	14917	9724	24641
1984	23214	14652	37866
1985	36718	17946	54664
1986	54565	20091	74656
1987	74494	23037	97531
1988	90905	31098	122003
1989	93365	52149	145514
1990	99263	66738	166001
1991	114851	69545	184396
1992	117194	78631	195825
1993	102758	99807	202565

Cont'd

1994	103946	105348	209294
1995	105612	111239	216851
1996	129840	97527	227367
1997	143064	96005	239069
1998	154434	94172	248606
1999	160021	92403	252424
2000	180252	71009	251261
2001	178145	67291	245436
2002	173946	61456	235402
2003	165814	58234	224048
2004	162260	50311	212571

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2005	161687	40570	202257
2006	164803	32963	197766
2007	170809	25972	196781
2008	173828	23126	196954
2009	177492	20048	197540
2010	179754	18816	198570
2011	183343	16959	200302
2012	186302	16462	202764
2013	190632	14267	204899
2014	196514	11983	208497