PREVALENCE OF HIV-DISCORDANT COUPLES IN SUB-SAHARAN AFRICA: WHAT HAS CHANGED OVER THE LAST DECADE?

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INTRODUCTION

As the HIV-1 epidemic in sub-Saharan Africa (SSA) has matured, the role of stable heterosexual couples (married or cohabitating) as a source of new infections has received more attention, in terms of both research and policy. Recent research has suggested that almost two-thirds of all new HIV infections in SSA occur among stable couples [1]. HIV-serodiscordant couples, stable couples in which only one partner is HIV-positive, are of particular concern given that the HIV-negative partners live with a high risk of infection from within their primary sexual relationship [1-8]. These serodiscordant relationships also present a particular set of challenges for the adoption of preventative sexual behaviors, such as condom use, in that they do not reflect the "high-risk" sexual partners/behaviors (multiple partners, casual partners, pay for/receiving pay for sex) that have been the primary focus of HIV prevention campaigns and messages. Indeed, stable relationships have long been touted as a source of protection against HIV [9-13]. In addition, research in SSA (and many other parts of the world) has shown that navigating safe-sex is often difficult for men and especially for women within stable couples [11, 14-21]. Consistently low HIV testing rates for individuals and couples throughout SSA also mean that many serodiscordant couples are likely unaware of their HIV status both individually and as a couple [22, 23]. Although testing rates are low, studies have shown that HIV-discordant couples who do receive individual and couple-centered voluntary counseling and testing are much more likely to reduce their risk of transmission through the adoption of safe-sex practices and receipt

of services such as anti-retroviral treatment and pre-exposure prophylaxis, where available [4, 7, 9, 10, 24-28]. Given all of these factors, HIV-serodiscordant couples have been identified as an important focus and opportunity for HIV prevention efforts as well as testing, counseling, and care services [7]. HIV-discordant couples also remain an urgent population for SSA-based HIV research. In particular, research that assesses change in the prevalence and demographics of HIV-discordant couples across time is needed in order to better understand the current HIV epidemic in SSA and to implement successful strategies for prevention and services.

The existing body of research looking at the prevalence of HIV-discordant couples across SSA, based largely on single year cross-sectional data, has found HIV-serodiscordancy within heterosexual couples to be widespread throughout SSA [29-33]. Pullum and Staveteig [33], using single time point data between 2006 and 2012 for 10 sub-Saharan countries included in the Demographic Health Surveys (DHS), found that while the majority of married/cohabitating couples throughout SSA were HIV-negative concordant the next highest percentage of couples tended to be HIV-discordant (4.6%-11.2%), followed by HIV-positive concordant couples (both partners are HIV positive) (1.5%-10.3%). Notable exceptions of this trend were Lesotho and Swaziland where a greater percentage of couples were HIV-positively concordant (18.9% in Lesotho and 28.8% in Swaziland) than discordant (17.1% in Lesotho and 16.4% in Swaziland). These observed percentages of serodiscordancy were roughly half the expected values based on a model of independence, which, according to Pullum and Staveteig, indicate that an indirect partner selection was likely taking place. Pullum and Staveteig [33] also found the proportion of stable couples that were HIV-discordant to be higher for countries with a higher general population HIV prevalence rate, a finding that that has been corroborated by other research [30,

34, 35]. This means that the prevalence rates of HIV-discordant couples have tended to be higher in Eastern and Southern countries since general population HIV prevalence and incidence rates of countries in SSA are regionally patterned (with Southern and Eastern countries having much higher rates than Western and Central Africa). However, several of these studies also show that for stable couples with at least one HIV-positive partner, rates of discordancy (as opposed to positive concordancy) have tended to be lower in countries with higher general population prevalence rates, a finding that demonstrates the complexity of serodiscordancy prevalence and its relationship to general prevalence [34, 35].

An earlier study by Eyawo et al. [32] using DHS data for 14 countries collected between 2003-2006 found the prevalence of HIV-discordant couples to range from .81% in Senegal to 13.58% in Lesotho. Again, Lesotho had the highest percentage of HIV-discordant couples (of those studied). However, there was an apparent marked increase (approx. 4.5%) in the percentage of HIV-discordant couples living in Lesotho between this 2004 DHS survey and the 2009 DHS survey analyzed by Pullum and Staveteig [33]. For the other 5 countries that overlap between the two studies, the percentage of discordant couples also appears to have increased for the country of Cameroon (5.07% in 2004 and 5.9% in 2011) and to have decreased for the countries of Kenya (7.28% in 2003 and 6% in 2008-9), Malawi (9.74% in 2004 and 8.5% in 2010), Tanzania (7.87% in 2003-4 and 4.6% in 2011-2), and Zimbabwe (12.87% in 2005-6 and 11.2% in 2010-1). Using the numbers provided by these two studies, it also seems that the prevalence of HIV-positive concordant couples has decreased for all 6 of the countries. While these two studies, when taken together, provide some clues as to the changes that have occurred in the past

decade with respect to HIV-discordancy prevalence trends in SSA, there hasn't been an empirical examination of this change over time within a single, standardized study.

An important aspect of the prevalence rates of HIV-discordant couples living in SSA is the role of gender. Assessing prevalence trends in terms of which gender is more likely to be the index (HIV-positive) case within serodiscordant couples is important for not only understanding the general characteristics and demographics of these couples but also for identifying which gender is more likely to be at high risk for seroconversion within these couples. In their research, Pullum and Staveteig [33] point out that statistically speaking, a high rate of female positive discordant couples is logical (if we assume that couples form at random) since HIV prevalence in the general population is typically higher for women than men. Through their own study (which did not treat couple formation as random), Pullum and Staveteig [33] found HIV rates to be generally the same for both the men and women within the couples. Other research, including a meta-analysis of HIV-discordant couples studies, have produced similar findings [31, 32, 35, 36]. However, HIV prevention efforts aimed at stable couples have historically targeted men as they have widely been regarded as the source of HIV within a couple [9, 37, 38].

Prevalence rates of female and male HIV-positive discordant couples, like individual HIV prevalence rates, are the result of biological (efficiency of transmission and exposure to infection), proximate (being sexually active, condom use, circumcision, biological susceptibility, extra-marital partners, etc.), and underlying (cultural, socio-economic, and demographic contexts, intervention programs) determinants [39]. However, important considerations specific to the HIV status of stable couples are the processes involved in couple formation and

dissolution. Serodiscordant couples can form as discordant or become discordant after their formation (See Figure 1 for the different pathways to HIV couple status). HIV-discordant couples that form as negative concordant are most likely to become discordant through extramarital sex. For couples that are HIV-discordant from their inception, there are different possibilities as to the sexual context in which infection likely occurred for the positive partner. The formation of an HIV-discordant stable couple may in fact be the result of a previous serodiscordant or positive concordant stable relationship on the part of the index partner that ended due to either death or divorce. Research has demonstrated the significant impact of HIV on couple dissolution, especially for women, as well as the impact of couple dissolution on HIV incidence for the context of SSA (38, 40-48). Another important consideration specific to the HIV prevalence rates of couples is that the HIV status of a couple can change over time in ways that an individual's HIV status cannot. Not only do relationships begin and end but HIV-negative concordant couples can become discordant and discordant couples can become HIV-positive concordant. Population-level HIV prevalence rates of couples, and their regional variations across SSA, reflect all of these determinants and processes at play in the HIV status of couples.

Millions of HIV-negative individuals in SSA are living with a high risk for infection within serodiscordant relationships. Research examining these couples in terms of current prevalence rates and changes over time are critical for understanding the HIV epidemic in SSA and for implementing successful prevention and care strategies. This study used data for 17 countries in SSA at multiple time points between 2003 and 2016 in order to examine the prevalence rates of

discordant couples in comparison to HIV concordant (positive and negative) couples over time within and across countries.

METHODS

This study used data collected from 38 DHS surveys in 17 countries in sub-Saharan Africa [49]. DHS surveys are nationally representative, repeated cross-sectional household surveys, collected approximately every five years in order to provide on-going data on population and health for more than 90 countries worldwide [49]. Each DHS survey collects data using multiple methods including several questionnaires, biomarker measurement/testing, and global positioning system (GPS) receivers. In terms of sampling, DHS surveys employ a stratified, two-stage cluster design where the primary sampling unit is a geographical frame defined by a recent census, electoral zone, satellite, or administrative list and the stratification involves the separation of urban and rural by region [49]. Survey samples are generally representative at the national, residential (urban/rural), and regional (departments/states) levels.

The data used for this study comes from the couples datasets of the DHS data. These datasets pair the men and women who participated in the individual questionnaire and named each other as "cohabitating partners" (only heterosexual couples are included). According to the DHS questionnaire the designation of "cohabitating partners" includes married couples as well as couples living as though married. Agreement between the women's identification of a cohabitating partner and men's identification of a cohabitating partner is necessary in order for inclusion in the couples file. The couples datasets contain data collected from the individual men's and women's questionnaires but the unit of analysis is the couple with the unit of

observation the individual men and women who make up the couples. It's important to note that men who name (and are able to be matched to) multiple cohabitating partners are listed multiple times in the couples data since the unit of analysis is the couple. However, the majority of the men included in this study were represented in only one case/couple.

For the purposes of this study, HIV biomarker data was merged with the couples data following DHS methodology so that each individual within every couple had an HIV status.[1] Complete/definitive HIV test results were required of both partners within a couple in order to be included in the analyses for this study.[2] HIV results for several of the surveys indicated whether the respondent tested positive for HIV-1 or HIV-2 or both HIV-1 and HIV-2. Following DHS protocol only the HIV-1 positive results (including both HIV-1 and HIV-2 positive) were included in analyses. The survey samples in this study reflect a complete case approach to analyzing HIV prevalence.[3]

Given the DHS data collection methodology for the couples and HIV datasets, the sample for this study was limited to heterosexual couples where both partners were physically present in the household at the time of data collection, were in the survey's country-and-gender-specific designated age range, successfully completed the individual questionnaire, named each other as a "cohabitating partner," were tested for HIV, had definitive HIV results, and were either HIV-1 positive or negative (see Figure 2). There were 17 sub-Saharan African countries that had data meeting these sample criteria for at least two different surveys (see Table 1 for country descriptives). In terms of general population HIV prevalence, ten of the countries had "low" HIV prevalence, at or below 2%, for all time points (Burkina Faso 2003/2010; Congo DR

2007/2013-4; Ethiopia 2005/2011; Ghana 2003/2014; Guinea 2005/2012; Liberia 2007/2013; Mali 2006/2012-3; Niger 2006/2012; Senegal 2005/2010-1; Sierra Leone 2008/2013), three had "medium" HIV prevalence, between 3% and 7%, at all time points (Cameroon 2004/2011; Kenya 2003/2008-9; Rwanda 2005/2010/2014-5), and four had "high" HIV prevalence, at or above 8%, for all time points (Lesotho 2004/2009/2014; Malawi 2004/2010/2015-6; Zambia 2007/2013-4; Zimbabwe 2005-6/2010-1/2015). In terms of regions within SSA, based on DHS classifications, eight of the countries are located in Western Africa (Burkina Faso, Ghana, Guinea, Liberia, Mali, Niger, Senegal, and Sierra Leone), two of the countries are located in Central Africa (Cameroon and Congo DR), six countries are located in Eastern Africa (Ethiopia, Kenya, Malawi, Rwanda, Zambia, and Zimbabwe, and one country is located in Southern Africa (Lesotho).

The age ranges of men and women eligible for participation in the DHS surveys differed by country. For all of the countries included in this study the age range of women was 15-49. For men, the age range was 15-49 for Liberia, 15-54 for Kenya, Malawi, and Zimbabwe, and 15-59 for the rest of the countries. In order to analyze the largest sample sizes possible the age range of men was not limited in this study and therefore varied for individual countries. This was a limitation for between-country comparisons but did not affect within-country time trend analyses.

As the only nationally representative, standardized surveys available containing HIV data for couples in more than one-third of the countries of sub-Saharan Africa and for multiple time points, the DHS surveys were well suited for this study and allowed for a country-based analysis in which comparisons could be made across time and across countries. A significant limitation,

however, is that DHS data are cross-sectional, meaning that it is not possible to make any causal conclusions. The relatively high response rates for DHS surveys, including HIV testing, were also an important consideration when choosing this data. Men had relatively lower HIV testing (and survey) response rates than women so complex survey weights based on men's HIV testing response rates were utilized in all analyses (see Table 2 for response rates). [4]

ANALYTIC STRATEGY

Descriptive analyses were performed to answer two questions:

I. What are the prevalence rates of HIV-discordant couples (in relation to HIV-positive concordant and HIV-negative concordant couples) for each survey and how do these rates vary by (a) region and general population HIV prevalence rate and (b) gender of the index partner?

II. How have the prevalence rates of HIV-discordant couples (in relation to HIV-positive concordant and HIV-negative concordant couples) changed over time for each country and how do these changes vary by (a) region and general population HIV prevalence rate and (b) gender of the index partner?

To answer the first question, simple weighted tabulations were performed for each of the 38 surveys in order to ascertain the weighted percentage of concordant negative, concordant positive, discordant (discordant female positive and discordant male positive) couples for each country and time point. To answer the second question, the surveys (reflecting different time points) for each individual country were pooled and within-country time trend analyses were performed using confidence intervals for the weighted prevalence rates of the HIV couple types

for each time point. Observed prevalence rates falling outside of the expected prevalence confidence intervals in these analyses were utilized as indicators of statistically significant change across time. For the pooled data analyses, sampling weights for each survey were re-normalized based on country and time point population numbers in order to account for population changes over time within each country. All analyses were performed using STATA version 13 [52]. The data and analyses for this study complied with the University of Colorado Institutional Review Board's classification of non-human subjects research and therefore no ethical approval was necessary, however, given the sensitive nature of biomarker data, the author accepted and signed a Terms of Use Statement with the DHS Program. Funding source for this study presented no conflict of interest.

RESULTS

I. PREVALENCE RATES

As shown in Table 3, for all countries and time points, HIV-negative concordant couples had the highest prevalence rates (64.02%-99.56%) of the different HIV status couple types. HIV-discordant couples had the next highest prevalence rates for all countries and time points except for Lesotho (2004/2009/2014), Rwanda (2010), Senegal (2005), and Zimbabwe (2005-6/2015) where HIV-positive concordant couples had slightly higher prevalence rates than discordant couples. The prevalence rates of HIV-discordant couples within all couples ranged from 0.27% in Niger (2012) to 17.08% in Lesotho (2009). However, as shown in Table 4, the prevalence rates of HIV-discordant couples within couples with at least one HIV-positive partner ranged from 41.01% in Lesotho (2004) to 93.44% in Sierra Leone (2013). Looking at the most recent time points for countries, the prevalence rates of HIV-discordant couples ranged from 0.27% in

Niger (2012) to 15.12% in Lesotho (2014) within all couples and ranged from 43.22% in Lesotho (2014) to 93.44% in Sierra Leone (2013) within positive couples.

a. Region and General Population HIV Prevalence

Higher prevalence rates of couples with at least one positive partner (discordant and concordant) within all couples closely corresponded, both as individual measures and combined, with higher general population HIV prevalence rates for each country and time point. Higher individual and combined prevalence rates of HIV-discordant and HIV-positive concordant couples also corresponded, although not as closely, with the Eastern and Southern regions of SSA. Comparing the prevalence rates of HIV-discordant couples to HIV-positive concordant couples, couples with at least one HIV-positive partner were more likely to be HIV-discordant in countries with lower general population HIV prevalence rates, as well as in countries in Western and Central Africa. These two trends when taken together help explain how Lesotho was able to have both the highest rate of discordance (within all couples) of any country and time point and the lowest rate of discordance (within positive couples) of any country and time point. An interesting exception to this trend was the 2005 survey for Senegal where couples with at least one HIV-positive partner were slightly more likely to be HIV-positive concordant than HIV-discordant despite having a very low general HIV rate of 0.9% (based on UNAIDS estimates).[5] Zambia is another interesting exception to this trend with high general HIV rates of 13.6% (2007) and 13.1% (2014) and yet a higher percentage of HIV-discordant couples than HIV-positive concordant couples.[6]

b. Gender

Looking at the prevalence rates of HIV-discordant couples by the gender of the HIV-positive partner for the individual countries and time points in Table 5, men were more likely than women to be the index partner (23 vs. 15 surveys). Interestingly, this trend was found at each time point for all four of the countries with "high" (at or above 8%) general population HIV prevalence rates (Lesotho, Malawi, Zambia, Zimbabwe) as well as all of the countries and time points that had higher prevalence rates of HIV-positive concordant couples than HIV-discordant couples. Although men were more likely to be the index partner for the majority of surveys, the difference between the proportion of male and female HIV-positive discordant couples was fairly small for many of the surveys with an overall average of 48.55% of discordant couples having a female index partner. Also, looking at the most recent time point for each country revealed that for 8 of the 17 countries, women were more likely to be the index partner in HIV-discordant couples.

II. CHANGE OVER TIME

In terms of change over time, several countries showed statistically significant prevalence trends for HIV-discordant couples (see Table 6). The prevalence rates of HIV-discordant couples decreased over time in Malawi, Niger, and Zimbabwe while there was an overall increase in Lesotho (with differences in the direction of change between individual time points). For Malawi, Niger, and Zimbabwe there was also an increase in the prevalence rate of negative concordant couples over time. For Guinea and Rwanda, however, a decrease was observed in the prevalence of negative concordant couples over time. For HIV-positive concordant couples, Burkina Faso, Malawi, and Zimbabwe showed a decrease in prevalence rates over time while

Ethiopia and Rwanda experienced an increase. For both Rwanda and Zimbabwe the overall changes over time (between time one and time three) in the prevalence of HIV-positive concordant couples were complicated by the change between individual time points where change between time two and time three moved in the opposite direction as the change between time one and time two for both countries. Looking at changes in the weighted proportions of positive concordant and discordant couples within couples with at least one positive partner, Rwanda, Senegal, and Zimbabwe all experienced change over time with respect to which couple type (HIV-discordant or HIV-positive concordant) made up the majority of positive couples (see Table 4). Of these countries, Senegal showed the most drastic change with the proportion of HIV-discordant couples increasing from 48.6% in 2005 to 71.1% in 2010-1.

a. Region and General Population HIV Prevalence

The statistically significant changes in the prevalence of HIV-discordant couples for Malawi, Niger, Zimbabwe, and Lesotho mirror the directional changes in the general population HIV prevalence rates for each of the countries over the same amount of time. This relationship of directional change held for the prevalence of HIV-concordant (positive and negative) couples, as well, with the notable exception of Rwanda for both concordant couple types and Guinea for HIV-negative concordant couples. The decrease in the prevalence of negative concordant couples over time for Guinea and Rwanda (1.2% for Guinea and 0.94% for Rwanda) and increase in the prevalence of HIV-concordant couples for Rwanda is interesting given the increase of ART availability in both of these countries over the same amount of time and decrease in the general population HIV prevalence rate for Guinea and Rwanda (based on UNAIDS estimates).[7]

b. Gender

Looking at the statistically significant change over time in the prevalence of HIV-discordant couples in terms of the gender of the index partner, the prevalence of female-positive discordant couples increased overall in three countries (Guinea, Lesotho, and Rwanda) while male-positive discordant couples increased in two countries (Liberia and Mali). Female-positive discordant couples decreased in two countries (Niger and Zimbabwe) while male-positive discordant couples decreased in three countries (Malawi, Niger, and Zimbabwe). Niger and Zimbabwe were the only two countries to show statistically significant changes (decrease) over time for both female-positive and male-positive discordant couples.

The weighted prevalence rates of discordant couples also showed interesting changes over time with respect to the gender of the index partner for the majority of discordant couples (see Table 5). For Burkina Faso, Ghana, and Guinea, all Western African countries with low general HIV prevalence rates, the majority of discordant couples had a male index partner at the first time point but the majority had a female index partner at the second time point, while Liberia and Sierra Leone (also Western African countries with low general HIV prevalence rates) experienced the opposite trend. The weighted prevalence rates of HIV-discordant couples also demonstrated that over time the proportions of female-positive and male-positive discordant couples became more equal for the majority of countries (13 of 17 countries).

DISCUSSION

The findings of this study provide new insight into the HIV epidemic in sub-Saharan Africa. While the results overwhelmingly demonstrate the country-specific dynamics of this epidemic as it pertains to stable couples, three important trends were evident. First, while the majority of

couples were HIV-negative concordant for every time and point and country, HIV-discordant couples represented the next largest proportion of all couples (and the largest proportion of positive couples) for the majority of countries and time points, including the most recent time points for each country. In absolute population numbers of stable couples, the country and time-point specific DHS data used in this study reveal that over the last decade in SSA rates of HIV-discordancy within countries affected as few as 6,444 couples (Senegal 2005) and as many as 345,425 couples (Kenya 2003).

Second, HIV-discordant (as well as HIV-positive concordant) prevalence trends within all couples largely mirrored the general population HIV prevalence trends (in terms of higher rates) for countries, a finding that supports previous research on sero-discordant couples at single time points [30, 34, 35]. Also supportive of these previous studies is the finding that the strong relationship between positive couple rates within all couples and general population HIV prevalence rates also resulted in general regional patterns of HIV-discordancy (and all HIV-status couple types). This study also provides new evidence to support this relationship by showing, through the use of time trend analyses, that HIV-discordant prevalence trends largely reflected the directional changes in the general population HIV prevalence trends over time. This finding provides further support for the relationship between the HIV prevalence of couples and the general population and also potentially provides evidence for the argument that stable couples are driving the HIV epidemic in SSA, a speculation which cannot be tested by the data or analyses presented here. Also in support of this previous research, is the related finding that for countries with high general HIV prevalence rates, positive couples are about equally as likely

to be discordant as concordant as opposed to countries with low general HIV prevalence rates, where positive couples are much more likely to be discordant than concordant [34, 35].

A third important finding and trend involves the gender of the index partners in HIV-discordant couples. Descriptive analyses showed men as more likely to be the index partner in HIV discordant couples for these 17 countries and multiple time points. However, the difference between the proportion of male-positive discordant couples and female-positive discordant couples for most countries and time points was fairly small and change over time suggested a trend towards increasing equality between the proportions. Even with this gendered trend showing women and men as being more similar than different in terms of likelihood of being the index partner within HIV discordant couples, women were still more likely to be the vulnerable (in terms of prevalence) partner for sero-conversion within discordant couples in SSA, particularly in Eastern and Southern African countries with high general HIV prevalence rates. This finding provides more regional and time trend context for the previous research that has shown generally equal rates for the gender of the index partner in discordant couples [31, 32, 35, 36].

There are several limitations related to the data used in this study. First, the cross-sectional nature of the data precludes any causal statements related to the prevalence findings for couples over time. Second, the logistical aspects of data collection and sample creation limited the number of couples included in this study in way that is likely biased against migrants as well as individuals who refused HIV testing.

The vast majority of individuals in SSA will live a portion of their life within at least one stable relationship. With research showing almost two-thirds of all new HIV infections in SSA occurring among stable couples, it has become a critical necessity to understand the prevalence rates of different HIV-status couple types, especially HIV-discordant couples, and how they have changed over time in order to implement effective prevention and care services [1]. This study identified important trends in the prevalence rates of these couples for 17 different countries and multiple time points. Perhaps the most important finding is that HIV-discordant couples remain the majority of all positive couples collectively throughout SSA and therefore remain a critical population in terms of HIV programs and services. While more research is needed in order to understand why HIV-discordant couples remain the majority of all HIV positive couples in SSA, especially in countries with a low general HIV prevalence, this study serves as a necessary first step in understanding the demographic changes of HIV-discordant couples over time.

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FIGURE 1: Couples and HIV Status

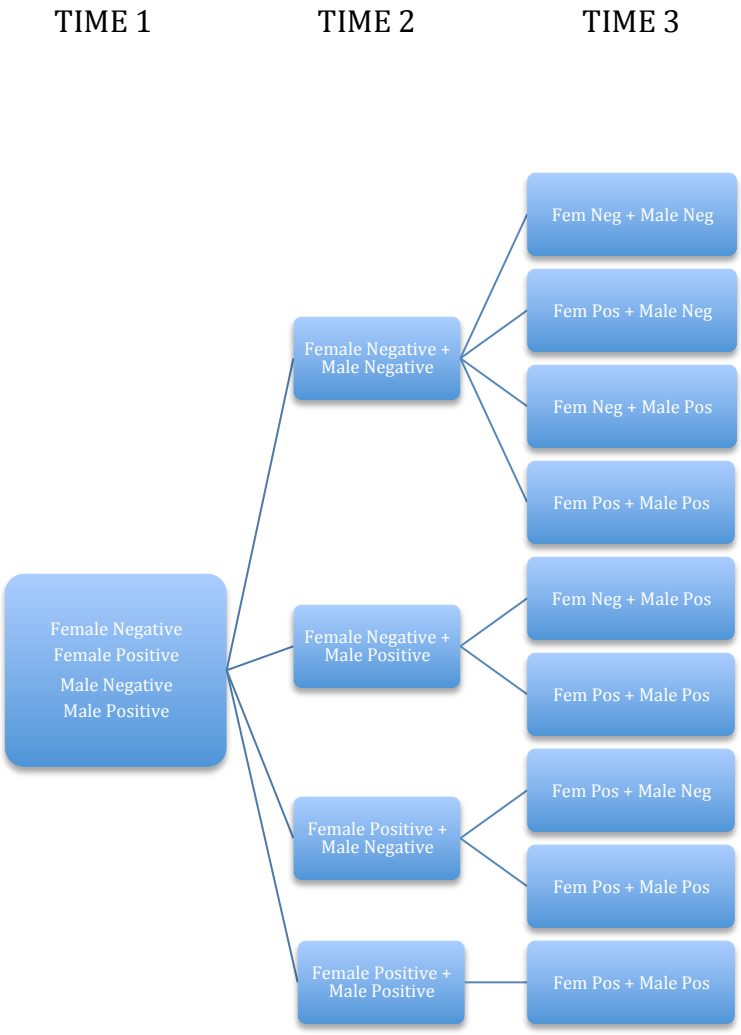

FIGURE 2: Sample Criteria

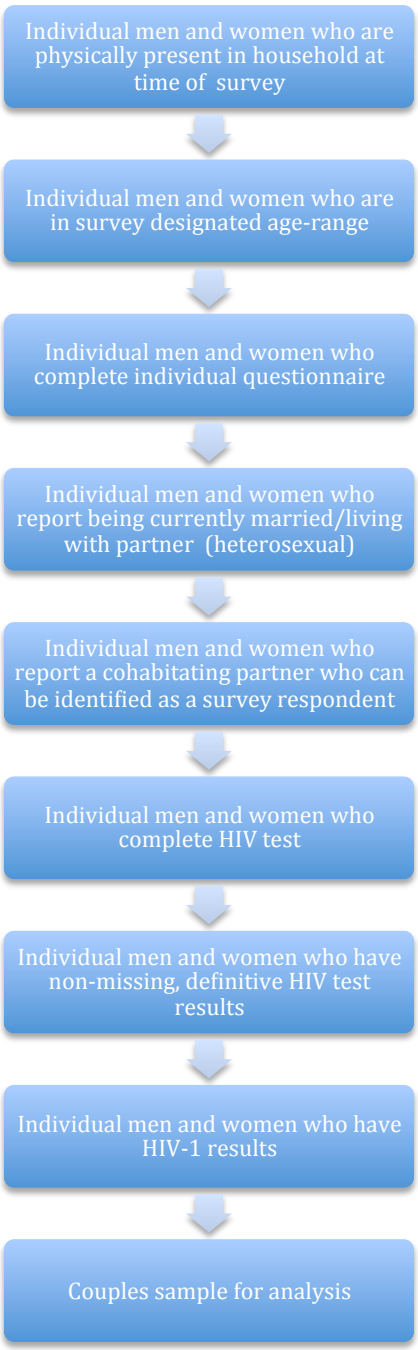

TABLE 1 COUNTRY DESCRIPTIVES

COUNTRY	Region	Population*	Total Fertility Rate*	GDP*	Primarily Rural or Urban*	HIV Prev. % pop 15-49*	ART Coverage % people living with HIV*
BURKINA FASO	Western						
2003		12.7 million	6.4	$4.2 billion	Rural	1.7	1%
2010		15.6 million	5.9	$9.0 billion	Rural	1	32%
GHANA	Western						
2003		20.4 million	4.5	$7.6 billion	Rural	2.6	0%
2014		27.0 million	4.2	$38.6 billion	Urban	1.7	30%
GUINEA	Western						
2005		9.7 million	5.7	$2.9 billion	Rural	1.7	2%
2012		11.3 million	5.2	$5.7 billion	Rural	1.6	25%
LIBERIA	Western						
2007		3.5 million	5.3	$739 million	Rural	1.8	4%
2013		4.3 million	4.8	$1.9 billion	Rural	1.2	20%
MALI	Western						
2006		13.2 million	6.8	$6.9 billion	Rural	1.3	8%
2013		16.5 million	6.3	$12.8 billion	Rural	1.3	24%
NIGER	Western						
2006		14.1 million	7.7	$3.6 billion	Rural	1	2%
2012		17.7 million	7.6	$6.9 billion	Rural	0.6	21%
SENEGAL	Western						
2005		11.3 million	5.2	8.7 billion	Rural	0.9	1%
2011		13.3 million	5.2	14.4 billion	Rural	0.7	28%
SIERRA LEONE	Western						
2008		6.2 million	5.4	$2.5 billion	Rural	1.7	4%
2013		6.9 million	4.7	$4.9 billion	Rural	1.5	17%
CAMEROON	Central						
2004		17.0 million	5.4	$15.8 billion	Rural	5.3	3%
2011		20.5 million	4.9	$26.6 billion	Urban	4.8	18%
CONGO DR	Central						
2007		58.4 million	6.6	$16.4 billion	Rural	1.5	4%
2014		73.7 million	6	$34.0 billion	Rural	0.9	26%
ETHIOPIA	Eastern						
2005		76.7 million	5.7	$12.4 billion	Rural	N/A	NA
2011		90.0 million	4.8	$32 billion	Rural	N/A	NA
KENYA	Eastern						
2003		34.1 million	5	$14.9 billion	Rural	8.3	0%
2009		40.2 million	4.7	$37 billion	Rural	6.1	26%
MALAWI	Eastern						
2004		12.7 million	6	$3.5 billion	Rural	14.5	1%
2010		15.2 million	5.5	$7 billion	Rural	11.2	26%
2016		18.1 million	5.0 (2015)	$5.4 billion	Rural	9.1 (2015)	61% (2015)
RWANDA	Eastern						
2005		9.0 million	5.1	$2.6 billion	Rural	3.4	10%
2010		10.2 million	4.4	$5.8 billion	Rural	3.1	48%
2015		11.6 million	3.8	$8.3 billion	Rural	2.9	79%
ZAMBIA	Eastern						
2007		12.7 million	5.9	$14.1 billion	Rural	13.6	17%
2014		15.6 million	5.4	$27.2 billion	Rural	13.1	57%
ZIMBABWE	Eastern						
2006		13.1 million	4	$5.4 billion	Rural	17.2	5%
2011		14.4 million	4	$12.1 billion	Rural	15.3	39%
2015		15.8 million	3.9	$16.1 billion	Rural	14.7	62%
LESOTHO	Southern						
2004		1.9 million	3.6	$1.5 billion	Rural	22.6	1%
2009		2 million	3.3	$1.9 billion	Rural	23.2	24%
2014		2.1 million	3.2	$2.5 billion	Rural	22.8	37%

* World Bank data--world development indicators (UNAIDS estimates for HIV prevalence and ART coverage; UN World Pop Prospects for population stats and TFR; World Bank national accounts for GDP)

TABLE 2 DHS SURVEY RESPONSE RATES

COUNTRY	Household Response Rate	Ind Response Rate Men	Ind Response Rate Women	HIV Response Rate Men	HIV Response Rate Women
Western					
BURKINA FASO					
2003	99%	91%	96%	86%	92%
2010	99%	97%	98%	94%	96%
GHANA					
2003	99%	94%	96%	80%	89%
2014	99%	95%	97%	90%	95%
GUINEA					
2005	99%	99%	97%	88%	93%
2012	100%	97%	98%	94%	97%
LIBERIA					
2007	97%	93%	95%	80%	87%
2013	99%	95%	98%	88%	92%
MALI					
2006	99%	91%	99%	84%	92%
2012-3	98%	93%	96%	79%	91%
NIGER					
2006	98%	92%	96%	84%	91%
2012	98%	88%	95%	79%	90%
SENEGAL					
2005	98%	86%	94%	76%	85%
2010-1	98%	87%	93%	76%	84%
SIERRA LEONE					
2008	98%	93%	94%	85%	88%
2013	99%	96%	97%	89%	93%
Central					
CAMEROON					
2004	98%	93%	94%	90%	92%
2011	99%	96%	97%	92%	94%
CONGO DR					
2007	99%	95%	97%	86%	90%
2013-4	100%	97%	99%	94%	96%

COUNTRY	Household Response Rate	Ind Response Rate Men	Ind Response Rate Women	HIV Response Rate Men	HIV Response Rate Women
Eastern					
ETHIOPIA					
2005	99%	89%	96%	76%	83%
2011	98%	89%	95%	82%	89%
KENYA					
2003	96%	86%	94%	70%	76%
2008-9	98%	89%	96%	79%	86%
MALAWI					
2004	98%	86%	96%	63%	70%
2010	98%	92%	97%	91%	94%
2015-6	99%	95%	98%	87%	93%
RWANDA					
2005	100%	97%	98%	96%	97%
2010	100%	99%	99%	98%	99%
2014-5	100%	100%	100%	99%	99%
ZAMBIA					
2007	98%	91%	97%	72%	77%
2013-4	98%	91%	96%	84%	90%
ZIMBABWE					
2005-6	95%	82%	90%	63%	76%
2010-1	96%	86%	93%	69%	80%
2015	99%	92%	96%	81%	88%
Southern					
LESOTHO					
2004	95%	85%	94%	68%	81%
2009	98%	95%	98%	88%	94%
2014	99%	94%	97%	89%	94%

TABLE 3 PREVALENCE RATES OF HIV COUPLE TYPES

COUNTRY	TOTAL NUMBER OF COUPLES weighted	FEMALE POSITIVE DISCORDANT	MALE POSITIVE DISCORDANT	TOTAL DISCORDANT	POSITIVE CONCORDANT	NEGATIVE CONCORDANT	HIV PREVALENCE GENERAL POPULATION (DHS SURVEY; AGE 15-49)
Western							
BURKINA FASO							
2003	2,209	0.72%	1.03%	1.75%	0.47%	97.78%	1.8
2010	4,996	0.70%	0.52%	1.23%	0.18%	98.59%	1
GHANA							
2003	1,779	1.28%	1.53%	2.81%	0.99%	96.20%	2.2
2014	1,755	1.66%	0.83%	2.50%	0.77%	96.73%	2
GUINEA							
2005	1,828	0.63%	0.92%	1.55%	0.40%	98.04%	1.5
2012	2,175	1.29%	1.02%	2.31%	0.84%	96.84%	1.7
LIBERIA							
2007	2,393	1.23%	0.74%	1.97%	0.27%	97.76%	1.6
2013	1,593	1.06%	1.69%	2.75%	0.49%	96.76%	2.1
MALI							
2006	2,538	0.84%	0.33%	1.17%	0.36%	98.47%	1.3
2012-3	2,759	0.88%	0.85%	1.73%	0.22%	98.06%	1.1
NIGER							
2006	2,301	0.38%	0.60%	0.99%	0.17%	98.84%	0.7
2012	2,669	0.11%	0.16%	0.27%	0.17%	99.56%	0.4
SENEGAL							
2005	1,251	0.15%	0.25%	0.40%	0.42%	99.18%	0.7
2010-1	1,597	0.31%	0.55%	0.85%	0.35%	98.80%	0.7
SIERRA LEONE							
2008	1,641	1.00%	0.74%	1.75%	0.50%	97.75%	1.5
2013	3,556	1.20%	1.36%	2.56%	0.18%	97.26%	1.5
Central							
CAMEROON							
2004	2,026	2.67%	2.43%	5.10%	2.29%	92.61%	5.4
2011	2,871	3.14%	2.78%	5.92%	1.46%	92.62%	4.3
CONGO DR							
2007	2,117	1.05%	0.58%	1.64%	0.24%	98.13%	1.3
2013-4	4,178	0.89%	0.52%	1.42%	0.23%	98.35%	1.2
Eastern							
ETHIOPIA							
2005	2,704	1.02%	0.79%	1.82%	0.31%	97.88%	1.4
2011	6,908	0.66%	0.42%	1.08%	0.61%	98.31%	1.5
KENYA							
2003	1,116	4.59%	2.86%	7.45%	3.61%	88.95%	6.7
2008-9	1,294	3.20%	2.75%	5.95%	3.06%	90.98%	6.3
MALAWI							
2004	1,324	4.01%	5.72%	9.72%	7.02%	83.26%	11.8
2010	3,462	3.78%	4.67%	8.45%	6.30%	85.25%	10.6
2015-6	3,378	3.91%	4.51%	8.42%	5.56%	86.02%	9
RWANDA							
2005	2,171	0.81%	1.40%	2.21%	1.71%	96.08%	3
2010	2,841	0.90%	1.32%	2.23%	2.38%	95.39%	3
2014-5	2,947	1.34%	1.47%	2.81%	2.05%	95.14%	3
ZAMBIA							
2007	2,383	4.56%	6.56%	11.13%	8.01%	80.86%	14.3
2013-4	6,791	5.20%	6.11%	11.31%	8.19%	80.50%	13.3
ZIMBABWE							
2005-6	2,005	5.19%	8.05%	13.24%	14.69%	72.07%	18.1
2010-1	2,675	4.49%	6.72%	11.20%	10.32%	78.48%	15.2
2015	3,151	3.82%	5.03%	8.86%	10.86%	80.28%	13.8
Southern							
LESOTHO							
2004	570	4.62%	8.96%	13.57%	19.53%	66.90%	23.4
2009	843	7.62%	9.46%	17.08%	18.90%	64.02%	23
2014	708	6.94%	8.18%	15.12%	19.87%	65.01%	24.6

TABLE 4 PREVALENCE RATES OF COUPLE TYPES WITH AT LEAST ONE HIV POSITIVE PARTNER (POSITIVE COUPLES)

COUNTRY	POSITIVE COUPLES OF TOTAL COUPLES	FEMALE POSITIVE DISCORDANT OF POSITIVE COUPLES	MALE POSITIVE DISCORDANT OF POSITIVE COUPLES	DISCORDANT OF POSITIVE COUPLES	POSITIVE CONCORDANT OF POSITIVE COUPLES
Western					
BURKINA FASO					
2003	2.22%	32.27%	46.59%	78.86%	21.14%
2010	1.41%	50.06%	37.31%	87.37%	12.63%
GHANA					
2003	3.80%	33.66%	40.22%	73.88%	26.12%
2014	3.27%	50.93%	25.40%	76.33%	23.67%
GUINEA					
2005	1.96%	32.43%	46.97%	79.40%	20.60%
2012	3.16%	40.82%	32.46%	73.29%	26.71%
LIBERIA					
2007	2.24%	54.89%	33.13%	88.02%	11.98%
2013	3.24%	32.76%	52.18%	84.94%	15.06%
MALI					
2006	1.53%	54.80%	21.82%	76.62%	23.38%
2012-3	1.94%	45.18%	43.62%	88.81%	11.19%
NIGER					
2006	1.16%	33.07%	51.92%	84.99%	15.01%
2012	0.44%	24.70%	36.25%	60.95%	39.05%
SENEGAL					
2005	0.82%	18.44%	30.16%	48.60%	51.40%
2010-1	1.20%	25.58%	45.53%	71.11%	28.89%
SIERRA LEONE					
2008	2.25%	44.71%	33.10%	77.81%	22.19%
2013	2.74%	43.77%	49.67%	93.44%	6.56%
Central					
CAMEROON					
2004	7.39%	36.06%	32.91%	68.97%	31.03%
2011	7.38%	42.54%	37.69%	80.23%	19.77%
CONGO DR					
2007	1.87%	56.21%	31.11%	87.33%	12.67%
2013-4	1.65%	54.35%	31.83%	86.18%	13.82%

COUNTRY	POSITIVE COUPLES OF TOTAL COUPLES	FEMALE POSITIVE DISCORDANT OF POSITIVE COUPLES	MALE POSITIVE DISCORDANT OF POSITIVE COUPLES	DISCORDANT OF POSITIVE COUPLES	POSITIVE CONCORDANT OF POSITIVE COUPLES
Eastern					
ETHIOPIA					
2005	2.12%	48.18%	37.27%	85.45%	14.55%
2011	1.69%	39.01%	25.02%	64.02%	35.98%
KENYA					
2003	11.05%	41.53%	25.83%	67.36%	32.64%
2008-9	9.02%	35.50%	30.51%	66.01%	33.99%
MALAWI					
2004	16.74%	23.93%	34.14%	58.07%	41.93%
2010	14.75%	25.62%	31.66%	57.28%	42.72%
2015-6	13.98%	27.94%	32.28%	60.22%	39.78%
RWANDA					
2005	3.92%	20.57%	35.72%	56.29%	43.71%
2010	4.61%	19.63%	28.75%	48.38%	51.62%
2014-5	4.86%	27.64%	30.16%	57.80%	42.20%
ZAMBIA					
2007	19.14%	23.84%	34.30%	58.14%	41.86%
2013-4	19.50%	26.66%	31.32%	57.99%	42.01%
ZIMBABWE					
2005-6	27.93%	18.57%	28.84%	47.41%	52.59%
2010-1	21.52%	20.85%	31.21%	52.06%	47.94%
2015	19.72%	19.40%	25.52%	44.91%	55.09%
Southern					
LESOTHO					
2004	33.10%	13.95%	27.06%	41.01%	58.99%
2009	35.98%	21.17%	26.31%	47.48%	52.52%
2014	34.99%	19.83%	23.38%	43.22%	56.78%

TABLE 5 PREVALENCE RATES OF HIV DISCORDANT COUPLE TYPES

COUNTRY	DISCORDANT COUPLES OF TOTAL COUPLES	FEMALE POSITIVE COUPLES OF DISCORDANT COUPLES	MALE POSITIVE COUPLES OF DISCORDANT COUPLES
Western			
BURKINA FASO			
2003	1.75%	40.92%	59.08%
2010	1.23%	57.30%	42.70%
GHANA			
2003	2.81%	45.56%	54.44%
2014	2.50%	66.72%	33.28%
GUINEA			
2005	1.55%	40.84%	59.16%
2012	2.31%	55.70%	44.30%
LIBERIA			
2007	1.97%	62.36%	37.64%
2013	2.75%	38.57%	61.43%
MALI			
2006	1.17%	71.52%	28.48%
2012-3	1.73%	50.88%	49.12%
NIGER			
2006	0.99%	38.91%	61.09%
2012	0.27%	40.53%	59.47%
SENEGAL			
2005	0.40%	37.95%	62.05%
2010-1	0.85%	35.97%	64.03%
SIERRA LEONE			
2008	1.75%	57.46%	42.54%
2013	2.56%	46.85%	53.15%
Central			
CAMEROON			
2004	5.10%	52.29%	47.71%
2011	5.92%	53.03%	46.97%
CONGO DR			
2007	1.64%	64.37%	35.63%
2013-4	1.42%	63.06%	36.94%

COUNTRY	DISCORDANT COUPLES OF TOTAL COUPLES	FEMALE POSITIVE COUPLES OF DISCORDANT COUPLES	MALE POSITIVE COUPLES OF DISCORDANT COUPLES
Eastern			
ETHIOPIA			
2005	1.82%	56.39%	43.61%
2011	1.08%	60.93%	39.07%
KENYA			
2003	7.45%	61.66%	38.34%
2008-9	5.95%	53.78%	46.22%
MALAWI			
2004	9.72%	41.21%	58.79%
2010	8.45%	44.73%	55.27%
2015-6	8.42%	46.40%	53.60%
RWANDA			
2005	2.21%	36.54%	63.46%
2010	2.23%	40.57%	59.43%
2014-5	2.81%	47.83%	52.17%
ZAMBIA			
2007	11.13%	41.00%	59.00%
2013-4	11.31%	45.98%	54.02%
ZIMBABWE			
2005-6	13.24%	39.18%	60.82%
2010-1	11.20%	40.05%	59.95%
2015	8.86%	43.19%	56.81%
Southern			
LESOTHO			
2004	13.57%	34.01%	65.99%
2009	17.08%	44.58%	55.42%
2014	15.12%	45.89%	54.11%

TABLE 6 TIME TREND ANALYSIS

COUNTRY	N weighted	FEMALE POSITIVE DISCORDANT COUPLES	MALE POSITIVE DISCORDANT COUPLES	DISCORDANT COUPLES	POSITIVE CONCORDANT COUPLES	NEGATIVE CONCORDANT COUPLES
Western						
BURKINA FASO†[1 2]	7,036					
2003		0.72%	1.03%	1.75%	0.47%	97.78%
2010		0.70%	0.52%	1.23%	**0.18%**	98.59%
GHANA	3,525					
2003		1.28%	1.53%	2.81%	0.99%	96.20%
2014		1.66%	0.83%	2.50%	0.77%	96.73%
GUINEA	4,044					
2005		**0.63%**	0.92%	1.55%	0.40%	**98.04%**
2012		1.29%	1.02%	2.31%	0.84%	96.84%
LIBERIA	3,903					
2007		1.23%	**0.74%**	1.97%	0.27%	97.76%
2013		1.06%	1.69%	2.75%	0.49%	96.76%
MALI	5,054					
2006		0.84%	**0.33%**	1.17%	0.36%	98.47%
2012-3		0.88%	0.85%	1.73%	0.22%	98.06%
NIGER**[1] *[2]	4,546					
2006		0.38%	**0.60%**	**0.99%**	0.17%	**98.84%**
2012		**0.11%**	**0.16%**	**0.27%**	0.17%	**99.56%**
SENEGAL	2,770					
2005		0.15%	0.25%	0.40%	0.42%	99.18%
2010-1		0.31%	0.55%	0.85%	0.35%	98.80%
SIERRA LEONE	5,012					
2008		1.00%	0.74%	1.75%	0.50%	97.75%
2013		1.20%	1.36%	2.56%	0.18%	97.26%
Central						
CAMEROON†[1]	4,858					
2004		2.67%	2.43%	5.10%	2.29%	92.61%
2011		3.14%	2.78%	5.92%	1.46%	92.62%
CONGO DR	6,453					
2007		1.05%	0.58%	1.64%	0.24%	98.13%
2013-4		0.89%	0.52%	1.42%	0.23%	98.35%

COUNTRY	N weighted	FEMALE POSITIVE DISCORDANT COUPLES	MALE POSITIVE DISCORDANT COUPLES	DISCORDANT COUPLES	POSITIVE CONCORDANT COUPLES	NEGATIVE CONCORDANT COUPLES
Eastern						
ETHIOPIA†[1]	8,663					
2005		1.02%	0.79%	1.82%	**0.31%**	97.88%
2011		0.66%	0.42%	1.08%	0.61%	98.31%
KENYA	2,311					
2003		4.59%	2.86%	7.45%	3.61%	88.95%
2008-9		3.20%	2.75%	5.95%	3.06%	90.98%
MALAWI	7,856					
2004		4.01%	**5.72%**	**9.72%**	**7.02%**	**83.26%**
2010		3.78%	4.67%	8.45%	6.30%	85.25%
2015-6		3.91%	4.51%	8.42%	5.56%	86.02%
RWANDA	7,837					
2005		**0.81%**	1.40%	2.21%	**1.71%**	**96.08%**
2010		0.90%	1.32%	2.23%	2.38%	95.39%
2014-5		**1.34%**	1.47%	2.81%	2.05%	95.14%
ZAMBIA	8,816					
2007		4.56%	6.56%	11.13%	8.01%	80.86%
2013-4		5.20%	6.11%	11.31%	8.19%	80.50%
ZIMBABWE ***[1 2]	7,181					
2005-6		**5.19%**	**8.05%**	**13.24%**	**14.69%**	**72.07%**
2010-1		4.49%	6.72%	11.20%	**10.32%**	78.48%
2015		**3.82%**	**5.03%**	**8.86%**	10.86%	**80.28%**
Southern						
LESOTHO	2,057					
2004		**4.62%**	8.96%	**13.57%**	19.53%	66.90%
2009		7.62%	9.46%	17.08%	18.90%	64.02%
2014		6.94%	8.18%	15.12%	19.87%	65.01%

Design-based F test

*** P ≤ .001
** P ≤ .01
* P ≤ .05
† P ≤ .1

[1] model with discordant category
[2] model with gender of index partner categories
bolded numbers are statistically significant

SUPPLEMENTAL FILE (END NOTES)

[1] For this reason, the 2001 survey for Mali and the 2002 survey for Zambia were not able to be included in this study since the de-identified coding of the HIV data made it impossible to merge with the couples data.

[2] The DHS protocol for HIV biomarker data, which involves the informed, voluntary, and anonymous testing of blood spots from a finger prick, is ethically reviewed and must be approved by each host country.

[3] Several studies have compared complete cases analysis (using list-wise deletion) to multiple imputation and Heckman-type selection models for dealing with missing data in terms of accuracy in assessing HIV prevalence using DHS data. These studies show that while standard errors may be more accurate using multiple imputation or Heckman-type selection models, prevalence rate estimates are largely unaffected [50, 51]. Interestingly, Hogan et al. [51] found that complete case analysis as well as conventional imputation both likely underestimate (slightly) national HIV prevalence rates for many countries in SSA compared to Heckman-style selection models. Unfortunately, the Heckman-style selection model utilized by Hogan et al. [51] cannot be used for all of the DHS surveys due to missing selection variables and selection model correlation parameters.

[4] It is important to note that the survey weights used in this study were based on individual response rates and that the response rates for couples are likely to differ, and be lower, compared to individuals. Unfortunately, data on the response rates for the couples included in the DHS surveys was not available, only for the individual men and women who make up the couples. Becker and Sayer (2009) have proposed a couple-based sampling weight for the DHS couples data in order to account for this difference between individual and couple response rates. Since this study used couples data as well as HIV data, DHS protocol was followed and the men's HIV sampling weight was utilized.

[5] The general prevalence rate based on DHS data was 0.7%.

[6] The general prevalence rate based on DHS data was 14.3% (2007) and 13.3% (2013-4).

[7] The general prevalence rate of Guinea, based on DHS data, increased from 1.5% to 1.7% while Rwanda remained constant at 3%.