MODELLING HIV RISK USING SURVEY DATA

USING POPULATION SURVEY DATA TO MODEL DETERMINANTS OF HIV STATUS AND SEXUAL RISK BEHAVIOURS

BY

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Abstract

Sub-Saharan Africa (SSA) continues to be disproportionately burdened by the HIV/AIDS epidemic. In 2011, the region saw 1.8 million new infections, contributing to a prevalence of 4.9% among adults, or 23.5 million people living with HIV/AIDS. This thesis uses data collected by the Demographic and Health Surveys (DHS) to answer questions about risk factors and behaviours associated with HIV acquisition. I use logistic regression models to assess the impact of purported risk factors on sexual behaviours and HIV status. In chapter one, I evaluate the association between respondents' condom use and their awareness of their own "local" epidemic. In chapter two, the association between hormonal contraceptives and risk of HIV infection is examined. The purpose of these analyses is to contribute to the body of literature that identifies factors that mitigate or contribute to risk for HIV infection, and help to inform public health policy.

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This thesis is dedicated to those who fought and continue to fight: for research, for rights, for a treatment and a cure

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HIV disclosure, stigma and risk behaviour: Regression analysis of condom use in sub-Saharan Africa

HIV disclosure, stigma and risk behaviour: Regression analysis of condom use in sub-Saharan Africa

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1.1 Abstract

Condoms are a highly effective yet underutilized tool in the effort to prevent HIV transmission. Many socio-demographic factors have been linked to increased uptake of condom use, yet the effect of knowing someone infected with HIV on a person's risk behaviour is not clear. We model the effects of knowing a person with HIV on condom use at last sex, in the context of sociodemographic and other HIV-awareness variables using data from seven sub-Saharan African countries between 2005 and 2009. We find that knowing a person with HIV is significantly associated with increased probability of condom use at last sex. In addition, using condoms was significantly associated with correct beliefs about HIV/AIDS, higher education, increased wealth, lower age, urban residence, marital status, religion, and the type of sex partner at last sex. These findings suggest that disclosure of HIV status may contribute to population-level protective effects, and highlight an additional reason for public health to be concerned about HIV-related stigma.

1.2 Introduction

Infectious disease prevention research extends well beyond the relationship between host and pathogen. Human behavior is often critical to understanding transmission [13]. There is ample evidence that knowledge of an outbreak can change behavior: measles outbreaks correlate with an uptake in the MMR vaccine[13], the SARS outbreak in China resulted in many people who stayed home or wore face masks while outdoors [13], and there is evidence that knowing a person with HIV/AIDS (PWHA) results in increased condom use [14, 24, 17]. Understanding and influencing human

behavior is particularly important for HIV prevention, since there is currently no cure and no effective vaccine.

In Southern and Eastern Africa, HIV/AIDS prevalence frequently exceeds 20% of the population, with 1.9 million new cases in 2010 [45]. HIV is associated with tremendous stigma in many or most communities: incurable, potentially fatal, and burdened with misconceptions, HIV may be the most stigmatized disease of our time [40]. HIV-related stigma and discrimination create barriers at every level of HIV prevention, treatment and care [22]. While fear of HIV may promote some protective behaviors, it also silences critical conversations and promotes concealment of HIV status among individuals and populations [40]. At the level of the population, HIV-related stigma may drive condom use down; Individuals are unlikely to use condoms if they cannot openly discuss or suggest condoms, for fear of implying that they or their partner may be infected [24].

There are numerous opportunities to prevent the transmission of HIV both by changing human risk behaviors and through the use of pharmaceuticals. The two main human behaviors that can slow the spread of HIV are using barrier methods and having fewer sexual partners, especially fewer concurrent partners. Barrier methods (including traditional and female condoms) are highly effective at curbing transmission. When used correctly and consistently, condoms can reduce transmission by 90-100% [44]. However, many populations are reticent about using condoms and use remains low [7].

Sexual concurrency has been put forth as an explanation for the high levels of HIV prevalence in sub-Saharan Africa [41]. Campaigns aimed at reducing sexual concurrency have had some success reducing the spread of HIV. A notable example

was the "zero-grazing" campaign in Uganda where the number of reported extra-marital and extra-couple partners was reduced, and national HIV incidence dropped. However, in the years since the campaign ended, concurrency and HIV incidence are again on the rise [41].

Another behavioral change that has the potential to slow the HIV/AIDS epidemic is refraining from sex entirely, or abstinence. Abstinence can halt sexual transmission entirely. However, abstinence is not a viable long-term prevention method for most adults.

Pharmaceutical methods may be used to prevent HIV transmission. Uninfected individuals may use anti-retrovirals (ARVs) to reduce the risk of sero-conversion, in the event of exposure to the virus. These approaches, known as pre- or post-exposure prophylaxis (PreP or PeP), requires individuals take ARVs before or after exposure, respectively. Neither method is 100% effective when used correctly, and timing and drug adherence drastically reduce efficacy [8]. Infected individuals may engage in "treatment as prevention" (TasP) where infected individuals take ARVs to lower their viral load such that transmission is nearly impossible . However, in limited resource settings such as sub-Saharan Africa, ARVs are expensive and such interventions may be cost prohibitive.

Given the cost of pharmaceutical approaches, the ineffectiveness of abstinence campaigns, and the persistence of sexual concurrency, increased condom use should be an attractive behavioral intervention to public health officials. Despite being cheap, readily available, and effective at preventing HIV transmission, they are under utilized in many high-prevalence regions and high-risk groups in Africa [44].

Condom use remains low among many high risk groups [1, 33] while HIV prevalence and incidence in sub-Saharan Africa are alarmingly high [45], highlighting major opportunities for condom promotion. Although a great deal of funding has been dedicated to condom promotion, negative attitudes toward condoms persist in many regions of SSA [44]. Such low rates of reported or intended condom use suggest that better efforts can be made to increase the uptake of condoms as an HIV preventative method. Increased condom use has been consistently associated with numerous factors including: higher wealth, high socio-economic status, age, urban residence, higher education, type of sex partner, marital status male gender, and religion [7, 23, 6, 33, 49]. Despite the presence of factors that may be associated with reduced sexual risk behaviour, there are numerous barriers to promoting condom use among the populations most at risk for HIV.

There are a multiple of reasons why condom use has not increased more broadly, including low perceived risk, personal preference, and a variety of barriers preventing people from using condoms [7, 25]. One of the barriers that drives condom use down is the stigma associated with buying and using condoms; People fail to buy or use condoms because others may assume that either they are or their partner is HIV positive. Monogamous partners may interpret a request for condom use as an indication that their partner suspects them of infidelity, or that the other partner has been unfaithful [7]. Women especially may face difficulties in negotiating condom use with partners; low sexual autonomy among women is associated with inconsistent use of condoms [3, 25, 35]. For these reasons, it is important to evaluate men and women separately when attempting to determine the factors that limit or encourage condom use.

An additional reason that condom use remains low among some populations is a lack of perceived risk of HIV. Perceived vulnerability to HIV has been shown to be associated with increased condom use among youth in Ghana [1] and Madagascar [28]. Not only must individuals be aware of methods to reduce risk, they must have positive attitudes regarding the efficacy of condoms [19] and their own self-efficacy with respect to using them [1]. Consequently, if individuals are aware of methods of prevention and perceived risk is what is preventing them form making behavioral changes, then we would expect that knowing a PWHA would increase their perceived risk and they would be more likely to use condoms or other barrier methods.

Other studies have attempted to determine the effect of personal experience with HIV/AIDS on condom use or other sexual risk behaviors, obtaining inconsistent results: some studies found that knowing a PWHA is associated with a decrease in risk behavior [14, 24, 17]; while others failed to find such a relationship [19, 6, 34]. However, comparing the results of these studies is problematic, as some include only men [24], others only women [6], and several limit their analysis to youth [34, 18, 7, 19]. Deeper problems with these studies may be the root of inconsistent findings; sexual risk behaviours, including condom use, are highly confounded with partner type [6, 7], marital status [24], and age [43, 49, 7, 6], and in the context of HIV prevention, condom use is dependent on education [18], and accurate AIDS and condom knowledge [6].

The objectives of this study are to determine the effects on risk behavior of knowing a PWHA, which can be seen as a proxy for awareness of the epidemic and percieved self risk. We analyze the effect of knowing a PWHA on condom use across multiple countries in sub-Saharan Africa, for both men and women, while taking into

account HIV and condom knowledge using the Demographic Health Survey (DHS) data set. The DHS (`www.measuredhs.com`) are a collection of nationally representative databases which assess gender, socio-economic variables, vaccination health and disease. The surveys are concerned with population health trends in 85 developing countries; each includes hundreds of response variables and thousands of respondents.

To date, no multi-national analyses have investigated the effect of knowing PWHAs while taking into account the way HIV knowledge must mediate this factor. We hypothesize that lack of statistical power, and/or failure to account for the confounds described above may account for other studies' failure to observe significance. We previously applied the modelling approach used here to each of the 7 countries used in this study, and found weakly positive relationships between condom use and knowing a PWHA for both genders in all 7 countries (See Appendix). We hypothesised that the combined actions of pooling respondents and incorporating critical confounds would permit us to observe a significant correlation between knowing a PWHA and condom use.

The present study pools both men's and women's from seven countries across sub-Saharan Africa. Delineating the effects of knowing someone with HIV is potentially valuable to planning prevention strategies that focus on increasing disclosure and reducing stigma. Moreover, understanding the interplay of individuals awareness of their local epidemic and their own risk behaviors is valuable to understanding the role that stigma plays in the HIV epidemic.

Table 1.1: Summary of predictors used in analysis

Variable	Levels	n	percentage
Country	Kenya	8412	14.9
	Lesotho	5870	10.4
	Namibia	9063	16.0
	Senegal	9619	17.0
	Swaziland	5293	9.4
	Uganda	7960	17.1
	Zimbabwe	10262	18.2
Gender	Male	15252	27.0
	Female	41227	73.0
Type of residence	Urban	18972	33.6
	Rural	37507	66.4
Highest educational level	None	11119	19.7
	Primary	21850	38.7
	Secondary	20151	35.7
	Higher	3359	5.9
Religion	None/Other	4001	7.1
	Catholic/Orthodox	11308	20.0
	Other Christian	29658	52.5
	Muslim	11512	20.3
Marital Status	Never married	11406	20.2
	Currently married	41622	73.7
	Formerly married	3451	6.1
People can avoid AIDS by using condoms	Yes	45938	81.3
	No	10541	18.7
Last intercourse used condom	Yes	12397	21.9
	No	44082	78.1
A person with HIV/AIDS may look healthy	Yes	48112	85.2
	No/DK	8367	14.8
Relationship to last sex partner	Cohabiting partner	41914	74.2
	Non-cohabiting partner	12716	22.5
	Other/casual partner	1772	3.1
	Commercial sex worker	77	.13
Knows someone with HIV/AIDS	Yes	26675	47.2
	No	29804	52.7
	Total Respondents	56 479	100

1.3 Methods

We used data from DHS surveys conducted from 2005-2009 in sub-Saharan African countries. Criteria for inclusion in the study were: presence of variables of interest (listed in Table 1), non-trivial HIV prevalence. Men's and women's responses from Kenya (2008-09), Lesotho (2009), Namibia, (2006-07), Senegal (2005), Swaziland (2006-07), Uganda (2006), and Zimbabwe (2005-06) were compiled (n=91,191). Individuals who have never had sex (n=17,698), or who had not had sex in the previous twelve months (n=11,213) were excluded from analysis. Respondents with NA responses to any other variable of interest were excluded, resulting in 56 479 respondents included in the analysis (See Figure 1.1). Variables were selected from DHS surveys [10] to best approximate those established to be significant predictors in previous research.

We use a mixed effects, logistic regression model, using the glmer function in. The response variable in this model is the binary outcome (Yes/No) of the variable "Was a condom used at your last sexual intercourse?". The model sets cluster, province and country as random effects to account for correlations between individuals from the same geographic areas and ethnicities.

Socio-demographic predictors were selected for use as fixed effects based on the literature cited above, and include: age, wealth, marital status, religion, gender, residence, education, and the type of sex partner at last intercourse. We used 4-knot splines to model respondents' age and the DHS' wealth index variable, which is a composite, standardized measure of a household's cumulative standard of living. HIV-awareness predictors were incorporated with the aim of testing the hypotheses that awareness of HIV promotes condom use. The variable"Knows someone with

HIV/AIDS" reflects whether the respondent indicated they know or knew someone who has or has died of the "virus that causes AIDS". Respondents awareness of their own vulnerability to HIV was tested, using predictors "Knows condoms protect from HIV", "Persons with HIV/AIDS may look healthy". We also tested for an interaction between these "Knows someone with HIV/AIDS" and "Knows condoms protect from HIV", hypothesizing an additive effect of these two predictors.

1.4 Results

In this thesis, 56,479 sexually active respondents were included in the analysis (Figure 1.1). Condom use at last sex was generally low, with 21.9% of respondents reporting condom use at last sex, and ranged from rates as low as 7.8% (Ugandan women) to the highest reported use, 57% among men in Namibia. Condom use was higher among men than women in every country except Senegal.

HIV prevalence in surveyed countries ranged from among the lowest in all of Africa to the highest in the world. HIV prevalences at the time of survey were: Kenya (6.3%); Lesotho (23.6%); Namibia (14.6%); Senegal (0.8%); Swaziland (25.8%); Uganda (6.3%); and Zimbabwe (17.8%) [45]. As hypothesized, knowing a person with HIV is associated with greater probability of condom use at last sexual intercourse ($p < 0.01$). In addition, affirmative responses to "Knows condoms protect from HIV/AIDS" and "Knows someone with HIV/AIDS may look healthy" are also positively associated with condom use ($p < 0.001$ and $p < 0.01$, respectively). The interaction between condom knowledge and knowing a person with HIV/AIDS was non-signficant, and plots shown here are based on models that do not include the interaction term.

All eight socio-demographic predictors were significantly associated with the probability of condom use at last sex ($p < 0.001$). Figure 1.3 illustrates the weighted averages associated with the levels of categorical variables. Figure 1.4 shows the relationships between continuous variables (wealth and age) and condom use. As observed in previous studies, increased condom use was associated with higher education, lower age, greater wealth, urban residence, type of religion, the type of partner at last sex, and being single. In addition, being male was associated with greater condom use.

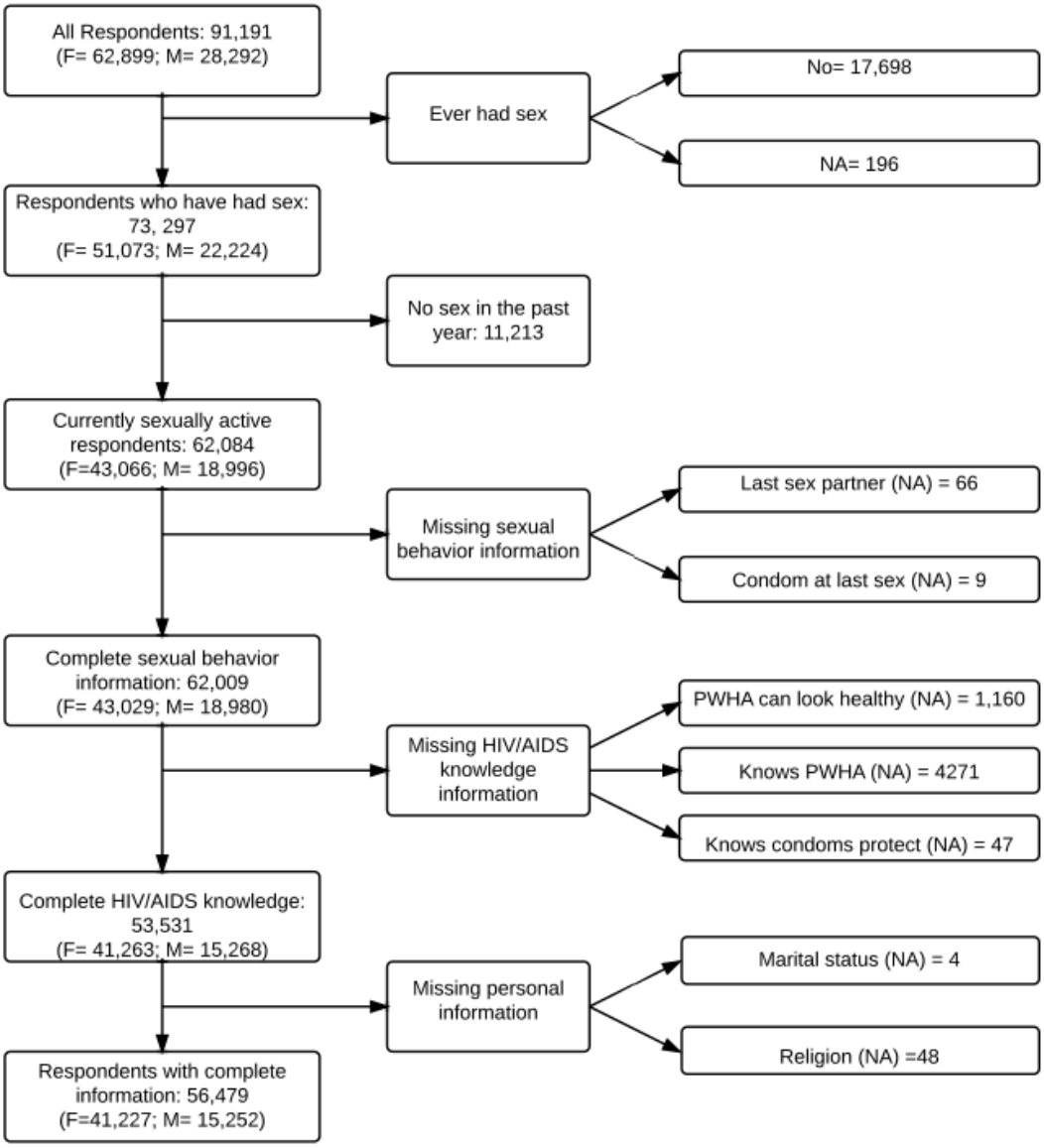

Figure 1.1: Schematic representation of respondent selection. Respondents were eliminated in absence of sexual behaviour or based on other missing information

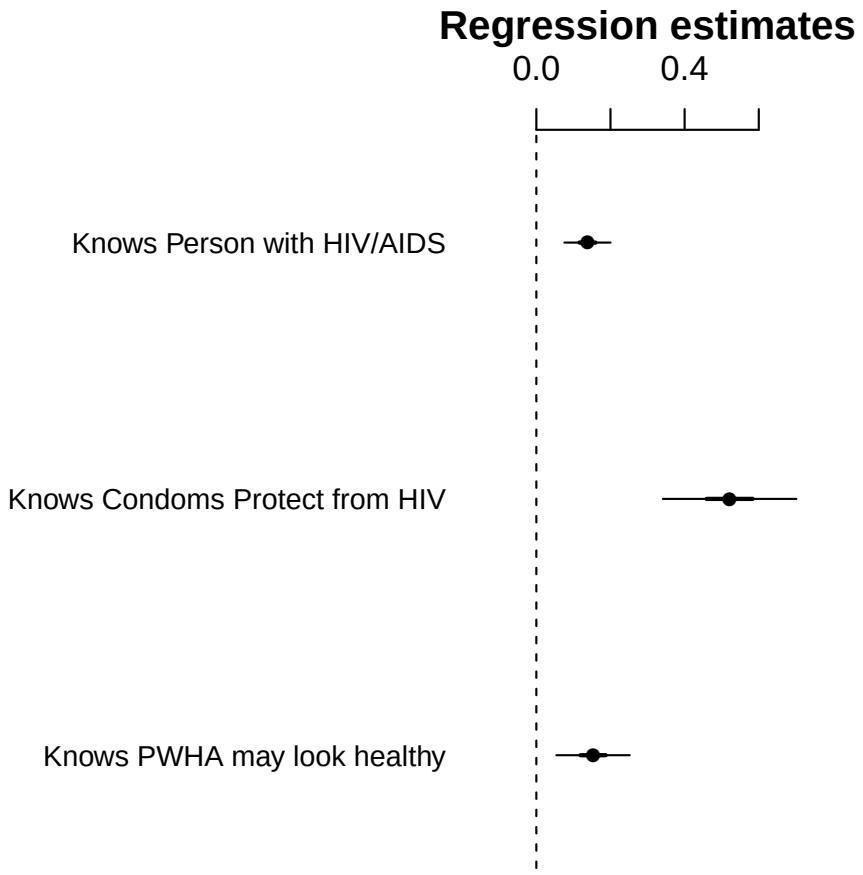

Figure 1.2: Coeffecients of regression estimates for HIV/AIDS awareness factors. Estimates for factors "Knows person with HIV/AIDS", "Knows condoms protect from HIV/AIDS", "Knows persons with HIV/AIDS may look healthy" are all positively associated with condom use, $p < 0.01$

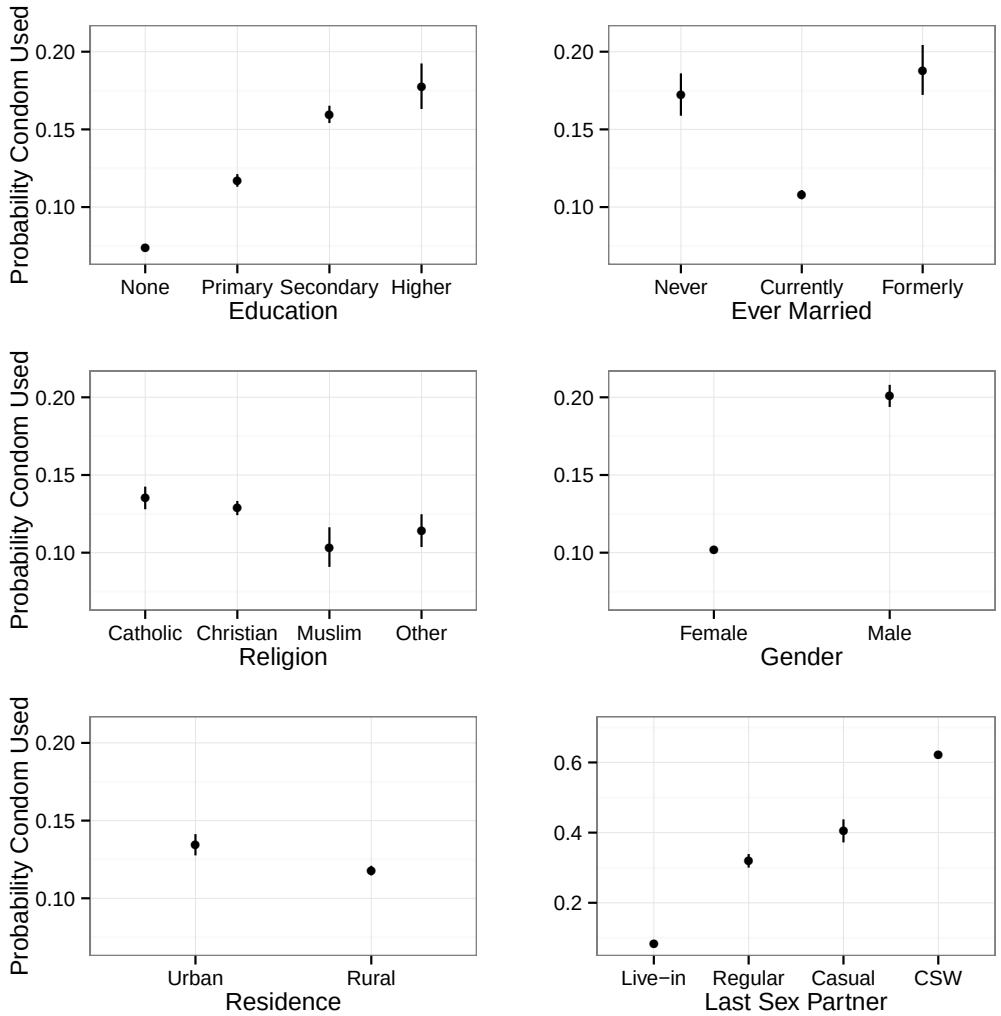

Figure 1.3: Weighted averages associated with model predictors of condom use. All figures shown on same scale, with exception of bottom right, "Last Sex Partner". All factors are significant ($p < 0.001$)

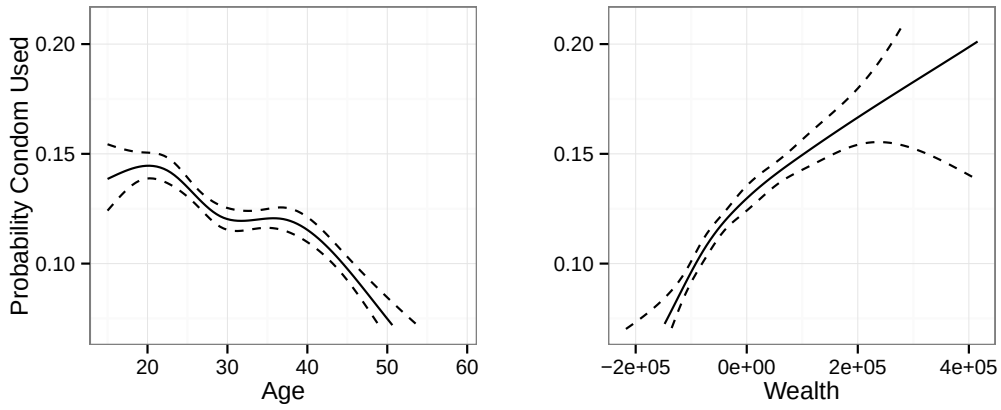

Figure 1.4: Splined values of age and wealth as predictors of condom use. Greater wealth and lower age are associated with higher levels of condom use ($p < 0.001$).

1.5 Discussion

The analysis here represents data collected in seven countries from 2005 to 2009, and finds a positive relationship between reported condom used and knowing a person with HIV/AIDS. Previous reports of individual countries have found contradictory and inconclusive relationships between these variables. We suggest a lack of power may explain the inconsistency in the literature.

People share values, experiences, and demographic characteristics with friends and associates. Some of these characteristics are themselves risk factors for exposure to HIV (i.e. poor knowledge of condoms, likelihood to engage in transactional sex). Multi-colinearity is a fundamental problem when asking a question as we do here; For this reason, it may be difficult to detect increased likelihood of condom use associated with knowing a person with HIV/AIDS, because that effect may be masked by the characteristics that make one likely to know a person with HIV. Neglecting to include possible confounds, such as low condom knowledge among groups already vulnerable to HIV, may have contributed to some of the previous analyses' failure to observe a relationship between knowing PWHA and condom use.

The literature on the factors that predict condom use was critical to informing the design of this model. However, because the DHS data is derived from surveys not designed to inform our specific question, we were challenged to use proxies for some factors, and exclude others. The response variable, "Condom used at last sex", is the best approximation of overall condom use that could be derived from the DHS data. Other measures of condom use were considered; the survey item that asks respondents about current contraception may contain "condom" as a response, but information regarding recency or regularity is impossible to ascertain from this item.

The large discrepancy between male and female condom use appears paradoxical, since the vast majority of last sexual encounters are assumed to be heterosexual. However, transactional sex is a major component of sexual behaviour in SSA [3]. In this dataset, men report substantially higher condom use when intercourse was with a sex worker (Figure 1.3, bottom right). In a situation where relatively few (female) commercial sex workers engage in protected intercourse with relatively large numbers of male clients, we can expect to see higher reported frequencies of protected sex among men than among women. In addition, the recruitment and sampling methods of the DHS may systematically exclude female sex workers, but not their male clients.

These findings highlight the potential public health impact of evaluating and diminishing HIV-related stigma. Disclosure of HIV+ status by infected individuals in these countries appears to have positively affected their peers' condom use. The positive effect of knowing someone with HIV cannot be taken without considering necessary co -predictors however; correct knowledge about one's risk and ability to protect oneself were both significant predictors of increased condom use as well, and as such HIV/AIDS education remains a critical component to increasing condom use in SSA.

Chapter 2

Do hormonal contraceptives contribute to HIV risk? Multi-level modeling of DHS data

2.1 Abstract

There are over 14 million women using hormonal contraceptives (HC) in sub-Saharan Africa (SSA), a region with the highest HIV prevalence in the world. These women face inordinate risk of HIV infection, driven by biological, social, and economic factors. There is some ecological and biological evidence for increased HIV risk associated with HC. Determining whether HC increases risk of HIV acquisition or transmission is of great value because women of reproductive age are among the highest risk groups for HIV, and the main users of HC. Further, HC is important to women's reproductive autonomy and contributes substantially to reducing unwanted pregnancies.

The analysis involves multilevel logistic regression analysis applied to pooled Demographic and Health Surveys data from 10 countries in sub-Saharan Africa conducted during 2003-2009. Predictors of HIV status include socio-demographic, sexual and reproductive risk factors, including any history of use of HC. Men's and women's data are modeled separately. An "aggregate" model, with all forms of HC pooled, tests for an association between any history of HC use and HIV status. An additional analysis is conducted where injectable, oral and implanted HC are allowed to be independent predictors of HIV status.

We find that use of any HC is positively, significantly associated with women's HIV risk in the simplest (naive) models, but this effect disappears in more complex versions of the model where social, behavioural and other confounding risk factors are included. Modeling by type of HC shows that oral HC is is positively associated with HIV in naive models for both men and women, but this effect disappears in more complex models. There is siginficant risk of HIV associated with injectable HC in the women's naive and full models. This analysis finds HC is not associated with increased risk for men.

These findings suggest that there may be a relationship between injectable HC use and increase HIV risk, but no increases in risk are associated with oral contraceptives or men's exposure via their partners' use of HC.

2.2 Introduction

An estimated 23.5 million people in sub-Saharan Africa (SSA) are living with HIV, 58% of whom are women and girls [46]. Women's HIV prevalence exceeds men's in nearly every country in sub-Saharan Africa, and curtailing women's HIV incidence is

a major priority for public health [46].

Women's risk for HIV infections is driven by biological, social, and economic factors that are especially prominent in the poorer nations of SSA. Evidence suggests women are subject to greater biological susceptibility (per contact transmission) when exposed to HIV through sexual intercourse, with some estimates of male-to-female transmission doubling that of female-to-male transmission [4]. Social mores and structural violence may reduce some women's perceived or actual ability to determine whether she uses a condom. Women tend to report lower condom use than men in general, posing an interesting question about who their male partners are using condoms with. Women in several African regions report difficulty negotiating safe sex due to power imbalances in their relationships, including threats of physical violence [3, 25, 35]. Transactional sex, or sex in exchange for money, food, protection or other services, is especially common where women are the poorest, least educated members of their community. Female sex workers are 13.5 times more likely to have HIV than are other women [46]. Numerous factors are already working in tandem, making women disproportionately susceptible to HIV infection. Decreasing the impact of these gender-associated risk factors is critical to reducing HIV incidence.

Women's HIV burden in SSA is driven by several factors that act to increase risk and decrease autonomy. Over 14 million women in SSA use hormonal contraceptives (HC), 60% of whom use injectable forms [32]. Reports have begun to accumulate indicating that HC contributes to increasing women's susceptibility, and may also increase transmission from HIV-positive women to negative partners. However, there is little agreement on the issue, as other studies report no effect of HC on HIV risk.

Biological plausibility of the potential for HC to elevate transmission of HIV has

been evaluated in several reviews [16, 42]. Progesterone-based contraceptives have been shown to increase susceptibility to simian immunodeficiency virus (SIV) infection in rhesus macaques, accelerate disease progression, and increase viral shedding in vaginal tissue. However, treatment with estrogen-type contraceptives has been associated with a protective effect in macaques, and there is even less consensus on the biological effects of either hormone on humans [16, 42].

Numerous ecological studies, beginning shortly after the virus was identified [36] have attempted to elucidate whether HC increases women's and/or men's susceptibility to HIV infection. However, researchers have and continue to produce conflicting results. Many authors have found a positive association with oral and injectable HC [2, 15, 36], or only injectable forms [47], while others have failed to find any effect[39, 31, 30], and others still have found conflicting results within their own study [38].

Similarly, research has sought to demonstrate a link between HC use and women's HIV progression, suggesting it may lead to increased female-to-male transmission. A review of the the evidence on female-to-male transmission describes a shortage of direct evidence that support the claim the HC use increases transmissibility, finding that increased viral load was not observed in women using HC in nearly all studies reviewed, and that more research on this phenomenon is needed [37].

There are several problems inherent to this research question. There is an enormous potential for confounding condom use (or lack thereof) when evaluating HC use, and reports unsurprisingly find that HC users report less condom use [47]. Many of the "prospective cohort" studies of HC are in fact piggy-backing on other cohort studies or randomised controlled trials (RCTs), whose principal aim is to study the

impact of herpes simplex treatment or microbicides on women's HIV incidence. As such, these women are not necessarily representative of general population, and there is the possibility of drug interactions and infection comorbidity are contributing to observed effects. In all of these studies, HC users are self-selected, and they may differ from non-users in important ways that are not captured by the studies' covariates. Because HC is a personal, long-term, and important choice for most women, it is unrealistic to plan to resolve these issues with an RCT. As a consequence, the World Health Organisation has called for additional research into the potential role of HC in women's and men's HIV risk [48].

The objectives of this study are to model population survey data, collected by the Demographic and Health Surveys, to assess the risk of HIV infection associated with using HC in men and women.

2.3 Methods

We used a mixed-effects, generalized linear regression model, using the glmer function in R. The response variable in this analysis is HIV status, as determined by DHS-administered ELISA testing. We modelled men and women separately, using data for both groups from 11 DHS surveys: Burkina Faso, 2003, Cameroon, 2004, Ethiopia, 2005, Ghana, 2003, Guinea, 2005, Kenya, 2008-09, Kenya, 2003, Malawi, 2004, Mali, 2006, Niger, 2006, Zambia, 2007, and Zimbabwe, 2005-06.

The main predictor of interest in this analysis is ever having used hormonal contraceptives. The predictor "ever any HC" was an aggregate of oral, injectable and implanted hormonal contraceptives and was used in the main analysis. A secondary analysis was conducted where the three HC types were allowed to be independent

predictors of HIV status. We constructed a multi-level model that built on a naive model. The naive model included only the HC variables and random effects. The models became increasingly complex as socio-demographic, sexual risk, and reproductive risk factors were included, forming the "base", "sex risk" and "full" models, respectively. Socio-demographic predictors were included in the model based on literature that identified risk factors associated with HIV positive status in sub-Saharan Africa. Urban residence and being unmarried have been associated with increased risk of HIV [26], while age, wealth religion, and education have complex, context dependent roles in predicting HIV risk [11, 12, 26]. We used 4-knot splines for the continuous age and wealth variables to allow for the non-linear patterns observed in other studies.

Sexual behaviour and reproductive history were included in the models as well, chosen in part based on other models and HIV risk literature [2, 15, 20, 21, 27, 29, 30, 38, 47], and partly in support of our hypothesis. Because we believe the potential effects of HC may be seriously confounded with sexual risk behaviours and medical care associated with pregnancy and childbirth, we chose to include the following sexual risk factors: history of ever using condoms, years of sexual activity, and having had an STI-associated genital ulcer in the past 12 months. In addition, the number of children and history of pregnancy terminations were included to take into account the risks of HIV exposure associated with pregnancy, childbirth and related medical care in SSA.

2.4 Results

HIV prevalence among the pooled survey respondents included in this analysis (N= 37906 women, 9033 men) was 8.9% among women and 6.3% among men. Thirty three percent of the women and 28% of men reported ever having used any form of HC.

The effect of aggregate HC use on women's HIV risk is positive and highly significant in the naive model, but becomes negatively associated with risk of HIV infection in the base and sexual risk models, and is non-significant in the full model. When broken down into HC type, the naive model shows a positive association between HIV infection and both injectable and oral HC (oral: $p < 0.05$; injectable: $p < 0.001$) (Figure 2.1). This relationship becomes negative or non-significant in all three of the more complex models for oral contraceptive use. The HIV risk for injectable contraceptive use remains positive in three additional models, but the effect is significant only for the full model ($p < 0.05$). The effects of implanted contraceptives were small with large confidence intervals, likely due to low power (N=558); coefficients for implanted HC were not included in Figures 2.1 & 2.2 for this reason.

The effect of aggregate HC on men's risk for HIV followed a similar pattern to the women's data: Use of any HC was significantly, positively associated with HIV infection in the naive model ($p < 0.05$), but became negatively associated with HIV in more complex models, demonstrating significant effect sizes in two (sex risk and full) of the three models. Looking at HC type separately, we observed non-significant relationships between HIV status and both oral and injectable HC in the null models, and a significant, negative relationship in all three of the increasingly complex models for both types of HC (Figure 2.2).

The effects of the socio-demographic, sexual and reproductive risk factors yield interesting results (Figures 2.3-2.8). HIV-positive status is significantly associated with urban residence in women ($p < 0.001$), but has only a weak positive association among men. Intermediate (i.e. "Primary" and "Secondary") levels of education are associated with the highest rates of HIV in both men and women. Being formerly married is the riskiest marital status for both men and women, however, being never married is also highly risky for women while it appears protective for men (Figures 3 & 4). Wealth is a complex predictor as demonstrated in earlier reports; for women, it is most risky to be very poor or to be of average income, though confidence intervals become very large at the extreme levels of wealth (Figure 2.5). For men, HIV risk increases nearly steadily as wealth does. HIV risk peaks at mid-ranges for age, though the peak is somewhat earlier for men, lending support to the picture of young women having sex with older men in many countries.

Several of the sexual and reproductive risk factors showed interesting trends. Having had an recent STI ulcer was significant for both sexes but especially predictive of HIV infection for women ($p < 0.001$). While years of sexual activity drastically increased women's risk (Figure 2.7) and was highly significant ($p < 0.001$), the effect on men's risk was nearly non-existent (Figure 8, p=0.82). A history of condom use was associated with being HIV positive in both sexes ($p < 0.001$).

2.5 Discussion

Our models show that simple models find a positive effect of HC on HIV risk, an effect that disappears when important confounds are accounted for. While previous research has put forth biological mechanisms for increased risk associated with HC

use, we argue that behavioural factors best explain our observed results. Among women, we observe a negative association between oral HC and HIV+ status, but cannot rule out a positive relationship between injectable HC and HIV risk. Among men, all models more complex than the naive observe a negative association between history of HC and HIV+ status.

Oral HC is associated with lower risk of HIV the complex versions of the women' models, leaving one to ask, "Why would oral HC be protective?". It is quite possible that women who possess the skills, autonomy and independence to control their own reproduction may have other forms of empowerment, not captured by the factors included here. Such empowerment may contribute to sexual autonomy (demanding the use of a condom, refusing unwanted sexual advances, etc.) or other behaviours that protect from HIV.

If there is indeed increased risk associated with injectable HC, it's possible that at least part of that risk is due to the method of administering the hormones, rather than the hormones themselves. Contaminated syringes pose a high risk of transmission [] and may be especially common in regions where new syringes aren't consistently available. It is also possible that paternalistic medical practice may have a strong influence on the choice of HC type; doctors may preferentially prescribe injectable HC to women who they perceive to be less likely to adhere to an oral HC regimen.

Finally, men's risk for HIV is negatively associated with reporting that their partner has used either oral or injectable HC. This "protective" effect may be an artifact of knowing enough about their partner(s) to confidently answer questions about her contraceptive use. In any case, these findings do not support the hypothesis that HC use increases female-to-male transmission risk.

Working with DHS data presents several limitations. The principle limitation to this study is the difficulty interpreting causation from cross-sectional data. While some predictors are certainly not caused by HIV status (i.e. age, gender, religion) others may be subtly influenced (wealth, education, marital status) and others are quite possibly highly confounded (STI ulcer in past year, ever used condoms). We chose our contraceptive variables with this in mind, opting for the variable "Ever used method" which encompasses past and current use, rather than current use, since recent choices in contraceptives may be in response to one's HIV infection.

DHS data is self-reported, collected via face-to-face interviews, often in the proximity of respondents' spouse, family members or peers. Respondents may lie or decline answering some questions if they fear a breach of confidentiality. Even if confidentiality is assured, self-report is susceptible to "social desirability bias", or the tendency to give answers that one believes are desirable or socially acceptable[9].

Respondents are excluded from this analysis due to one or more "NA" responses. It is possible that NAs are not randomly distributed but systematically exclude individuals with a particular response type; for example, individuals who know or suspect they are infected with HIV may decline the DHS' HIV test.

Finally, the DHS surveys were not written or conducted to answer the specific research questions posed here. As such, we are limited by the variables available to us when attempting to account for a factor we believe to be important to the analysis. This is of particular note with respect to attempting to quantify sexual behaviour and contraceptive use.

Despite these limitations, the DHS data offers several strengths: we are able to pool data over several time points and geographical regions, resulting in excellent

statistical power and generalizability.

These findings contribute to the growing literature on men's and women's HIV risk associated with HC use. Our results suggest that there is no increased risk associated with oral HC for men or women, nor any associated with injectable HC for men. Our finding that injectable HC may contribute to HIV risk in women is in line with trends in this literature that find injectable HC to be solely or more strongly associated with HIV risk [15, 47]. These findings should, however, be interpreted carefully, as mathematical modelling suggests the public health risk of advising against HC is only outweighed if the risk of using HC is estimated to large [5], a criterion that this analysis does not satisfy.

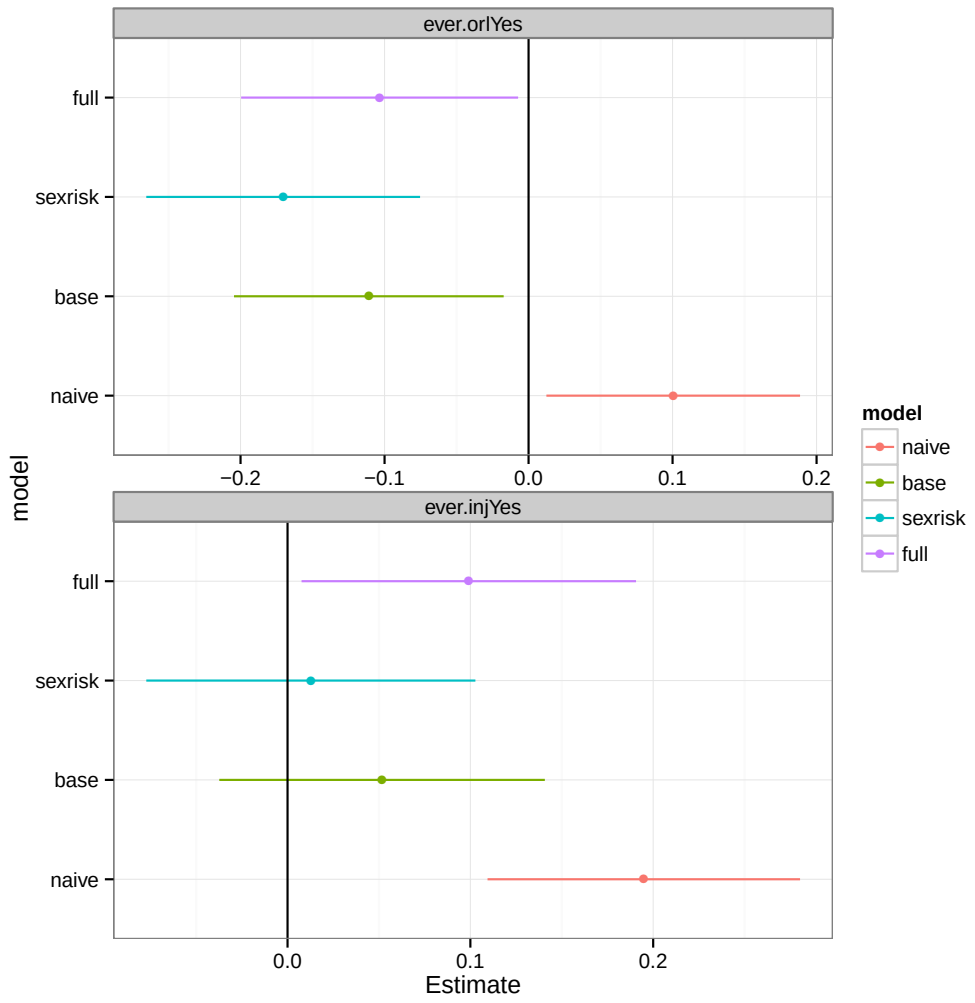

Figure 2.1: Coeffecients of regression estimates: Top: Effect of oral contraceptives on women's risk of being HIV positive. Oral contraceptives appear to increase risk in naive model but become protective in more complex models. Bottom: Effect of injectable contraceptives on women's risk of being HIV positive. Estimates for all models are positive, but only naive and full models are significantly associated with being HIV positive.

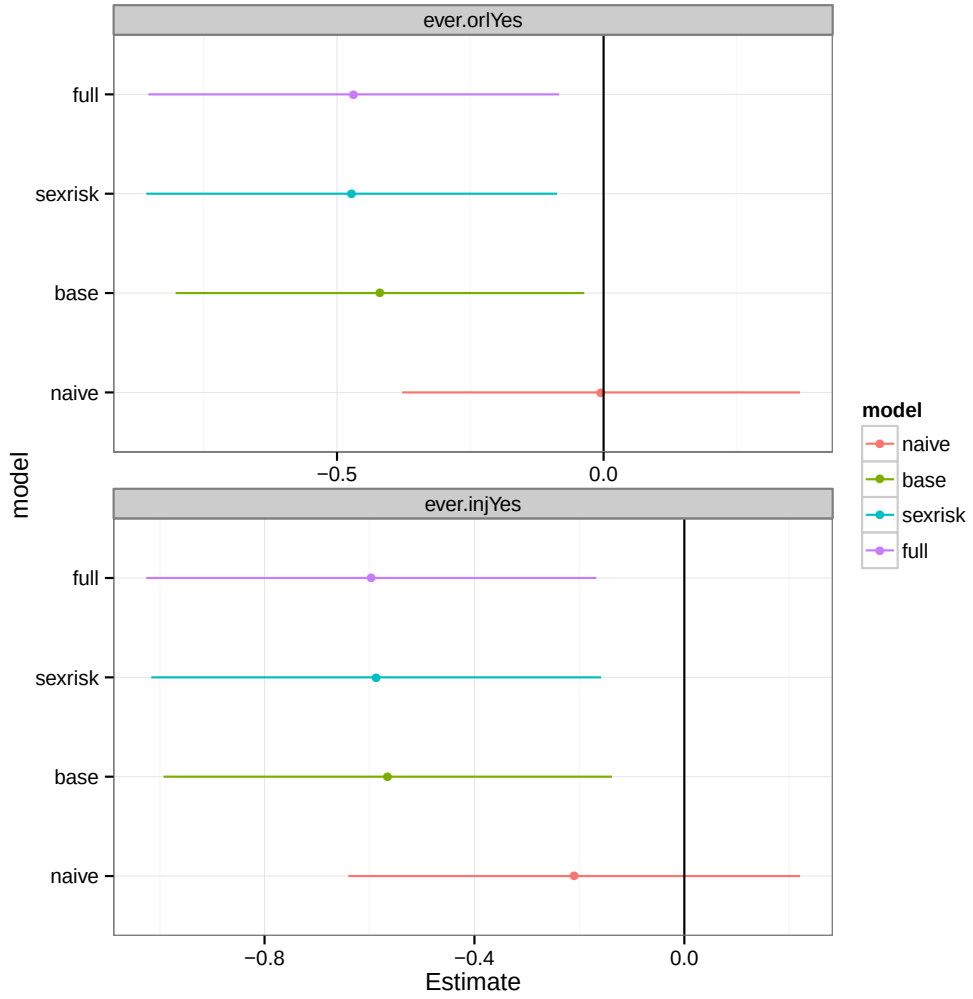

Figure 2.2: Coeffecients of regression estimates: Top Effect of oral contraceptive use on men's HIV risk. Bottom: Effect of injectable contraceptives on men's risk of being HIV positive. Estimates are negative in all models but the naive models.

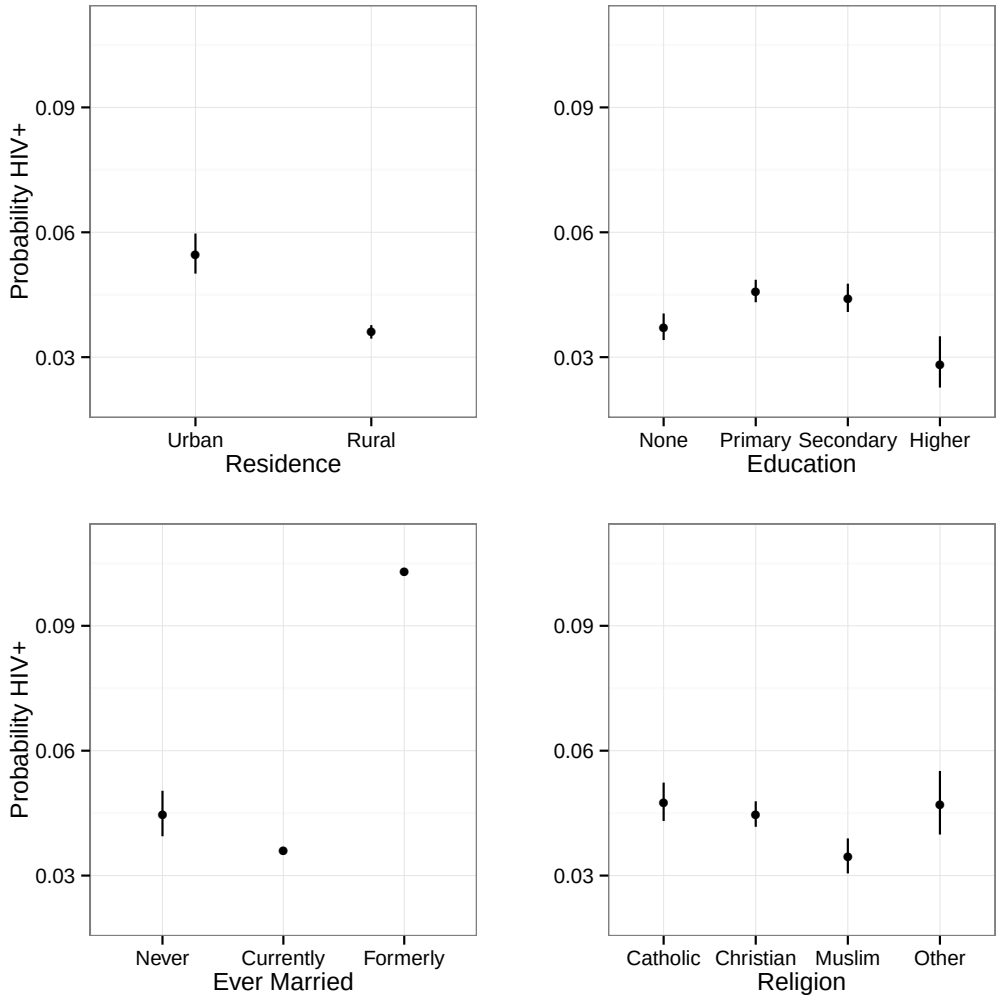

Figure 2.3: Prediction plots of regression model: Women's HIV risk as predicted by sociodemographic predictors

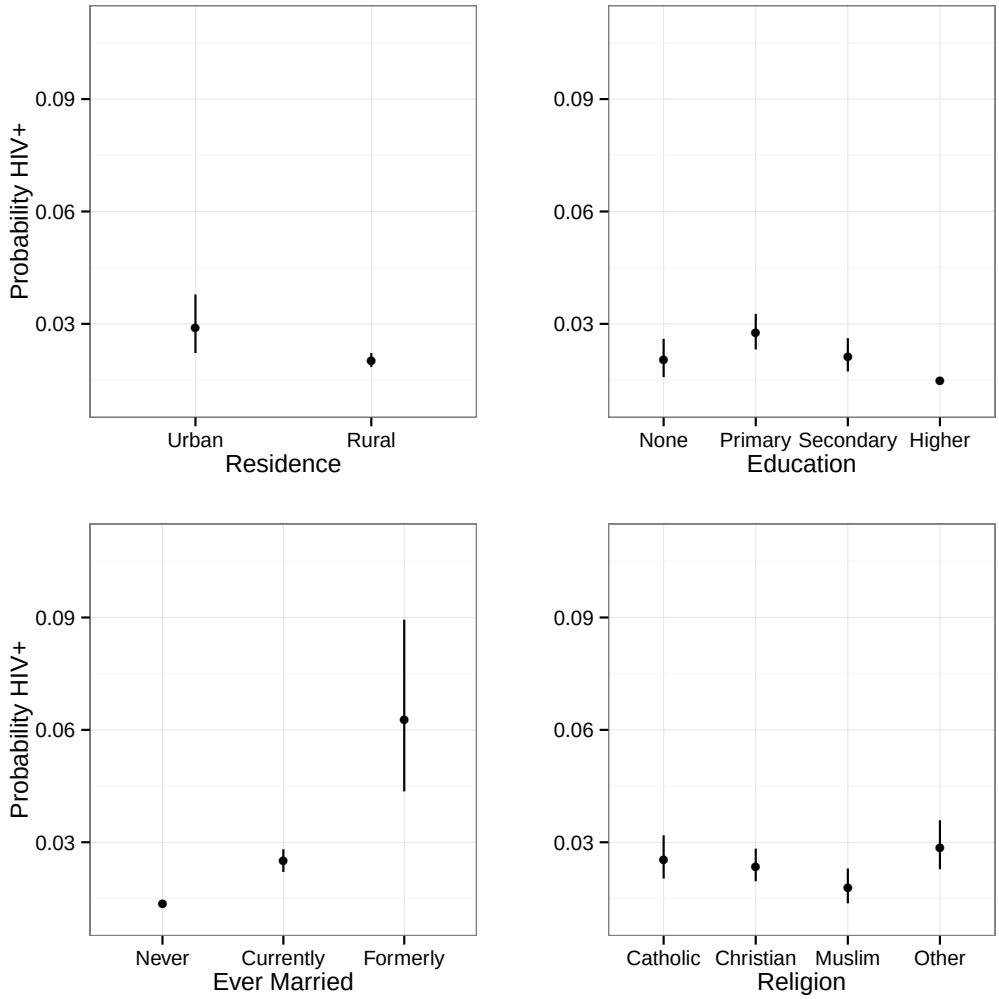

Figure 2.4: Prediction plots of regression model: Men's HIV risk as predicted by sociodemographic predictors

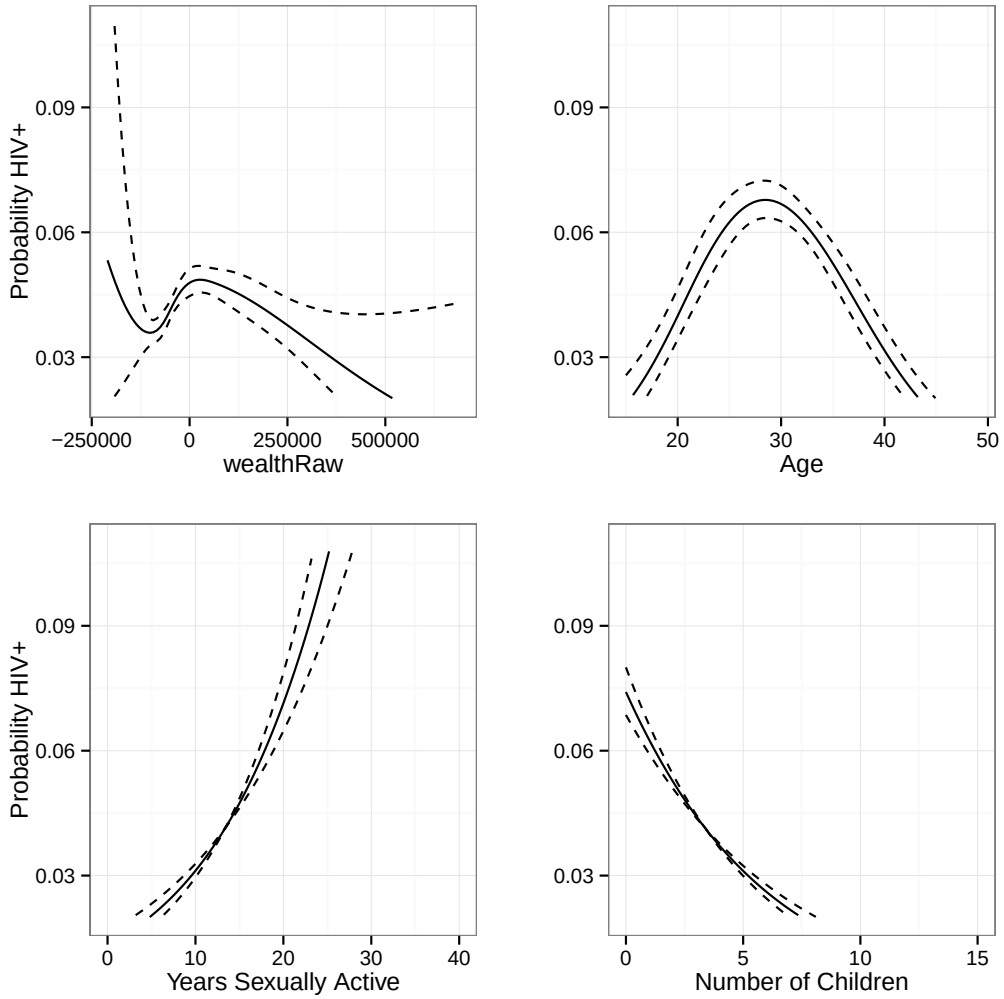

Figure 2.5: Prediction plots of regression model: Women's HIV risk as predicted by sociodemographic factors and reproductive history

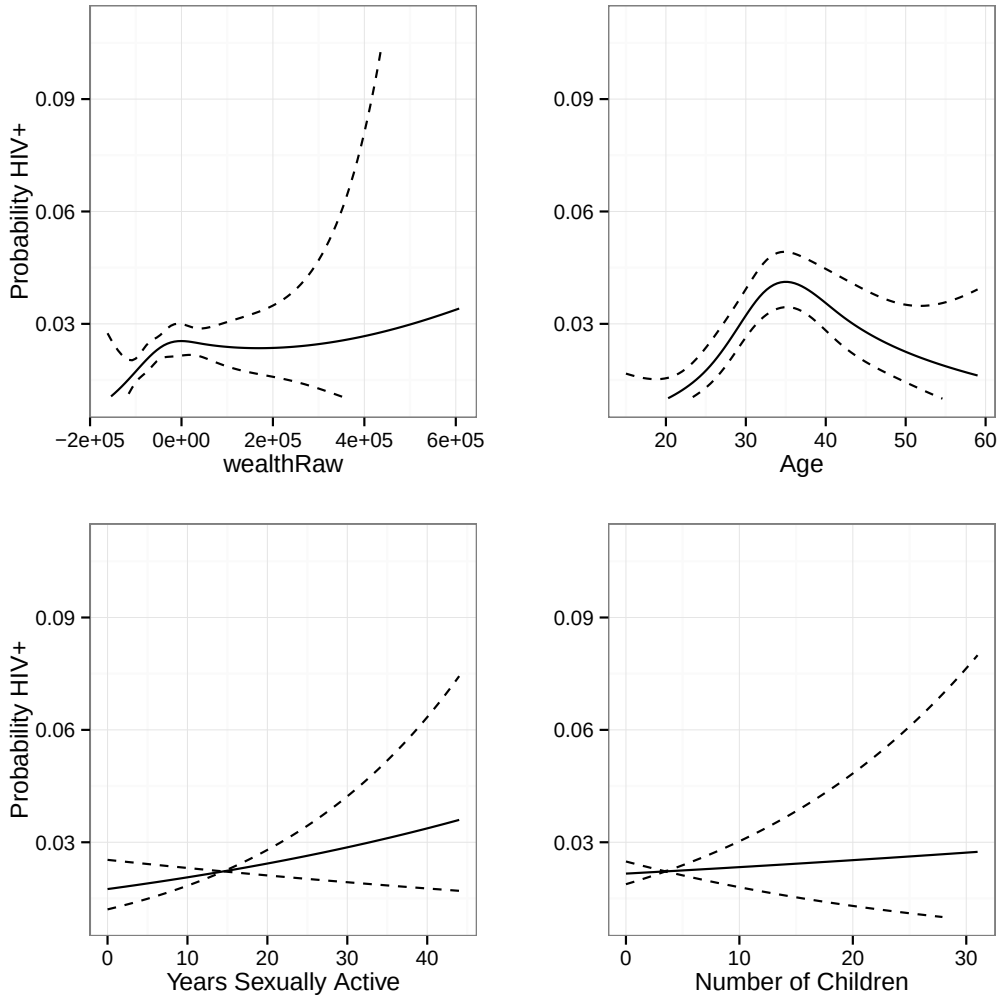

Figure 2.6: Prediction plots of regression model: Men's HIV risk as predicted by sociodemographic factors and reproductive history

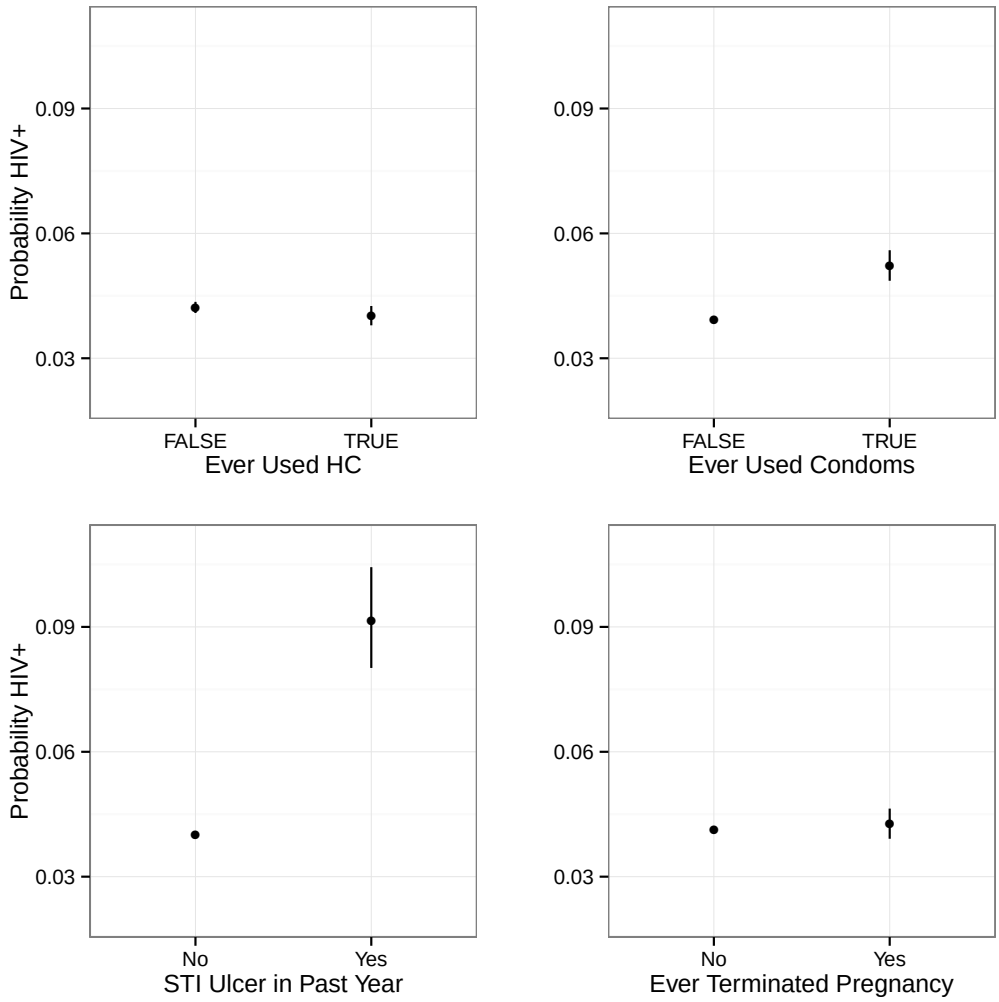

Figure 2.7: Prediction plots of regression model: Women's HIV risk as predicted by sexual risk factors.

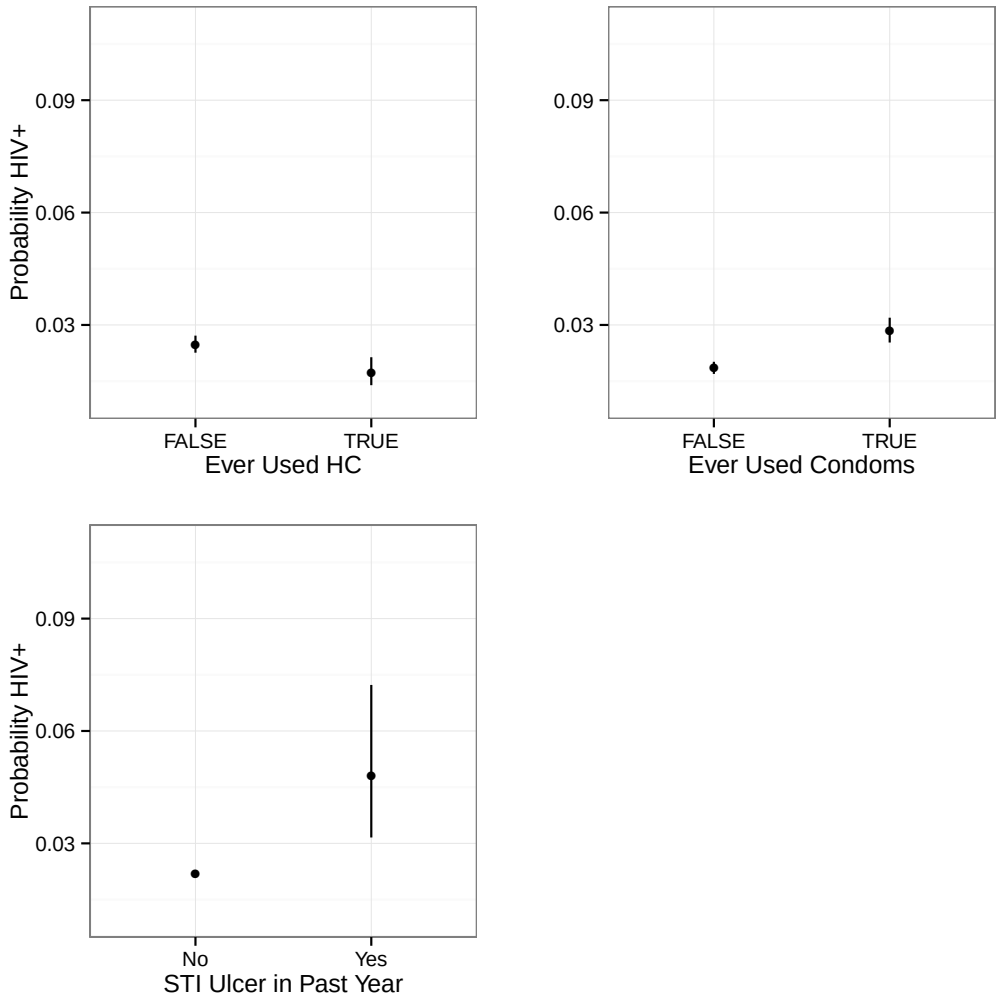

Figure 2.8: Prediction plots of regression model: Women's HIV risk as predicted by sexual risk factors.

Appendix A

Single-country analyses of Condom Use and HIV/AIDS epidemic awareness

All data from the 7 countries – Kenya (2008-09), Lesotho (2009), Namibia, (2006-07), Senegal (2005), Swaziland (2006-07), Uganda (2006), and Zimbabwe (2005-06) – included in chapter one, "HIV disclosure, stigma and risk behaviour: Regression analysis of condom use in sub-Saharan Africa", were pooled in the reported analysis. We observed a significant relationship between knowing a person with HIV and condom use. However, it was hypothesised in this thesis that other studies' failure to observe this effect was due to lack of power and failure to account for critical confounds. The model used in chapter one was also applied to both genders in each country individually, finding weak but consistently positive associations between knowing a person with HIV and condom use (See figures A1-A12; two of the figures are missing because of technical problems with the analyses). These findings support the assertion

that sufficient power is key to observing a significant effect of knowing a PWHA on condom use, and accounts for inconsistency observed in the literature.

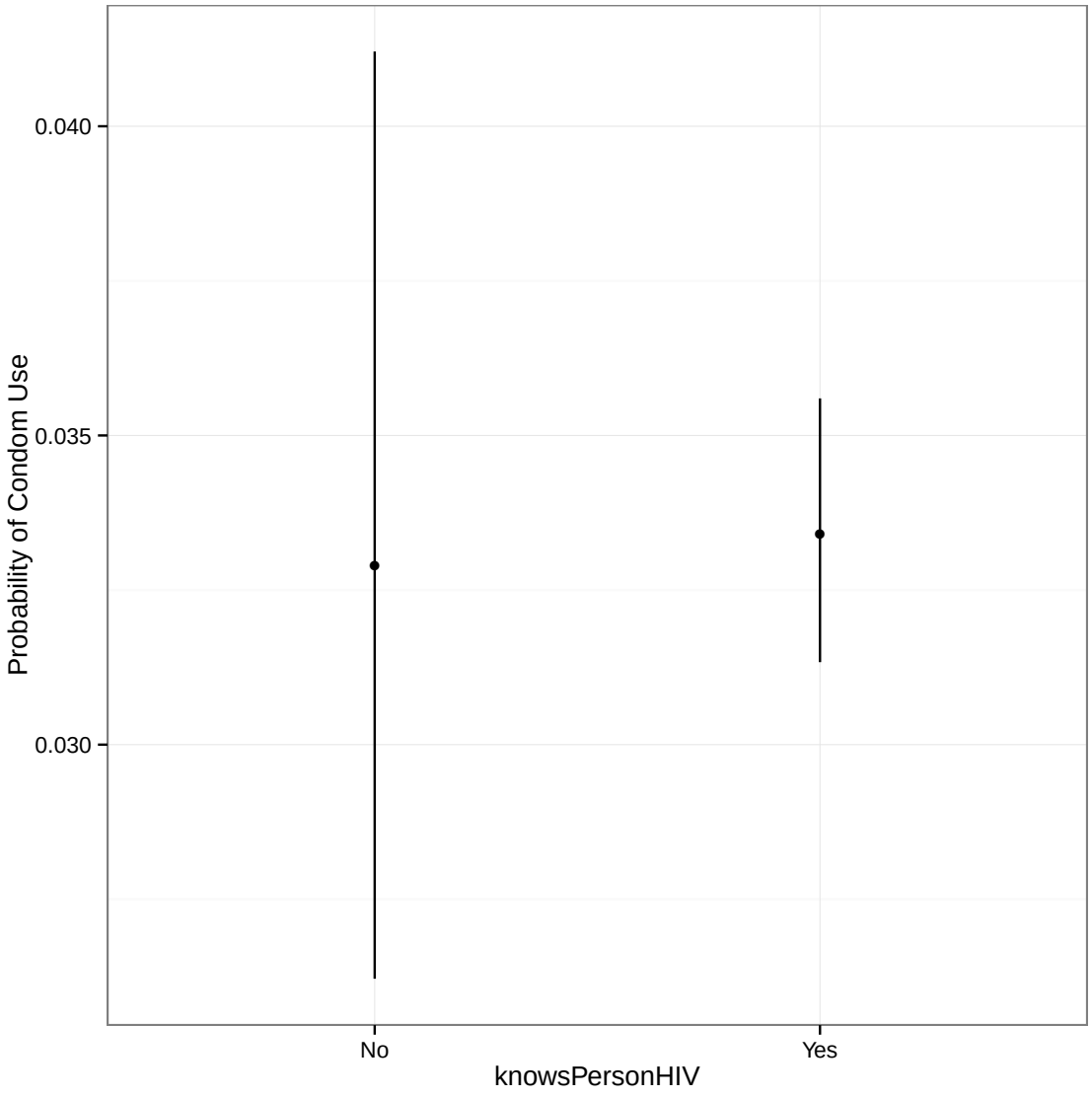

Figure A.1: Kenya, 2008-09 (women): Effect of knows PWHA on probability of condom use

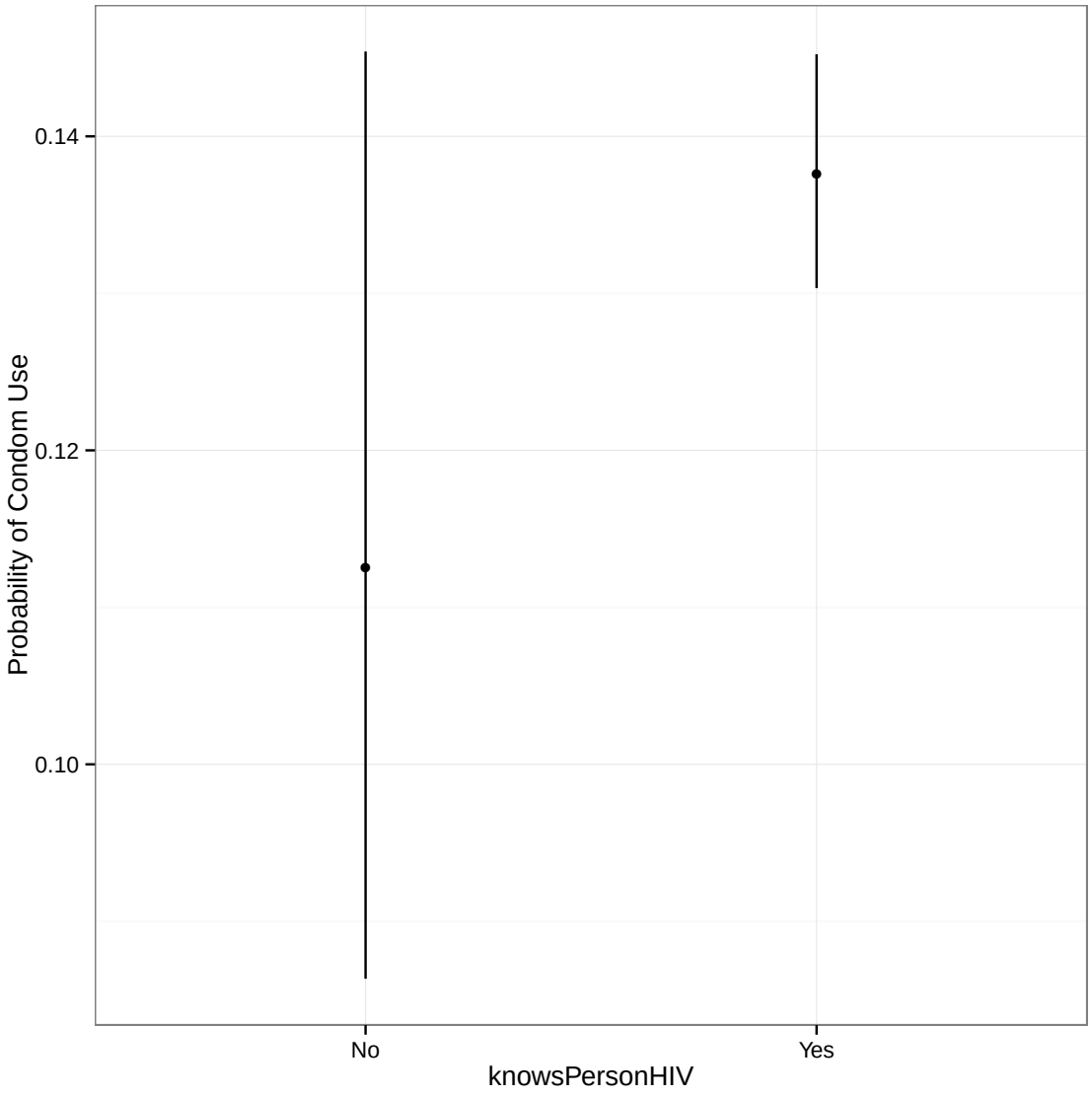

Figure A.2: Kenya, 2008-09 (men): Effect of knows PWHA on probability of condom use

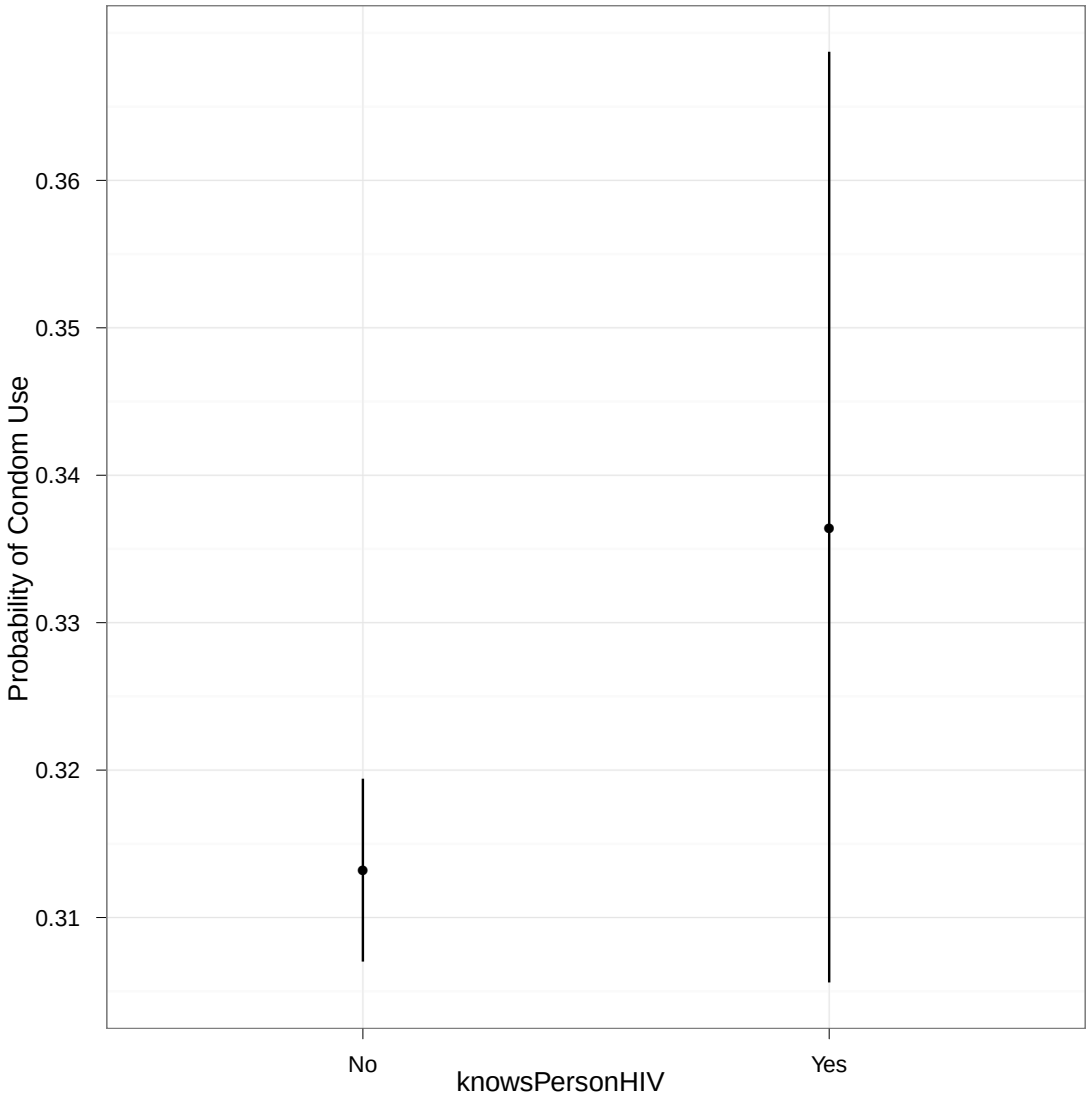

Figure A.3: Lesotho, 2009 (women): Effect of knows PWHA on probability of condom use

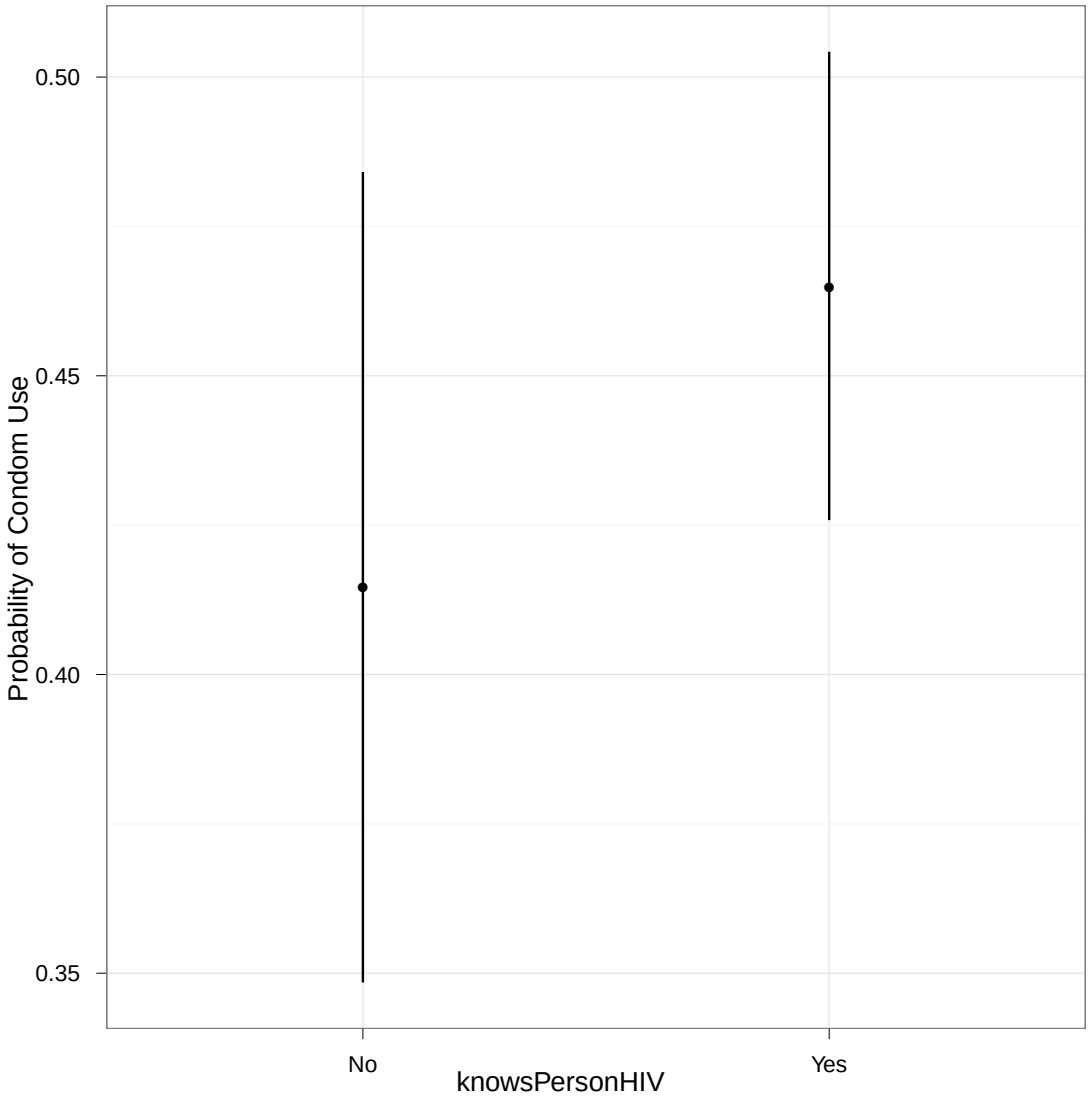

Figure A.4: Lesotho, 2009 (men): Effect of knows PWHA on probability of condom use

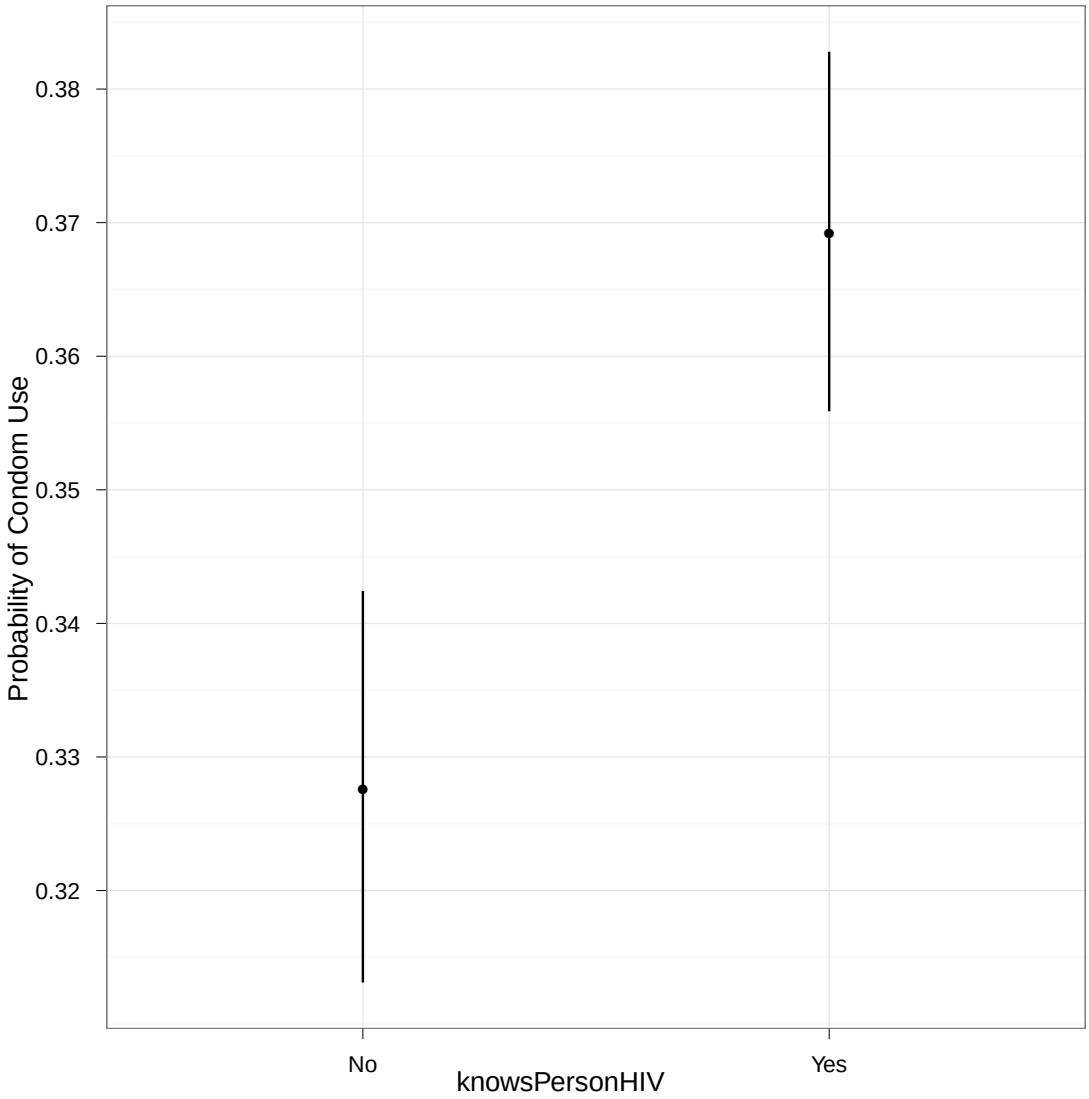

Figure A.5: Namibia, 2006 (women): Effect of knows PWHA on probability of condom use

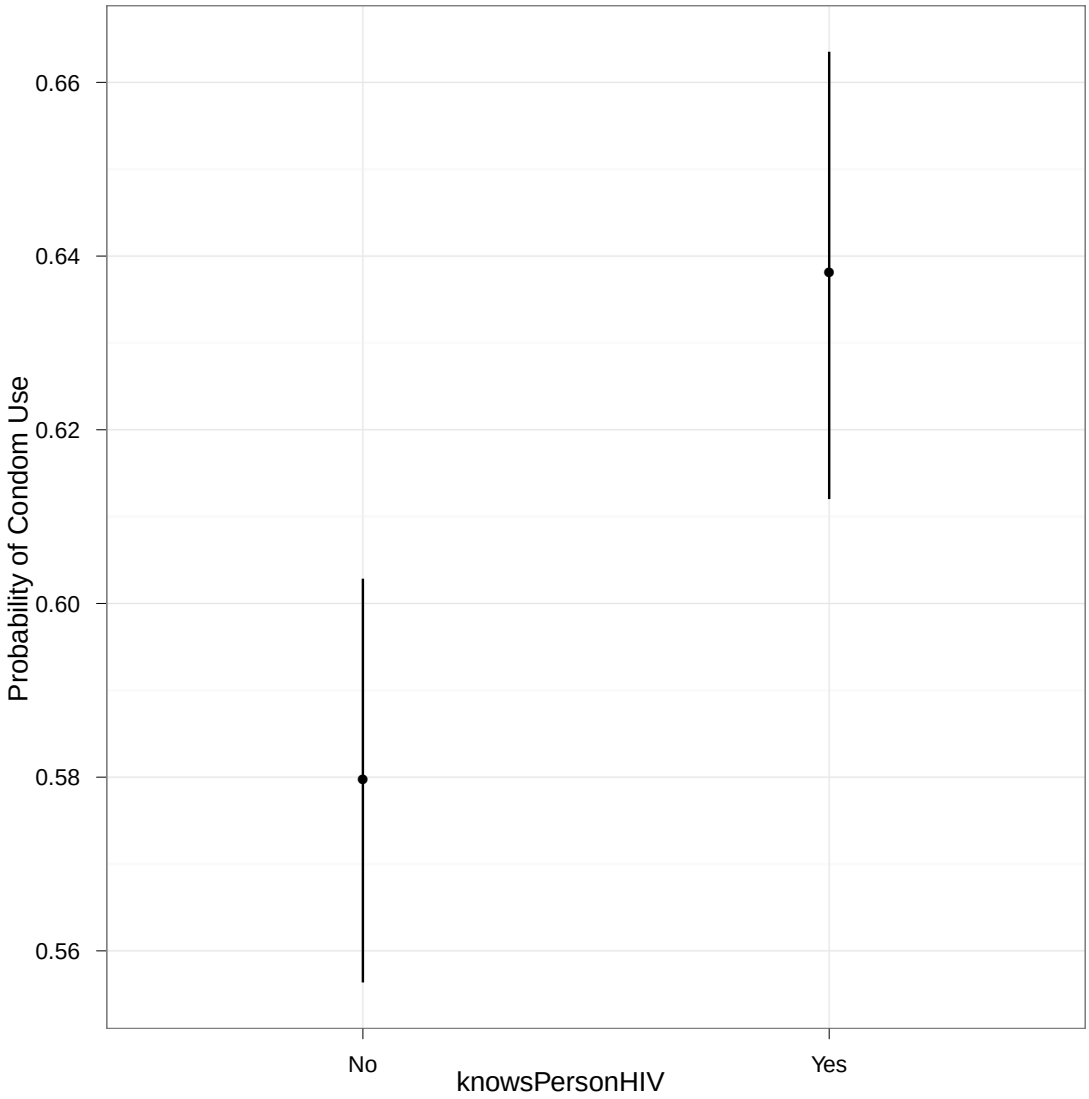

Figure A.6: Namibia, 2006 (men): Effect of knows PWHA on probability of condom use

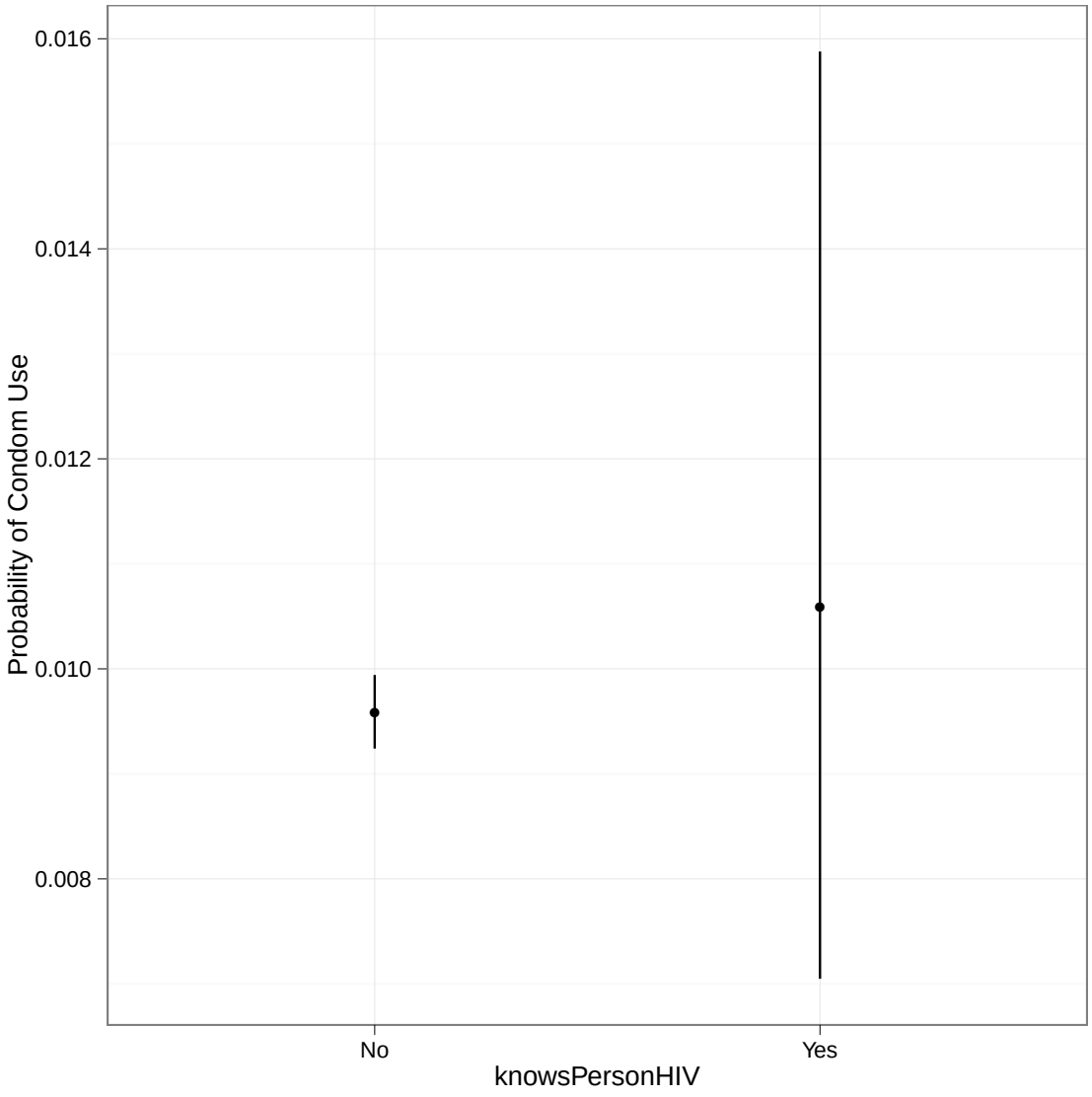

Figure A.7: Senegal, 2005 (women): Effect of knows PWHA on probability of condom use

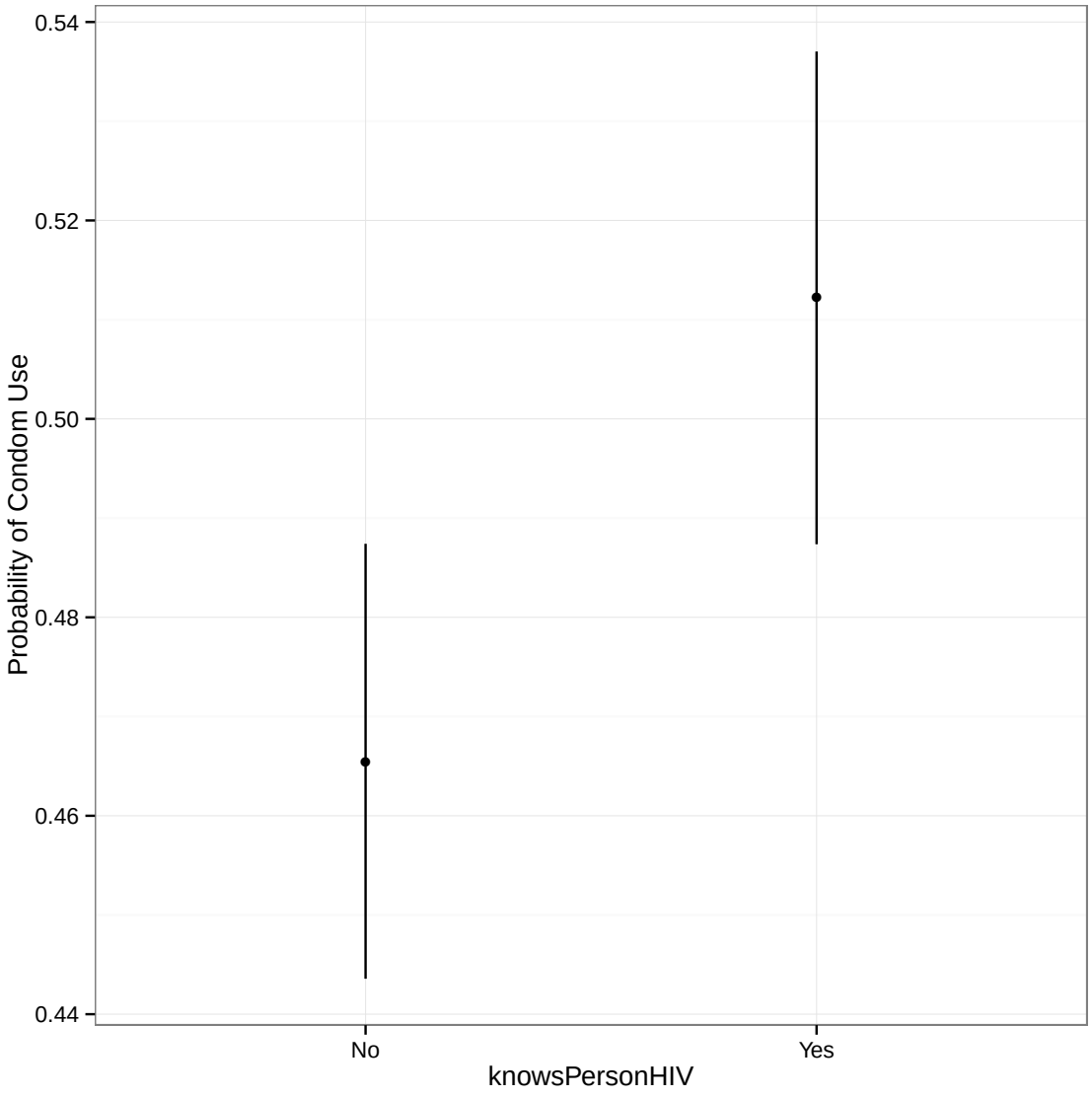

Figure A.8: Swaziland, 2006-07 (men): Effect of knows PWHA on probability of condom use

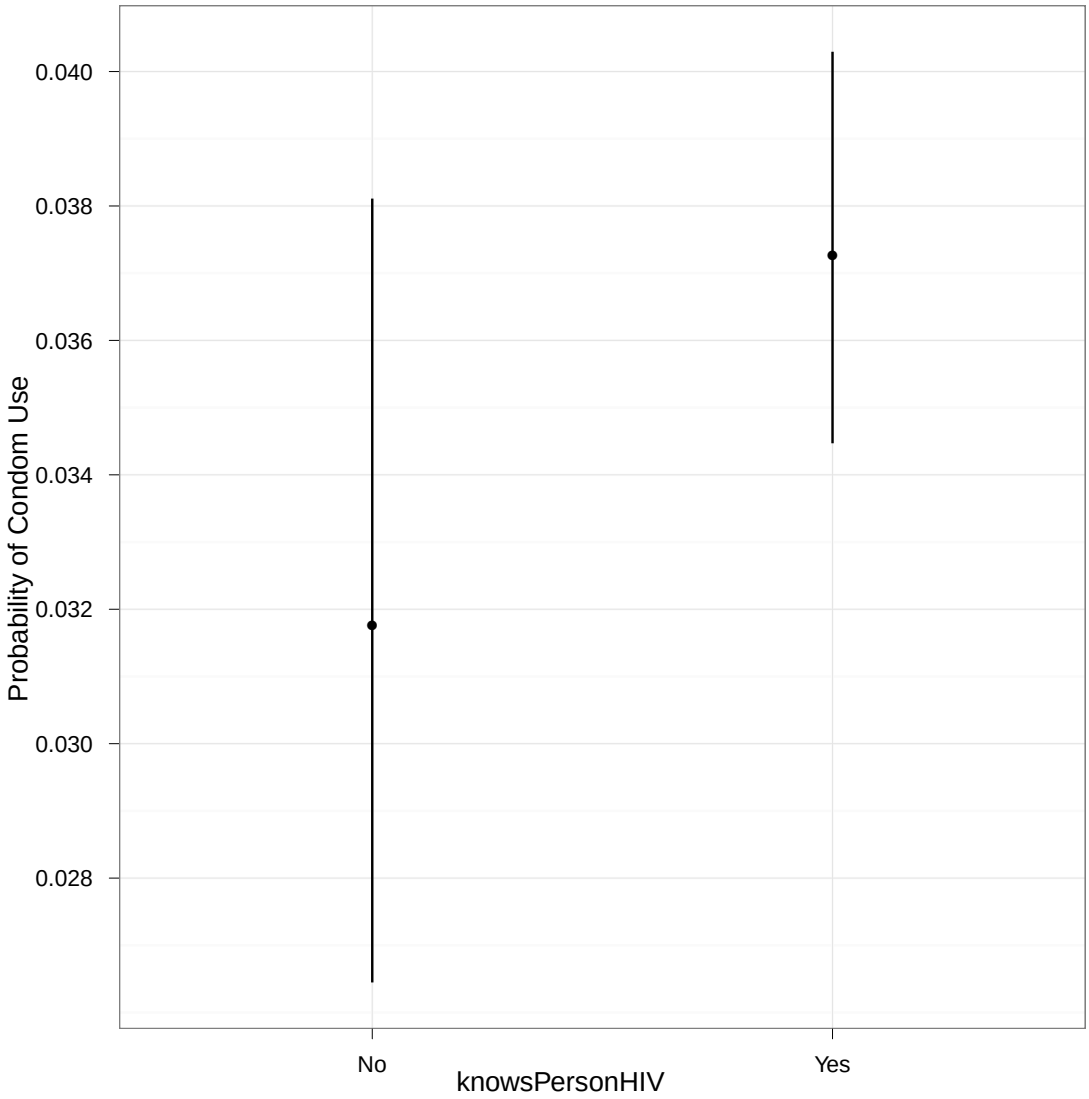

Figure A.9: Uganda, 2006 (women): Effect of knows PWHA on probability of condom use

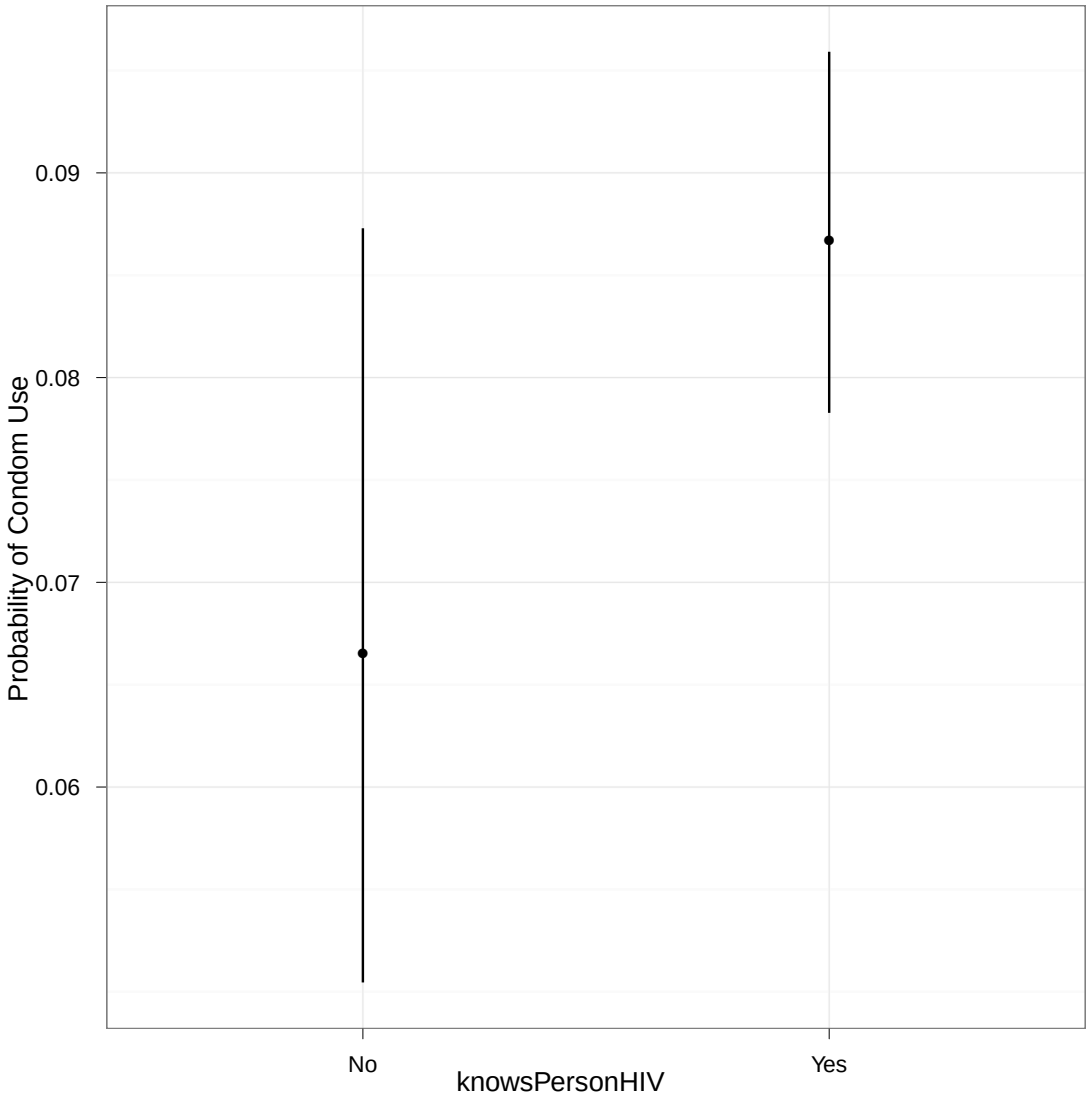

Figure A.10: Uganda, 2006 (men): Effect of knows PWHA on probability of condom use

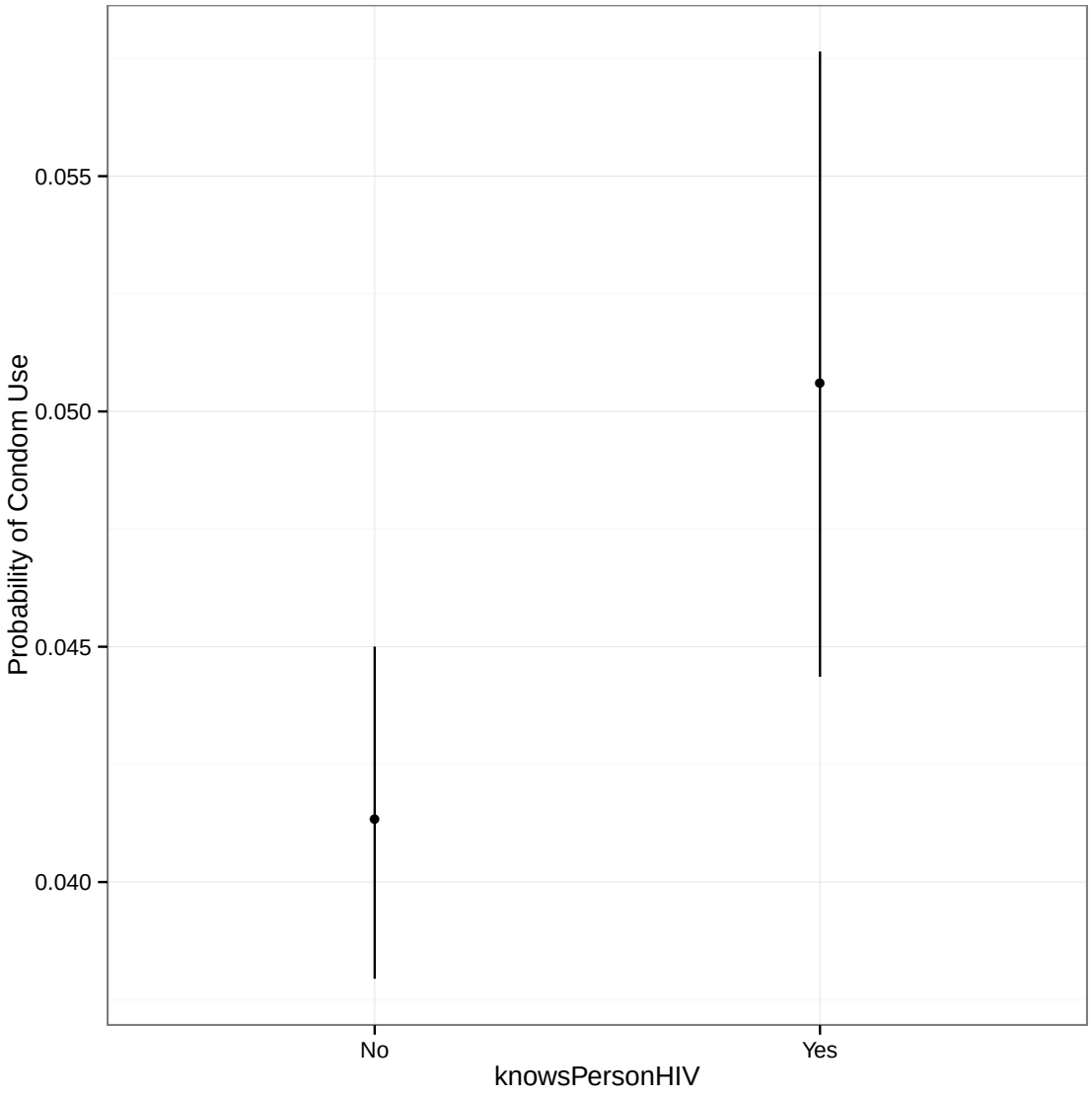

Figure A.11: Zimbabwe 2005-06 (women): Effect of knows PWHA on probability of condom use

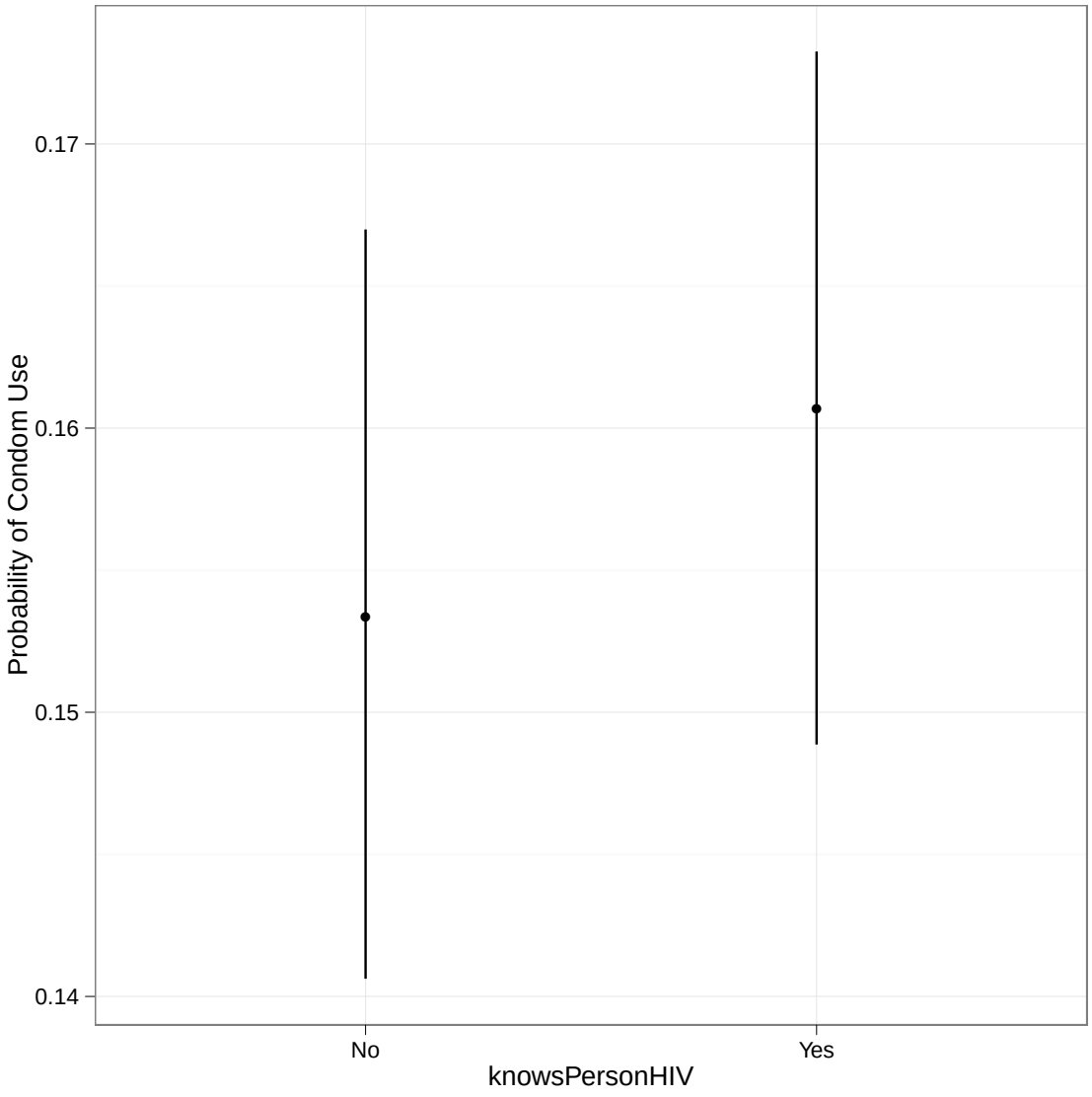

Figure A.12: Zimbabwe 2005-06 (men): Effect of knows PWHA on probability of condom use

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