Preventing unintended pregnancy and HIV transmission: the effect of the HIV treatment cascade on contraceptive use and choice in rural KwaZulu-Natal

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Abstract

Background

For women living with HIV, contraception using condoms is recommended because it prevents not only unintended pregnancy but also both acquisition of other sexually-transmitted diseases and onward transmission of HIV. Dual-method dual-protection contraception (condoms with other contraceptive methods) is preferable over single-method dual-protection contraception (condoms alone) because of its higher contraceptive effectiveness. We estimate the effect of progression along the HIV treatment cascade on contraceptive use and choice among HIV-infected women in rural South Africa.

Methods

We linked population-based surveillance data on contraception collected by the Wellcome Trust Africa Centre for Health and Population Studies to data from the local antiretroviral treatment (ART) program in Hlabisa sub-district, KwaZulu-Natal. In bivariate probit regression, we estimated the effects of progressing through the cascade on contraceptive choice among HIV-infected, sexually active women aged 15-49 years (N=3169), controlling for a wide range of potential confounders.

Findings

Contraception use increased across the cascade from <40% among HIV-infected women who did not know their status to >70% among women 4-7 years on ART. Holding other factors equal, (i) awareness of HIV status, (ii) ART initiation, and (iii) being on ART for 4-7 years increased the likelihood of single-method/dual-method dual protection by the following percentage points (pp), compared to women who were unaware of their HIV status: (i) 4.6 pp (p=0.030)/3.5 pp (p=0.001); (ii) 10.3 pp (p=0.003)/5.2 pp (p=0.007) ; and (iii) 21.6 pp (p<0.001)/11.2 pp (p<0.001).

Conclusion

Progression along the HIV treatment cascade significantly increased the likelihood of contraception in general and contraception with condoms in particular. ART programs are likely to contribute to HIV prevention through the behavioral pathway of changing contraception use and choice.

Introduction

All women have the reproductive health rights "to decide freely and responsibly on the number and spacing of their children and to have access to the information, education and means to enable them to exercise these rights."[1] For all women, the ability to freely choose the method of contraception that best fulfills her individual reproductive health needs and wants is an essential component of these rights.[2] Among women living with HIV, prevention of unintended pregnancy is one effective approach to prevent mother-to-child transmission of the virus.[3] In making contraceptive choices, women living with HIV have to consider a number of additional risks that are different from those that HIV-uninfected women are facing. Compared to HIV-uninfected women, HIV-infected women are at greater risk of morbidity and mortality during pregnancy and motherhood[4] and are at increased risk of severe illness from sexually transmitted infections (STI) other than HIV.[5-7] HIV-infected women also face the risk of superinfection with a second strain of HIV, which may cause more rapid disease progression and limit treatment options.[8,9] Finally, women living with HIV are at risk of transmitting HIV to their uninfected partners.

Male and female condoms can provide dual protection against unintended pregnancy as well as acquisition and transmission of STI, including HIV. Other methods of contraception, such as oral and injectable contraceptive drugs and male or female sterilization can prevent unintended pregnancy but do not serve the additional purpose of protecting against STI acquisition and transmission. While condoms alone provide dual protection, dual-method contraception with condoms and another method is more effective for preventing unintended pregnancies than single-method contraception with condoms alone. In the following, we will use the term *single-method dual protection* to indicate condom use alone and *dual-method dual protection* to indicate concurrent use of condoms and at least one other contraceptive method. We will use the term *single protection* to indicate contraception without condoms. Although women who are HIV-infected can use all of the same contraceptive methods as women who are HIV-uninfected, WHO recommends that HIV-infected women use dual protection, and ideally dual-method

dual protection to maximize effectiveness in preventing both pregnancy and STI acquisition and transmission.[10]

The large-scale use of antiretroviral treatment (ART) has changed what it means to live with HIV and to live in one of the communities in sub-Saharan Africa that are severely affected by the HIV epidemic.[11] ART substantially reduces HIV-related mortality[12] and can dramatically improve life expectancy in communities with high HIV prevalence.[11] By reducing the concentration of HIV in body fluids, ART can also substantially decrease the risk of HIV transmission from an infected to an uninfected partner.[13] While these biological effects of antiretroviral medication are well established, our knowledge of the behavioral effects of ART programs is limited.

The HIV patient pathway from infection to long-term treatment, the "HIV treatment cascade",[14] can be divided into several steps. First, an HIV-infected woman learns about her positive HIV status in an HIV testing and counseling session that usually also includes information about HIV infection, options for long-term care and treatment, the importance of disclosure of HIV status to family members and sexual partners, and approaches to prevention of onward transmission of HIV.[15] Next, the HIV-infected woman can enroll in pre-ART programs for regular review of ART eligibility, prevention of opportunistic infections, and contraceptive counselling and counselling to prevent onward transmission of HIV.[16-18] At some point after becoming eligible for HIV treatment, the HIV-infected women may initiate ART; ART initiation is usually preceded by treatment education including information on the importance of ART adherence, disclosure, and practicing safe sex behaviors.[19] Finally, as the HIV-infected woman remains enrolled in the ART program, she will regularly visit ART clinics for assessment of treatment success and continued counselling, including on contraception and prevention of HIV transmission. Progression along the HIV treatment cascade thus implies ongoing counseling and knowledge gain on contraceptive choices for HIV-infected women and prevention of HIV transmission. Additionally, the repeated interactions with the health system along the cascade imply access to contraceptive methods. HIV testing and counseling

centers and ART clinics commonly provide male and female condoms and they are often located close to other health care facilities, such as primary care clinics and family planning centers,[20] where contraceptive methods are available. It is thus plausible that HIV-infected women will increasingly use contraception due to improved access to contraceptive methods through health care utilization along the HIV treatment cascade. However, the type and magnitude of any such effects is unknown.

Here, we use a rare data opportunity – linked population-based surveillance data and ART program data – to examine whether progression along the HIV treatment cascade affected contraceptive use among the HIV-infected women in a community in rural KwaZulu-Natal with high HIV prevalence[21] and incidence.[22] A previous study in the same community found that ART coverage of HIV-infected populations protected HIV-uninfected individuals from acquiring HIV.[23] In addition to the biological effect of ART, one of the potential causal mechanisms underlying this effect of ART coverage on HIV acquisition could be effects of the ART scale-up on dual protection. To elucidate this possible behavioral pathway from ART scale-up to HIV incidence, we estimate the effects of progression through the HIV treatment cascade on single- and dual-protection contraception.

Methodology

Setting and data collection

We use data collected by the Wellcome Trust Africa Centre for Health and Population Studies (Africa Centre). Since 2000, the Africa Centre has operated a longitudinal Health and Demographic Surveillance System, covering the entire population living in a 438 km^2 surveillance area (about 100,000 individuals) in the rural UMkhanyakude district in northern KwaZulu-Natal, South Africa.[24] HIV prevalence in the adult population in this community was 29% in 2011[21] and incidence has been around 3 per 100 person-years for the last decade,[22] with a slight decline in recent years.[23] ART coverage of all HIV-infected adults in the community has risen from 0% in 2003 to 31% in 2011.[21] The surveillance includes longitudinally linked annual HIV testing and data on contraceptive choice based on interviews with all adults living in

the surveillance. During the individual interviews, all respondents are asked whether they know their HIV status and all women are asked about their contraceptive use. Individuals do not learn their HIV status based on population surveillance to better maintain anonymity of test results; individuals may seek HIV testing and learn about their positive HIV status in HIV testing and counseling centers or by testing in public- or private-sector clinics. The surveillance also includes linked longitudinal data on demographic, social and economic factors. To determine progression through the HIV treatment cascade, we linked the data on pre-ART and ART clinic visits collected in the treatment program to the population-based surveillance data, using the South African identification number, first name, last name, and birth dates for linkage.[25]

In 2004, the South African Department of Health in collaboration with the Africa Centre started the Hlabisa HIV Treatment and Care Programme with support from the Presidential Emergency Fund for AIDS Relief (PEPFAR). The program delivers ART through the 17 primary care clinics in Hlabisa sub-district. The program provides free HIV testing and counselling, ART, and male and female condoms. The program includes an active pre-ART component enrolling patients for ongoing counseling and monitoring of CD4 count, HIV disease progression, and health status to determine ART eligibility. Prior to ART initiation, all patients participate in three group sessions and individual counseling. After initiation, ART patients make monthly visits to the program to see a nurse and a counselor and to participate in group and individual counseling sessions.[20] Because women who intend to be pregnant or are "not on reliable contraception" should receive a different first-line ART regimen than other patients according to the South African national ART guidelines,[18] contraception and fertility intentions are part of the conversation that ART patients should have with their health care provider during the monthly clinic visits.

Study population

The study population included all women who met the following eligibility criteria: they were of

reproductive age (15-49 years); they had either tested HIV-positive in the Africa Centre HIV surveillance or were enrolled in the Hlabisa HIV Treatment and Care Programme; they reported being sexually active within the past year; and they reported on their contraceptive use in the Women's General Health Survey. We used the latest report on contraceptive use available for each woman who met these eligibility criteria. We used data beginning in 2005, because the Hlabisa HIV Treatment and Care Programme started enrolling patients only at the end of 2004.[20] We use data from the observation period 2005-2012.

Contraceptive use variables

Until 2009, fieldworkers inquired about contraceptive use in the individual interviews by asking "Are you currently doing anything, or using any contraceptive method, to delay or avoid getting pregnant?" If a woman answered yes, interviewers asked her to specify which methods she was using; the pre-coded options included the "pill", "intrauterine device (IUD)", "Depo-Provera injection", "Nur-Isterate injection", "male condom", "female condom", "female sterilization", "male sterilization", and "other". The question changed slightly in 2009, when interviewers started asking "Have you ever used contraception?" Women who answered yes were asked "Which method are you currently using?" and could respond with the options "none", "male condom", "female condom", "female sterilization", "male sterilization", "injections", "pill", and "other". One reason for this slight change in the question was that hardly any women had reported IUD use in earlier years. As defined above, we categorized the different contraceptive methods into single protection, single-method dual protection, and dual-method dual protection contraception (**Table 2**).

Explanatory variables

We capture progression through the HIV treatment cascade with dummy variables indicating knowledge of HIV status, enrolment in pre-ART, and having received ART for 0-1, 1-2, 2-4, and 4-7 years. In addition, in the multivariable regression analysis, we controlled for variables that have been found to determine contraceptive use in other studies:[26-28] age, education, relationship status, parity, current

pregnancy, self-reported health status, the distance from a woman's place of residence to the nearest primary and the nearest secondary road, household wealth, and calendar year. With the exception of the pre-ART and time on ART data, all other information, including about awareness of HIV status, were available through the Africa Centre surveillance. We used school grade attainment data available to capture education. We coded women as being married or in a conjugal relationship if she reported that she was married, engaged or cohabitating. We coded age in years and included age squared to capture non-linear age relationships with contraception use. Following a previous study in this community,[29] we created wealth quintiles based on the ranking of individuals on the first principal component obtained in a principal component analysis of information on 27 household assets, such as vehicles, stoves, beds, and livestock. We include the distances from a woman's place of residence to the nearest primary and the nearest secondary road to capture geographical access to health care, because in this community car ownership is rare and people usually walk to the nearest road to fetch a mini-bus in order to drive to a health care facility.[30]

Analysis

Our primary research question here was whether progression along the HIV treatment cascade affected single- and dual-protection contraception. To answer this question, we chose the bivariate probit model, because the two binary decisions – whether or not to use single-protection contraception (i.e., any contraceptive method except for condoms) and whether or not to use single-method dual protection contraception (i.e., condoms) – are likely dependent based on both theoretical considerations (the two contraceptive approaches are imperfect substitutes) and the empirical literature.[31,32] In addition to the bivariate probit regression coefficients (Table 3), we estimated average marginal effects (AMEs) for not using any contraception, using single protection, using single-method dual protection, and using dual-method dual protection (Table 4). Conceptually, the AME for a dummy variable is the average across all the individual marginal effects for that dummy variable for each person in the dataset. These individual marginal effects are obtained by computing each person's probability of having the outcome when the

dummy variable is set to zero and when it is set to unity, in both cases keeping the values of all the other explanatory variables to the values given for that person.[33] The AMEs in Table 4 represent the change in the probability of having the outcome when a certain stage of the cascade is reached as compared to the stage that is the reference category, expressed in percentage points (pp). For instance, a woman who has been on ART for 4-7 years is 21.6 percentage points more likely to use single-method dual protection compared to an HIV-infected woman who does not know her HIV status.

Findings

There were 7,443 HIV-infected women aged 15-49 years who participated in the Africa Centre Health and Demographic Surveillance between 2005 and 2012. Of these women, 5,510 (74.0%) reported on their sexual activity at least once, and 4,625 (83.9%) of women who reported on their sexual activity had been sexually active within the past year. Among the 4,625 women who had been sexually active, data on all variables for the multiple regression analysis was available for 3,169 (68.5%). Here, we present the complete-case analyses of this sample of 3169 women.

Table 1 describes the characteristics of the 3169 women in this sample. The majority of the HIV-infected women had not yet enrolled in the ART program (68%); 17% were HIV-infected but unaware of their status, 29% were HIV-infected and aware of their status but not yet in treatment, and 9% had unknown awareness of their HIV-positive status (with HIV-positive status detected in surveillance and not reported to participants). Among the remaining women, 22% were enrolled in pre-ART and 22% were on ART. Slightly more observations occurred in the latter half of the observation period (68% in 2009-20012) than in the earlier half (32% in 2005-2008). **Table 2** shows the distribution of contraceptive methods across the women in this sample of sexually active HIV-infected women; 54% used any contraception and 32% used either single- or dual-method dual protection. **Figure 1** shows descriptively contraceptive choice through the HIV treatment cascade. Overall, contraceptive use increased steadily across the stages of the cascade from <40% among HIV-infected women who did not know their status to >70% among women

who had received ART for 4-7 years. The increase in contraceptive use occurred largely due to an increase in the use of dually protective methods.

These trends were even more pronounced when we estimated the effect of progression through the HIV treatment cascade on contraceptive use in the bivariate probit analysis, controlling for age, education, partnership status, pregnancy status, parity, health status, household wealth, distance to the nearest primary and secondary roads, and calendar year. The coefficient ρ, which measures the correlation between the error terms of the two regressions that we jointly estimated in bivariate probit analysis, was negative (-0.292) and highly significant ($p<0.0001$) indicating that the two contraceptive choices should indeed be jointly estimated because of a relationship between the choices that is not found in the observed explanatory variables. **Table 3** shows the regression coefficients and **Table 4** the AME from this analysis. Compared to HIV-infected women who were unaware of their positive HIV status and holding other factors equal, the likelihood of single-method dual protection increased by 4.6 percentage points (pp) when women became aware of their HIV status ($p=0.030$), by 10.3 pp when they initiated ART ($p=0.003$), and by 21.6 pp when they had received ART for 4-7 years ($p<0.001$). The likelihood of dual-method dual protection increased by 3.5 pp when women became aware of their HIV status ($p=0.001$), by 5.2 pp when they initiated ART ($p=0.007$), and by 11.2 pp when they had received ART for 4-7 years ($p<0.001$).

As robustness checks of the findings presented here, we repeated the analyses with HIV-uninfected women also included in the sample and with multiple imputation of missing covariates among women who reported being sexually active. The findings from the analysis that includes HIV-negative women are described in detail in the online **appendix**, including the full tables with the descriptive statistics and the regression results. This additional analysis has several advantages (large sample size, ability to compare contraceptive choice by HIV status) but also suffers from the disadvantage of reverse causality bias because contraceptive choice is an important determinant of HIV status. However, the findings based on

the sample including both HIV-infected and –uninfected women are essentially the same as those based on the smaller sample including only HIV-infected women. The findings from the multiply imputed analysis are also similar to those of the main analysis, suggesting that the missing data does not cause significant bias. In the online **appendix**, we also describe and discuss the effects of the other explanatory variables on contraceptive choice.

Discussion

We examine for the first time the effect of progression along the HIV treatment cascade on contraceptive use. Among HIV-infected women, dually protective methods of contraception can prevent unintended pregnancies, HIV transmission, and the acquisition of other STIs. In a poor, rural community in KwaZulu-Natal, South Africa, we find that both overall contraceptive use and dual-protection contraception increase significantly as HIV-infected women move from earlier to later stages in the treatment cascade. Descriptively, the probability of contraception increases from <40% among HIV-infected women who did not know their status to >70% among HIV-infected women 4-7 years on ART. Controlling for a wide range of potential confounders of the relationship between the stages of the treatment cascade and contraceptive use, we find that progression along the cascade significantly increases the overall probability of contraception as well as single- and dual-method dual protection.

While significant increases in dual protection occurred across the entire cascade, these increases were substantially larger following ART initiation compared to the stages in the cascade when women learnt of their HIV status or were enrolled in pre-ART care. The large ART-associated increases are plausible based on several mechanisms. First, in preparation for ART women receive intensive counseling, including on methods to prevent transmission of HIV to sexual partners. Second, women on ART may be more likely to discuss their contraceptive behaviors and fertility intentions with ART health workers during the routine ART follow-up visits, because based on the South African national ART guidelines[18] the ART regimen needs to be changed when a woman intends to become pregnant or stops using reliable

contraception. These discussions may enhance education on the benefits of contraception with condoms. Third, the ART clinics in this community provide male and female condoms free of charge, so that ART clinic visits imply access to dually protective contraceptives. It is possible that the availability of free condoms in the ART program is a reason for the larger increases observed in single-method dual protection than in dual-method dual protection. Last, the ART clinics are located on the premises of the primary-care clinics and thus in close proximity to family planning and reproductive health services, where contraception information and condoms are available. Future research needs to elucidate whether information and counseling or condom availability is responsible for the large dual protection-enhancing effect of ART observed in this study and to explore whether more intensive counseling and increased condom availability in HIV testing centers and pre-ART clinic visits could further increase use of dual-protective methods earlier in the HIV treatment cascade.

Our results have several important implications for policy and research. First, the ART effects on contraception with condoms could enhance the biological treatment-as-prevention effects.[13,23] The effects of progression through the HIV cascade found here will also counteract "risk compensation",[34] i.e., increased sexual risk taking among HIV-uninfected populations because the availability of ART decreases both the risk of contracting HIV through unprotected sex as well as the expected health losses after contracting HIV.

Second, despite the significant and large increases in dual protection across the HIV treatment cascade, in all cascade stages large proportions of HIV-infected women continue using only single-protection contraception. While there are significant effects of learning about one's positive HIV status on both overall contraceptive use and contraception with condoms, these effects are small compared to the ART effects. Future intervention research is needed to determine how HIV counseling and testing can be enhanced to achieve larger dual protection effects than currently.

Third, while dual-methods dual protection increases as women progress across the HIV treatment cascade, these increases are small relative to the increases in the use of single-method dual protection, which is not as effective as dual-method dual protection in preventing unintended pregnancy. Future research needs to establish what interventions – e.g., targeted provision of contraceptives, new types of contraceptives, or stronger incentives to use contraceptives – can lead to additional condom use among women who currently use other contraceptives and the addition of other contraceptives among women who currently use condoms.

Our study has several strengths but also important limitations. One important strength of this study is that information about contraception is elicited in the community and not in patient interviews after HIV counseling or testing or visits to an ART clinic, where previous studies have elicited this information.[35-39] While we cannot rule out social desirability biases, such biases seem much less likely when questions about contraception are asked in patients' homes and as part of an interview on a wide range of issues rather than in situations when patients are likely to just have been counselled that they should use condoms to prevent transmission of HIV to partners. Home-based interviews are removed from the social norm-setting context associated with ART and HIV counseling. Additionally, unlike in patient interviews the fieldworkers conducting home-based interviews are unaware of the HIV status of their interviewees; social norms related to HIV status are thus unlikely to affect responses.

Other strengths of this study include the large sample size and the fact that we could here for the first time directly compare the effects of different important stages across the cascade, including gaining HIV status knowledge, pre-ART, and ART initiation. An important limitation is that we cannot rule out that unobserved confounders have biased the observed relationships between the stages of the cascade and contraceptive choice. One important unobserved factor that could have confounded our results is fertility intention. Fertility intention may decrease when a woman learns about her positive HIV status;[35,36] in this

case, the estimated effect of HIV awareness on contraceptive choice found in this study may be and overestimate of the true effect. Conversely, fertility intentions may increase after ART initiation as a woman's health and future outlook improves;[37-39] in this case, the effects of ART on contraception and dual protection found in this study may be underestimates of the true effects. Follow-up studies need to establish causal effects more firmly. Because we cannot randomly assign individuals to different stages in the cascade, quasi-experimental studies will be the only option to strengthen causal inference on the question whether stages in the cascade, such as pre-ART enrolment or ART initiation lead to changes in contraceptive choice. Examples of quasi-experimental approaches that could be feasible for this purpose include instrumental variable approaches (using, for instance, distance to the nearest ART clinic as an instrument for ART initiation) or regression discontinuity designs using the fact that ART is initiated in patients by applying a threshold rule to the continuous variable CD4 count.[40,41]

Conclusion

Progression along the HIV treatment cascade significantly increased the likelihood of contraception in general and contraception with condoms in particular. The largest increases in contraception with condoms occurred following ART initiation. Future integration of HIV and reproductive health services can build on these achievements to further increase the use of dual-protection contraception, especially in the early stages of the HIV treatment cascade. Our results further suggest that ART programs contribute to HIV prevention through the behavioral pathway of changing contraception uptake and choice.

Table 1: Sample characteristics

Stages in the HIV treatment cascade	
HIV+, unaware of HIV status	539 (17)
HIV+, awareness of HIV status unknown	292 (9)
HIV+, aware of HIV status	928 (29)
Pre-ART	708 (22)
0-1 years on ART	201 (6)
1-2 years on ART	163 (5)
2-4 years on ART	220 (7)
4-7 years on ART	118 (4)
Age	30.73 (7.80)
Education (in school grades attained)	10.58 (2.81)
Marital/conjugal relationship status	795 (25)
Distance to nearest major road (in km)	5.94 (6.31)
Distance to nearest secondary road (in km)	1.33 (1.11)
Pregnancy status	133 (4)
Parity	0.28 (0.98)
Household wealth quintile	
Poorest	654 (21)
2nd	653 (21)
3rd	660 (21)
4th	654 (21)
Richest	548 (17)
Calendar year	
2005	249 (8)
2006	329 (11)
2007	316 (10)
2008	89 (3)
2009	282 (9)
2010	485 (15)
2011	741 (23)
2012	678 (21)
Observations	3169

The numbers are N (%) for categorical variables – stages in the HIV treatment cascade, partner, pregnancy, wealth quintile and calendar year – and mean (standard deviation) for continuous variables – age, school grade attainment and distance to nearest major road. ART = antiretroviral treatment, km = kilometers, HIV+ = HIV-infected

Table 2: Distribution of contraceptive use

	N (%)
No contraception	**1468 (46)**
Single protection	**729 (17)**
Injections	546 (17)
Pill	80 (3)
Female sterilization	95 (3)

Male sterilization	11 (0)
Single-method dual protection	**777 (26)**
Male condom only	741 (23)
Female condom only	29 (1)
Male condom and female condom	7 (<1)
Dual-method dual protection*	**195 (6)**
Male condom & injections	160 (3)
Male condom & pill	21 (1)
Male condom & female sterilization	6 (<1)
Male condom & male sterilization	2 (<1)
Female condom & injections	6 (<1)
Female condom & pill	1 (<1)
Female condom & female sterilization	0 (0)
Female condom & male sterilization	0 (0)
Observations	3169

*One individual was using more than two types of contraception.

Table 3: Effects of progression through the HIV treatment cascade on contraception: bivariate probit regression coefficients effects

	Single protection			Single-method dual protection		
	Coefficient	**95% CI**	**p-value**	**Coefficient**	**95% CI**	**p-value**
Stages in the HIV treatment cascade						
HIV+, unaware of HIV status	1			1		
HIV+, awareness of HIV status unknown	-0.138	(-0.623 - 0.348)	0.578	0.410	(0.014 - 0.806)	0.042
HIV+, aware of HIV status	0.149	(-0.011 - 0.308)	0.068	0.244	(0.092 - 0.396)	0.002
Pre-ART	0.161	(-0.011 - 0.333)	0.067	0.135	(-0.034 - 0.305)	0.117
0-1 years on ART	0.080	(-0.152 - 0.313)	0.499	0.439	(0.214 - 0.665)	<0.001
1-2 years on ART	0.233	(-0.014 - 0.480)	0.064	0.425	(0.178 - 0.671)	0.001
2-4 years on ART	-0.032	(-0.263 - 0.199)	0.785	0.827	(0.602 - 1.051)	<0.001
4-7 years on ART	0.103	(-0.179 - 0.385)	0.475	0.903	(0.623 - 1.183)	<0.001
Age	0.072	(0.021 - 0.124)	0.006	0.084	(0.033 - 0.134)	0.001
Age squared	-0.001	(-0.002 - -0.000)	0.012	-0.002	(-0.002 - -0.001)	<0.001
Education	0.023	(0.002 - 0.043)	0.032	0.014	(-0.006 - 0.034)	0.164
Marital/conjugal relationship status	0.059	(-0.061 - 0.179)	0.335	-0.026	(-0.144 - 0.093)	0.671
Pregnancy status	-0.481	(-0.782 - -0.180)	0.002	-0.036	(-0.327 - 0.255)	0.809
Parity	0.051	(-0.006 - 0.108)	0.082	-0.085	(-0.146 - -0.023)	0.007
Health						
Poor health	1			1		
Fine health	-0.091	(-0.602 - 0.420)	0.726	0.180	(-0.369 - 0.729)	0.52
Good health	-0.089	(-0.630 - 0.451)	0.746	0.045	(-0.527 - 0.616)	0.878
Very good health	-0.05	(-0.554 - 0.454)	0.847	0.217	(-0.325 - 0.758)	0.432
Excellent health	-0.404	(-0.953 - 0.146)	0.15	0.312	(-0.254 - 0.878)	0.28
Household wealth quintile						
Poorest	1			1		
2nd	0.050	(-0.102 - 0.202)	0.52	-0.025	(-0.175 - 0.124)	0.74
3rd	0.034	(-0.119 - 0.187)	0.659	0.009	(-0.140 - 0.158)	0.908
4th	0.045	(-0.110 - 0.200)	0.571	-0.056	(-0.210 - 0.097)	0.472
Wealthiest	-0.105	(-0.270 - 0.060)	0.213	0.107	(-0.053 - 0.267)	0.189
Distance to nearest major road	0.002	(-0.006 - 0.009)	0.676	-0.012	(-0.020 - -0.004)	0.003
Distance to nearest secondary road	0.000	(-0.044 - 0.043)	0.991	0.007	(-0.036 - 0.050)	0.747
Calendar year						
2005	1			1		
2006	-0.182	(-0.708 - 0.343)	0.496	0.495	(0.059 - 0.931)	0.026
2007	-0.220	(-0.754 - 0.315)	0.421	0.635	(0.195 - 1.074)	0.005
2008	-0.637	(-1.305 - 0.030)	0.061	0.936	(0.442 - 1.430)	<0.001
2009	0.606	(0.056 - 1.156)	0.031	0.497	(0.030 - 0.965)	0.037

2010	0.473	(-0.068 - 1.015)	0.087	0.647	(0.193 - 1.102)	0.005
2011	0.450	(-0.088 - 0.987)	0.101	0.704	(0.255 - 1.153)	0.002
2012	0.538	(-0.001 - 1.076)	0.050	0.475	(0.023 - 0.928)	0.040
Observations			3169			
ρ=-0.292 χ^2 = 80.96, p-value<0.0001						

ART = antiretroviral treatment, HIV+ = HIV-infected

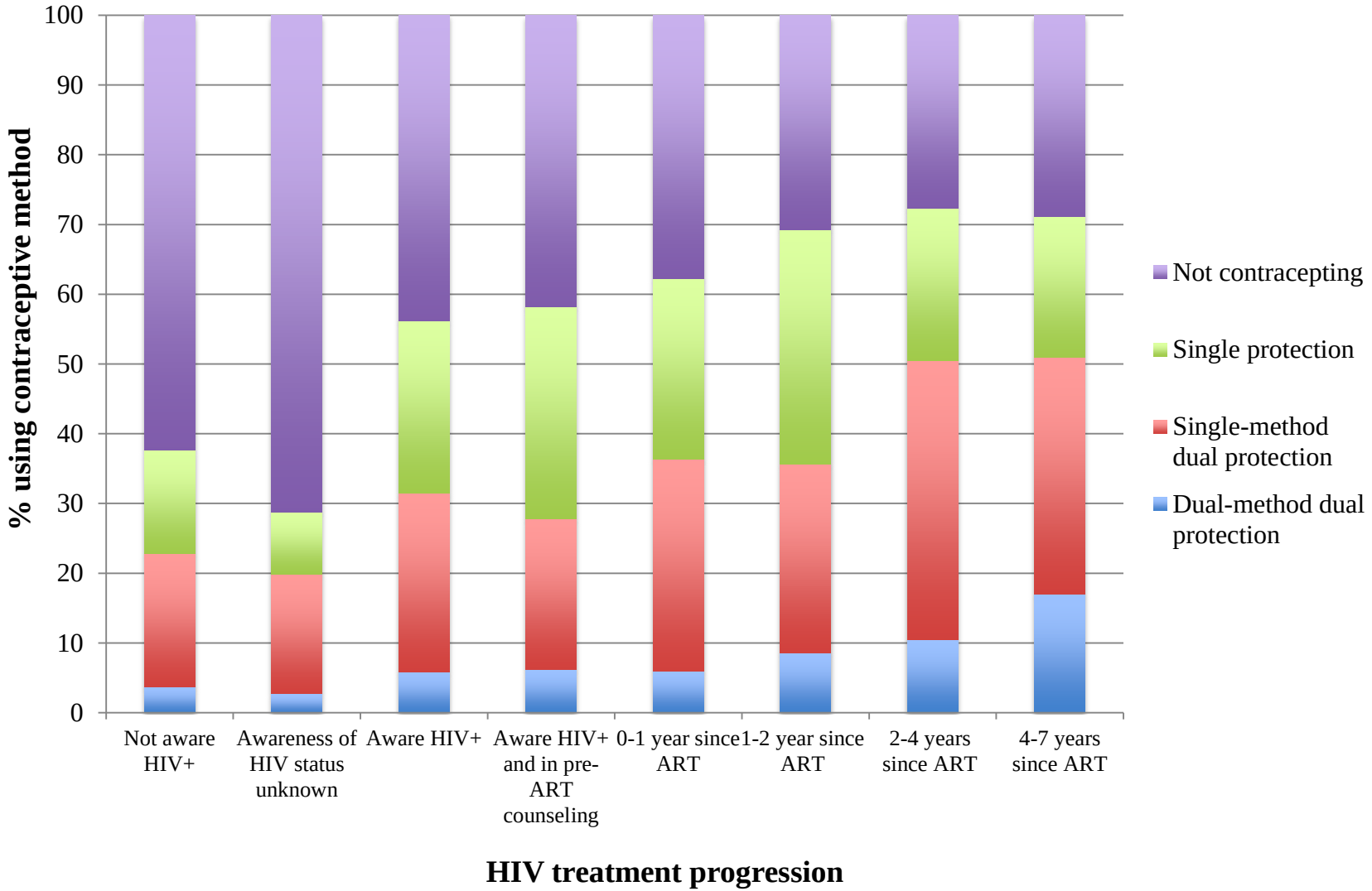
Table 4: Effects of progression through the HIV treatment cascade on contraception: average marginal effects

	No contraception			Single protection			Single-method dual protection			Dual-method dual protection		
	AME (in pp)	**95% CI**	**p-value**	**AME** (in pp)	**95% CI**	**p-value**	**AME** (in pp)	**95% CI**	**p-value**	**AME** (in pp)	**95% CI**	**p-value**
Stages in the HIV treatment cascade												
HIV+, unaware of HIV status	Ref			Ref			Ref			Ref		
HIV+ awareness unknown	-0.078	(-0.206 - 0.049)	0.228	-0.064	(-0.164 - 0.036)	0.207	0.121	(-0.005 - 0.246)	0.059	0.022	(-0.042 - 0.086)	0.498
HIV+, aware of HIV status	-0.094	(-0.140 - -0.047)	<0.001	0.012	(-0.028 - 0.052)	0.558	0.046	(0.005 - 0.088)	0.030	0.035	(0.014 - 0.056)	0.001
Pre-ART	-0.070	(-0.122 - -0.019)	0.008	0.025	(-0.020 - 0.070)	0.273	0.019	(-0.028 - 0.065)	0.431	0.027	(0.004 - 0.049)	0.021
0-1 years on ART	-0.129	(-0.195 - -0.063)	<0.001	-0.026	(-0.081 - 0.029)	0.352	0.103	(0.034 - 0.172)	0.003	0.052	(0.014 - 0.089)	0.007
1-2 years on ART	-0.156	(-0.225 - -0.086)	<0.001	0.006	(-0.057 - 0.069)	0.858	0.079	(0.006 - 0.152)	0.034	0.071	(0.027 - 0.115)	0.002
2-4 years on ART	-0.212	(-0.273 - -0.151)	<0.001	-0.088	(-0.134 - -0.043)	<0.001	0.222	(0.150 - 0.294)	<0.001	0.078	(0.037 - 0.120)	<0.001
4-7 years on ART	-0.249	(-0.318 - -0.180)	<0.001	-0.079	(-0.136 - -0.021)	0.007	0.216	(0.126 - 0.306)	<0.001	0.112	(0.053 - 0.171)	<0.001
Age	-0.037	(-0.052 - -0.021)	<0.001	0.009	(-0.004 - 0.022)	0.177	0.014	(0.000 - 0.027)	0.046	0.014	(0.008 - 0.020)	<0.001
Age squared	0.001	(0.000 - 0.001)	<0.001	0.000	(-0.000 - 0.000)	0.366	-0.000	(-0.001 - -0.000)	0.007	-0.000	(-0.000 - -0.000)	<0.001
Education	-0.009	(-0.015 - -0.002)	0.007	0.004	(-0.001 - 0.009)	0.147	0.001	(-0.004 - 0.007)	0.598	0.003	(0.001 - 0.006)	0.007
Marital/conjugal relationship status	-0.007	(-0.044 - 0.029)	0.689	0.016	(-0.015 - 0.047)	0.316	-0.011	(-0.043 - 0.020)	0.487	0.003	(-0.011 - 0.017)	0.695
Pregnancy status	0.110	(0.020 - 0.200)	0.016	-0.098	(-0.156 - -0.041)	0.001	0.023	(-0.061 - 0.107)	0.589	-0.035	(-0.056 - -0.014)	0.001
Parity	0.009	(-0.009 - 0.027)	0.332	0.019	(0.004 - 0.034)	0.012	-0.025	(-0.041 - -0.008)	0.003	-0.003	(-0.010 - 0.004)	0.396
Health												
Poor health	Ref			Ref			Ref			Ref		
Fine health	-0.025	(-0.190 - 0.139)	0.761	-0.035	(-0.159 - 0.088)	0.575	0.054	(-0.101 - 0.209)	0.496	0.007	(-0.057 - 0.071)	0.828
Good health	0.009	(-0.164 - 0.182)	0.919	-0.024	(-0.156 - 0.108)	0.724	0.019	(-0.139 - 0.177)	0.816	-0.004	(-0.066 - 0.058)	0.903
Very good health	-0.041	(-0.203 - 0.120)	0.616	-0.029	(-0.162 - 0.103)	0.665	0.057	(-0.082 - 0.196)	0.423	0.014	(-0.042 - 0.070)	0.634
Excellent health	-0.003	(-0.181 - 0.174)	0.970	-0.104	(-0.210 - 0.001)	0.053	0.119	(-0.057 - 0.296)	0.184	-0.012	(-0.068 - 0.045)	0.689
Household wealth quintile												
Wealth Quintile 1	Ref			Ref			Ref			Ref		
Wealth Quintile 2	-0.005	(-0.051 - 0.040)	0.815	0.014	(-0.026 - 0.053)	0.493	-0.010	(-0.050 - 0.030)	0.610	0.002	(-0.016 - 0.020)	0.817
Wealth Quintile 3	-0.010	(-0.056 - 0.036)	0.666	0.007	(-0.032 - 0.046)	0.718	-0.001	(-0.041 - 0.040)	0.970	0.004	(-0.014 - 0.021)	0.686
Wealth Quintile 4	0.003	(-0.044 - 0.050)	0.892	0.015	(-0.025 - 0.055)	0.461	-0.017	(-0.058 - 0.023)	0.400	-0.001	(-0.019 - 0.017)	0.913
Wealth Quintile 5	-0.004	(-0.053 - 0.046)	0.885	-0.032	(-0.072 - 0.007)	0.111	0.036	(-0.010 - 0.082)	0.121	0	(-0.019 - 0.019)	0.990
Distance to nearest primary road	0.002	(0.000 - 0.005)	0.039	0.001	(-0.001 - 0.003)	0.161	-0.003	(-0.005 - -0.001)	0.005	-0.001	(-0.002 - -0.000)	0.050
Distance to nearest secondary road	-0.002	(-0.015 - 0.012)	0.806	-0.001	(-0.012 - 0.010)	0.904	0.002	(-0.010 - 0.013)	0.771	0.001	(-0.004 - 0.006)	0.813
Calendar year												
2005	Ref			Ref			Ref			Ref		
2006	-0.093	(-0.230 - 0.044)	0.185	-0.08	(-0.183 - 0.024)	0.131	0.148	(0.010 - 0.286)	0.035	0.024	(-0.046 - 0.095)	0.502
2007	-0.125	(-0.260 - 0.009)	0.068	-0.098	(-0.195 - -0.000)	0.049	0.192	(0.049 - 0.334)	0.008	0.032	(-0.044 - 0.107)	0.413

2008	-0.170	(-0.319 - -0.021)	0.025	-0.167	(-0.238 - -0.096)	<0.001	0.336	(0.169 - 0.503)	<0.001	0.001	(-0.073 - 0.075)	0.976
2009	-0.244	(-0.371 - -0.117)	<0.001	0.070	(-0.068 - 0.208)	0.323	0.037	(-0.097 - 0.172)	0.588	0.137	(0.025 - 0.249)	0.017
2010	-0.252	(-0.377 - -0.128)	<0.001	0.026	(-0.099 - 0.151)	0.680	0.095	(-0.040 - 0.230)	0.169	0.131	(0.028 - 0.235)	0.013
2011	-0.265	(-0.392 - -0.138)	<0.001	0.022	(-0.100 - 0.144)	0.725	0.118	(-0.012 - 0.248)	0.075	0.125	(0.032 - 0.218)	0.008
2012	-0.232	(-0.365 - -0.098)	0.001	0.069	(-0.063 - 0.200)	0.305	0.053	(-0.074 - 0.180)	0.414	0.110	(0.019 - 0.201)	0.018
Observations	3169											

AME = average marginal effects, pp = percentage points, CI = confidence interval, Ref = reference category, ART = antiretroviral treatment, HIV+ = HIV-infected

Figure 1: Progression through the HIV treatment cascade and contraceptive use


% using contraceptive method
100
90
80
70
60
50
40
30
20
10
0
Not aware HIV+
Awareness of HIV status unknown
Aware HIV+
Aware HIV+ and in pre-ART counseling
0-1 year since ART
1-2 year since ART
2-4 years since ART
4-7 years since ART
HIV treatment progression
Not contracepting
Single protection
Single-method dual protection
Dual-method dual protection

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