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HIV infection among young women in Africa:

the Healthy Carriage Hypothesis

By

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Abstract

The study investigates the possibility of healthy carriage of HIV in adult heterosexual transmission of HIV in Africa. The paper first investigates inconsistencies in the pattern of male to female infection rates in four studies conducted in African populations: Kisumu in Kenya, Ndola in Zambia, Yaoundé in Cameroon, and the Radar project in South Africa. Results show that young women age 15-24 are more infected than their male partners, which is inconsistent with the assumed pattern of male to female transmission, whereas young men in the same age group are less infected than their female partners, which is consistent with the assumed pattern of female to male transmission. A simulation model is built to analyse the possible parameters of the heterosexual transmission that could explain these discrepancies. Results show that no realistic values of the parameters investigated (mean annual transmission rate and mean number of partners in particular) could explain the fast rise of seroprevalence among young women, whereas realistic values could explain observed values of seroprevalence among young men. The author then develops a hypothesis of transmission by healthy carriage, which is found to both biologically plausible and epidemiologically sound. Policy implications of this theory are discussed in the context of high HIV seroprevalence rates of Eastern and Southern Africa.

Key Words: HIV/AIDS, Seroprevalence, Adolescent, Healthy carriage, sub-Saharan Africa

Introduction

The fast spread of the HIV infection in Africa since 1980 surprised many observers. In contrast to developed countries where the epidemic has been largely kept under control, the HIV epidemic has been raging in Eastern and Southern Africa over the past 25 years, and HIV seroprevalence is still increasing in several countries, with values as high as 50% in certain areas for young adults. (UNAIDS, 2004; Asamoah-Odei et al., 2004).

The HIV/AIDS epidemic of Eastern and Southern Africa has several distinctive features. First, it is a generalized epidemic, which implies that the HIV virus is circulating in the general population, and not only in special groups (such as homosexuals or drug addicts in developed countries) or in core groups (such as commercial sex workers and their clients). Second, young women tend to infect themselves very early in life: most cases of new infection among women occur before age 25 years, and a majority even before age 20 (World Bank, 1999; UNAIDS, 2004; Fylkesnes et al. 1997; Gregson et al. 2002).

There is little doubt that HIV is transmitted mostly by heterosexual transmission in Africa (Garenne et al., 2003; Schmid et al., 2004). Even though this has been contested by some authors, other modes of transmission have never been formally proven (Gisselquist et al. 2003). One of the strongest pieces of evidence that transmission is mostly heterosexual is that seroprevalence among young women increases parallel to the age at first intercourse (Garenne et al., 2003).

An important study of HIV risk factors was conducted in four African cities, two with high levels of seroprevalence and two with low levels of seroprevalence (Buvé et al. 2001; Caraël and Holmes, 2001). This study did not identify any clear risk factor of HIV infection, outside of the well documented effect of male circumcision, which reduces by half the risk of transmission from female to male (Auvert et al. 2001; Bayley et al. 2001; Bongaarts et al. 1989, Weiss, 2000). In addition, the study noted a correlation with other sexually transmitted infections (STI's), in particular the herpes virus (HPV). This study is important in many respects. First it shows that the virus is circulating in the general population, and that random effects is the main reason for HIV infection. Second, the study documented in details the high risk for very young women, which, according to investigators, remains largely unexplained (Glynn et al., 2001).

The aim of this paper is to analyze in more details the situations of high HIV seroprevalence among young women in Africa. The approach followed it to consider a “near equilibrium” situation, that is to analyse the patterns of transmission at a point where seroprevalence is already high. We do not plan to document the dynamics of the epidemics, where seroprevalence could reach high values of 40% to 50% over a period of 15 to 25 years after the start of the epidemic. This issue will be dealt with in a companion paper (Garenne & Leclerc, 2005). Here, the focus is on the pattern of transmission from males to females and from females to males in a situation of already high seroprevalence. In a “near equilibrium” situation, the age specific transmission from males to females should match the age pattern of infection among women, and conversely the age specific transmission from females to males should match the age pattern of infection among men. The approach is purely demographic, and based on age and sex specific patterns of intercourse and HIV transmission. The attention is drawn on the precise age patterns of first intercourse and on age specific partnerships rates. Data to pursue and test the investigation were drawn from high quality empirical studies with information on age and sex specific HIV seroprevalence and partnerships. Other parameters to build the model were drawn from the HIV/AIDS literature.

Data and model

The empirical data used to analyze the current situation of near-equilibrium transmission of HIV were taken from two sources: data from the four-city study conducted by Dr. Anne Buvé and colleagues, and published in a special issue of AIDS (Caraël & Holmes, 2001), and the data from a site of a public health intervention program in rural South Africa, run by Dr. Pronyk and colleagues (Pronyk et al. 2002). All these data refer to representative samples of local populations with medium to high HIV seroprevalence, they are of high quality, and furnish in addition to age specific seroprevalence in the population a large number of details on sexual behaviour, in particular the age distribution of partners and of the numbers of partners. The first series of data are from urban populations in Cameroon (Yaounde), Kenya (Kisumu) and Zambia (Ndola). We did not use the data from Cotonou (Benin), since the seroprevalence was very low, and little could be done with the few cases of HIV positive persons. The last site chosen for the empirical analysis lies near the town of Burgerdorp in Limpopo province of South Africa, in the eastern part of the high veld, and deals with a rural population, typical of the former homelands. Details on the study can be found on the internet site of the Radar project (www.wits.ac.za/radar). Seroprevalence among the 15-30 year old was low in Yaounde, medium in Radar, and high in Kisumu and Ndola). Male circumcision rates were high in Yaounde and Radar, and low in Kisumu and Ndola (Table 1).

The model that was used for this analysis is based on a concept of near-equilibrium of HIV transmission in generalized epidemics. This means that in a generalized (also called mature) epidemics, most of the transmission of HIV occurs in the general population, and not in core groups as it is the case in a starting epidemic. There is much evidence that this is the situation in most of Eastern and Southern Africa, where the data were taken for empirical analysis. The four-city study showed that infection, as measured by HIV seropositivity, was largely independent from classic risk factors, such as sexual behaviour or socio-economic status. Even though persons with higher numbers of sexual partners were more infected than others, the risk ratios were small (ranging from 1.2 to 1.9 in the four sites) and mean numbers of sexual partners did not account for differences in seroprevalence between the cities. Similarly, in the Radar study, there were only minor differences between HIV seropositive and seronegative persons in terms of sexual behaviour and socioeconomic status. This means that infection is primarily random at this stage. Models of HIV diffusion in a population do not have to assume any individual risk factors: a purely random transmission model will show infection of a large part of the population in medium term, say 10 or 20 years after the introduction of a virus, and persons who are infected do not need to show any special characteristics or any special risk factor. Random transmission will also lead to a positive correlation between number of partners and infection. Random heterosexual transmission of HIV is the key hypothesis for our model.

Critical for our demonstration is the comparison of age specific seroprevalence rates among women (or men) in the population with those of their partners who are assumed to be the main source of infection, and with the expected proportions of persons likely to be infected by these partners given what is known of heterosexual transmission in Africa. When the observed proportion of infected persons matches what could be expected given the infection rate among the partners, then the classic pattern of transmission is validated. However, if this is not the case (at will be seen for women), then another mode of transmission will be hypothesized.

The model predicting the expected proportion of persons likely to be infected at age (x) is a simple model of random transmission from seropositive partners to seronegative persons. The focus here is on young adults (age 15-30), and therefore critical parameters of the model are the age at first intercourse, the number of sexual partners between first intercourse and current age (x), and the seroprevalence among the partners of persons currently age (x). The underlying hypotheses of the model could be summarized the following way:

H1: Transmission is only heterosexual, from infected (seropositive) man to female sexual partner or from infected (seropositive) woman to male sexual partner. The transmission period ranges from the age at first intercourse (x_0) to current age (x). Age at first intercourse ranges from 10 to 30 years, and current age from 15 to 30 years, although the model could be easily extended to other ages as well. Partners are chosen in the whole population, age 10-70 years.

H2: The probability of transmission per act is assumed to be constant between age 15 and 30; therefore the likelihood of contamination, if the partner is infected, depends only on the duration of the relationship between the two partners. We therefore assume that in a relationship, whether regular or casual, the pattern of intercourse is the same. The baseline transmission rate is taken at 0.153 per person-year of exposure in couples with regular intercourse, a value taken from a study conducted in Masaka, Uganda (Carpenter et al. 1999), and which is consistent, though somewhat higher, with most other values found in the world among discordant couples not using condoms. This value is further discussed later depending on whether the male partner is circumcised.

H3: Heterogeneity among persons is considered here for three parameters only: the age at first intercourse, the age distribution of partners, and the number of partners. In each case study, empirical values of proportions of persons who ever had sex, distributions of age of partners and of numbers of partners were computed for each age (in year) and for each sex separately. We therefore neglected the heterogeneity in the number of intercourse per year (for which we had no precise data), and the interactions between intercourse, number of partners, age of the partner, and age at first intercourse.

Written in formulae, the model can be written the following way:

(R1) $$P(x) = \sum_{x_0=10}^{30} E(x_0) \times P(x/x_0)$$

(R2) $$P(x/x_0) = \sum_{k=1}^{k\max} N(k/x) \times P(x, x_0/k)$$

(R3) $$P(x, x_0/k) = 1 - \prod_{i=1}^{k} \left[1 - \left(V(x_i) \times P(x_i, d_i)\right)\right]$$

(R4) $$P(x_i, d_i) = 1 - (1 - P1)^{d_i}$$

where:

- P(x) = probability of ever being infected by age (x), with $0 \le P(x) < 1$
- $E(x_0)$ = distribution of age at first intercourse, with $\sum_{x_0=10}^{30} E(x_0) = 1$
- $P(x/x_0)$ = probability of being infected by age (x), if intercourse started at age x_0
- N(k/x) = distribution of the cumulated number of partners at a given age (x), k= 1 to kmax

  with $\sum_{k=1}^{k\max} N(k/x) = 1$
- $P(x,x_0/k)$ = Probability of being infected by age (x) if the person had (k) partners between (x_0) and (x)
- V(x) = Probability that partners of persons age (x) is infected = seroprevalence among partners of persons age (x)
- $P(x_i, d_i)$ = Probability of being infected with partner (i) if partner is seropositive, relationship starts at age (xi) for a duration of relationship (di).
- P1 is the mean annual heterosexual transmission rate.

Assuming average duration of relationships:

$$d_i = (x - x_0)/k$$

$$x_i = x_0 + (i-1) \times (x - x_0)/k \quad \text{for } i \le k$$

V(x) is simply calculated as the product of age specific seroprevalence rates for the opposite sex by the age distribution of partners. This is done for each sex separately, and by single year of age.

The time unit of the model is the year. So, all ages were considered year by year, between 10 and 30; duration of the relationships were taken in years or fraction of years, so that a short relationship (casual) bears only a tiny risk compared to a longer relationship. Results presented in 5-year age groups are simply the age-standardized average of the 1-year age specific values.

To avoid erratic fluctuations, values of the key parameters taken from the empirical studies were smoothed using simple modelling. The age specific seroprevalence was smoothed using a third degree polynomial Logit model on age. The age specific distributions of partners' age were smoothed using a Beta distribution between age 10 and 70 (minimum and maximum age of partners), with the same mean and variance as the empirical values. The age specific distributions of the number of partners were smoothed using a Negative Binomial distribution, with the same mean and variance as the empirical values.

Results

Main characteristics of the sample

The four samples had about 1000 to 2000 persons age 15-30, with somewhat more women than men (Table 1). The only minor bias in age distribution of respondents was the low frequency of persons under age 20, and in particular of age 15 and 16 (-30% to -40% of expected values), except in the Radar project, where there was no deficit. This is probably a selection for persons more likely to have had intercourse, which tends to over-estimate seroprevalence in this age group. The bias seems to be small however, since the age pattern of infection in the Radar project was basically the same as in the others.

The pattern of age at first intercourse was the same in the four studies, with minor differences between men and women and between the sites, which allowed to compute an average pattern (Figure 1). All observed distributions were fitted with a Coale and McNeil model (Coale and McNeil, 1972). First intercourse starts around age 12, and by age 25 virtually everyone has ever had sex. The mean age at first intercourse, calculated from full distributions between age 10 and 30, was similar in the four studies, ranging from 17.0 to 18.7 for men (standard deviation from 3.2 to 5.1), and from 16.7 to 18.2 for women (standard deviation from 2.3 to 4.6). Dispersion of age at first intercourse was higher in the South African site primarily because first union is postponed to a much later age in this country. Exposure to sex from age at first intercourse up to age (x) was therefore similar among men and women, and similar between the sites. By age 30, men and women had been exposed to sexual intercourse for an average of 13.0 years, again with minor differences between sites (range from 12.4 to 13.8 for females and from 12.4 to 14.0 for males). More important for our purpose, the mean duration of exposure to sex by age 20, if anything, was slightly higher for males than for females (4.2 versus 3.8 years), here again with minor differences between sites. Duration of exposure to sex by age (x) is a critical parameter for our model.

Distributions of ages of partners were fitted with a Beta function between age 10 and age 70, for each single year of age of the respondent, matching the same mean and the same variance. The age pattern was again basically the same for the four sites, allowing to compute an average pattern, with major differences between men and women. For women, the distributions of partner's ages is always wide, the mean increases linearly with age, the variance remains quite stable, and distributions are somewhat skewed since only few women have partners younger than themselves. For women age 15, ages of partners range from 12 to 40, whereas at age 45, they range from 35 to 65. For the men, the pattern is different, and depends very much on the age of respondent, since men tend to have partners younger than themselves. Therefore, not only the mean age of partners increases with age, but the variance as well, since the range varies also dramatically. For men age 15, partner's ages range from 12 to 18, whereas for men age 45 they range from 15 to 50. Among the 15-30 year old, the mean age of sexual partners was similar in the four studies, ranging from 19.0 to 20.6 for men (standard deviation from 3.4 to 4.1) and from 27.7 to 30.3 for women (standard deviation from 5.9 to 7.9). Here again, the younger age of partners in the South African site is primarily due to the fact that most partners are not spouses but casual partners. This different distribution of age of partners has major implications for age specific risks of HIV transmission, since partner's age is a major determinant of partner's infection status and therefore of the spread of infection.

The distributions of numbers of partners were fitted with negative binomial distributions, here again by matching for the same mean and the same variance as observed, for each single year of age. The distributions of numbers of partners differed by age and by sex, since for young age groups the mode was one, whereas at older ages it tended to increase, and was usually around 4 or 5 for men and 2 or 3 for women at age 35. There were also more differences in the mean number of partners: the reported number was much higher in Yaounde (12.1 for men and 4.6 for women) than in the other sites, and much lower in the South African site, which is a rural site (3.9 for men and 2.5 for women). The range in the number of partners was however basically the same, from 1 to 30, with very few persons (< 1%) reporting more than 30 partners.

Age pattern of infection

The four studies showed basically the same age pattern of infection, despite the different levels of HIV seroprevalence, from which an average pattern was designed (Figures 2 and 3). For women, seroprevalence is already above zero at age 15-16, ranging from 1.5% in Yaounde to 12.7% in Kisumu, and increases very fast with age to peak around age 25, after which prevalence tends to decline. This means that most women infect themselves in the short window of time between first intercourse (age 17-18) and age 25, despite a short exposure to sexual intercourse (8 years on the average). For men, the pattern is different, with few infections before age 20, and a steep increase until age 30-35. Men infect themselves also quite rapidly, but somewhat later than women. Similar patterns have been found elsewhere in Africa in a variety of settings. This observation matches apparently the age distribution of partners, though we will see later is inconsistent with known patterns of transmission.

Infection rates among partners

We computed the infection rates among partners, simply by multiplying the infection rates in the opposite sex by the distributions of partners' age. This was done by single age from age 15 to 30, then cumulated by age group. Results revealed a surprising pattern (Table 2). For women, the infection rates were always higher in the population age (x) than among their partners, contrary to what was expected. Risk ratios ranged from 1.14 (Ndola) to 1.45 (Yaounde) for all ages 15-29, differences being highly significant in three sites, and borderline in Ndola. For men on the contrary, the pattern was the opposite (Figure 3). Infection rates were lower than among their partner (as expected), with a risk ratio ranging from 0.39 (Yaounde) to 0.84 (Radar). Note that the only way persons could be more infected than their partners is by having very high numbers of partners. Since men tend to have more partners than women, one would have expected the opposite: that men could have been likely to be more infected than their partners and women less so: but the contrary was found in all four studies.

Comparison of observed and expected seroprevalence

The observed seroprevalence was compared to the expected prevalence assuming a standard pattern of transmission. Results confirmed the previous findings (Table 3). Among women age 15-29, the observed prevalence was about three times higher than expected from the seroprevalence among partners and the standard pattern of transmission. The risk ratio was on the average 9.2 at age 15-19 (range 6.4 to 14.1), 3.4 at age 20-24 (range 2.7 to 3.9) and 2.0 at age 25-29 (range 1.5 to 2.3), and all these ratios were significantly higher than 1. On the contrary for men, the risk ratios of observed over expected were much lower. They were not significantly different from one in Yaounde and Kisumu. In Ndola and Radar, they were higher than one, but still much lower than the women's ratios. Differences between male and female risk ratios were highly significant in all four sites ($P<0.001$).

Changing parameters

Previous estimates of expected seroprevalence were calculated using a standard yearly infection rate among discordant couples of 0.153. This is an average value, and several studies have shown a range of risk ratios roughly from 0.5 to 2.0, depending on a variety of factors. For instance, male circumcision reduces the risk of female to male HIV transmission by about 50%. Similarly, infection with other sexually transmitted infections (STI's), such as herpes (HSV) increases the risk of male to female HIV transmission by a factor of 2 or more. So, values of annual transmission under regular exposure ranging from 0.075 to 0.300 are all likely values in specific populations.

We recalculated the values of the parameters needed to fit the observed values of seroprevalence, for each sex. Results indicate that for women, values of P1 required to infect the observed proportions of women were totally unrealistic (Table 5). Values are often higher than 1, which is in practice not possible (Ndola, all ages, Kisumu up to age 20), and in most cases higher than 0.30 up to age 25. This means that no realistic value of male to female transmission could explain the observed HIV seroprevalence among young women. Only after age 30, high values of P1 combined with longer exposure would account for high values of seroprevalence.

For the men, on the contrary, realistic values ranging from 0.11 to 0.34 could account for the observed HIV seroprevalence. An average value of 0.24, could account for most observed values, and would be typical of Kisumu. A lower value of 0.12, possibly due to universal male circumcision, would match the pattern in Yaounde. Higher values in Ndola could be accounted for by high prevalence of HSV. The high value of Radar in the young age group could be due to a bias of the survey, or could be due to another risk factor, including late circumcision for some people.

The most striking feature of the simulation exercise with varying values of P1 was the huge difference between men and women. Differences between the two sexes were all highly significant (higher than expected for women, equal to expected for men).

An alternative hypothesis : healthy carriage of HIV

In an earlier paper (Garenne and Lydié, 2001), we have developed an alternative hypothesis of HIV transmission. This theory assumes the possibility of transmission by healthy carriage, that is that men could carry the virus from an infected woman to a susceptible woman. There are strong arguments to say that this hypothesis is biologically plausible. To summarize the argument, the HIV virus first enters the human body through epithelial dendritic cells, in particular Langerhans cells. From there, either the local infection aborts, or the virus is carried to the lymph nodes, where it infects blood cells. The passage from local to systemic infection seems highly random, so that a person can carry the virus in epithelial cells without being fully infected. The time during which the local infection can last is about one week. Let us assume a man who has intercourse with an infected (seropositive woman), who is lucky enough to remain not systematically infected (seronegative man), and who has intercourse within a week with another non infected woman, he may well carry the HIV virus, and if infection succeeds, may infect the second woman. To have a demographic effect, this healthy carriage requires only large numbers of men who have intercourse with two women within a short period of time (within a week). This seems to be the case in a number of African countries, though precise data are lacking to develop a full model.

Discussion

In this paper, we have analyzed the age and sex patterns of HIV seroprevalence in several populations with high levels of infection. When making realistic assumptions, it was not possible to match the age pattern of infection among the young women with the age pattern of infection of their male partners, whereas the opposite was possible, that is matching the age pattern of infection among the young men with the age pattern of infection of their female partners.

Models which predicted large epidemics were based on different assumptions, such as higher number of partners, constant difference between ages of partners, and high rates of partner change (Anderson and May, 1991 and 1992).

Further calculations around the equilibrium of high seroprevalence showed that parameters necessary to account for the empirical age pattern of infection among women were unrealistic.

This led us to develop an alternative hypothesis of healthy carriage. This hypothesis is not symmetrical for men and women, since it assumes that only men could have intercourse with two women within a short period of time. If this hypothesis holds, it could explain why women are more infected than their male partners, whereas the men remain less infected than their partners for many years after first intercourse. This hypothesis is biologically plausible and epidemiologically sound.

One could further argue that the reverse might be true as well, that is that women could also be healthy carriers. If this true, this might explain why sometimes new born babies are found seropositive to mothers who are seronegative. Indeed, seronegative women might host the HIV virus in vaginal epithelial cells, and be therefore able to infect babies during delivery. However, alternative hypotheses could be made in this case, such as mothers in the process of seroconverting, who are already fully infected but not yet seropositive. Furthermore, it may be also be possible that women who have intercourse with two men within a short period of time might pass the HIV virus without being seropositive themselves. This does not contradict our main hypothesis if many more men display this behaviour of multiple partnerships within a short period of time than women, which seems to be the case in countries investigated.

The case of relatively high infection rates among 15-16 year old women remains puzzling. We interpreted it as a selection bias of women more likely to have had intercourse to be included in seroprevalence surveys. However, this might be another phenomenon of very high susceptibility for women who had very early first sexual intercourse. Combined with unexpected exposure to a healthy carrier, this might explain how they could be so heavily infected so early in life.

Further research is obviously needed in this field. First, formal evidence that healthy carriage exists in populations needs to be shown. Second, that this is a demographic phenomenon, and not only a rare occurrence. Third, that asymmetry of behaviours and healthy carriage between men and women match observed patterns of sex-specific seroprevalence in populations. Testing this hypothesis would require innovative field work in heavily infected populations.

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Table 1: Main characteristics of the samples, young adults age 15-30.

Variable	Men				Women			
	Yaounde Cameroon	Kisumu Kenya	Ndola Zambia	Radar So. Africa	Yaounde Cameroon	Kisumu Kenya	Ndola Zambia	Radar So. Africa
Sample size	595	407	372	858	687	630	633	1114
HIV seroprevalence								
- Mean	2.5%	14.5%	16.7%	8.7%	7.3%	31.9%	33.2%	15.7%
- Peak	6.5%	34.2%	38.7%	16.1%	12.7%	39.2%	47.1%	19.7%
Age at first intercourse								
- Mean	17.0	17.4	18.7	17.4	17.5	18.7	18.2	16.7
- St. Dev.	3.2	3.7	3.6	5.1	2.3	3.8	3.1	4.6
Age of sexual partners								
- Mean	20.6	19.0	19.8	18.4	30.3	29.4	29.9	27.7
- St. Dev.	4.1	3.4	3.9	3.4	6.9	7.9	5.9	6.9
Number of sexual partners								
- Mean	12.1	6.1	6.5	3.9	4.6	2.6	2.2	2.5
- St. Dev.	11.8	6.9	8.3	4.7	5.5	1.4	1.7	2.3
Male circumcision								
- % Circumcised	99.1	27.5	9.0	88.8				
- Median age circ.	4	11	10	13				

Table 2: Ratios of observed HIV seroprevalence to the proportions who ever had sex

Sex and age	Yaounde Cameroon	Kisumu Kenya	Ndola Zambia	Radar South Africa	Average
Females					
15-19	0.04	0.48	0.32	0.16	0.20
20-24	0.09	0.42	0.42	0.18	0.23
25-29	0.13	0.40	0.47	0.19	0.25
Males					
15-19	0.01	0.03	0.05	0.09	0.04
20-24	0.01	0.16	0.15	0.11	0.09
25-29	0.04	0.31	0.31	0.15	0.17

Note: All data are age-standardized, after fitting. Average of ratios is the geometric mean.

Table 3: Risk ratios of observed HIV seroprevalence to calculated seroprevalence of their partners

Sex and age	Yaounde Cameroon	Kisumu Kenya	Ndola Zambia	Radar South Africa	Average
Females					
15-19	0.82	1.44	0.91	1.16	1.06
20-24	1.56	1.39	1.20	1.29	1.35
25-29	1.61	1.32	1.20	1.34	1.36
Males					
15-19	0.19	0.15	0.33	0.61	0.28
20-24	0.28	0.57	0.63	0.83	0.54
25-29	0.50	0.91	0.87	0.97	0.79

Note: All data are age-standardized, after fitting. Average of ratios is the geometric mean.

Table 4: Risk ratios of HIV seroprevalence among persons to that expected under null hypothesis, with constant annual transmission (P1= 0.153)

Sex and age	Yaounde Cameroon	Kisumu Kenya	Ndola Zambia	Radar South Africa	Average
Females					
15-19	6.40	14.14	9.33	8.29	9.15
20-24	3.58	3.87	3.69	2.71	3.43
25-29	2.26	1.89	2.20	1.53	1.95
All	2.84	3.12	3.05	2.32	2.82
Males					
15-19	1.30	0.98	3.87	4.60	2.18
20-24	0.73	1.34	2.18	1.69	1.38
25-29	0.83	1.26	1.64	1.12	1.18
All	0.83	1.27	1.83	1.48	1.30

Note: All data are age-standardized, after fitting. Average of ratios is the geometric mean.

Table 5: Values of the annual transmission rate (P1) necessary to infect the observed proportions of persons

Age (x)	Yaounde Cameroon	Kisumu Kenya	Ndola Zambia	Radar South-Africa	Average
Females					
20	0.75	>1.00	>1.00	0.58	0.812
25	0.58	0.76	>1.00	0.29	0.597
30	0.28	0.26	>1.00	0.15	0.326
Males					
20	0.12	0.16	0.33	0.34	0.217
25	0.11	0.21	0.29	0.16	0.182
30	0.12	0.16	0.24	0.13	0.157

Figure 1: Typical age pattern of first intercourse and mean duration since first sex (average of four studies)

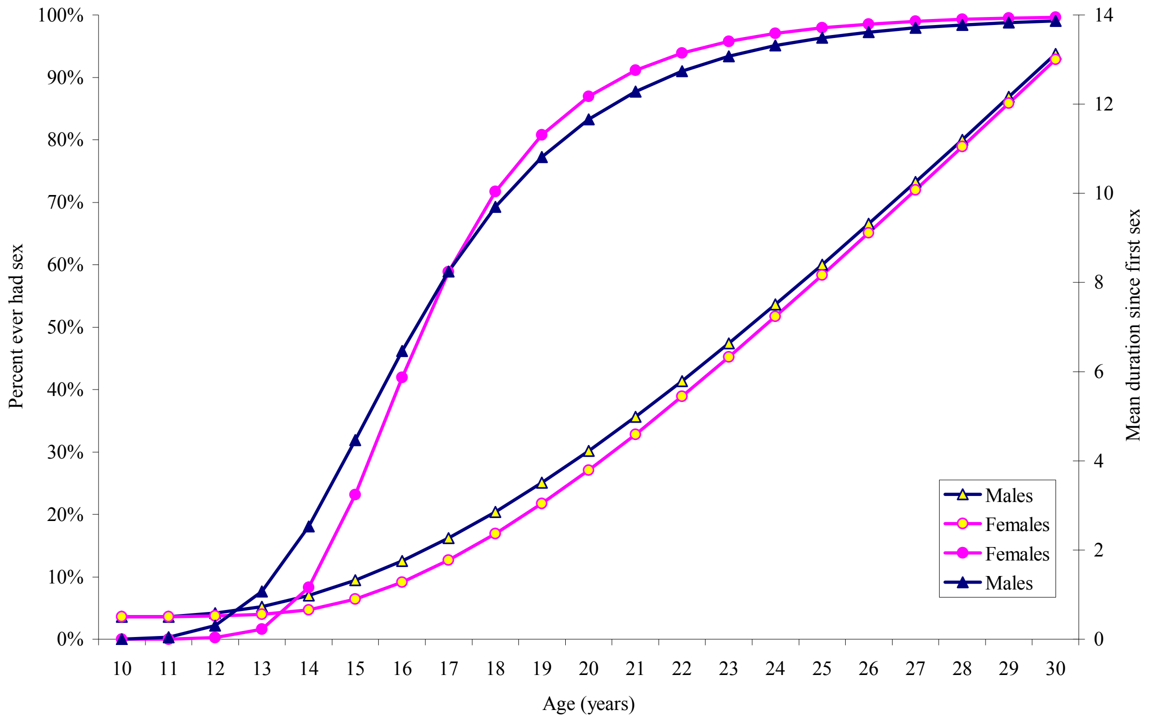

Figure 2: Age pattern of seroprevalence among women and their male partners, age 15-30, average of the four studies

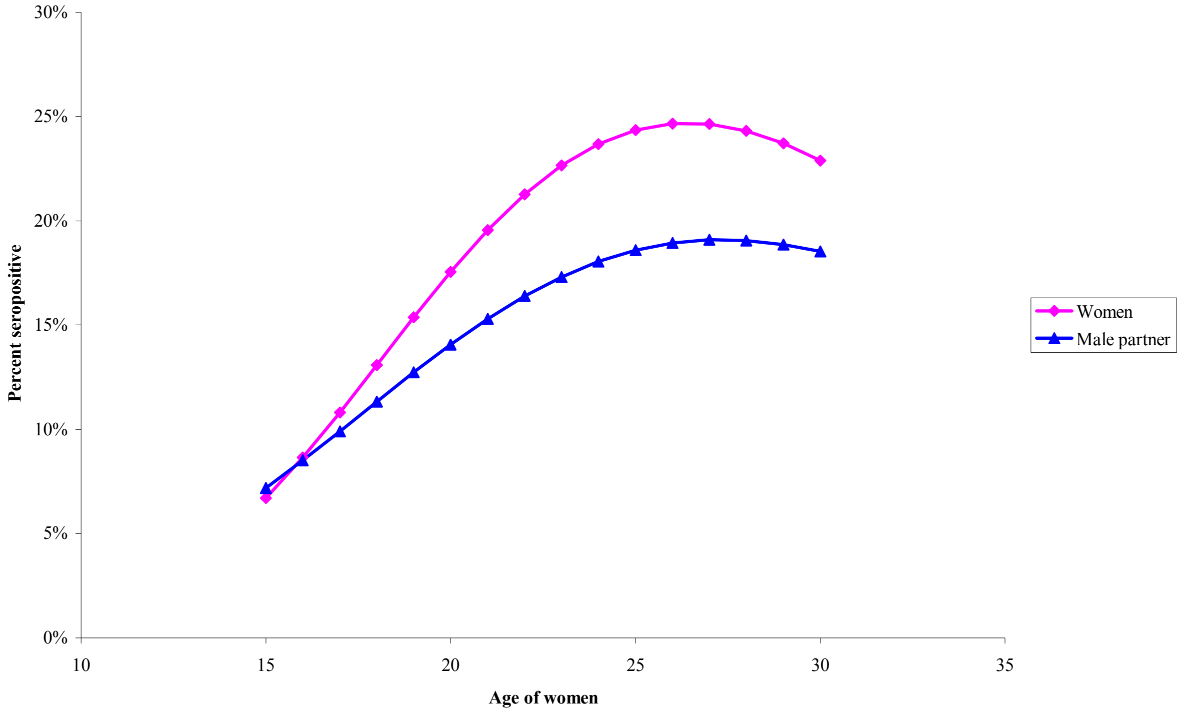

Figure 3: Age pattern of seroprevalence among men and their female partners, age 15-30, average of the four studies