Published in final edited form as:

AIDS. 2009 March 13; 23(5): 621–629. doi:10.1097/QAD.0b013e3283269e13.

Refusal bias in HIV prevalence estimates from nationally representative seroprevalence surveys

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Abstract

Objectives—To assess the relationship between prior knowledge of one's HIV status and the likelihood to refuse HIV testing in populations-based surveys and explore its potential for producing bias in HIV prevalence estimates.

Methods—Using longitudinal survey data from Malawi, we estimate the relationship between prior knowledge of HIV-positive status and subsequent refusal of an HIV test. We use that parameter to develop a heuristic model of refusal bias that is applied to six Demographic and Health Surveys, in which refusal by HIV status is not observed. The model only adjusts for refusal bias conditional on a completed interview.

Results—Ecologically, HIV prevalence, prior testing rates and refusal for HIV testing are highly correlated. Malawian data further suggest that amongst individuals who know their status, HIV-positive individuals are 4.62 (95% confidence interval, 2.60–8.21) times more likely to refuse testing than HIV-negative ones. On the basis of that parameter and other inputs from the Demographic and Health Surveys, our model predicts downward bias in national HIV prevalence estimates ranging from 1.5% (95% confidence interval, 0.7–2.9) for Senegal to 13.3% (95% confidence interval, 7.2–19.6) for Malawi. In absolute terms, bias in HIV prevalence estimates is negligible for Senegal but 1.6 (95% confidence interval, 0.8–2.3) percentage points for Malawi. Downward bias is more severe in urban populations. Because refusal rates are higher in men, seroprevalence surveys also tend to overestimate the female-to-male ratio of infections.

Conclusion—Prior knowledge of HIV status informs decisions to participate in seroprevalence surveys. Informed refusals may produce bias in estimates of HIV prevalence and the sex ratio of infections.

Keywords

Africa; data collection; epidemiology; HIV; nonresponse; population surveillance; prevalence

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Both authors equally contributed to the design of the study, data analysis and drafting of the manuscript.

Introduction

Historically, most published estimates of HIV prevalence in sub-Saharan Africa were based on sentinel surveillance data from antenatal clinics (ANCs). Because of the importance of reasonably accurate HIV prevalence figures for policy formulation and resource allocation, the validity of these estimates have been subject to extensive scrutiny. ANC-based estimates typically overestimate true prevalence, and that is attributed to the representativeness of women attending ANCs and the under-representation of remote rural areas in surveillance systems [1–12]. The identification of bias has led to the development of correction schemes to improve extrapolations from ANC data [2,13–15], but questions continue to surround the uniform applicability of these adjustments [10].

Expanding resources and progress in medical technology has brought HIV testing increasingly within the reach of nationally representative household surveys, and that generated new prospects of resolving the type and magnitude of bias in ANC sentinel surveillance-based estimates or to provide a new gold standard for HIV prevalence estimates altogether [8,16–19]. The inclusion of HIV serostatus testing in several Demographic and Health Surveys (DHSs) and AIDS Indicator Surveys (AISs) is pushing the agenda in that respect.

Data from population-based surveys are a valuable addition to ANC estimates, but they are also subject to bias because of limitations of the sampling frame (e.g., the exclusion of high-risk groups in army barracks, prisons or health facilities) and nonresponse because of individual mobility and refusal. The association between mobility and HIV infection has been documented extensively [10,20–26]. In comparison, relatively little is known about the relationship between refusal and HIV infection in population-based studies [8,17,19]. Population-based seroprevalence surveys are believed to underestimate true HIV prevalence, but most studies have failed to identify significant refusal bias [19,26–29]. One publication reports significant bias, but the refusal for HIV testing in that study is uncharacteristically high [30]. These studies do not, however, account for the possibility that respondents' refusal for testing is informed by prior knowledge of their HIV status. We hypothesize that HIV-positive individuals who are aware of their HIV status are less likely to consent to testing in a seroprevalence survey than those who previously tested negative and those who were not previously tested. Furthermore, we demonstrate that these 'informed refusals' can bias HIV prevalence from nationally representative surveys, particularly in settings where HIV prevalence, refusal rates and HIV testing coverage are relatively high.

Methods

This study consists of three parts. First, we explore the ecological association between refusal rates, prior testing rates and HIV prevalence in 14 African countries. Second, we use regression models for analyzing the individual-level relationship between prior testing and consent for retesting in six DHSs and longitudinal survey data from the Malawi Diffusion and Ideational Change Project (MDICP). Finally, we develop a heuristic model of bias in HIV seroprevalence surveys that is based on observed HIV prevalence, the prior testing rate, the refusal rate and assumptions about the relation between prior knowledge of one's HIV status and consent for testing. We apply the model to DHS for Senegal (2003), Ghana (2003), Cameroon (2004), Malawi (2004), Lesotho (2004) and Zimbabwe (2005–2006).

HIV testing in the Demographic and Health Surveys

The DHS (<http://www.measuredhs.com/>) are a widely used source for social science and public health policy research in developing countries. In 2001, the DHS (and AIS) started administering HIV tests via the collection of dried blood spots. Study participants are typically approached for testing following a successful interview, but the protocol is not uniform. With

the exception of Cameroon (2004), the proportion of respondents who were tested but not interviewed was under 1%. We ignore this category of respondents. The DHS and AIS do not usually give feedback to respondents about test results. Instead, respondents receive referrals for free counseling and testing at local Voluntary Counseling and Testing (VCT) establishments. In some countries, the survey team was followed by mobile units that offered VCT services.

HIV testing in the Malawi Diffusion and Ideational Change Project

The MDICP (<http://malawi.pop.upenn.edu>) revolves around a longitudinal survey with HIV testing in waves three (MDICP3) and four (MDICP4). We thus know which respondents were tested in MDICP3, and if so, their HIV status and whether or not they chose to learn their results. In addition, we know whether or not the respondent agreed to be retested in MDICP4. We use these data to obtain an empirical estimate of the relationship between HIV status and subsequent consent for testing for respondents with knowledge of their HIV test result. The original MDICP1 sample from 1998 included around 1500 ever-married women and their spouses. In MDICP3, the sample was augmented with a group of adolescents (both sexes). In 2004 (MDICP3), a total of 3284 individuals were approached for an HIV test using OraSure saliva swabs (OraSure Technologies, Inc., Bethlehem, Pennsylvania, USA) [31]. Posttest counseling was offered in VCT tents in or close by the villages of the respondents 1–3 months after testing. In 2006 (MDICP4), testing was done by means of a finger-prick rapid test. Respondents could choose to be tested in their home or in a VCT tent in the village, and posttest counseling was done 20–30 min after the test. Respondents were given the option to be tested and counseled or to be tested without posttest counseling or the return of test results. For individuals who received their test result in MDICP3 and were contacted again in MDICP4, we calculate the relative risk (RR) of refusing for HIV-positive individuals compared with HIV-negative ones using a log–binomial model. Henceforth, we label this RR the E parameter.

A heuristic model of refusal bias

Even though refusals may be informed by prior knowledge of HIV-positive status, it does not mean that they necessarily produce substantial bias in national or local estimates of HIV prevalence. Bias will also depend on the refusal and prior testing rates. From the DHSs, we obtain the proportion of the population tested previously, the refusal rate amongst respondents tested previously, the refusal rate in those not tested previously and the HIV prevalence in those who consented to testing, each stratified by sex and place of residence (urban/rural). Assuming that the risk of refusing for individuals who know that they are HIV positive is E times greater than the risk of refusing for individuals who know that they are HIV negative, a simple probability calculation yields an estimate of HIV prevalence amongst those who refused and, hence, an estimate of the population-level HIV prevalence (see appendix). The adjusted population HIV prevalence is estimated for each population subgroup (urban/rural, men/women) separately. The country-level estimate is calculated as a weighted average of the prevalence in each subgroup. To construct weights, we use the population distribution by place of residence from the United Nations world urbanization prospects database [32], and sex ratios are assumed to be in balance. Estimates of bias are presented in terms of the absolute difference in the observed and adjusted HIV prevalence as well as by their ratio.

In this calculation, four additional assumptions are made. First, refusal is uncorrelated with HIV status among those who have not been previously tested. Second, prior testing for HIV is independent of HIV status. This means that individuals who are HIV negative are just as likely to know their HIV status as individuals who are HIV positive. In most DHSs, however, HIV-positive individuals are more likely to have previously received an HIV test (Table 1). This assumption is made to be conservative because bias will be larger if HIV-positive individuals are indeed more likely to know their status. Third, we only consider refusal bias by those who

have been successfully contacted and completed the individual interview portion. In conservative fashion, the model thus ignores potential bias resulting from higher absenteeism in HIV-positive individuals and a greater propensity to refuse the survey outright (and not just the HIV test). Finally, the adjustment rests on the generalizability of the *E* parameter from the MDICP to the DHSs. Obvious differences in context and study populations aside, one possible source of divergence in the refusal dynamics between the two are differences in the survey and testing protocols [33]. In the DHSs, for example, test results are not returned to respondents, whereas that was standard practice in the MDICP4 (even though respondents were offered the choice to test without posttest counseling or the return of test results).

Results

Prior testing and refusal: ecological and individual-level associations

Figure 1 illustrates the prior testing rate, HIV prevalence and the refusal rate by type of place of residence and sex for 14 African countries. Refusal rates range from under 1% in rural Rwanda to 25% in urban populations of Malawi, Ethiopia, Lesotho and Zimbabwe. Refusal rates vary quite importantly by place of residence and sex; the median refusal rates in urban and rural areas are 16.3 and 8.8%, respectively; the median refusal rates for men and women are 14.6 and 9.2%, respectively. Rates of prior testing vary from under 1% for women in rural Guinea and Niger to 43% for women in urban Rwanda. The median rate of prior testing is 11.7% and is a little higher for men than for women. The difference by place of residence is larger; the median prior testing rates for urban and rural areas are 17.2 and 8.1%, respectively. Figure 1 is also suggestive of a three-way ecological relationship between HIV prevalence, prior testing and refusal. Rwanda and Uganda have relatively high prior testing rates and low refusal rates. Excluding these two countries, the ecological correlation between either of these variables is greater than 0.5.

The relationship between prior testing status and refusal also holds at the individual level; with the exception of Malawi, the odds for refusing an HIV test are higher in individuals who have been tested before (irrespective of the outcome, Table 1). This possibly means that consent for testing is informed by respondents' prior knowledge of their HIV status. The DHSs do not, however, allow us to investigate that relationship further because the HIV status of those who refuse testing is unobserved (one just knows whether the respondent has been tested before or not). As an alternative, we estimate this parameter using MDICP data.

Of the 3284 respondents who were approached for a test in MDICP3, 90.8% consented. Among those, 67.2% came back for posttest counseling. Of the respondents who were tested and received their results in MDICP3, 76.9% were successfully contacted again in MDICP4 (1462 or 78.5% of the HIV-negative individuals and 67 or 52.3% of the HIV-positive individuals). In that group of respondents, the refusal rate for an HIV test in MDICP4 is 4.5%, and HIV-positive individuals are 4.62 [95% confidence interval (CI), 2.60–8.21] times more likely than HIV-negative ones to refuse repeat testing [34].

Bias in HIV prevalence estimates

Nonresponse rates from the DHSs and model inputs are presented in Table 2. National-level refusal rates (conditional on a completed individual interview) vary from just over 4.4% in Cameroon to 27.4% in Malawi. As is also shown in Fig. 1, refusal rates are usually higher in urban areas and among men. Excluding urban Cameroon, where many women are tested during ANC visits, prior testing rates are higher for men as well. Nonresponse on the individual and household interviews combined is usually as important as the refusal rate for an HIV test itself (Malawi is an exception). Nonresponse rates on the individual interview are often higher in urban than in rural areas and for men compared with women.

Refusal-adjusted HIV prevalence estimates based on the inputs in Table 2 are presented in Table 2 itself and Fig. 2. For Senegal, Ghana, Lesotho and Cameroon, the adjusted national-level HIV prevalence estimates (medium scenario) are between 1.5 and 5.0% higher than the observed values. For Zimbabwe and Malawi, however, the observed survey prevalence will underestimate the true population prevalence by 8.5% (95% CI, 4.8–12.0) and 13.3% (95% CI, 7.2–19.6), respectively. In absolute terms, the difference between the adjusted and observed prevalence is under 0.3 percentage points for Senegal, Ghana and Cameroon. For Lesotho, it is 0.9 (95% CI, 0.5–1.2) points, and for Zimbabwe and Malawi, it is 1.5% (95% CI, 0.8–2.1) and 1.6% (95% CI, 0.8–2.3) percentage points, respectively.

National-level figures sometimes conceal considerable heterogeneity by sex and place of residence. Because of higher prior testing and refusal rates, the bias is usually higher in urban than in rural areas. In urban populations in Zimbabwe and Malawi, for example, the absolute difference between the adjusted and observed HIV prevalence is 3.1 (95% CI, 1.8–4.3) and 5.2 (95% CI, 2.9–7.3) percentage points, respectively. The estimated bias is often also larger for men than for women, and particularly so in urban areas. In Senegal and Cameroon, the differences are unimportant, but in Zimbabwe, the observed ratio of female-to-male infections in urban areas is 1.35; the adjusted ratio is 1.24 (95% CI, 1.20–1.29). In Lesotho, the observed ratio in urban areas is 1.54 compared with an adjusted value of 1.42 (95% CI, 1.38–1.47). At the national level, the observed and adjusted ratios are 1.45 versus 1.39 (95% CI, 1.36–1.42) for Zimbabwe and 1.37 versus 1.33 (95% CI, 1.32–1.35) for Lesotho. The national-level differences are not as important because the disproportionate bias among men is smaller in rural areas, where the majority of the population lives.

Discussion

Most evaluations of nonresponse bias in seroprevalence surveys acknowledge that refusals correlate with observed sociodemographic and behavioral characteristics but ignore that they may be informed by prior knowledge of one's HIV status. In a Malawian sample of respondents who are aware of their status, HIV-positive individuals are 4.62 (95% CI, 2.60–8.21) times more likely than HIV-negative ones to refuse repeat testing. When applying that estimate in a heuristic model of refusal bias with other inputs from the DHSs, we find that refusal bias in country-level HIV prevalence estimates is negligible in Senegal (1.5%; 95% CI, 0.7–2.9) and Ghana (2.8%; 95% CI, 1.3–5.6), moderate in Lesotho (3.9%; 95% CI, 2.3–5.3) and Cameroon (5.0%; 95% CI, 2.4–8.4) and considerable in Zimbabwe (8.5%; 95% CI, 4.8–12.0) and Malawi (13.3%; 95% CI, 7.2–19.6). In absolute terms, the difference between observed and refusal-adjusted HIV prevalence estimates may be as high as 1.5 (95% CI, 0.8–2.1) and 1.6 (95% CI, 0.8–2.3) percentage points for Zimbabwe and Malawi, respectively. Bias is even larger in subpopulations in which prior testing and refusal rates are relatively high. This is often the case for urban populations with high prevalence rates. As the most extreme cases, HIV prevalence estimates are underestimated by 21.9% (95% CI, 12.0–33.5) for urban men in Zimbabwe and by 31.6% (95% CI, 17.4–44.3) and 29.4% (95% CI, 16.6–40.4) for men and women in urban areas of Malawi, respectively. Because bias is generally larger for men than for women, data from seroprevalence surveys also tend to overestimate the female-to-male sex ratio of infections.

Interestingly, these findings indicate that urban areas often weigh less than they should in population-based survey estimates of HIV prevalence, whereas they were traditionally over-represented in ANC-based estimates. Because of the difference in seroprevalence estimates from surveys and ANC data, however, the United Nations Joint Programme on HIV/AIDS (UNAIDS) now recommends adjusting ANC data for urban areas downward by a factor of 0.8 (previously only rural ANC data were adjusted following such a procedure) [11,35]. Our results indicate that such an adjustment may not be uniformly appropriate. In addition, our finding

that bias is largest in populations in which prior testing rates are highest suggests that the potential for bias in seroprevalence estimates may increase in conjunction with efforts to improve VCT coverage. Extrapolations from these static observations to trends over time should, however, be made with necessary caution.

Our results also suggest that some countries' recent downward revisions in HIV prevalence estimates may need to be revisited [35]. In the case of Malawi, for example, national-level adult HIV prevalence estimates were previously estimated at 14.2 for 2003 and 14.1 for 2005 [36]. The 2004 Malawi DHS reported an observed prevalence of 11.8% (95% CI, 11.0–12.7) and a nonresponse-adjusted estimate of 12.7% (95% CI, 12.0–13.3) [37]. Following the new UNAIDS guidelines that value estimates from nationally representative seroprevalence surveys more heavily, the 2003 and 2005 HIV prevalence estimates are now reported by the Malawian government as 12.9 and 12.4%, respectively [38]. Our model establishes the 2004 HIV prevalence estimate at 13.2% (95% CI, 12.5–13.9), and there are reasons to believe that our estimates are conservative.

First, we assume that HIV-positive and HIV-negative individuals are equally likely to have been tested before. Second, our model does not account for sources of bias related to the sampling frame. Third, we do not account for the potential relationship between respondents' perceived likelihood of infection, true HIV status and refusal in the subgroup that has never been tested before. Fourth, we only account for refusals conditional on a completed survey interview (because we require survey information for estimating one of the parameters in our model). This is conservative because HIV-positive individuals who know their status are not only more likely to refuse testing but also to refuse an interview, particularly if it contains discomforting questions about current and prior sexual behavior. Fifth, other forms of nonresponse (e.g., absenteeism) may compound the refusal bias estimated here. With the exception of Malawi, refusal for testing accounted for roughly half of the total nonresponse. Note, however, that the correlation of HIV status with other forms of nonresponse is not necessarily of the same magnitude as its association with refusal for testing. Because all types of nonresponse are generally higher for men than for women, other forms of nonresponse are not only likely to increase bias in HIV prevalence estimates but also in the observed sex ratio of infections.

Our model is merely suggestive, however, and should not be used for adjusting the HIV prevalence estimates from nationally representative surveys. The main limitation of this study is that we had access to only one sample for estimating the RR of refusal in HIV-positive and HIV-negative individuals (i.e., the E parameter in our model). This parameter may depend on a variety of conditions such as sex, place of residence, VCT coverage, access to antiretroviral therapy, the elapsed time between prior testing and the serosurvey and the study protocol for the return of test results to the respondent. In that respect, it is important to acknowledge that the MDICP testing protocol is different from the protocol used in the DHS or AIS. The level of refusal itself may be important as well; in populations in which the refusal rate is higher, refusals may be less selective and not to the same extent informed by prior knowledge.

Acknowledgments

The Malawi Diffusion and Ideational Change Project data have been collected using two National Institutes of Health funded grants, RO1 HD044228 and RO1 HD/ MH41713. Further support was received from a Hewlett Foundation grant to the University of Colorado at Boulder for the African Population Studies Research and Training Program. We acknowledge ORC Macro for granting us access to DHSs and AISs data. We wish to thank Patrick Heuveline, Susan Watkins, Basia Zaba and the journal's reviewers for useful comments on earlier versions of the manuscript.

Appendix

Let $H = 1$ be that an individual is HIV positive, $T = 1$ that an individual has been tested and knows his or her HIV status and $R = 1$ the event that an individual refuses the test. The prevalence observed in the serosurvey is $P(H = 1|R = 0)$; that is, the probability that an individual is HIV positive given he or she consented to testing. We thus ignore individuals who are absent for testing as well as other forms of nonresponse (i.e., we assume that these forms of nonresponse are independent of HIV status). We are interested in finding an equation for $P(H = 1)$, the true population prevalence of HIV unconditional on consenting for testing. In addition to the sample HIV prevalence, we can estimate the following quantities from DHS data:

$P(T = 1)$, the proportion of the population that knows their HIV status;

$P(R = 1|T = 1)$, the probability that an individual refuses, given that he or she knows his or her HIV status;

$P(R = 1|T = 0)$, the probability that an individual refuses, given that he or she does not know his or her HIV status.

From the MDICP data, we can estimate the RR of refusal for individuals who know that they are HIV positive compared with individuals who know that they are HIV negative, that is,

$$E = \frac{P(R=1|H=1,T=1)}{P(R=1|H=0,T=1)} \quad (1)$$

We further assume that being tested previously does not depend on one's HIV status, mathematically that is $P(H = 1|T = 1) = P(H = 1)$. Also, we assume that HIV status does not influence refusal for individuals who do not know their HIV status. That is,

$$\begin{aligned} P(R=1|H=1,T=0) &= P(R=1|H=0,T=0) \\ &= P(R=1|T=0) \end{aligned}$$

With these assumptions, we can use the rules of conditional probability to find an equation relating our unknown quantity $P(H = 1)$ to known probabilities. We start using the law of total probability to express

$$\begin{aligned} P(H=1|R=0) &= P(H=1|T=0,R=0)P(T=0|R=0) \\ &\quad + P(H=1|T=1,R=0)P(T=1|R=0) \\ &= 1|R=0 \end{aligned} \quad (2)$$

Now we write each component of the sum in terms of quantities that are given. Recalling our assumption that $P(H = 1|T = 1) = P(H = 1)$, we see that

$$\begin{aligned} P(H=1|T=0,R=0) &= \frac{P(R=0|H=1,T=0)P(H=1|T=0)}{P(R=0|T=0)} \\ &= P(H=1) \end{aligned} \quad (3)$$

Next, Bayes theorem yields

$$P(T=0|R=0) = \frac{P(R=0|T=0)P(T=0)}{P(R=0|T=0)P(T=0)+P(R=0|T=1)P(T=1)} \quad (4)$$

For the third term, recalling (1), a bit of algebra shows that

$$P(H=1|T=1,R=0) = \frac{\left[1 - \frac{E \cdot P(R=1|T=1)}{1+(E-1) \cdot P(H=1)}\right] \cdot P(H=1)}{1-P(R=1|T=1)} \quad (5)$$

Finally, Bayes Theorem gives that

$$P(T=1|R=0) = \frac{P(R=0|T=1)P(T=1)}{P(R=0|T=0)P(T=0)+P(R=0|T=1)P(T=1)} \quad (6)$$

Substituting (3) – (6) into (2) yields a function including $P(H=1)$ and quantities that are known from the DHS survey. Rearranging terms in the equation yields a quadratic equation in $P(H=1)$. It can be shown that exactly one of the roots of the equation will be in the interval $[0,1]$, the estimate of $P(H=1)$ or the population's HIV prevalence.

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Fig. 1. Prior testing and refusal rates in 14 African countries by HIV prevalence (size of the circles) and disaggregated by rural/ urban residence and sex (in %)

Countries included in the graph are Cameroon (2004), Ethiopia (2005), Ghana (2003), Guinea (2005), Kenya (2003), Lesotho (2004), Malawi (2004), Niger (2006), Rwanda (2005), Tanzania (2003–04), Senegal (2005), Uganda (2004–05), Zambia (2002) and Zimbabwe (2005–06). The prior testing rate is defined as the percentage of respondents who have ever been tested for HIV and received the results of the last test. In Zambia and Tanzania, it is the percentage tested before irrespective of the receipt of the test result. The refusal rate is defined as the percentage of respondents who refused the HIV test conditional on having completed the survey interview. The circles labeled with an R or U denote population subgroups in Rwanda and Uganda. They stand out with relatively low refusal rates for the level of prior testing. Reproduced from Demographic and Health Surveys and AIDS Indicator Surveys.

Fig. 2. Observed HIV prevalence, adjusted HIV prevalence and their ratio by country, sex and type of place of residence

The bars represent the observed and adjusted HIV prevalence under the medium scenario in which HIV-positive individuals who know their status are 4.62 times more likely to refuse than HIV-negative individuals who know their status. The grey dots represent the ratio of the adjusted over observed prevalence. The whiskers on the ratio correspond to values for the ratio estimated under the assumption that HIV-positive individuals are between 2.60 and 8.21 times more likely to refuse or to the 95% confidence interval around the estimate of the E parameter.

Table 1
Individual-level association between refusal, prior testing status and HIV status

	Refusal by prior testing status	Prior testing by HIV status
Cameroon (2004)	2.41 (1.90–3.04)	1.80 (1.40–2.31)
Ghana (2003)	1.46 (1.12–1.90)	1.77 (1.05–2.98)
Lesotho (2004)	1.34 (1.00–1.79)	2.09 (1.58–7.66)
Malawi (2004)	0.96 (0.79–1.16)	1.19 (0.88–1.60)
Senegal (2005)	1.97 (1.18–3.30)	2.58 (0.75–8.84)
Zimbabwe (2005–06)	1.15 (1.02–1.30)	1.38 (1.20–1.60)

Values are odds ratio (95% confidence interval). Confidence intervals are based on robust standard errors (adjusted for the nonindependence of observations within survey clusters).

Table 2
Distribution of nonresponse rates and model inputs by type of place of residence and sex (%)

	Urban		Rural		Total	Urban		Rural		Total
	Men	Women	Men	Women		Men	Women	Men	Women	
Senegal (2005)										
Nonresponse										
Non response HH interview ^a	3.5	2.8	0.6	0.6	1.8	2.1	2.1	0.7	0.7	1.3
Non responseInd interview ^a	14.5	6.5	13.6	6.2	9.8	7.8	5.0	5.2	3.8	5.2
Refused HIV test ^b	7.5	7.1	5.9	6.3	6.7	15.3	5.8	8.1	4.2	7.9
Model inputs ^b										
Prior test ^c	5.4	4.9	3.0	1.5	3.7	10.9	9.4	4.7	5.7	7.3
Refused HIV test–prior test	10.5	15.7	8.5	7.3	11.9	22.9	4.1	8.4	5.7	10.8
Refused HIV test–no prior test	7.3	6.3	5.7	6.2	6.4	14.3	5.9	8.2	4.1	7.7
Observed HIV prevalence ^d	0.4	1.0	0.5	0.8	0.7	1.6	2.9	1.7	2.5	2.2
Model outputs–adjusted HIV prevalence										
Low	0.4	1.0	0.5	0.8	0.7	1.7	2.9	1.7	2.6	2.2
Medium	0.4	1.0	0.5	0.8	0.7	1.8	2.9	1.7	2.6	2.2
High	0.4	1.0	0.5	0.8	0.7	1.9	3.0	1.7	2.6	2.3
Cameroon (2004)										
Nonresponse										
HH interview ^a	4.6	3.6	1.5	1.3	2.8	4.9	2.0	4.2	1.9	3.1
Ind Interview ^a	9.5	7.1	4.3	4.3	6.3	19.8	5.4	13.0	4.2	9.1
Refused HIV test ^b	6.6	6.5	1.6	1.7	4.4	41.0	39.2	25.7	24.5	27.4
Model inputs ^b										
Prior test ^c	19.0	27.4	8.0	10.2	17.9	25.1	23.3	12.4	11.0	13.6
Refused HIV test–prior test	10.6	10.0	2.3	2.8	8.4	35.2	39.4	19.6	25.2	27.0
Refused HIV test–no prior test	5.7	5.2	1.5	1.7	3.7	43.3	38.9	26.4	24.1	27.9
Observed HIV prevalence ^d	4.7	8.2	2.9	4.8	5.1	16.4	18.0	8.9	12.5	11.7
Model outputs–adjusted HIV prevalence										
Low	4.9	8.5	2.9	4.8	5.2	19.2	21.0	9.2	13.0	12.5
Medium	5.0	8.8	2.9	4.8	5.4	21.5	23.3	9.6	13.5	13.2
Malawi (2004)										

	Urban			Rural			Urban			Rural		
	Men	Women	Total	Men	Women	Total	Men	Women	Total	Men	Women	Total
High	5.3	9.2	4.8	2.9	4.8	5.6	23.6	25.3	10.1	14.1	13.9	
Nonresponse												
HH interview ^a	11.7	10.5	2.6	3.0	5.9	4.9	5.9	5.9	4.6	4.6	5.1	
Ind Interview ^a	12.3	4.2	6.2	16.3	28.1	10.2	28.1	14.9	11.7	6.6	13.7	
Refused HIV test ^b	36.4	28.9	8.0	12.6	29.4	15.1	29.4	22.2	15.9	9.9	17.7	
Model inputs ^b												
Prior test ^c	13.3	16.7	11.5	8.3	24.0	11.9	24.0	28.8	11.4	17.5	19.5	
Refused HIV test—prior test	39.4	17.5	11.2	21.5	31.1	18.8	31.1	20.5	19.0	9.4	19.3	
Refused HIV test—no prior test	36.2	31.0	7.5	10.9	28.7	14.7	28.7	23.0	15.2	10.0	17.2	
Observed HIV prevalence ^d	21.4	33.1	24.3	18.2	16.0	22.3	16.0	21.6	13.9	20.8	17.9	
Model outputs—adjusted HIV prevalence												
Low	23.1	34.0	24.6	18.6	18.0	22.8	18.0	23.2	14.3	21.2	18.7	
Medium	24.4	34.6	24.8	18.9	19.6	23.2	19.6	24.3	14.7	21.4	19.4	
High	25.4	35.0	25.0	19.2	21.1	23.5	21.1	25.3	15.1	21.7	20.0	

DHS, Demographic and Health Survey; HH, household; Ind, individual.

^aReproduced from Tables A1 and A2 in DHS final reports (website: <http://www.measuredhs.com>).

^bTabulated from raw DHS datasets. Survey weights are used for calculating prior testing and refusal rates; HIV weights are used for calculating HIV prevalence. Reported figures are conditional on a completed interview. The age range for women is 15–49 years. For men, it is 15–59 years for Cameroon, Ghana, Lesotho and Senegal and 15–54 years for Malawi and Zimbabwe.

^cDefined as the percentage of respondents who reported to have been tested before and to have received the results of the test.

^dThe national HIV prevalence is calculated as a weighted average of the prevalence of each population subgroup. The population distribution is taken from the United Nations world urbanization prospects database [32], and the sex ratios are assumed to be in balance. These are not necessarily realistic assumptions, but they allow for comparison with the adjusted country level HIV prevalence estimate, which is calculated in the same fashion.