Effectiveness of a no-sex or safe-sex month in reducing HIV transmission

Benjamin Armbruster[a] & Aaron M Lucas[a]

Objective To build a deterministic compartmental model for exploring the effects on the transmission of human immunodeficiency virus (HIV) of a population abstaining from sex or practising only "safe" sex for one month each year.

Methods A model of HIV transmission was built to simulate the effects of the intervention (i.e. an annual no-sex or safe-sex month in which no transmission occurred) in three countries, under several optimistic assumptions. The reduction in the modelled annual incidence of transmission that was attributable to this "test" intervention was compared with that seen with an alternative intervention. In the latter, monthly incidences of transmission were each reduced by one twelfth, so that, essentially, the month-long interruption was spread evenly across a full year.

Findings Over the first modelled year, the test intervention averted only 2.5% (Kenya), 3.3% (South Africa) and 1.6% (Swaziland) more HIV infections than the alternative interruption. According to the model, if the test intervention were repeated each January, it would avert only 2% (Kenya), 2% (South Africa) and 1% (Swaziland) more HIV infections over 5 years than the alternative intervention.

Conclusion Although it did not appear markedly more effective than the alternative intervention, the test intervention may still be more feasible and therefore worthwhile. Before the test intervention can be recommended, the cost-effectiveness and feasibility of such an annual month-long break in HIV transmission need to be assessed and compared with those of other interventions that may reduce new HIV infections, such as circumcision and concurrency-reduction campaigns.

Abstracts in عربي, 中文, Français, Русский and Español at the end of each article.

Introduction

Despite significant investment in programmes for the treatment and prevention of human immunodeficiency virus (HIV) infection, the prevalence of such infection in sub-Saharan Africa remains stubbornly high. In 2009, for example, an estimated 24.8% of the adults living in Botswana and 17.8% of those living in South Africa were thought to be HIV-positive.[1] Prevention is, in general, particularly poor: for every two individuals starting treatment, five become infected with HIV.[2] Recently, many international organizations, including the Joint United Nations Programme on HIV/AIDS (UNAIDS), The World Bank and the World Health Organization (WHO), have called for a realignment of prevention strategies and new, innovative ways to blunt the impact of the HIV epidemic, especially in those countries that are most affected.[3,4] A novel strategy proposed by Parkhurst and Whiteside[5] – a population-wide "month off" from risky behaviour, with no sex or exclusively safe sex over that period – gained a substantial amount of publicity, with articles[6–8] and mentions[9–14] in many high-profile outlets. Unlike most other interventions seeking to modify sexual behaviour, this strategy expects participants to change their behaviour for a relatively short time, albeit once a year. It may also have relatively low set-up and promotional costs. Furthermore, such a "month-off" intervention has the potential for creating a strong national movement[5] and at least two countries, Kenya and Swaziland, are already considering campaigns based on this intervention.[6,15]

As Parkhurst and Whiteside state in their discussion, the crux of the intervention they propose lies in forcing many individuals who are newly infected with HIV to pass through the acute stage of their infection without engaging in any behaviour that may be risky in terms of the transmission of the HIV.[5] The acute phase of HIV infection, which lasts roughly 2 months, is associated with high rates of infectivity.[5] Infectivity drops dramatically following the acute stage and then remains low for several years, until the development of acquired immunodeficiency syndrome (AIDS).[16] A month-long break in risky behaviour could substantially reduce the viral load in a population, not only by interrupting all transmission for a month but also by cutting the number of individuals who are in the acute stage of HIV infection when the risky behaviour resumes. It has been suggested that the prevalences of HIV infection in countries with large Muslim populations are kept relatively low by the Muslim practice of abstaining from sex during the daylight hours of the month of Ramadan.[5]

Since a clinical trial of an annual, month-long break from risky behaviour would be unethical and pose huge logistical problems, Parkhurst and Whiteside suggested that such an intervention should be mathematically modelled, to guide future policy discussions.[5] We therefore constructed a model to assess the impact of a month-long interruption in HIV transmission (the "test intervention") on the prevalence and incidence of HIV infection in three countries in sub-Saharan Africa: Kenya, South Africa and Swaziland. While South Africa was modelled simply as an example of a country where HIV infection is hyperendemic, Kenya and Swaziland were investigated because their governments are considering implementing the test intervention. The model was used to evaluate the potential benefits of the test intervention and to give insight into the associated policy debate.[6,15]

Methods

Model structure

Our model replicates the characteristics of the HIV epidemics in Kenya, South Africa and Swaziland. Each of these countries represents a hyperendemic setting for which the relevant data

a Department of Industrial Engineering and Management Sciences, Northwestern University, 2145 Sheridan Road, Evanston, IL 60208, United States of America.
Correspondence to Benjamin Armbruster (e-mail: armbruster@northwestern.edu).

on HIV prevalence and demographics are readily available. The model focuses on the progression of HIV-1 infection among adults aged 15–49 years. The relevant demographic information was provided by the United Nations Population Division.[17]

We constructed a simple deterministic model of transmission, illustrated in Fig. 1, that divides the population into several compartments. Table 1 lists the parameters for the model. The model tracks the number of individuals in each compartment over time by using state variables (S, I_1, I_2, I_3, I_4, I_5, I_6 and I_7), and it describes the flow of individuals among the compartments by using the differential equations outlined in Appendix A (available at: http://users.iems.northwestern.edu/~armbruster/Armbruster2012-BullWHO-AppendixA.pdf). The system of differential equations was simulated in version 7.9.0 of the MATLAB software package (MathWorks, Natick, United States of America) using the ODE solver, ode45. Each modelled population was divided into eight compartments: one compartment, S, for uninfected, susceptible individuals; five compartments, I_1 to I_5, for individuals in different stages of HIV infection who

Fig. 1. The compartmental model used to explore the effectiveness of two interventions for the control of human immunodeficiency virus (HIV)
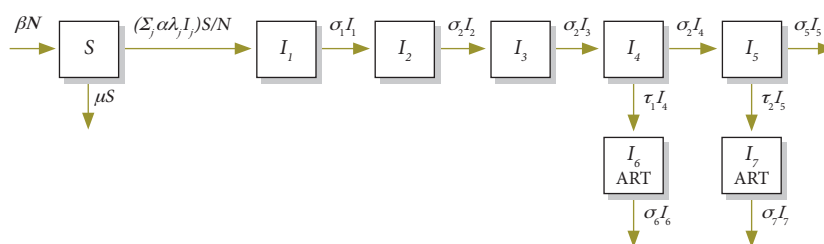
ART, antiretroviral therapy.
Note: See main text for explanations of the symbols.

are not receiving antiretroviral therapy (ART); and two compartments for individuals on ART, I_6 and I_7. The rates σ_1 to σ_7 define the annual transition rates between compartments. Compartment I_1 contains individuals in the acute stage of HIV infection; I_2, I_3 and I_4 contain those in the chronic stage, and I_5 contains those in the final stage, who have AIDS. We chose to split the chronic stage into three compartments so that the survival time without ART gave a good fit to a Weibull distribution with a median survival of 11 years. This distribution fits the data collected during the CASCADE collaboration study well.[16,27]

The sum of the sizes of each of the eight compartments, $S + \Sigma_j I_j$, gives the size of the total modelled population, N. We defined α as the transmission rate in the chronic stage. The transmission rate aggregates several factors influencing HIV transmission, such as heterogeneity in sexual risk, coital frequency, rates of new partners and rates of condom use. While these factors, and the consequent transmission rate, may change over the course of the epidemic, it is reasonable to assume that they remain constant over the 1-year and 5-year horizons that we considered (May et al.[28] gave an in-depth discussion of transmission rates in compartmental models). The multiplier,

Table 1. Parameters used in the models of HIV transmission in Kenya, South Africa and Swaziland, and their sources

Parameter	Kenya	South Africa	Swaziland	Source
Per-capita birth rate, β (births per year)[a]	0.044	0.037	0.051	Ref[17]
Per-capita exit rate other than for HIV, μ (exits/year)[b]	0.020	0.022	0.012	Ref[1,17]
Prevalence of HIV infection in 2011 among those aged 15–49 years (%)	5.7	17.4	25.0	EPP[1,18–25]
Prevalence of HIV infection in 2013 among those aged 15–49 years (%)	5.6	16.9	24.2	EPP[1,18–25]
Transmission rate in chronic stage, α (infections per year)	0.066	0.061	0.075	Calibrated
Relative infectivity in acute stage, λ_1	10	10	10	Ref[16]
Relative infectivity in chronic stage, λ_2, λ_3 and λ_4	1	1	1	Ref[16]
Relative infectivity in final stage, λ_5	5	5	5	Ref[16]
Relative infectivity on ART, λ_6 and λ_7	0.01	0.01	0.01	Ref[16]
Progression rate in acute stage, σ_1 (individuals per year)	6	6	6	Ref[16]
Progression rate from each chronic stage, σ_2, σ_3 and σ_4 (individuals per year)	0.327	0.327	0.327	Ref[16]
Mortality rate from final stage with no ART, σ_5 (deaths per year)	0.606	0.606	0.606	Ref[16]
Entry rate from third chronic stage to ART, τ_1 (individuals per year)	0.013	0.013	0.012	Ref[1]
Entry rate from final stage to ART, τ_2 (individuals per year)	0.058	0.061	0.053	Ref[1]
Mortality rate from first ART compartment, σ_6 (deaths per year)	0.040	0.040	0.040	Ref[26]
Mortality rate from second ART compartment, σ_7 (deaths per year)	0.026	0.026	0.026	Ref[26]

ART, antiretroviral therapy; EPP, UNAIDS Estimation and Projection Package; HIV, human immunodeficiency virus.
[a] Calculated by dividing 20% of the population aged 15–19 years in 2010 by the population aged 15–49 years.
[b] The sum of the non-HIV death rate, 3.5 per 1000 person–years, and the rate that individuals age out of the population of interest by reaching an age of 50 years, 16.5 per 1000 person–years. The non-HIV death rate used was the crude death rate in 2010, 13.9 per 1000 person–years, minus an estimate of the annual number of deaths due to HIV/AIDS in 2010: 310 000 people divided by the population aged 15–49 years in 2010.[1,17] The rate at which individuals aged out of the population of interest was calculated by dividing 20% of the population aged 45–49 years by the population aged 15–49 years.

λ_j, denotes the infectivity of individuals in compartment I_j relative to that of individuals in the chronic stage of infection, such that, for example, the transmission rate in the acute stage is $\lambda_1\alpha$. We used the same values for the relative infectivity rates, λ_j, and for the durations of the various stages of infection that Granich et al. used for their stochastic model.[16] Granich et al. estimated the relative infectivities in the acute and final stages of HIV infection, λ_1 and λ_5, by comparing three analyses[29–31] of the data collected in Rakai, Uganda, on HIV transmission in serodiscordant couples.[32] Since Hollinsworth et al. estimated that the acute stage lasts 3 months and is 26 times as infectious as the chronic stage[30], in the sensitivity analysis we considered scenarios in which σ_1^{-1} was set to 3 months and λ_1 was set to 26. We also considered scenarios in which those in the final stage of HIV infection without ART: (i) do not contribute to new infections, so that λ_5 is zero; (ii) contribute to infections and are more infectious than assumed in the base case, with λ_5 set to 7; or (iii) have a relatively short survival time, with σ_5^{-1} set to 9 months.

Following Granich et al.,[16] we assumed that, after the acute stage, an HIV-positive person's count of CD4+ T-lymphocytes (CD4) drops to a mean of 774 cells/μl and then shows a subsequent linear decline, of about 72 cells per μl each year, until the person's death. The rate in decline of CD4 counts after the acute stage is calculated on the assumption that the median time until death without ART is 11 years. Thus, using the durations shown in Table 1, the individuals in compartments I_4 and I_5 are estimated to have CD4 counts of 335 and 116 cells/μl, respectively. According to guidelines published by WHO in 2006 and 2010, individuals in compartment I_5 (2006 guidelines) or individuals in compartments I_4 and I_5 (2010 guidelines) are eligible for ART.[33,34] The proportions provided in the 2010 UNAIDS global report[1] were used to calculate the annual per capita entry rates into the ART compartments by equating the inflow to each ART compartment with the outflow. To estimate the lifespans of HIV-positive individuals undergoing treatment, as affected by CD4 counts when treatment began, we used the results of a recent analysis of data from a large cohort study in Uganda.[26] These results were stratified by initial CD4 count and also by 5-year age groups. The life expectancies of individuals aged 30–34 years who had 0–49,

50–99, 100–149, 150–249 and ≥ 250 CD4 cells/μl when they initiated ART were 14.2, 24.7, 36.0, 40.3 and 37.2 years, respectively. We took the mean for the first three CD4 groups in this age group, 25.0 years, as the life expectancy for those entering treatment from I_5 and the mean for the last two CD4 groups, 38.75 years, as the life expectancy for those initiating treatment from I_4.

Calibration

The UNAIDS' Estimation and Projection Package (EPP)[18] was used to project the HIV prevalences in the three testbed countries for 2011 and 2013. As suggested by the documentation that forms part of this software package, serosurveillance data from both population-wide surveys and antenatal clinics were used as inputs. Historical data from UNAIDS[1,19] on treatment coverage were also included. For South Africa, the results of a nationwide survey in 2008 and the prevalence time-series from a 2009 survey of antenatal clinics were used.[20,21] For Kenya and Swaziland, Demographic Health Survey (DHS) serosurveillance data and prevalence histories recorded by antenatal clinics were employed.[22–25] Among adults living in South Africa in 2009, the HIV prevalence estimated using the EPP, 17.6%, was close to the estimates made by UNAIDS[1] and Statistics South Africa,[35] which were 17.8% and 17.0%, respectively. Similarly, the corresponding EPP estimates for Kenya and Swaziland in 2009, 25.7% and 5.9%, respectively, were close to the estimates made by UNAIDS, which were 25.9% and 6.3%, respectively.[1]

We set the initial number of infected individuals in compartments I_1 to I_7 so that overall prevalence, $(\Sigma_j I_j)/N$, matched the EPP projection for 2011 and, initially, the inflows to compartments I_2 to I_7 matched the outflows. It seemed reasonable to match the inflows with the outflows because the EPP projections of prevalence are quite flat around 2011 for all three countries that were modelled. In the year 2010, the South African National Department of Health, while discussing the HIV epidemic in South Africa, stated that "the national estimate and provincial figures indicate a stable prevalence over the past four years."[21] Despite this reported or presumed stability in prevalence, epidemics initiating with 50% more individuals in treatment or with twice as many individuals with acute infection

than assumed in a steady-state scenario were modelled in the sensitivity analysis.

The annual transmission rate for the chronic stage, α, was set so that the model-estimated prevalences matched the EPP projections. For this, a calibrated annual rate was found by the least-squares minimization of the differences between the model-estimated prevalences for the years 2011 and 2013 and the corresponding prevalences estimated in the EPP. For some scenarios in the sensitivity analysis – those that affected the goodness of the fit between the model-derived estimates and the EPP projections – α was recalibrated so that, for the year 2013, the model-derived prevalence again matched the EPP projection.

Modelling the intervention

In the proposed intervention, the population of a country is mobilized to engage in total abstinence or safe sex for 1 month each year. In the present study, this "test" intervention was modelled by eliminating HIV transmission (i.e. setting the transmission rate α to 0) throughout the first month of every year. This assumes 100% compliance in the intervention and that the intervention does not lead to other changes in behaviour, such as increased risky behaviour during the other 11 months of each year. In the sensitivity analysis, we considered a scenario with 50% compliance, one with a 2-week period of no transmission, and one with a 2-month period of no transmission. We compared the modelled effects of the test intervention with the status quo and also with a hypothetical "alternative" intervention that reduces HIV transmission by one twelfth. (For the above three scenarios in the sensitivity analysis, the transmission factors for the alternative intervention are reduced by factors of 0.5/12, 14/365 and 2/12, respectively.) It was assumed that a comparison of the effects of the test and alternative interventions would highlight the "interruption effect" of the test intervention, that is, the effect of concentrating transmission control into a single month each year rather than spreading it throughout the year. We simulated the status quo, the test intervention and the alternative intervention over 1 year (until 2012) and over 5 years (until 2016) and compared the modelled HIV infection prevalences and numbers of new infections. No attempt was made to simulate the effects

Table 2. **Main results from the models of the base case scenarios for human immunodeficiency virus (HIV) transmission in Kenya, South Africa and Swaziland**

Variable	Intervention	Kenya after:		South Africa after:		Swaziland after:	
		1 year	5 years	1 year	5 years	1 year	5 years
HIV infection prevalence (%)	None	5.68	5.43	17.15	16.13	24.59	22.93
	Test	5.64	5.20	17.04	15.60	24.42	22.11
	Alternative	5.64	5.20	17.04	15.60	24.42	22.11
New infections (%)[a]	None	0.50	2.49	1.20	5.86	1.94	9.77
	Test	0.45	2.22	1.09	5.27	1.76	8.80
	Alternative	0.45	2.23	1.09	5.28	1.76	8.81
Infections averted (%)[b]	None	9.44	10.75	9.28	10.08	9.18	9.96
	Alternative	9.21	10.54	9.00	9.87	9.04	9.86

[a] Percentage of initial population.
[b] Percentage of the new infections seen without any intervention.

Fig. 2. **Modelled prevalences of human immunodeficiency virus (HIV) infection from 2011 to 2016, as seen under the status quo, the test intervention and the alternative intervention**
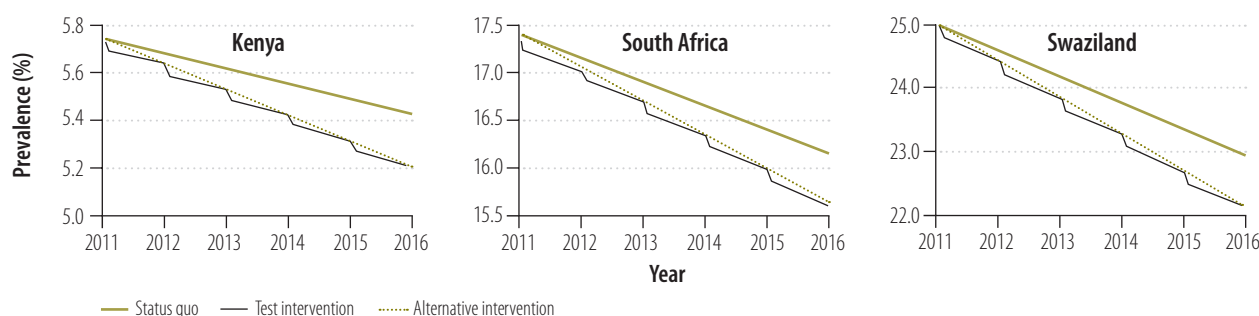
Note: The graphs of the three countires are shown on difference scales. The three components are not intended for visual comparison.

of the test intervention over longer timescales because any such intervention would need to prove itself quickly and because those who initially suggested the potential benefits of a yearly month without HIV transmission stated that this intervention was meant to be short-term.[5–7] To focus on the two modelled interventions, we assumed that no additional interventions were initiated during the study period and that, under the status quo, the epidemic followed the calibrated model.

Results

Base case

Table 2 and Fig. 2 show the results for the base case scenarios. Compared with the status quo, the test and alternative interventions each resulted in slightly fewer new infections and a slightly lower prevalence at the end of the modelled period. In all three countries that were modelled, over both 1-year and 5-year periods, the decrease

in prevalence seen with the test intervention, if any, was nearly identical to that seen with the alternative. In Kenya, for example, over a 1-year period, the number of new infections was about 0.5% of the initial population, whether the status quo, the test intervention or the alternative intervention was modelled. Over a 5-year period, the alternative intervention allowed more new infections, as a percentage of the initial population, than the test intervention but the difference was slight (0.01%). In South Africa, over a 1-year period, both the test intervention and the alternative reduced the number of new infections, from roughly 1.2% of the initial population under the status quo to about 1.1% under either intervention. Similarly, over a 1-year period in Swaziland, both the test intervention and the alternative reduced the number of new infections, from about 1.9% of the initial population under the status quo to about 1.8% under either intervention. Note that, wherever the

effectiveness of the test intervention and the alternative are shown as identical in the main text, this apparent identity is the result of rounding and hides minor differences that may have affected calculations.

For South Africa, the test intervention and the alternative averted, respectively, about 9.3% and 9.0% of the new infections seen under the status quo, when applied for 1 year. The corresponding results for Kenya and Swaziland were similar (Table 2). In all three countries that were modelled, the number of new infections averted over a 1-year period with the test intervention or the alternative was slightly more than one twelfth (8.3%) of the new infections seen when neither intervention was applied. Over a 1-year period, the test intervention averted roughly 2.5%, 3.3% and 1.6% more new infections than the alternative in Kenya, South Africa and Swaziland, respectively.

In South Africa, over 5 years, the number of new infections was about

Table 3. **Main results from the sensitivity analysis of the model of human immunodeficiency virus (HIV) transmission in Kenya, South Africa and Swaziland**

Scenario	Kenya				South Africa				Swaziland			
	Test		Alternative		Test		Alternative		Test		Alternative	
	1 year	5 years	1 year	5 years	1 year	5 years	1 year	5 years	1 year	5 years	1 year	5 years
0. Basecase	9.44	10.75	9.21	10.54	9.28	10.08	9.00	9.87	9.18	9.96	9.04	9.86
1. Intervention occurs in mid-year	9.06	10.29	9.21	10.54	8.84	9.65	9.00	9.87	8.26	9.64	9.04	9.86
2. Intervention occurs at the end of the year	8.27	9.90	9.21	10.54	8.19	9.33	9.00	9.87	8.26	9.38	9.04	9.86
3. 50% compliance[a]	4.77	5.47	4.63	5.33	4.68	5.10	4.52	4.98	4.63	5.04	4.54	4.97
4. Two-week intervention[a]	4.40	5.04	4.26	4.91	4.32	4.71	4.16	4.58	4.27	4.65	4.18	4.58
5. Two-month intervention[a]	18.53	20.83	18.25	20.61	18.24	19.68	17.88	19.44	18.06	19.48	17.94	19.44
6. Three-month acute stage, σ_1	9.79	11.16	9.41	10.89	9.60	10.40	9.16	10.14	9.50	10.28	9.21	10.14
7. More infectious acute stage λ_1	10.56	12.04	10.26	11.94	10.33	11.08	9.85	10.95	10.21	10.98	9.96	11.00
8. I_5 contributes nothing to new infections, λ_5	10.46	12.90	9.93	12.50	10.22	11.82	9.60	11.41	10.12	11.77	9.68	11.52
9. I_5 is more infectious, λ_5	9.25	10.38	9.07	10.19	9.10	9.77	8.89	9.60	8.99	9.62	8.91	9.55
10. I_5 is shorter, with σ_5^{-1} set to 9 months	9.78	11.46	9.47	11.20	9.59	10.64	9.22	10.39	9.46	10.45	9.24	10.32
11. Number initially in acute stage doubled	9.93	10.86	9.21	10.53	9.77	10.18	9.00	9.86	9.65	10.04	9.03	9.84
12. Number initially in treatment doubled	9.46	10.84	9.23	10.63	9.33	10.32	9.06	10.10	9.27	10.36	9.13	10.24

[a] For scenarios that affect the duration of the intervention, the transmission with the alternative intervention was reduced comparably.

Note: For scenarios that affected the status quo, α was recalibrated.

5.9% of the initial population under the status quo and about 5.3% under either the test intervention or the alternative. Each intervention therefore averted about 10% of the new infections under the status quo, although the test intervention averted approximately 2% more new infections than the alternative. In Kenya and Swaziland, similarly, the test intervention averted 2% and 1% more new infections than the alternative when run over 5 years, respectively. Unsurprisingly, the number of new infections seen over 5 years in each country was close to five times the number seen over 1 year. The percentage of the new infections seen under the status quo that were averted under either intervention was, however, slightly higher over 5 years than over 1 year because averting infections in the first year reduces the numbers of new infections that occur in subsequent years.

Sensitivity analysis

The results of the sensitivity analysis are summarized in Table 3. As expected, the number of averted infections was roughly halved when compliance in the intervention was cut from 100% to 50% or when the test intervention was only run for 2 weeks instead of a month, and it was roughly doubled when the test intervention was run for 2 months. In general, in every scenario considered in the sensitivity analysis, the performance of the test intervention was very similar to that of the correspondingly adjusted alternative intervention. The test intervention averted slightly more infections than the alternative intervention except when it was applied at mid-year or at the conclusion of the year; then the last transmission-free period occurred so close to the end of 2015, the end-point for the assessment of effectiveness, that it had little if any detectable impact. The test intervention appeared most superior to the alternative intervention in the scenario in which the initial number of individuals in the acute stage was doubled (scenario 11). In that scenario, at the end of the first year, the test intervention outperformed the alternative, in terms of new infections averted, by 8%, 8% and 7% in Kenya, South Africa and Swaziland, respectively. However, most of the between-intervention differences seen were less than half of these values, and they were also smaller over 5 years than over 1 year.

Discussion

The effects of the test intervention appeared very similar to those of the alternative intervention. Although both of these interventions aim to reduce annual transmission of HIV by one twelfth, the test intervention concentrates this reduction into one month of zero transmission while the alternative spreads the reduction evenly throughout the year. Unsurprisingly, both interventions averted slightly more than one twelfth of the new infections, since averting infections reduces the numbers of infective individuals from which subsequent transmission can occur. That the differences between the test and alternative interventions, in terms of averted infections, were generally slight suggests that there is little benefit in concentrating transmission reduction into a month free of non-safe sex, primarily to reduce transmission from individuals in the acute phase of infection. The unique interruption effect of the test intervention, a month-long 100% decrease in risky behaviour, only seems to have a small, second-order role in reducing incidence when applied to the population at large; the overall reduction in transmission plays a larger role.

In the base case scenario, the between-intervention difference in the proportion of new infections averted was marginally less over a 5-year horizon than over a 1-year horizon. One possible explanation is that the turnover in the population (births and deaths) mitigates the effects of any intervention such that, over a relatively long period, the difference between the test intervention and the alternative would be less.

We used a straightforward, deterministic, compartmental, disease-transmission model to analyse the effects of the test intervention in three hyperendemic countries. Simple models have a long and successful history in the epidemiology of infectious disease and they are generally the rule rather than the exception. Prominent examples are Granich et al. (*Lancet* 2008[16]), Williams et al. (*PLoS Medicine* 2006[36]), Kahn et al. (*PLoS Medicine* 2006[37]), and the EPP model used by UNAIDS for its HIV infection prevalence projections.[18,38] Such models are used to understand the behaviour of a population-wide intervention and the magnitude of its effects. (Network and microsimulation models are well suited to situations where the intervention is tailored to the individual or their position in the sexual-contact network or across specific demographic groups.) Except for the differentiation of the stage of infectiousness, one limitation of our model is that it takes little account of the heterogeneity in sexual risk and sexual mixing. This may limit the model's ability to quantify any intervention-attributable drops in prevalence and new infections precisely. However, such precise evaluation was not our aim. We merely sought to analyse the magnitude of the test intervention in relation to a comparable risk reduction spread throughout the entire year. Additionally, the introduction of any kind of heterogeneity would only be useful if we were modelling the participation of only select subgroups in the intervention or if we were concerned about the long-term stability of the epidemic, which we were not. Moreover, since the epidemic curve is calibrated to match the EPP projections, any fluctuations introduced by stratifying the model or doing away with proportionate mixing would be small. Lastly, since, in general, the scenarios we considered in our extensive sensitivity analysis did not greatly affect the performance of either the test or alternative intervention (the exceptions being scenarios 1–3, which assumed 50% compliance or varied the length of the test intervention by a factor of 2), we doubt that a modest incorporation of heterogeneity would have substantially changed the apparent performances of the interventions. We mainly modelled 100% compliance. With reduced compliance, having only a portion of the population participating in the intervention, the difference in effectiveness between the test intervention and the alternative would probably be only smaller.

In all of the modelled scenarios, we assumed that an equal proportion of individuals participated in the two interventions. If substantially more of the population participated in the month-long intervention than the alternative, then the month-long intervention might be more effective. It remains unclear, however, whether it would be more cost-effective to increase participation in the alternative intervention than to increase compliance in the transmission-free month.

Another limitation of the study is that no risk-compensation effects, such as individuals compensating, with additional risky behaviour, for the no-sex or safe-sex month, were considered in the model. The incorporation of such effects would decrease the effectiveness of both interventions. We were also conservative in assuming 100% compliance in the base case scenario. In fact, there is a possibility that the test intervention would increase risky behaviour by encouraging the non-compliers to seek out one another, allowing HIV to spread beyond existing partnerships.

We do not conclude that an intervention based on a yearly no-sex or safe-sex month would be ineffective, merely that it would be as effective as an alternative policy that spreads out the reduction in transmission across the whole year. Kenya and Swaziland are purportedly considering the promotion of a yearly month without non-safe sex.[6,15] Since the effectiveness of such an intervention is not largely attributable to the unique "interruption" feature, the practicalities and costs of such an intervention, and compliance in it, should be compared with those of other ways of reducing aggregate HIV transmission, such as male circumcision, concurrency-reduction messages and condom-promotion strategies. ■

ملخص

فعالية عدم ممارسة الجنس أو الممارسة الجنسية الآمنة لمدة شهر في خفض انتقال فيروس العوز المناعي البشري

الغرض بناء نموذج مجزأ حتمي لاستكشاف الآثار على انتقال فيروس العوز المناعي البشري (HIV) لعينة من السكان الذين يعزفون عن الجنس أو لا يمارسون سوى الجنس "الآمن" لمدة شهر واحد سنويًا.

الطريقة تم بناء نموذج لانتقال فيروس العوز المناعي البشري بغرض محاكاة آثار التدخل (أي، عدم ممارسة الجنس أو الممارسة الجنسية الآمنة طوال شهر سنويًا لم يحدث فيه أي انتقال) في ثلاثة بلدان، في ظل عدد من الافتراضات المتفائلة. وتمت مقارنة الانخفاض في الحدوث السنوي المنمذج للانتقال الذي يعزى إلى هذا التدخل "الاختباري" بالانخفاض الذي تم مشاهدته مع تدخل بديل. وانخفض الحدوث الشهري للانتقال لكل واحد على اثني عشر، بحيث انتشر التوقف طوال شهر بالتساوي على مدار سنة كاملة.

النتائج على مدار سنة النموذج الأولى، تفادى التدخل الاختباري

فقط نسبة 2.5 % (كينيا)، 3.3 % (جنوب أفريقيا) و1.6 % (سوازيلاند) من عدوى فيروس العوز المناعي البشري أكثر من التدخل البديل. ووفقًا للنموذج، في حالة تكرار التدخل الاختباري في شهر يناير من كل عام، سيتم تفادي نسبة 2 % (كينيا)، 2 % (جنوب أفريقيا) و1 % (سوازيلاند) فقط من عدوى فيروس العوز المناعي البشري على مدار 5 سنوات أكثر من التدخل البديل.

الاستنتاج على الرغم من أنه لم يبدو أكثر فعالية بشكل واضح مقارنة بالتدخل البديل، لا يزال التدخل الاختباري أكثر جدوى ومن ثم يستحق الاهتمام. ويلزم تقييم مردودية هذا الانقطاع السنوي طوال شهر وجدواه في انتقال فيروس العوز المناعي البشري قبل التوصية بالتدخل الاختباري ومقارنتهما بنظيريهما في التدخلات الأخرى التي يمكنها أن تقلل من عدوى فيروس العوز المناعي البشري الجديدة، مثل الختان وحملات التقليل من المعاشرة الجنسية.

摘要

旨在减少艾滋病毒传播的无性或安全性行为月的有效性

目的 建立确定性的区划模型，以研究每年一个月杜绝性行为或只进行"安全"性行为的人口传播艾滋病毒（HIV）的影响。

方法 建立基于若干乐观的假设的艾滋病毒传播模型，在三个国家模拟干预效果（即在每年一个月的无性或安全性行为期间无传播发生）。将建模的年传播发病率因为此"测试"干预而减少的情况与替代干预的情况进行比较。而后者，将三个国家的月传播发病率都减去十二分之一，这样，将一个月长的中断在全年平均分布。

结果 在建立模型的第一年，较之替代的干预，测试干预仅更多避免2.5%（肯尼亚）、3.3%（南非）和1.6%（斯威士

兰）的艾滋病毒感染。根据此模型，在5年期间内，如果在每年的一月份重复此测试干预，较之替代的干预，仅更多避免2%（肯尼亚）、2%（南非）和1%（斯威士兰）的艾滋病毒感染。

结论 虽然较之替代干预，测试干预没有出现明显的更好效果，但仍可能是更可行的干预，因此是值得实行的。在推荐测试干预之前，需要评估每年长达一个月的艾滋病毒传播中断的成本效益和可行性，并与其他可能减少新发艾滋病毒感染的干预措施比较，如包皮环切术和并发减少活动。

Résumé

Efficacité d'un mois d'abstinence ou de rapports sexuels protégés pour réduire la transmission du VIH

Objectif Élaborer un modèle comportemental déterministe pour étudier les effets de l'abstinence sexuelle ou de rapports sexuels exclusivement protégés d'une population, pendant un mois chaque année, sur la transmission du virus de l'immunodéficience humaine (VIH).

Méthodes Un modèle de transmission du VIH a été créé pour simuler les effets de l'intervention (c'est-à-dire un mois d'abstinence sexuelle ou de rapports sexuels protégés chaque année, au cours duquel aucune transmission n'a eu lieu) dans trois pays, en appliquant plusieurs hypothèses optimistes. La réduction de l'incidence de transmission annuelle modélisée attribuable à ce «test» a été comparée à celle qui a été observée avec une intervention alternative. Dans ce dernier cas, les incidences de transmission mensuelles ont diminué d'un douzième, de sorte que, pour l'essentiel, l'interruption d'un mois a été répartie également sur une année complète.

Résultats Au cours de la première année modélisée, le test n'a évité que 2,5% (Kenya), 3,3% (Afrique du Sud) et 1,6% (Swaziland) d'infections

supplémentaires par le VIH par rapport à l'interruption alternative. Selon le modèle, si le test était recommencé chaque mois de janvier, il ne permettrait d'éviter que 2% (Kenya), 2% (Afrique du Sud) et 1% (Swaziland) d'infections supplémentaires par le VIH sur 5 ans par rapport à l'intervention alternative.

Conclusion Bien qu'il ne semble pas nettement plus efficace que l'intervention alternative, le test peut néanmoins être plus faisable et donc intéressant. Avant que le test ne puisse être recommandé, le rapport coût-efficacité et la faisabilité d'une telle interruption annuelle de transmission du VIH doivent être évalués et comparés avec ceux d'autres interventions pouvant réduire de nouvelles infections par le VIH, comme la circoncision et les campagnes de réduction du nombre de partenaires sexuels.

Резюме

Эффективность меры «месяц воздержания от секса или безопасного секса в целях ограничения передачи ВИЧ-заболеваний»

Цель Создать детерминистическую камерную модель для изучения влияния фактора воздержания населения от секса или практики только безопасного секса в течение 1 месяца каждый год на распространение вируса иммунодефицита человека (ВИЧ).

Методы Исходя из оптимистичных предпосылок, в 3 странах была создана модель передачи ВИЧ для стимулирования населения к принятию мер для решения этой проблемы (например, месяц воздержания от секса или безопасного секса, в течение которого не происходит распространение заболевания). На базе этой модели было проведено сравнение степени снижения годовой частоты передачи вируса, достигнутой в результате данной «пробной» меры, со степенью снижения передачи вируса в результате иных вмешательств. При каждом из альтернативных типов вмешательства частота передачи вируса была снижена на одну двенадцатую, то есть,. месячный период прерывания занятия сексом был равномерно распределен в рамках 1-годичного периода.

Результаты В течение первого года в рамках модели, данная пробная мера вмешательства помогла снизить частоту передачи ВИЧ-заболеваний лишь на 2,5% (Кения), 3,3% (Южная Африка), и 1,6% (Свазиленд) более эффективно, чем альтернативные меры вмешательства. Согласно модели, если повторять данную пробную меру вмешательства в январе каждого года, то в течение 5 лет это поможет снизить частоту передачи ВИЧ-заболеваний лишь на 2% (Кения), 2% (Южная Африка) и 1% (Свазиленд) более эффективно, чем альтернативные меры вмешательства.

Вывод Несмотря на то, что данная пробная мера не намного более эффективна, чем альтернативные меры, она все же является реальной и поэтому целесообразной. Перед тем, как рекомендовать данную пробную меру вмешательства, следует провести оценку рентабельности и целесообразности такого 1-месячного прерывания сексуальной деятельности в год для снижения частоты передачи ВИЧ-заболеваний, а также провести сравнение с другими мерами вмешательства, которые могут помочь снизить распространение новых ВИЧ-заболеваний, такими как обрезание крайней плоти полового члена мужчины и кампании по снижению количества параллельных партнеров.

Resumen

La eficacia de un mes de abstinencia o de sexo sin riesgos para reducir la transmisión del VIH

Objetivo Construir un modelo determinista compartimental para explorar los efectos sobre la transmisión del virus de la inmunodeficiencia humana (VIH) en una población en la que se practique la abstinencia sexual o se mantengan relaciones sexuales «sin riesgos» durante un mes cada año.

Métodos Se construyó un modelo de transmisión del VIH para simular los efectos de la intervención (esto es, un mes al año en el que se practicara la abstinencia o el sexo sin riesgos durante el que no se produjera ninguna transmisión) en tres países, con numerosos supuestos optimistas. La reducción en la incidencia anual de la transmisión tomada como ejemplo atribuible a esta intervención de prueba se comparó con la observada en una intervención alternativa. En la última, las incidencias mensuales de transmisión se redujeron en una doceava parte de manera que, esencialmente, la interrupción de un mes se extendió uniformemente a lo largo de todo el año.

Resultados Durante el primer año tomado como modelo, la intervención de prueba evitó solo un 2,5% (Kenya), 3,3% (Sudáfrica) y 1,6% (Swazilandia) más de infecciones por el VIH que la interrupción alternativa. Según el modelo, si la intervención de prueba se repitiera cada enero, evitaría solo un 2% (Kenya), 2% (Sudáfrica) y 1% (Swazilandia) más de infecciones por el VIH durante cinco años que la intervención alternativa.

Conclusión Aunque no pareció notablemente más efectiva que la intervención alternativa, la intervención de prueba podría ser más viable y, por tanto, merecer más la pena. Antes de poder recomendar la intervención de prueba, es necesario evaluar la rentabilidad y viabilidad de tales interrupciones mensuales al año en la transmisión del VIH y compararse con las de otras intervenciones que podrían reducir las infecciones nuevas por el VIH tales como la circuncisión y las campañas de reducción del número de parejas sexuales.

References

1. *2010 report on the global AIDS epidemics*. Geneva: Joint United Nations Programme on HIV/AIDS; 2010. Available from: http://www.unaids.org/en/media/unaids/contentassets/documents/unaidspublication/2010/20101123_globalreport_en.pdf [accessed 8 March 2012].

2. *The Millennium Development Goals report 2010*. New York: United Nations; 2010. Available from: http://www.un.org/millenniumgoals/pdf/MDG%20Report%202010%20En%20r15%20-low%20res%2020100615%20-.pdf [accessed 8 March 2012].

3. Potts M, Halperin DT, Kirby D, Swidler A, Marseille E, Klausner JD et al. Reassessing HIV prevention. *Science* 2008;320:749. doi:10.1126/science.1153843 PMID:18467575

4. Piot P, Bartos M, Larson H, Zewdie D, Mane P. Coming to terms with complexity: a call to action for HIV prevention. *Lancet* 2008;372:845–59. doi:10.1016/S0140-6736(08)60888-0 PMID:18687458

5. Parkhurst JO, Whiteside A. Innovative responses for preventing HIV transmission: the protective value of population-wide interruptions of risk activity. *South Afr J HIV Med* 2010;11. (1). Available from http://www.sajhivmed.org.za/index.php/sajhivmed/article/view/612 [accessed 8 March 2012]

6. Smith AD. Aids experts call for month of sex abstinence. *The Guardian*. 5 July 2010. Available from: http://www.guardian.co.uk/world/2010/jul/04/hiv-abstinence-aids-africa [accessed 8 March 2012].

7. Alcorn K. 'No sex' months proposed as fire-break for HIV in worst-affected countries. *Aidsmap*. 30 June 2010. Available from: http://www.aidsmap.com/page/1446228/ [accessed 8 March 2012].

8. DeCapua J. HIV/AIDS prevention efforts need new, innovative thinking. *Voice of America*. 5 July 2010. Available from: http://www1.voanews.com/english/news/health/decapua-aids-new-thinking-5jul10-97801654.html [accessed 8 March 2012].

9. DeCapua J. New World Bank AIDS chief says prevention challenges remain. *Voice of America*. 9 July 2010. Available from: http://www1.voanews.com/english/news/africa/decapua-world-bank-aids-chief-9jul10-98120304.html [accessed 8 March 2012].

10. Nyaira S. Zimbabwe HIV prevalence rate slips to 13 percent as men change their ways. *Voice of America*. 7 July 2010. Available from: http://www1.voanews.com/zimbabwe/news/health/Zimbabwe-HIV-Prevalence-Rate-Eases-Further-97950544.html [accessed 8 March 2012].

11. Freakonomics. A call for one month of abstinence. *The New York Times*. 9 July 2010. Available from: http://freakonomics.blogs.nytimes.com/2010/07/09/a-call-for-one-month-of-abstinence/[accessed 15 June 2012].

12. CDC National Prevention Information Network. AIDS scientists call for month of sex abstinence: campaign 'could cut new transmissions by 45 percent'. 5 July 2010. Available from: http://www.cdcnpin.org/scripts/display/NewsDisplay.asp?NewsNbr=55642 [accessed 8 March 2012].

13. Cowen T. A new anti-AIDS strategy? *Marginal Revolution*. 5 July 2010. Available from: http://www.marginalrevolution.com/marginalrevolution/2010/07/a-new-antiaids-strategy.html [accessed 8 March 2012].

14. Smith AD. Scientists plea for abstinence to halt AIDS. *Taipei Times*. 5 July 2010. Available from: http://www.taipeitimes.com/News/world/archives/2010/07/05/2003477140 [accessed 8 March 2012].

15. Southern Africa: no sex for a month to prevent HIV. *PlusNews*. 9 November 2010. Available from: http://www.plusnews.org/report.aspx?Reportid=91037 [accessed 8 March 2012].

16. Granich RM, Gilks CF, Dye C, De Cock KM, Williams BG. Universal voluntary HIV testing with immediate antiretroviral therapy as a strategy for elimination of HIV transmission: a mathematical model. *Lancet* 2009;373:48–57. doi:10.1016/S0140-6736(08)61697-9 PMID:19038438

17. *World population prospects*. New York: United Nations; 2010. Available from: www.un.org/esa/population/ [accessed 8 March 2012].

18. *Estimation and projection package (EPP)*. Geneva: Joint United Nations Programme on HIV/AIDS; 2010. Available from: http://www.unaids.org/en/KnowledgeCentre/HIVData/Epidemiology/EPI_software2009.asp [accessed 8 March 2012].

19. *2008 report on the global AIDS epidemic*. Geneva: Joint United Nations Programme on HIV/AIDS; 2008.

20. Shisana O, Rehle T, Simbayi LC, Zuma K, Jooste S, Pillay-van Wyk V, et al. *South African national HIV prevalence, incidence, behaviour and communication survey 2008: a turning tide among teenagers?* Cape Town: HSRC Press; 2009.

21. *2009 National Antenatal Sentinel HIV & Syphilis Prevalence Survey*. Cape Town: National Department of Health; 2010. Available from: http://www.doh.gov.za/docs/reports/2010/hiv_syphillis_09.pdf [accessed 8 March 2012].

22. *Kenya Demographic and Health Survey 2008–09*. Calverton: Macro International Inc.; 2010. Available from: www.measuredhs.com/pubs/pdf/FR229/FR229.pdf [accessed 20 February 2012].

23. National AIDS and STI Control Program. *Sentinel surveillance for HIV and syphilis among pregnant women, 2010*. Nairobi: NASCOP; 2010. Available from: www.nascop.or.ke/3d [accessed 3 April 2012].

24. *11th national HIV serosurveillance among women attending antenatal care services: survey report 2008*. Mbabane: Swaziland Ministry of Health; 2008.

25. *Swaziland Demographic and Health Survey 2006–07*; Calverton: Macro International Inc.; 2008. Available from: www.measuredhs.com/pubs/pdf/FR202/FR202.pdf [accessed 20 February 2012].

26. Mills EJ, Bakanda C, Birungi J, Chan K, Ford N, Cooper CL et al. Life expectancy of persons receiving combination antiretroviral therapy in low-income countries: a cohort analysis from Uganda. *Ann Intern Med* 2011;155:209–16. PMID:21768555

27. CASCADE Collaboration. Time from HIV-1 seroconversion to AIDS and death before widespread use of highly-active anti-retroviral therapy. *Lancet* 2000;355:1131–7. doi:10.1016/S0140-6736(00)02061-4 PMID:10791375

28. May RM, Anderson R, Irwin M. The transmission dynamics of human immunodeficiency virus (HIV). *Philos Trans R Soc Lond B Biol Sci* 1988;321:565–607. doi:10.1098/rstb.1988.0108 PMID:2907158

29. Wawer MJ, Gray RH, Sewankambo NK, Serwadda D, Li X, Laeyendecker O et al. Rates of HIV-1 transmission per coital act, by stage of HIV-1 infection, in Rakai, Uganda. *J Infect Dis* 2005;191:1403–9. doi:10.1086/429411 PMID:15809897

30. Hollingsworth TD, Anderson RM, Fraser C. HIV-1 transmission, by stage of infection. *J Infect Dis* 2008;198:687–93. doi:10.1086/590501 PMID:18662132

31. Abu-Raddad LJ, Longini IM Jr. No HIV stage is dominant in driving the HIV epidemic in sub-Saharan Africa. *AIDS* 2008;22:1055. doi:10.1097/QAD.0b013e3282f8af84 PMID:18520349

32. Gray RH, Wawer MJ, Brookmeyer R, Sewankambo NK, Serwadda D, Wabwire-Mangen F et al. Probability of HIV-1 transmission per coital act in monogamous, heterosexual, HIV-1-discordant couples in Rakai, Uganda. *Lancet* 2001;357:1149–53. doi:10.1016/S0140-6736(00)04331-2 PMID:11323041

33. *Antiretroviral therapy for HIV infection in adults and adolescents: recommendations for a public health approach.* Geneva: World Health Organization; 2006. Available from: http://www.who.int/hiv/pub/arv/adult/en/index.html [accessed 3 April 2012].

34. *Antiretroviral therapy for HIV infection in adults and adolescents: recommendations for a public health approach*. Geneva: World Health Organization; 2010. Available from: http://www.who.int/hiv/pub/arv/adult2010/en/index.html [accessed 3 April 2012].

35. Statistics South Africa [Internet]. *Mid-year population estimates*. Pretoria: SSA; 2010. Available from: http://www.statssa.gov.za/publications/P0302/P03022010.pdf [accessed 3 April 2012].

36. Williams BG, Lloyd-Smith JO, Gouws E, Hankins C, Getz WM, Hargrove J et al. The potential impact of male circumcision on HIV in Sub-Saharan Africa. *PLoS Med* 2006;3:e262. doi:10.1371/journal.pmed.0030262 PMID:16822094

37. Kahn JG, Marseille E, Auvert B. Cost-effectiveness of male circumcision for HIV prevention in a South African setting. *PLoS Med* 2006;3:e517. doi:10.1371/journal.pmed.0030517 PMID:17194197

38. Joint United Nations Programme on HIV/AIDS. Improved methods and assumptions for estimation of the HIV/AIDS epidemic and its impact: Recommendations of the UNAIDS Reference Group on Estimates, Modelling and Projections. *AIDS* 2002;16:W1–14. doi:10.1097/00002030-200206140-00024 PMID:12045507