Distribution Agreement

Signature:

________________________________ ________________

Akua Aboah Taylor Date

Factors Associated with Unsuppressed Viral Loads Among Positive Partners Within HIV Sero-Discordant Couples and Population at Risk of Transmission.

-A Population-based Survey in Malawi, Tanzania, Zambia and Eswatini

By

Akua Aboah Taylor

Master of Public Health

Epidemiology

____ [Chair's signature]

Dr Patrick S. Sullivan

Committee Chair

____ [Member's signature]

Dr Andrew C. Voetsch

Field Advisor

Factors Associated with Unsuppressed Viral Loads Among Positive Partners Within HIV Sero-Discordant Couples and Population at Risk of Transmission.

-A Population-based Survey in Malawi, Tanzania, Zambia and Eswatini

By

Akua Aboah Taylor

MBChB., University of Ghana, 2013

BSc., University of Ghana,2008

Thesis Committee Chair: Dr Patrick S. Sullivan, D.V.M., Ph.D.

Field Advisor: Dr Andrew C Voetsch, Ph.D.

An abstract of

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of
Master of Public Health
in Epidemiology

2020

Abstract

Factors Associated with Unsuppressed Viral Loads Among Positive Partners Within HIV Sero-Discordant Couples and Population at Risk of Transmission.

-A Population-based Survey in Malawi, Tanzania, Zambia and Eswatini

By Akua Aboah Taylor

Introduction: Within-couple transmission among HIV sero-discordant couples make up a significant proportion of new HIV infections. Characteristics of sero-discordant couples associated with unsuppressed viral loads in the positive partner have been relatively underexplored. Our study aimed to identify individual and couple characteristics of sero-discordant couples associated with unsuppressed HIV viral loads and to estimate HIV negative partners at risk of being infected.

Methods: This was a cross-sectional study using data from Population-based Impact Assessment (PHIA) survey conducted in four Sub-Saharan African countries, namely Malawi, Tanzania, Zambia and Eswatini between, October 2015 and June 2017. We used weighted logistic regression analysis to identify factors associated with the HIV positive partner being virally unsuppressed. Individual interview weights were applied to estimate the number of HIV negative partners at risk of acquiring an infection from their positive partners.

Results: Of the 13,695 couples, 929(99.0%) were HIV sero-discordant and eligible for analysis. Among F-M+ couples, the odds of having unsuppressed viral loads was higher among HIV-positive male partners who were younger, between 25 to 34 years ((Odds Ratio)OR-5.06 95% CI: 4.88-2.23), lived in urban regions(OR-1.28 95% CI: 1.26-1.31) and had not disclosed their HIV status to their partners(OR-4.46 95% CI:4.36-4.56). Among F+M- couples, the odds of being virally unsuppressed was higher in HIV positive females who were between the ages of 15 and 24(OR-2.24 95% CI:2.12-2.31) and had not disclosed their HIV status to their partners(OR-4.06 95% CI: 3.97-4.15); odds were lower among females if they lived in the urban areas(OR-0.93 95% CI 0.92-0.95).Both male and female HIV positive partners had higher odds of being unsuppressed if they had no formal education. An estimated 178,196 HIV-negative persons are at risk of acquiring HIV infection from their positive partners due to unsuppressed viral loads.

Conclusions: Our study findings demonstrate that a significant proportion of people living with HIV in sero-discordant relationships are not virologically suppressed, with negative partners who are at risk of acquiring HIV. We recommend that Pre-Exposure prophylaxis (PrEP) be scaled up among negative partners in this high-risk population, to reduce the risk of HIV transmission.

Keywords: HIV, sero-discordant, unsuppressed viral loads

Factors Associated with Unsuppressed Viral Loads Among Positive Partners Within HIV Sero-Discordant Couples and Population at Risk of Transmission.

-A Population-based Survey in Malawi, Tanzania, Zambia and Eswatini

By

Akua Aboah Taylor

MBChB., University of Ghana, 2013

BSc., University of Ghana,2008

Thesis Committee Chair: Dr Patrick S. Sullivan, D.V.M., Ph.D.

Field Advisor: Dr Andrew C Voetsch, Ph.D.

An abstract of

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of
Master of Public Health
in Epidemiology

2020

ACKNOWLEDGEMENTS

My sincerest gratitude goes to my thesis advisors Dr Patrick Sullivan and Dr Andrew Voetsch for their guidance and contributions in the development of this thesis paper. I am truly honored to have had the opportunity to be mentored by such devoted and skilled public health experts.

I am also grateful to Paul Stupp and Sasi Jonnalagadda for their contributions.

Finally, I am also thankful to all who have made my education at Rollins School of Public Health successful.

CONTENTS

MANUSCRIPT

Factors Associated with Unsuppressed Viral Loads among Positive Partners within HIV Sero-Discordant Couples and Population at Risk of Transmission.

-A Population-based Survey in Malawi, Tanzania, Zambia and Eswatini

Akua Aboah Taylor[1], Andrew C. Voetsch[2], Paul Stupp[2], Sasi Jonnalagadda[2], Patrick S. Sullivan[1]

[1]Department of Epidemiology, Rollins School of Public Health, Emory University, Atlanta, GA

[2]Division of Global HIV and TB, Center for Global Health, Centers for Disease Control and Prevention, Atlanta, GA

ABSTRACT

Introduction: Within-couple transmission among HIV sero-discordant couples make up a significant proportion of new HIV infections. Characteristics of sero-discordant couples associated with unsuppressed viral loads in the positive partner have been relatively underexplored. Our study aimed to identify individual and couple characteristics of sero-discordant couples associated with unsuppressed HIV viral loads and to estimate HIV negative partners at risk of being infected.

Methods: This was a cross-sectional study using data from Population-based Impact Assessment (PHIA) survey conducted in four Sub-Saharan African countries, namely Malawi, Tanzania, Zambia and Eswatini between, October 2015 and June 2017. We used weighted logistic regression analysis to identify factors associated with the HIV positive partner being virally unsuppressed. Individual interview weights were applied to estimate the number of HIV negative partners at risk of acquiring an infection from their positive partners.

Results: Of the 13,695 couples, 929(99.0%) were HIV sero-discordant and eligible for analysis. Among F-M+ couples, the odds of having unsuppressed viral loads was higher among HIV-positive male partners who were younger, between 25 to 34 years ((Odds Ratio)OR-5.06 95% CI: 4.88-2.23), lived in urban regions(OR-1.28 95% CI: 1.26-1.31) and had not disclosed their HIV status to their partners(OR-4.46 95% CI:4.36-4.56). Among F+M- couples, the odds of being virally unsuppressed was higher in HIV positive females who were between the ages of 15 and 24(OR-2.24 95% CI:2.12-2.31) and had not disclosed their HIV status to their partners(OR-4.06 95% CI: 3.97-4.15); odds were lower among females if they lived in the urban areas(OR-0.93 95% CI 0.92-0.95).Both male and female HIV positive partners had higher odds of being unsuppressed if they had no formal education. An estimated 178,196 HIV-negative persons are at risk of acquiring HIV infection from their positive partners due to unsuppressed viral loads.

Conclusions: Our study findings demonstrate that a significant proportion of people living with HIV in sero-discordant relationships are not virologically suppressed, with negative partners who are at risk of acquiring HIV. We recommend that Pre-Exposure prophylaxis (PrEP) be scaled up among negative partners in this high-risk population, to reduce the risk of HIV transmission.

Keywords: HIV, sero-discordant, unsuppressed viral loads

INTRODUCTION

Globally, there are about 37.9 million people living with Human Immunodeficiency Virus (HIV)(1) . The fight to curb the Human Immunodeficiency Virus (HIV) epidemic, has made strides, with a global decline in HIV incidence estimated to be 16% between 2010 and 2018 (1). Attainment of such accomplishments is largely due to collaborative efforts globally and nationally, in implementation of prevention strategies. Such collaborative methods were seen during AIDS conference in 2014, when the Joint United Nations Program on HIV/AIDS(UNAIDS) together with its partners initiated the 90-90-90- campaign, a strategy with a target to eliminate HIV by 2030. The strategy involved, increasing HIV testing such that 90% of people infected with HIV became aware of their status, 90% of whom would be on antiretroviral therapy(ART), with 90% of those on ART achieving virologic suppression (2,3). The 90-90-90 targets being met, an estimated 73% of people living with HIV globally would be virologically suppressed (2). An HIV positive individual is said to be virologically suppressed, when the person's HIV RNA level is below a defined limit, such that it cannot be detected with viral analysis(4).

According to recent statistics, there has been considerable progress towards achieving the 90-90-90 goal. In, 2018, about 79% of people living with HIV globally were aware of their status, about 78% of those who knew their status were accessing treatment, and among those accessing treatment, about 86% were virally suppressed(1). Despite notable successes, targets are yet to be reached, with a significant number of new HIV cases and HIV related deaths annually(1,5); globally, there were 1.7 million (1.4million-2.3 million) new HIV cases and 770,000 (570,000-1.1million) AIDS-related deaths between 2018 and June 2019 (1).

Sub-Saharan Africa (SSA) has the highest prevalence of persons living with HIV, making up about 68% of the global population, with about a million new infections annually(1) . Prevalence of infection varies by age and sex, being two times higher in younger females as compared to males(1). Currently, an estimated 20.6 million people are living with HIV in Southern and Eastern Africa (accounting for about 50% of the global burden of the epidemic), with 800,000 new infections annually, about 310,000 AIDS related deaths and 33% of PLWHIV not on ART in 2018(1).

Heterosexual transmission between stable HIV sero-discordant(SDC) partners account for a significant proportion of new HIV infections in Sub-Saharan Africa(6,7), with annual transmission risk of infection within couples ranging from 4.2% to 47.4% per person-year, across countries (8). A stable couple relationship has been described as one in which the couple is married or cohabitating (9). Furthermore, SDC couples, in which one partner is HIV-positive and the other partner is HIV-negative (10), contribute substantially to the HIV epidemic in the region (9).Of stable couples where at least one of the partners had HIV, a mean proportion of 75.2% were SDC in low HIV prevalent countries (HIV prevalence < 10%) with a mean proportion of 49.6% among these couples being SDC in high prevalent countries (HIV prevalence ≥ 10%) (9). SDC couples are thus considered high risk groups in HIV transmission, and are therefore recognized as a priority for HIV prevention interventions (11–13). Some of these interventions include recommendations by the WHO guidelines for Couples HIV Counselling and Testing (CHTC), during which couples have the opportunity to disclose their status to each other, and ART for positive partners in sero-discordant relationships, irrespective of their CD4+ count(11).

Introduction of efficacious methods such as ART has led to marked reductions in transmission of HIV among sero-discordant couples (14,15). The risk of transmission has been shown to be zero per couple years of follow-up among sero-discordant couples who reported condomless sex, when the HIV positive partner was on anti-retroviral medication and was virologically suppressed (14,15). Additionally, the incidence rate of HIV among the negative partners in SDC couples was found to be 0.9 per 100 person-years (95% CI 0.6-1.3 per 100 person-years), when the HIV positive partner was on ART (16).With such effective prevention methods available, positive individuals on anti-retroviral therapy in SDC couples, have achieved viral suppression (14–16), contributing to the immense progress being made towards reducing transmission in this high-risk group.

Some negative partners in SDC partnerships are still at risk of contracting the virus, mainly because their partners are not virally suppressed. Factors such as being unaware of status positive status, poor access to treatment, non-adherence to medication, shorter duration on medication and resistance to medication have been known prevent a person's viral load levels from being suppressed (17–20). Studies have also shown that various characteristics and behavioral factors associated with individuals are associated with lack of suppression of viral loads; some of these factors include younger age at start of ART, male gender, food insecurity, as well as alcohol intake and tobacco use (19,21–23).

Sexual behaviors and practices are associated with a person achieving viral suppression (17). Persons who engage in high-risk sexual behaviors tend to be unaware of their HIV-positivity. In one study to establish an association between individuals' high risk sexual behaviors, HIV status awareness and viral load suppression, those who were unaware of their HIV positive status were over three times more likely to report inconsistent condom use (17). In the same study , individuals with a history of high-risk sexual behavior (persons with more than one sexual partner irrespective of whether condoms were used or not) were four times more likely to have unsuppressed viral loads (17). These individuals could potentially transmit the infection to others, which will further protract the time to achieving set targets.

Individual and couple characteristics of SDC couples that are associated with unsuppressed viral loads in the positive partner have been relatively underexplored. Few studies were found that have described individual and couple characteristics of persons in HIV SDC partnerships associated with the positive partner being virally unsuppressed (24). Lingappa et al, in describing characteristics of HIV-1 SDC couples, reported that after adjusting for age and African region, gender was statistically significantly associated with HIV-1 RNA levels, in that positive male partners in SDC partnerships had relatively higher plasma HIV-1 viral loads, (0.24 log10 copies/mL higher), as compared to female positive partners in SDC partnerships (24). Additionally, positive partners in SDC partnerships with CD4 + counts ≥500 cells /mcL had relatively lower plasma RNA levels (0.55 log10 copies/mL lower) as compared to those with CD4+ counts between 250 and 350 cells/mcL (24).

Not much is known about couples' characteristics of persons in SDC partnerships that are associated with unsuppressed viral loads. Because of the high-risk tendency of such partnerships, with the significant risk of sexual transmission to the negative partners, it is important that we understand these specific characteristics that put a person at risk of not having their viral loads suppressed. Additionally, estimating the proportion of HIV negative partners in sero-discordant relationships who stand at risk of acquiring the infection from their unsuppressed positive partners will enable us to understand the burden of HIV transmissibility in this population. With these identified determinants, targeted prevention strategies, such as scaling up of Pre-exposure prophylaxis (PrEP) among HIV-negative individuals whose HIV-positive partners have unsuppressed viral loads could be implemented. PrEP has been proven to reduce the incidence of HIV infection among high risk populations without an increased risk of acquiring other sexually transmitted infections (STIs) (25).

The aims of this study are (1) to determine individual and couple characteristics of sero-discordant couples associated with the positive partner not achieving virologic suppression and (2) to estimate the number of HIV negative partners that stand at risk of acquiring HIV from their positive partners. The analysis study will be conducted using data collected in four Southern and Eastern African countries, namely Malawi, Tanzania, Zambia and Eswatini.

METHODS

Study Design and Population

A comprehensive report of the methodology used can be found elsewhere (26).This was a cross-sectional study using data from Population-based Impact Assessment (PHIA) survey conducted in four Sub-Saharan African countries, namely Malawi, Tanzania, Zambia and Eswatini between, October 2015 and June 2017 (27) . In collaboration with the Ministries of Health of participating countries and the US Centers for Disease Control and Prevention (CDC), ICAP at Columbia University implemented the PHIA Project in countries, supported by the President's Emergency Plan For AIDS Relief (PEPFAR), to assess the impact of HIV programs there (27).

Data Collection and Selection Criteria

Sampling was conducted using a stratified multistage design (27). The first stage of sampling involved random selection of previously determined sections known as census enumeration areas from subnational geographic divisions, ensuring that the probabilities that were used in selection corresponded to the approximated sizes of the various populations (27). The second stage of the sampling process entailed random selection of households within chosen enumeration areas. The 3rd stage of sampling was done specifically to choose households with children under 15 years. After the second stage of sampling, households that were picked had a survey conducted if the head of household or their stand in consented (27). Individuals of ages 15 years and above were considered eligible to complete an adult questionnaire in Tanzania, Zambia and Eswatini after consent (28–30). For individuals in Malawi, consenting people between the ages of 15 and 64 years could complete a questionnaire (31). If an individual was found to have a sexual partner living in the same household, those partners were administered a questionnaire if they consented (27). For each participant, information on up to three sexual partners were recorded for some variables (27), such that an individual may be counted multiple times with different partners.

Laboratory procedures

After individuals were administered adult questionnaires, those who consented were provided laboratory testing. Blood samples were taken for biomarker tests (27). As a component of the home-based testing and counselling, every individual had an HIV test done applying the national HIV test algorithm specific to each country (26).Whole blood samples were used for the tests with individuals subsequently informed of results (27). Individuals who tested positive for HIV had additional tests such as CD4+ count, recency testing, detection of antiretroviral (ARV) medication and HIV RNA viral load levels (27).

Outcome Variable

The primary outcome of interest was the HIV RNA viral load from HIV positive individuals in SDC partnerships. In accordance with WHO guidelines, an individual was described as virally suppressed if viral load levels were <1000 copies/ml and virally unsuppressed if viral loads >= 1000 copies/ml at most recent testing (32).

Explanatory variables

Explanatory variables from the dataset that we considered for our analysis were age, gender, age difference within couples, education, residence, marital status, number of spouses/partners, and socio-economic status of couples (wealth quintile). In addition, variables considered were use of condoms during last sexual encounter, number of sexual partners in the last 12 months, knowledge/awareness of HIV status, disclosure of HIV status to partner, frequency of alcohol intake, history of ARV medication intake, history of tuberculosis diagnosis and CD4 + levels. Frequency of alcohol intake was categorized as never, less than once a month, 2-4 times a month, 2-3 times a week, and more than times a week. Awareness of HIV status was determined by either a participant's self-report or ARV medication detected in the participant's blood. Individuals CD4+ levels were categorized into five: less than a 100 cells/mm^3, 100-199 cells/mm3, 200-349 cells/mm^3, 350-399 cells/mm_3 and ≥ 500 cells/mm^3.

Ethics and Training of staff

In all countries, the Institutional Review Boards of the Centers for Disease Control and Prevention, Columbia University Medical Center and Westat reviewed and approved the survey processes(33–36).

In addition to the above institutions, country-specific institutions also reviewed and approved the processes:

Malawi: The National Health Sciences Research Committee in Malawi (33).

Tanzania: The Institutional Review Boards of the National Institute for Medical Research, and the Zanzibar Medical Research and Ethics Committee (34).

Zambia: The Tropical Diseases Research Centre in Zambia (35).

Eswatini: The Eswatini National Health Research Review Board (36).

Training that was giving to the staff taking part in the survey conduction is discussed in depth elsewhere (26).

Data Analysis

Individuals were considered for our analysis if they were ≥15 years and older and had a household sexual partner. We included couples in which one partner was HIV positive and the other was HIV negative in our analysis. Furthermore, couples qualified for analysis only if the HIV positive partner had a valid viral load test result. To avoid double counting of participants, females were selected as index cases and were matched to their corresponding male sexual partners who lived in the same household. Statistical analysis was done using Statistical Analysis Software (SAS) version 9.4 (SAS Institute, Inc., Cary N.C. USA). After analysis was done for individual countries, the datasets were pooled together, and analyzed to obtain overall estimates.

Descriptive analysis for individual and couple demographics was conducted on the various categorical and continuous variables to determine the proportions and means and standard deviations, respectively. Age variables were also categorized into five-year ranges for descriptive analysis. The age groups for chi-square analysis were categorized into 10-year age groups: 15-24, 25-34,35-44,45-54 and ≥55 years. For chi-square and regression analysis, couples were stratified into two groups depending on the gender of the HIV+ partner: F-M+ and F+M-. For each group, chi-square tests (or Fishers Exact tests where applicable) were used to compare the differences between individual and couple characteristics and viral load suppression of the HIV positive index/ partner.

Individual weights were determined to account for sampling and non-response among participants (27). This was derived from adjusted household weights and the probability of an individual being selected. Furthermore, blood test weights were computed depending solely on individual interviews, as all participants were offered blood tests(27). Weighted logistic regression (bivariate model) was used to identify individual and couple factors associated with the HIV positive person being virally unsuppressed, applying blood weights. Based on the dataset, covariates considered in the bivariate analysis were: 10-year age group, age difference within couple (no difference, 1-5 years,6-10 years, 11-15 years,16-20 years, ≥ 21 years), education (none, primary, secondary tertiary),employment, residence (urban, rural), marital status (married, living together), wealth quintile (lowest, second, middle, fourth, highest), number of sexual partners in last 12 months (0,1,≥1), condom use during last sexual encounter in last 12 months, awareness of HIV status (aware, unaware), disclosure of HIV status to partner, frequency of alcohol intake, and CD4+ count levels. We used the PROC FREQ command and individual interview weights to estimate the total number of HIV negative partners at risk of acquiring an infection from their positive partners and blood weights were used to estimate the proportion of HIV positive partners who were aware of their HIV positive status. Chi-square test statistics were used to determine if HIV status awareness varied by viral load suppression, while stratified on gender.

Pooled and individual country estimates of HIV prevalence was determined using blood test weights. Prevalence of HIV sero-discordant couples, by country and pooled were also determined, using blood test weights, and as a proportion of all stable couple relationships.

Data Availability

The datasets used for analysis are available at (https://phia-data.icap.columbia.edu/).

RESULTS

The survey response rates for females and males, respectively, were 81.6% and 70.9% in Malawi(37), 90% and 85% in Tanzania(38), 82.4% and 71.8% in Zambia(39), and 88.7% and 79.4% in Eswatini(40).

HIV prevalence (determined by HIV testing conducted in the study) was highest in Eswatini (27.0%), followed by Malawi (10.4%), Zambia (12.0%), and Tanzania (4.9%), with a pooled prevalence of 7.4% (Figure 1).Gender-specific prevalence is also reported in Figure 1. Of the 13,695 couples that were identified, 938 (6.9%) couples were found to be HIV sero-discordant, with Eswatini having the highest proportion (16.1%) (Figure 2). Of the 929 HIV positive participants 472 (50.8%) were females and 457(49.2%) were males. Among these, 929 (99.0%) couples had viral load results for the HIV positive partner and were eligible to be used for the analysis. The distribution of individual and couple characteristics are presented in Table 1. Overall, 50.8% of sero-discordant couples were F+M- (as defined in the methodology section). The mean age of the males was 42.5 years and females were 35.7 years, with medians of 41years and 35 years respectively. By couple type, the mean age for female and male partners was 36.1years and 43.3 years respectively among F-M+ couples and 35.3 years and 41.8 years respectively among F+M- couples. The mean age difference between the couples was 7.5 years, with 404 (43.1%) couples having an age difference between one to five years. Overall, 62.9% lived in the rural areas, 53.1% had primary level education and 56.2% had not worked in the last 12 months. Most (93.8%) participants had only one stable partner or spouse, 91 (5%) had two partners and 22 (1.2%) had three or more partners. Of the HIV positive partners, who were aware of their HIV positive status at the time of the survey,99.2% reported taking ARV medication at the time of the survey. Those not on ARV medication reported not taking medication because they did not feel it was needed or because the medication was not prescribed.

Altogether considering HIV positive participants in SDC partnerships, who were and were not on ART, 538 (57.5%) were virally suppressed (Table 2). Furthermore, 88.5% of HIV positive persons in SDC partnerships who were on ART were virally suppressed (Table 2).

Overall, 89.6% of all HIV-positive participants who were on ART had suppressed HIV viral loads. When stratified on gender, 90.3% of males and 87.0% of females on ART were virally suppressed (Table 2).

HIV-negative female with HIV-positive male partner (F- M+)

HIV-positive male partners between 15 to 24 years had a lower proportion of suppressed viral loads (33.3%) as compared to those in the 25 to 34 (49.0%), 35 to 44 (56.5%), 45 to 54 (73.9%) and 55 (88.2%) years and older age groups ($p<.0001$). Employment, residence and marital status did not vary by viral load suppression. Positive male participants who used condoms during their last sexual encounter had a higher proportion of suppressed viral loads (79.0%) as compared to those who did not (42.1%,) ($p<.0001$). HIV-positive males who had disclosed their status to their sexual partners had a higher proportion of suppressed viral loads (63.3%) as compared to those who hadn’t disclosed their status to their partners (23.8%) ($p <.0001$). Male participants who missed their ARV medication for less than 4 days had a higher proportion of suppressed viral loads (90.4%) as compared to those who missed their medication for 4 days or more (31.9%) ($p<.0001$). Diagnosis of tuberculosis did not appear to vary by viral load suppression.

HIV-positive male partners ages 15-24 years has higher odds of having unsuppressed viral loads as compared to those in the older age groups (Table 2). Couples with an age difference between 11 to 15 years had higher odds of having unsuppressed viral loads and couples with no age difference were more likely to have a positive partner with suppressed viral loads as compared to couples with 1 to 5 years age difference (Table 2). The odds of having unsuppressed viral loads was higher among HIV-positive male partners that had no formal education as compared to those who have had some formal education (Table 2). HIV-positive male partners who were employed, lived in the urban areas and were in the first and second wealth quintile also had higher odds of being virally unsuppressed (Table 2). Men who had more than one sexual partner in the last 12 months had higher odds of having unsuppressed viral loads compared to those who had one sexual partner (Table 2). Male HIV-positive partners had higher odds of being unsuppressed if they did not use condoms during their last sexual encounter and if they had not disclosed their HIV status to their partners (Table 2). Similarly, those with a history of alcohol intake had higher odds having unsuppressed viral loads as compared to those with no history of alcohol intake (Table 2).

HIV-positive female with HIV-negative male partner (F+M-)

The distribution of the various characteristics by viral load suppression and the odds ratios are presented in Table 3. Among this cohort, condom use during last sexual encounter in the last 12 months, which may be an indication of the frequency of condom use, as well as disclosure of status to partner distribution varied with viral load suppression. Knowledge of one’s HIV status or awareness of status, CD4 count level, duration on ART varied with viral load suppression, as shown in Table 3.

We did not observe any differences in the proportions of viral load suppression by age distribution, education, and residence. Overall, married couples had a higher proportion of suppressed viral loads (62.8%) as compared to the proportion among couples living together (47.6%; p = 0.01). Most (93.2%) HIV positive females had only one sexual partner in the last 12 months; however, it did not vary by viral load suppression. HIV positive females whose partners used a condom during the last sexual encounter had a higher proportion of suppressed viral loads (72.5%) as compared to those whose partners didn't (54.8%) (p -= 0.0003). Similarly, those who had disclosed their HIV status to their partners had a higher proportion of suppressed viral loads (68.4%) as compared to those who did not (39.7%) (p <.0001). There was no difference in the distribution of tuberculosis diagnosis, frequency of alcohol intake and number of days of missed pills by viral load suppression.

HIV-positive female partners between the ages of 15 and 24 had higher odds of being virally unsuppressed compared to older women (Table 3). Compared to couples with a 1 –5-year age gap, couples with a >20 years age gap had lower odds of having a positive partner who was virally unsuppressed (Table 3). Female partners with no formal education had higher odds of having unsuppressed viral loads as compared to those who had primary, secondary and tertiary education (Table 3). Additionally, the odds of having unsuppressed viral loads was higher among female partners if the couple was married and was in the first and second wealth quintile (Table 3). Female partners living in urban areas had higher odds of being virally suppressed compared to those living in the rural areas (Table 3). Those who had not disclosed their HIV status to their partners and those whose partners did not use condoms during their last sexual encounter were also had higher odds of being virally unsuppressed (Table 3). Similarly, female partners who drank alcohol had higher odds of being virally unsuppressed compared to those who had no history of alcohol consumption (Table 3).

Partners at risk of transmission and awareness of HIV-positive status

In all, an estimated 178,196 HIV-negative persons (92,711 male partners and 85,485 female partners) where are at risk of acquiring HIV infection from their HIV-positive partners due to unsuppressed HIV viral loads, irrespective of their partner's awareness of HIV positive status (Table 4). Approximately 237,687 (59.4%) of the HIV positive participants were aware of their status; 22.1% of female positive partners and 21.6% of male positive partners who were aware of the status had unsuppressed viral loads respectively (Figure 3). Female and male HIV-positive participants who were not aware of their status had a higher proportion of unsuppressed viral loads (85.6% and 84.0% respectively).

DISCUSSION

HIV SDC couples in sub-Saharan Africa are a high-risk population for HIV transmission (11–13). Our study found that the proportion of viral load suppression among HIV positive partners of SDC couples (both those on treatment and those who are not) was 57.5%. However, considering only those on treatment, 88.5% had achieved viral load suppression. This is an indication of the effectiveness of ART in reducing viral loads, thereby buttressing the need for expansion of ARV medication use in this population, in order to reduce viral loads and control transmission. Similarly, 89.6% of all HIV positive participants who were on ARV medication had achieved viral load suppression, inching us further towards the 90% target aimed at by the UNAIDS 90-90-90 campaign (2). This finding is relatively higher, compared to results obtained by Davey et al in their study, where 84% of persons on ART were virally suppressed (19). The increased proportion determined by our study could be attributed to differences in the population locations under study. Additionally, 178,196 HIV negative persons in this population are at risk of acquiring HIV from their positive partners, who are not virally suppressed. This highlights the magnitude of the population at risk if effective prevention strategies are not implemented broadly in this population. A relatively higher proportion of males (45.3% vs. 39.8% of females) did not have suppressed viral loads, which is consistent with previous studies (19,41). This may be due to the overall poor health -seeking behavior of men, as compared to women, making them more unlikely to visit clinics for HIV care (42).

Among both couple types, positive individuals who had not disclosed their HIV status to their partners were more likely to be virally unsuppressed as compared to those who had disclosed. This finding is consistent with results obtained from previous studies (43,44). Gill et al reported that pregnant and post-partum HIV positive women in Rwanda who had not disclosed their HIV status to their partners were more likely to have detectable HIV viral loads (43). This emphasizes the importance of couples disclosing their HIV status to each other, as promoted by the WHO guidelines through couple's HIV testing counselling (11). With both partners being aware of the other's status, the necessary precautions will be taken, in order to prevent within-couple transmission.

Another important finding from our study was that, among both F-M+ SDC couples and F+M- couples, positive partners were more likely to be virally unsuppressed if they had a low socio-economic status. Results were like that of a study on population-level HIV viral loads in Kenya, though results from their study were not statistically significant (45). Our results support the hypothesis that people with low socio-economic status may tend to prioritize other basic needs over health seeking-behavior and may not focus on seeking HIV care and treatment as consistently as they should. In both couple groups, younger age of participants and lower educational status were associated with a higher odd of unsuppressed viral loads. This agrees with previous published papers that show similar results (43). Gill et al reported that women with no education were likely to have detectable viral loads as compared to those with secondary education or higher (43). This highlights the role of education in reducing HIV transmission within SDCs in these communities. We did, however, discover some differences regarding residency of participants in relation to viral load suppression. Among F-M+, the male positive partners were more likely to be virally unsuppressed if the couples lived in urban areas, contrasting results from F+M- couples where the female positive partners were more likely to be virally unsuppressed if the couples lived in the rural areas. Results among the latter group matched those from the study in Kenya, where HIV positive participants who lived in the rural areas, had a higher odd of not being virologically suppressed, with results not being statistically significant (45). This is of importance as majority of the population under study (62.9%), as well as HIV positive women (59.3%) live in rural areas, thereby posing a risk of HIV transmission to a large population if viral loads are not suppressed. Further exploration as why these differences exist is, however warranted.

Results from our study showed a correlation between HIV prevalence and prevalence of HIV sero-discordant couples. To elaborate, Tanzania, which showed an overall low prevalence of HIV (4.9%) had a low prevalence of HIV SDC (4.5%) , with a similar pattern observed in Malawi, Zambia and Eswatini, where high HIV prevalence of 27% corresponded to a high prevalence of SDCs. This pattern agrees with results obtained by Chemaitelly et al, who reported that the proportion of stable couples that were HIV sero-discordant corresponded to individual country HIV prevalence, from lowest to highest (9). Their study, however, had relatively higher proportions of sero-discordant couples for Malawi (9.3%), Tanzania (6.4%), and Zambia (11.0%), with results for Eswatini similar to ours (16.4%) (9).Variability in populations and study times could be responsible for the dissimilarities observed between the two results. A hypothesis worth considering here would be possibility of increased prevention efforts contributing to the decline in overall HIV prevalence, and subsequently prevalence of SDCs.

Strengths and Limitations

Our study had several strengths, including high response rates from participants in all countries, a nationally representative sample and standardized data collection methods. Despite these strengths, our study was subject to several important limitations. With data on non-household sexual partners of participants not collected, information was lost in these aspects of our analysis, which could affect the validity results we obtained. This is because sexual behaviors with non-household partners could be different form that with household partners. Second, because some questions required participants to recall past activities, our data might have been subject to recall bias. Another limitation worth noting was that weighted proportions were not reported for distribution of baseline individual characteristics or for our chi-square and Fisher's analysis. This was because, some cells in our data had expected counts of less than five, and as such had to be analyzed with Fisher's exact test, in order to obtain valid results. Fisher's exact test could, however, not be used for analysis if weights were applied, as non-integer values would be yielded, which are not compatible with Fisher's test. However, we applied our weights during logistic regression analysis, as well as prevalence and risk estimations.

Conclusion and Recommendations

A significant proportion of people living with HIV in SDC partnerships in Malawi, Tanzania, Zambia and Eswatini were not virologically suppressed in 2015 to 2017, especially among HIV-positive partners who are unaware of their HIV status. Additionally, a substantial number of HIV negative partners are at risk of acquiring HIV because their positive partners are not virologically suppressed. There is substantial evidence that prevention (e.g., PrEP) have been effective in reducing the incidence of HIV infection among high risk populations (25).It is therefore our recommendation that PrEP be scaled up among the negative partners in SDC partnerships. Successful increase and extension in PrEP use has been attributed to various factors, including involvement of stakeholders at all levels, in prevention program planning (46). There are demographic and behavioral factors associated with SDC couples that can be used in identifying couples that pose a high risk of within-couple transmission. Couples with low socio-economic status, those in which the HIV positive female partners dwell in rural areas, those in which HIV positive partners have no formal education, and those in which HIV-positive partners have not disclosed their HIV status to their partners were more likely to have positive partners with unsuppressed HIV viral loads. With these identified factors, it is important for us to develop a predictive risk model that would inform our decision when identifying SDC couples at health facilities that would be 'high-risk' candidates for HIV transmission and should be offered PrEP.

With evidence showing that having undetectable HIV viral load levels implies that one cannot transmit the virus (47), couples in which the positive partner has undetectable viral load levels would be considered as ‘low-risk’ candidates for PrEP, and those with partners having detectable levels ‘high-risk’ candidates for PrEP.

Our study findings demonstrate how effective the various strategies implemented under the 90-90-90 campaign have been in combating the HIV epidemic. With almost all (99%) positive partners who were aware of their status on treatment, and subsequently a significant proportion achieving viral suppression, the need for increased screening to identify SDC couples is evident. With increased diagnoses, and thus, increased number of people aware of their HIV positive status, ART coverage can be increased in this population, and eventually a higher proportion people with suppressed viral loads. It is, therefore, important to develop and effect programs, as well as updating already existing programs that will not only focus on promoting ART use in identified positive partners of SDC couples, but meet the needs of negative partners in high- risk SDC partnerships, by expanding the use of PrEP, thereby, reducing the risk of acquiring the infection from their positive partners.

REFERENCES

1. UNAIDS_FactSheet_en.pdf. (https://www.unaids.org/sites/default/files/media_asset/UNAIDS_FactSheet_en.pdf). (Accessed November 30, 2019)

2. 90-90-90: An ambitious treatment target to help end the AIDS epidemic. :40.

3. WHO | New HIV testing guidance to help reach the 90-90-90 targets. *WHO*. (https://www.who.int/hiv/mediacentre/news/hiv-testing-90targets/en/). (Accessed November 30, 2019)

4. World Health Organization. Consolidated guidelines on the use of antiretroviral drugs for treating and preventing HIV infection: recommendations for a public health approach. 2016 (Accessed April 5, 2020).(http://apps.who.int/iris/bitstream/10665/208825/1/9789241549684_eng.pdf). (Accessed April 5, 2020)

5. WHO-CDS-HIV-19.7-eng.pdf. (https://apps.who.int/iris/bitstream/handle/10665/324797/WHO-CDS-HIV-19.7-eng.pdf?ua=1). (Accessed November 30, 2019)

6. Gouws E, Cuchi P. Focusing the HIV response through estimating the major modes of HIV transmission: a multi-country analysis. *Sex. Transm. Infect.* 2012;88(Suppl_2):i76–i85.

7. Dunkle KL, Stephenson R, Karita E, et al. New heterosexually transmitted HIV infections in married or cohabiting couples in urban Zambia and Rwanda: an analysis of survey and clinical data. *The Lancet*. 2008;371(9631):2183–2191.

8. Awad SF, Chemaitelly H, Abu-Raddad LJ. Estimating the annual risk of HIV transmission within HIV sero-discordant couples in sub-Saharan Africa. *Int. J. Infect. Dis.* 2018;66:131–134.

9. Chemaitelly H, Cremin I, Shelton J, et al. Distinct HIV discordancy patterns by epidemic size in stable sexual partnerships in sub-Saharan Africa. *Sex. Transm. Infect.* 2012;88(1):51–57.

10. Muessig KE, Cohen MS. Advances in HIV Prevention for Serodiscordant Couples. *Curr. HIV/AIDS Rep.* 2014;11(4):434–446.

11. WHO | Guidance on couples HIV testing and counselling - including antiretroviral therapy for treatment and prevention in serodiscordant couples. *WHO*. (https://www.who.int/hiv/pub/guidelines/9789241501972/en/). (Accessed November 30, 2019)

12. World Health Organization - 2012 - Guidance on Pre-Exposure Oral Prophylaxis (PrEP) f.pdf. (https://apps.who.int/iris/bitstream/handle/10665/75188/9789241503884_eng.pdf?sequence=1). (Accessed April 5, 2020)

13. Curran K, Baeten JM, Coates TJ, et al. HIV-1 Prevention for HIV-1 Serodiscordant Couples. *Curr. HIV/AIDS Rep.* 2012;9(2):160–170.

14. Rodger AJ, Cambiano V, Bruun T, et al. Sexual Activity Without Condoms and Risk of HIV Transmission in Serodifferent Couples When the HIV-Positive Partner Is Using Suppressive Antiretroviral Therapy. *JAMA*. 2016;316(2):171–181.

15. Rodger AJ, Cambiano V, Bruun T, et al. Risk of HIV transmission through condomless sex in serodifferent gay couples with the HIV-positive partner taking suppressive antiretroviral therapy (PARTNER): final results of a multicentre, prospective, observational study. *The Lancet*. 2019;393(10189):2428–2438.

16. Cohen MS, Chen YQ, McCauley M, et al. Prevention of HIV-1 Infection with Early Antiretroviral Therapy. *N. Engl. J. Med.* 2011;365(6):493–505.

17. Huerga H, Venables E, Ben-Farhat J, et al. Higher risk sexual behaviour is associated with unawareness of HIV-positivity and lack of viral suppression – implications for Treatment as Prevention. *Sci. Rep.* [electronic article]. 2017;7. (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5700952/). (Accessed November 14, 2019)

18. Ehlers VJ, Tshisuyi ET. Adherence to antiretroviral treatment by adults in a rural area of Botswana. *Curationis*. 2015;38(1).

19. Joseph Davey D, Abrahams Z, Feinberg M, et al. Factors associated with recent unsuppressed viral load in HIV-1-infected patients in care on first-line antiretroviral therapy in South Africa. *Int. J. STD AIDS*. 2018;29(6):603–610.

20. Etta EM, Mavhandu L, Manhaeve C, et al. High level of HIV-1 drug resistance mutations in patients with unsuppressed viral loads in rural northern South Africa. *AIDS Res. Ther.* [electronic article]. 2017;14. (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5531022/). (Accessed October 17, 2019)

21. Riley ED, Vittinghoff E, Koss CA, et al. Housing First: Unsuppressed Viral Load Among Women Living with HIV in San Francisco. *AIDS Behav.* 2019;23(9):2326–2336.

22. Shacham E, Agbebi A, Stamm K, et al. Alcohol Consumption is Associated with Poor Health in HIV Clinic Patient Population: A Behavioral Surveillance Study. *AIDS Behav*. 2011;15(1):209–213.

23. Hile SJ, Feldman MB, Alexy ER, et al. Recent Tobacco Smoking is Associated with Poor HIV Medical Outcomes Among HIV-Infected Individuals in New York. *AIDS Behav*. 2016;20:1722–1729.

24. Lingappa JR, Kahle E, Mugo N, et al. Characteristics of HIV-1 Discordant Couples Enrolled in a Trial of HSV-2 Suppression to Reduce HIV-1 Transmission: The Partners Study. *PLoS ONE* [electronic article]. 2009;4(4). (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2671170/). (Accessed November 18, 2019)

25. McCormack S, Dunn DT, Desai M, et al. Pre-exposure prophylaxis to prevent the acquisition of HIV-1 infection (PROUD): effectiveness results from the pilot phase of a pragmatic open-label randomised trial. *The Lancet*. 2016;387(10013):53–60.

26. Radin E, Sachathep K, Hladik W. Population-based HIV Impact Assessments (PHIA) Survey Methods, Response, and Quality in Zimbabwe, Malawi, and Zambia (Manuscript in Preparation).

27. PHIA Data Use Manual.pdf. (https://dms-filesystem.s3.amazonaws.com/uploads/170b96fe126534c7ec04076907e6f7ef/01_PHIA%20Data%20Use%20Manual.pdf). (Accessed October 3, 2019)

28. THIS 2016-2017 Data Use Manual Supplement.pdf. (https://dms-filesystem.s3.amazonaws.com/uploads/4bdcfae05507e8f236fe81b5f09b883f/02_THIS%20 2016-2017%20Data%20Use%20Manual%20Supplement.pdf). (Accessed April 4, 2020)

29. ZAMPHIA 2016 Data Use Manual Supplement.pdf. (https://dms-filesystem.s3.amazonaws.com/uploads/370b365e4208ca65c350e4c3c785e9a1/02_ZAMPHIA%202016%20Data%20Use%20Manual%20Supplement.pdf). (Accessed April 4, 2020)

30. SHIMS2 2016-2017 Data Use Manual Supplement.pdf. (https://dms-filesystem.s3.amazonaws.com/uploads/00744ef9d49991e5777c52383c78c31f/02_SHIMS2%202016-2017%20Data%20Use%20Manual%20Supplement.pdf). (Accessed April 4, 2020)

31. MPHIA 2015-2016 Data Use Manual Supplement.pdf. (https://dms-filesystem.s3.amazonaws.com/uploads/0c69bf9e270ac7680ab8b0dadf5b752a/002_MPHIA%202015-2016%20Data%20Use%20Manual%20Supplement.pdf). (Accessed April 4, 2020)

32. World Health Organization - 2013 - Consolidated guidelines on the use of antiretrovir.pdf. (https://apps.who.int/iris/bitstream/handle/10665/85321/9789241505727_eng.pdf?sequence=1). (Accessed April 5, 2020)

33. MPHIA-Final-Report_web.pdf. (https://phia.icap.columbia.edu/wp-content/uploads/2019/08/MPHIA-Final-Report_web.pdf). (Accessed April 5, 2020)

34. FINAL_THIS-2016-2017_Final-Report__06.21.19_for-web_TS.pdf. (https://phia.icap.columbia.edu/wp-content/uploads/2019/06/FINAL_THIS-2016-2017_Final-Report__06.21.19_for-web_TS.pdf). (Accessed April 5, 2020)

35. ZAMPHIA-Final-Report__2.26.19.pdf. (https://phia.icap.columbia.edu/wp-content/uploads/2019/03/ZAMPHIA-Final-Report__2.26.19.pdf). (Accessed April 5, 2020)

36. SHIMS2_Final-Report_05.03.2019_forWEB.pdf. (https://phia.icap.columbia.edu/wp-content/uploads/2019/05/SHIMS2_Final-Report_05.03.2019_forWEB.pdf). (Accessed April 5, 2020)

37. MALAWI POPULATION-BASED HIV IMPACT ASSESSMENT MPHIA 2015–2016 SUMMARY SHEET. (https://phia.icap.columbia.edu/wp-content/uploads/2018/10/MPHIA-SS_2018_FINAL.pdf)

38. TANZANIA HIV IMPACT SURVEY (THIS) A POPULATION-BASED HIV IMPACT ASSESSMENT 2016-2017. (https://phia.icap.columbia.edu/wp-content/uploads/2016/09/THIS_Final.pdf)

39. ZAMPHIA_Summary_Sheet_Final.pdf. (https://phia.icap.columbia.edu/wp-content/uploads/2019/02/ZAMPHIA_Summary_Sheet_Final.pdf). (Accessed April 28, 2020)

40. SWAZILAND HIV INCIDENCE MEASUREMENT SURVEY 2: A POPULATION-BASED HIV IMPACT ASSESSMENT SHIMS2 2016–2017 SUMMARY SHEET. (https://phia.icap.columbia.edu/wp-content/uploads/2019/05/SHIMS2_Final.pdf)

41. Barnes A, Nunn A, Karakala S, et al. State of the ART: Characteristics of HIV infected patients receiving care in Mississippi (MS), USA from the Medical Monitoring Project, 2009-2010. *J. Miss. State Med. Assoc.* 2015;56(12):376–381.

42. Yeatman S, Chamberlin S, Dovel K. Women's (health) work: A population-based, cross-sectional study of gender differences in time spent seeking health care in Malawi. *PloS One*. 2018;13(12):e0209586.

43. Gill MM, Hoffman HJ, Bobrow EA, et al. Detectable Viral Load in Late Pregnancy among Women in the Rwanda Option B+ PMTCT Program: Enrollment Results from the Kabeho Study. *PLoS ONE* [electronic article]. 2016;11(12). (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5179044/). (Accessed April 5, 2020)

44. Yotebieng M, Mpody C, Ravelomanana NL, et al. HIV viral suppression among pregnant and breastfeeding women in routine care in the Kinshasa province: a baseline evaluation of participants in CQI-PMTCT study. *J. Int. AIDS Soc.* [electronic article]. 2019;22(9). (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6732557/). (Accessed April 5, 2020)

45. Cherutich P, Kim AA, Kellogg TA, et al. Detectable HIV Viral Load in Kenya: Data from a Population-Based Survey. *PLoS ONE* [electronic article]. 2016;11(5). (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4871583/). (Accessed April 5, 2020)

46. Djomand G. Expansion of HIV Preexposure Prophylaxis to 35 PEPFAR-Supported Early Program Adopters, October 2016–September 2018. *MMWR Morb. Mortal. Wkly. Rep.* [electronic article]. 2020;69. (https://www.cdc.gov/mmwr/volumes/69/wr/mm6908a3.htm). (Accessed April 4, 2020)

47. HIV Viral Load and Transmissibility of HIV Infection: Undetectable Equals Untransmittable | HIV | JAMA | JAMA Network. (https://jamanetwork.com/journals/jama/article-abstract/2720997). (Accessed April 5, 2020)

TABLES

Table 1. Distribution of Baseline Individual and Couple Characteristics of 929 HIV Sero-discordant Couples 15 Years and Older Enrolled in Surveys Conducted in Malawi, Tanzania, Zambia and Eswatini – Pooled Estimates (MPHIA 2015-2016, THIS 2016-2017, ZAMPHIA 2016, SHIMS 2016-2017, n = 1858)

All Countries	**All Couples**			**F- M+**			**F+ M-**		
Characteristics	**Total N (%)**	**Male n (%)**	**Female n (%)**	**Total N (%)**	**Male n (%)**	**Female n (%)**	**Total N (%)**	**Male n (%)**	**Female n (%)**
Age (mean, SD)		42.5(11.5)	35.7(9.9)		43.3(10.6)	36.1(10.2)		41.8(12.1)	35.3(9.7)
Age (5-year categories)									
Overall	1858(100)	929(50.0)	929(50.0)	914(100)	457(50.0)	457(50.0)	944(100)	472(50.0)	472(50.0
15-19	19(1.0)	1(0.1)	18(1.9)	13(1.4)	1(0.2)	12(2.6)	6(0.6)	0(0.0)	6(1.3)
20-24	128(6.9)	24(2.6)	104(11.1)	57(6.2)	9(2.0)	48(10.5)	71(7.5)	15(3.2)	56(11.9)
25-29	247(13.3)	90(9.7)	157(16.9)	103(11.3)	26(5.7)	77(16.9)	144(15.3)	64(13.6)	80(17.0)
30-34	308(16.6)	134(14.4)	174(18.7)	138(15.1)	58(12.7)	80(17.5)	170(18.0)	76(16.1)	94(19.9)
35-39	318(17.1)	153(16.5)	165(17.8)	161(17.6)	81(17.7)	80(17.5)	157(16.6)	72(15.3)	85(18.0)
40-44	308(16.6)	164(17.7)	144(15.5)	168(18.4)	94(20.6)	74(16.2)	140(14.8)	70(14.8)	70(14.8)
45-49	190(10.2)	117(12.6)	73(7.9)	101(11.1)	67(14.7)	34(7.4)	89(9.4)	50(10.6)	39(8.3)
50-54	157(8.4)	97(10.4)	60(6.5)	85(9.3)	50(11.0)	35(7.7)	72(7.6)	47(10.0)	25(5.3)
55-59	81(4.4)	64(6.9)	17(1.8)	39(4.3)	31(6.8)	8(1.7)	42(4.4)	33(7.0)	9(1.9)
≥ 60	102(5.5)	85(9.1)	17(1.8)	49(5.4)	40(8.8)	9(2.0)	53(5.6)	45(9.5)	8(1.7)
Age Difference within couples (Mean, SD)	7.5(5.9)			7.6(5.8)			7.4(6.1)		
Age Difference within couples (5-year categories)									
0	28(3.0)			7(1.5)			21(4.4)		
1-5	401(43.2)			206(45.1)			195(41.3)		

6-10	275(29.6)			128(28.0)			147(31.1)		
11-15	121(13.0)			66(14.4)			55(11.7)		
16-20	68(7.3)			33(7.2)			35(7.4)		
≥ 21	36(3.9)			17(3.7)			19(4.0)		
Education									
None	220(11.8)	94(10.0)	126(13.6)	112(12.2)	49(10.7)	63(13.8)	108(11.4)	45(9.5)	63(13.3)
Primary	1115(60.0)	541(58.2)	574(60.0)	548(60.2)	270(59.1)	278(60.8)	567(60.0)	271(57.4)	296(62.7)
Secondary	465(25.0)	257(27.7)	208(22.8)	226(24.6)	121(26.5)	105(23.0)	239(25.3)	136(28.8)	103(21.8)
Tertiary	58(3.1)	37(4.0)	21(2.3)	28(3.0)	17(3.7)	11(2.4)	30(3.2)	20(4.2)	10(2.1)
Employment									
Employed	814(43.8)	542(58.3)	272(29.3)	375(41.0)	254(55.6)	121(26.5)	439(46.5)	288(61.0)	151(32.0)
Unemployed	1054(56.2)	387(41.7)	657(70.7)	539(59.0)	203(44.4)	336(73.5)	505(53.5)	184(39.0)	321(68.0)
Residence									
Urban	692(37.1)	346(37.2)	346(37.2)	308(33.7)	154(33.7)	154(33.7)	384(40.7)	192(40.7)	192(40.7)
Rural	1166(62.9)	583(62.8)	583(62.8)	606(66.3)	303(66.3)	303(66.3)	560(59.3)	280(59.3)	280(59.3)
Marital Status									
Married	1605(88.3)	809(89.3)	796(87.3)	837(92.4)	413(92.6)	420(92.3)	783(84.3)	396(86.1)	379(82.2)
Living Together	213(11.7)	97(10.7)	116(12.7)	69(7.6)	33(7.4)	35(7.7)	146(15.7)	64(13.9)	82(17.8)
Wealth Quintile									
Lowest	304(16.4)	152(16.4)	152(16.4)	140(15.3)	70(15.3)	70(15.3)	164(17.4)	82(17.4)	82(17.4)
Second	344(18.5)	172(18.5)	172(18.5)	180(19.7)	90(19.7)	90(19.7)	164(17.4)	82(17.4)	82(17.4)
Middle	404(21.8)	202(21.8)	202(21.8)	204(22.3)	102(22.3)	102(22.3)	200(21.2)	100(21.2)	100(21.2)
Fourth	426(23.0)	213(23.0)	213(23.0)	192(21.0)	96(21.0)	96(21.0)	234(24.8)	117(24.8)	117(24.8)
Highest	378(20.4)	189(20.4)	189(20.4)	198(21.2)	99(21.7)	99(21.7)	180(19.1)	90(19.1)	90(19.1)
Number of Partners									
1	1695(93.7)	786(89.4)	909(97.9)	853(94.8)	401(90.5)	452(98.9)	842(92.3)	385(88.3)	457(96.8)
2	91(5.0)	78(8.9)	13(1.4)	39(4.3)	36(8.1)	3(0.7)	52(5.7)	42(9.6)	10(2.1)
3	22(1.3)	15(1.7)	7(0.8)	8(0.9)	6(1.4)	2(0.4)	14(1.5)	9(2.1)	5(1.1)
Viral Load									

Suppressed					
Yes	534(57.5)	250(54.7)	284(60.2)	250(54.7)	284(60.2)
No	395(42.5)	207(45.3)	188(39.8)	207(45.3)	188(39.8)

Abbreviations: MPHIA – Malawi Population-based HIV Impact Assessment; THIS – Tanzania HIV Impact Survey; ZAMPHIA – Zambia Population-based Impact Assessment Survey; SHIMS2 – Swaziland HIV Incidence Measurement Survey 2; HIV – Human Immunodeficiency Virus

[a]Female positive index with Male negative partner
[b]Female negative index with Male positive partner
[c]Number of stable partners of spouses
[d] HIV RNA viral load suppressed (< 1000 copies/ml) or not suppressed (≥ 1000 copies/ml)

Table 2. Proportion of all HIV Positive Participants and HIV Positive Participants on Antiretroviral Therapy 15 Years and Older who are Virally Suppressed and Enrolled in Surveys Conducted in Malawi, Tanzania, Zambia and Eswatini – Pooled Estimates (MPHIA 2015-2016, THIS 2016-2017, ZAMPHIA 2016, SHIMS 2016-2017)

	All HIV+ participants		**HIV+ participants on ART**	
	Total Population (%)	**HIV Sero-discordant couples (%)**	**Total Population (%)**	**HIV Sero-discordant couples (%)**
Male	52.4	54.7	87.7	90.3
Female	62.9	60.2	90.5	87.0
Overall	59.1	57.5	89.6	88.5

Abbreviations: MPHIA – Malawi Population-based HIV Impact Assessment; THIS – Tanzania HIV Impact Survey; ZAMPHIA – Zambia Population-based Impact Assessment Survey; SHIMS2 – Swaziland HIV Incidence Measurement Survey 2; HIV – Human Immunodeficiency Virus; ART-Antiretroviral Therapy

Table 3. Individual and Couple Demographic and Behavioral Characteristics by Viral Load Suppression Status With Corresponding Weighted Odds Ratios and 95% Confidence Interval of 457 HIV Sero-discordant Couples (F – M+) [a] 15 Years and Older Enrolled in Surveys Conducted in Malawi, Tanzania, Zambia and Eswatini – Pooled Estimates(MPHIA 2015-2016, THIS 2016-2017, ZAMPHIA 2016, SHIMS 2016-2017, n (Unweighted) = 914)

	All Countries				All Countries		
	Overall	**Suppressed Viral load**	**Unsuppressed Viral load**	**P-value**	**Bivariate Model**		
Gender							
[b]Male	457(100)	250(54.7)	207(45.3)				
Age (10–year category)							
15-24	60(03.1)	20(33.3)	40(66.7)	<.0001	3.19	2.98-3.41	<.0001
25-34	157(34.4)	77(49.0)	80(51.0)		5.06	4.88-5.23	<.0001
35-44	154(33.7)	87(56.5)	67(43.5)		2.32	2.25-2.39	<.0001
45-54	69(15.1)	51(73.9)	18(26.1)		1.15	1.11-1.18	<.0001
≥ 55	17(3.7)	15(88.2)	2(11.8)		ref.		
Age difference within couples							
0	7(1.5)	6(85.7)	1(14.3)	0.48	0.16	0.14-0.18	<.0001
1-5	206(45.1)	111(53.9)	95(46.1)		ref.		
6-10	128(28.0)	70(54.7)	58(45.3)		1	0.98-1.02	0.97
11-15	66(14.4)	34(51.5)	32(48.5)		1.69	1.65-1.74	<.0001
16-20	33(7.2)	21(63.6)	12(36.4)		0.39	0.38-0.41	<.0001
≥ 21	17(3.7)	8(47.1)	9(52.9)		1.14	1.09-1.19	<.0001
Education							
None	49(10.7)	19(38.8)	30(61.2)	0.006	ref.		
Primary	244(53.4)	129(52.9)	115(47.1)		0.44	0.43-0.46	<.0001
Secondary	140(30.6)	83(59.3)	57(40.7)		0.27	0.26-0.27	<.0001
Tertiary	24(5.3)	19(79.2)	5(20.8)		0.15	0.14-0.16	<.0001
Employment							

Employed	254(55.6)	131(51.6)	123(48.4)	0.13	1.12	1.10-1.14	<.0001
Unemployed	203(44.4)	119(58.6)	84(41.4)		ref.		
Residence							
Urban	154(33.7)	81(52.6)	73(47.4)	0.52	1.28	1.26-1.31	<.0001
Rural	303(66.3)	169(55.8)	134(44.2)		ref.		
Marital Status							
Married	413(92.6)	230(55.7)	183(44.3)	0.07	0.69	0.66-0.71	<.0001
Living Together	33(7.4)	13(39.4)	20(60.6)		ref.		
Wealth Quintile							
Lowest	70(15.3)	36(51.4)	34(48.6)	0.05	1.94	1.88-2.00	<.0001
Second	90(19.7)	42(46.7)	48(53.3)		2.02	1.97-2.09	<.0001
Middle	102(22.3)	50(49.0)	52(51.0)		1.67	1.62-1.72	<.0001
Fourth	96(21.0)	63(65.6)	33(34.4)		0.71	1.62-1.72	<.0001
Highest	99(21.7)	59(59.6)	40(40.4)		ref.		
Number of Sexual partners in last 12 months							
0	27(6.2)	13(48.2)	14(51.8)	0.81			
1	299(69.1)	161(53.8)	138(46.2)		ref.		
≥2	107(24.7)	59(55.1)	48(44.9)		2.02	1.96-2.09	<.0001
[c]**Condom use during last sexual encounter**							
Yes	138(32.9)	109(79.0)	29(21.0)	<.0001	ref.		
No	254(20.6)	107(42.1)	147(57.9)		4.33	4.22-4.45	<.0001
No Sex	27(6.4)	13(48.2)	14(51.8)		2.82	2.70-2.95	<.0001
[d]**Disclosure of Status to Partner**							
Yes	324(74.8)	205(63.3)	119(36.7)	<.0001	ref.		
No	109(25.2)	26(23.8)	83(76.2)		4.46	4.36-4.56	<.0001
Alcohol Frequency							
Never	239(53.0)	140(58.6)	99(41.4)	0.03	ref.		
< 1 time a month	79(17.5)	41(51.9)	38(48.1)		1.64	1.60-1.68	<.0001

2-4 times a month	68(15.1)	40(58.8)	28(41.2)		1.21	1.18-1.25	<.0001
2-3 times a week	36(8.0)	13(36.1)	23(63.9)		2.87	2.77-2.97	<.0001
≥ 4 times a week	29(6.4)	11(37.9)	18(62.1)		2.2	2.11-2.30	<.0001
Cd4 category							
< 100	8(1.8)	0(0.0)	8(100.0)	<.0001	>1000.00	<0.001->1000.00	0.63
100-199	58(13.0)	21(36.2)	37(63.8)		2.99	2.89-3.08	<0.0001
200-349	108(24.1)	50(46.3)	58(53.7)		2.01	1.96-2.07	<0.0001
350-399	126(28.1)	71(56.4)	55(43.6)		2.24	2.18-2.29	<0.0001
≥ 500	148(33.0)	102(68.9)	46(31.1)		ref.		
[e]Aware of status							
yes	267(59.5)	214(80.2)	53(19.8)	<.0001	ref.		
no	182(40.5)	31(17.0)	151(83.0)		18.63	18.19-19.07	<.0001

Abbreviations: MPHIA – Malawi Population-based HIV Impact Assessment; THIS – Tanzania HIV Impact Survey; ZAMPHIA – Zambia Population-based Impact Assessment Survey; SHIMS2 – Swaziland HIV Incidence Measurement Survey 2; HIV – Human Immunodeficiency Virus; OR – Odds Ratio; CI - Confidence Interval

[a] Female negative index with Male positive partner
[b]Male positive partners
[c]Condom use during last sexual encounter in the past 12 months
[d]Disclosure of HIV status to partner
[e]Aware of HIV positive status

Table 4. Individual and Couple Demographic and Behavioral Characteristics by Viral Load Suppression Status With Corresponding Weighted Odds Ratios and 95% Confidence Interval of 472 HIV Sero-discordant Couples (F + M -) [a] 15 Years and Older Enrolled in Surveys Conducted in Malawi, Tanzania, Zambia and Eswatini – Pooled Estimates (MPHIA 2015-2016, THIS 2016-2017, ZAMPHIA 2016, SHIMS 2016-2017, n(Unweighted) = 944)

	All Countries				All Countries		
	Overall	**Suppressed Viral load**	**Unsuppressed Viral load**	**P-value**	**Bivariate Model**		
	N (%)	**n (%)**	**n (%)**		**OR**	**95% CI**	**P-value**
Gender							
[b]Female	472(100)	284(60.2)	188(39.8)				
Age (10-year category)							
15-24	62(13.1)	30(48.4)	32(51.6)	0.22	2.24	2.12-2.31	<.0001
25-34	174(36.9)	107(61.5)	67(38.5)		1.3	1.24-1.36	<.0001
35-44	155(32.8)	99(63.9)	56(36.1)		1.19	1.14-1.25	<.0001
45-54	64(13.6)	36(56.3)	28(43.7)		1.57	1.50-1.65	<.0001
≥ 55	17(3.6)	12(70.6)	5(29.4)		Ref.		
Age difference within couples							
0	21(4.5)	12(57.1)	9(42.9)	0.18	1.23	0.49-3.05	0.66
1-5	195(41.3)	121(62.0)	74(38.0)		ref.		
6-10	147(31.1)	92(62.6)	55(37.4)		0.98	0.63-1.52	0.92
11-15	55(11.6)	31(56.4)	24(43.6)		1.27	0.69-2.32	0.45
16-20	35(7.4)	22(62.9)	13(37.1)		0.97	0.46-2.03	0.93
≥ 21	19(4.0)	6(31.6)	13(68.4)		3.54	1.29-9.72	0.01
Education							
None	63(13.3)	35(55.6)	28(44.4)	0.72	ref.		
Primary	252(53.4)	152(60.3)	100(39.7)		0.81	0.79-0.82	<.0001
Secondary	143(30.3)	87(60.8)	56(39.2)		0.86	0.83-0.88	<.0001

Tertiary	14(3.0)	10(71.4)	4(28.6)		0.56	0.52-0.60	<.0001
Employment							
Employed	151(32.0)	84(55.6)	67(44.3)	0.17	1.64	1.61-1.67	<.0001
Unemployed	321(68.0)	200(62.3)	121(37.7)		ref.		
Residence							
Urban	192(40.7)	117(60.9)	75(39.1)	0.78	0.93	0.92-0.95	<.0001
Rural	280(59.3)	167(59.6)	113(40.4)		ref.		
Marital Status							
Married	379(82.2)	238(62.8)	141(37.2)	0.01	2.04	1.20-2.08	<.0001
Living Together	82(17.8)	39(47.6)	43(52.4)		ref.		
Wealth Quintile							
Lowest	82(17.4)	45(54.9)	37(45.1)	0.42	1.05	1.02-1.08	<.0001
Second	82(17.4)	44(53.7)	38(46.3)		1.3	1.26-1.34	<.0001
Middle	100(21.2)	63(63.0)	37(37.0)		0.73	0.71-0.75	<.0001
Fourth	117(24.8)	72(61.5)	45(38.5)		0.58	0.57-0.60	<.0001
Highest	90(19.1)	59(65.6)	31(34.4)		ref.		
Number of Sexual partners in last 12 months							
0							
1	438(93.2)	263(60.0)	175(40.0)	0.94	ref.		
≥2	32(6.8)	19(58.4)	13(40.6)		2.02	1.96-2.09	<.0001
[c]Condom use During last sexual encounter							
Yes	149(32.2)	108(72.5)	41(27.5)	0.0003	ref.		
No	314(67.8)	172(54.8)	142(45.2)		2.6	2.54-2.66	<.0001
[d]Disclosure of Status to Partner							
Yes	335(71.1)	229(68.4)	106(31.6)	<.0001	ref.		

No	136(28.9)	54(39.7)	82(60.3)		4.06	3.97-4.15	<.0001
[e]**Alcohol Frequency**							
Never	253(81.4)	195(77.1)	58(22.9)	0.68	ref.		
≤ 1 time a month	24(7.7)	21(87.5)	3(12.5)		1.35	1.31-1.39	<.0001
2-4 times a month	22(7.10	17(77.3)	5(22.7)		1.08	1.05-1.12	<.0001
2-3 times a week	8(2.6)	5(62.5)	3(37.5)		1.94	1.84-2.05	<.0001
≥ 4 times a week	4(1.3)	3(75.0)	1(25.0)		3.81	3.59-4.05	<.0001
Cd4 category							
< 100	8(1.7)	2(25.0)	6(75.0)	<.0001	11.09	10.20-12.07	<.0001
100-199	38(8.1)	13(34.2)	25(65.8)		8.8	8.44-9.18	<.0001
200-349	87(18.6)	34(39.1)	53(60.9)		2.41	2.35-2.47	<.0001
350-399	111(23.8)	61(54.9)	50(45.1)		1.2	1.17-1.22	<.0001
≥ 500	223(47.8)	169(75.8)	54(24.2)		ref.		
[f]**Aware of status**							
yes	327(69.9)	257(78.6)	70(21.4)	<.0001	ref.		
no	141(30.1)	24(17.0)	117(83.0)		19.64	19.18-20.10	<.0001

Abbreviations: MPHIA – Malawi Population-based HIV Impact Assessment; THIS – Tanzania HIV Impact Survey; ZAMPHIA – Zambia Population-based Impact Assessment Survey; SHIMS2 – Swaziland HIV Incidence Measurement Survey 2; HIV – Human Immunodeficiency Virus; OR – Odds Ratio; CI - Confidence Interval

[a] Female positive index with Male negative partner
[b]Female positive partner
[c]Condom use during last sexual encounter in the past 12 months
[d]Disclosure of HIV status to partner
[e]Fisher's exact test used in analysis
[f]Aware of HIV positive status

Table 5. Awareness of HIV status and Viral load Suppression Status of HIV Positive Participants With Corresponding Weighted Number of Partners who are at Risk of Infection, 15 Years and Older who Were Enrolled in Surveys Conducted in Malawi, Tanzania, Zambia and Eswatini – Pooled Estimates(MPHIA 2015-2016, THIS 2016-2017, ZAMPHIA 2016, SHIMS 2016-2017, n (Unweighted) = 917)

	Suppressed Viral Loads	**Unsuppressed Viral Loads**	**Total**
Female Positive Partners	n (%)	n (%)	N (%)
[a]Aware of HIV Status	96442(77.1)	28675(22.9)	125116(62.6)
[b]Not Aware of HIV Status	10759(14.4)	64036(85.6)	74795(37.4)
Total	107201(53.6)	92711(46.4) [c]	199912(100)
Male Positive Partners			
[a]Aware of HIV Status	76186(78.6)	20787(21.4)	96974(55.7)
[b]Not Aware of HIV Status	12360(16.0)	64698(84.0)	77058(44.3)
Total	88546(50.9)	85485(49.1) [d]	174031(100)

Abbreviations: MPHIA – Malawi Population-based HIV Impact Assessment; THIS – Tanzania HIV Impact Survey; ZAMPHIA – Zambia Population-based Impact Assessment Survey; SHIMS2 – Swaziland HIV Incidence Measurement Survey 2; HIV – Human Immunodeficiency Virus

[a]Aware of HIV positive status
[b]Not aware of HIV positive status
[c] Male negative partners at risk of acquiring HIV infection
[d]Female negative partners at risk of acquiring HIV infection

FIGURES

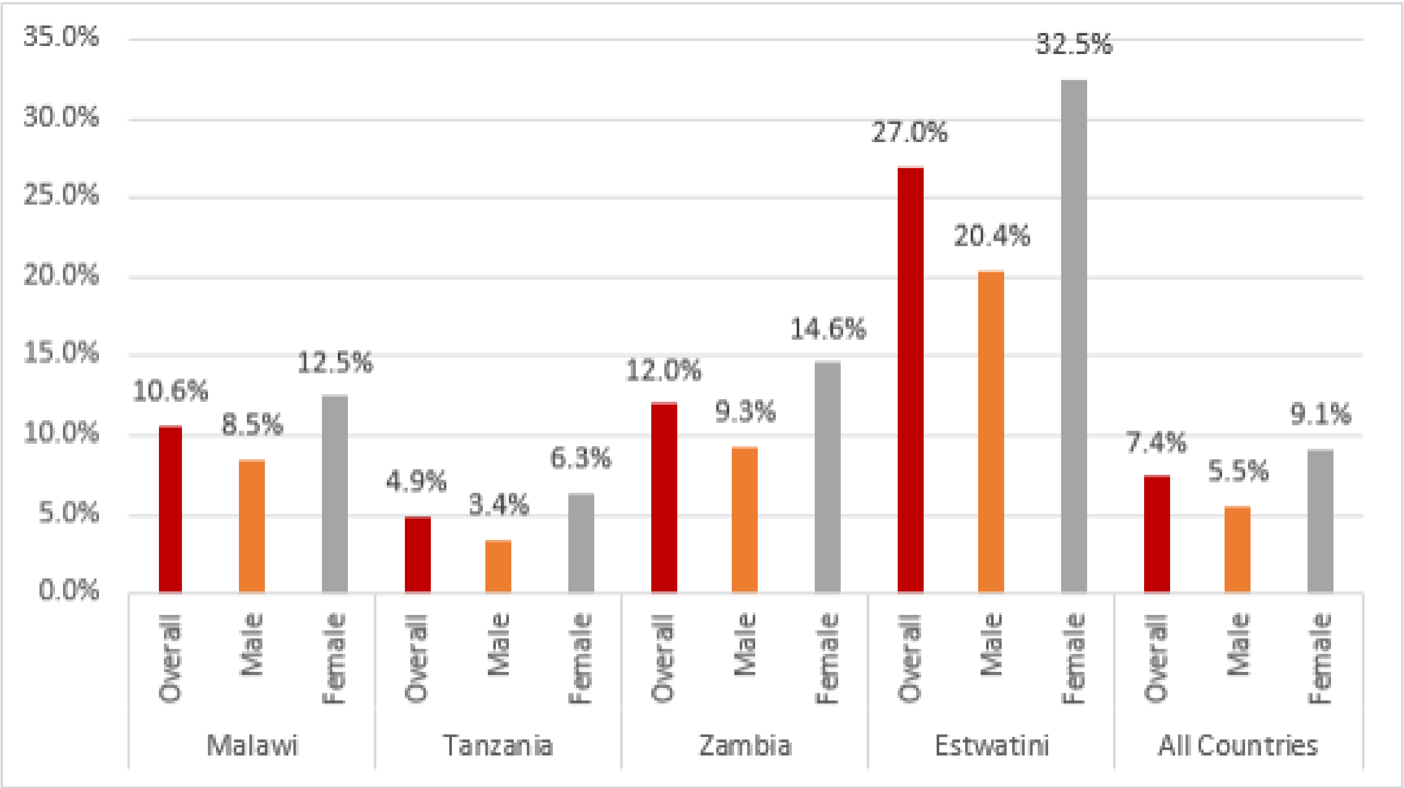

Figure 1. Prevalence of HIV in Malawi, Tanzania, Zambia and Eswatini - Overall and by Gender

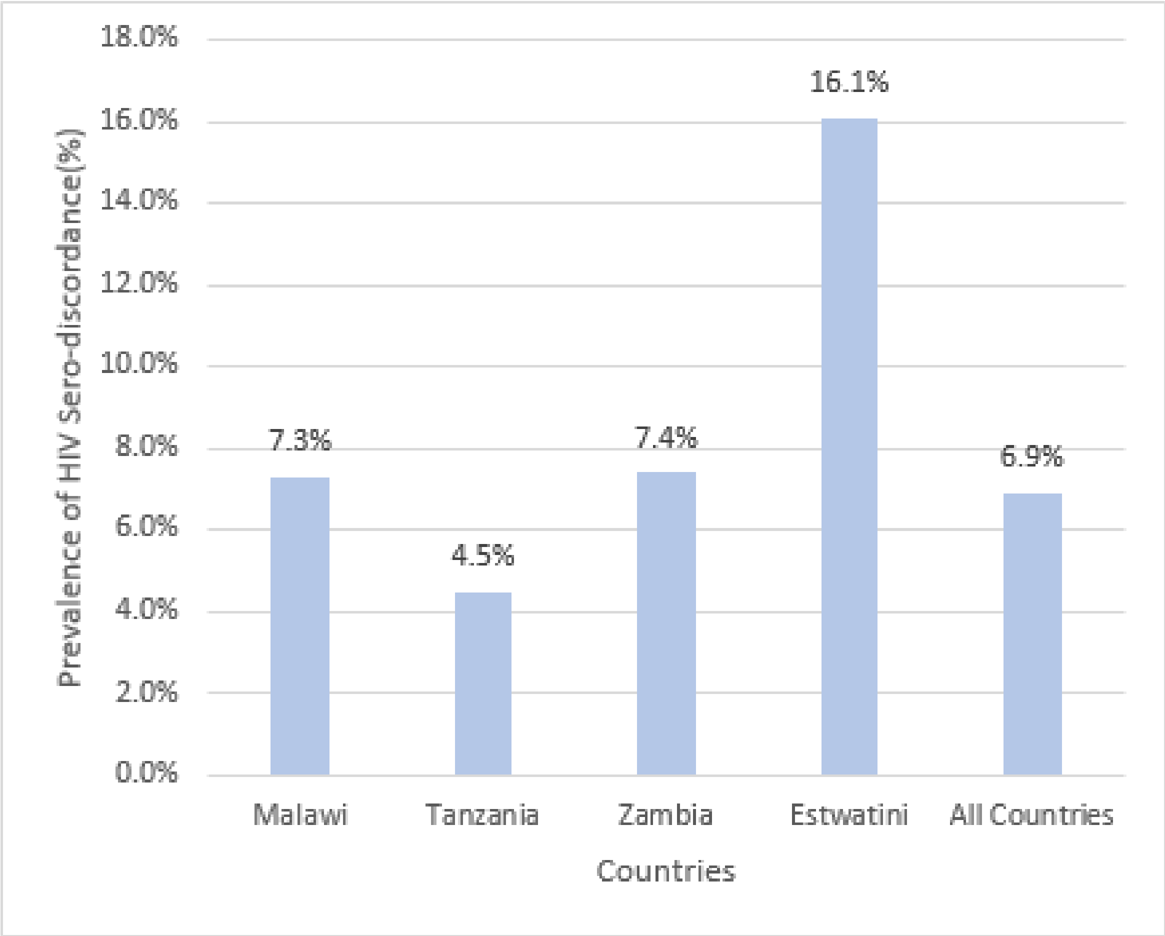

Figure 2. Prevalence of HIV Sero-Discordant Couples in Malawi, Tanzania, Zambia and Eswatini as well as all countries pooled together

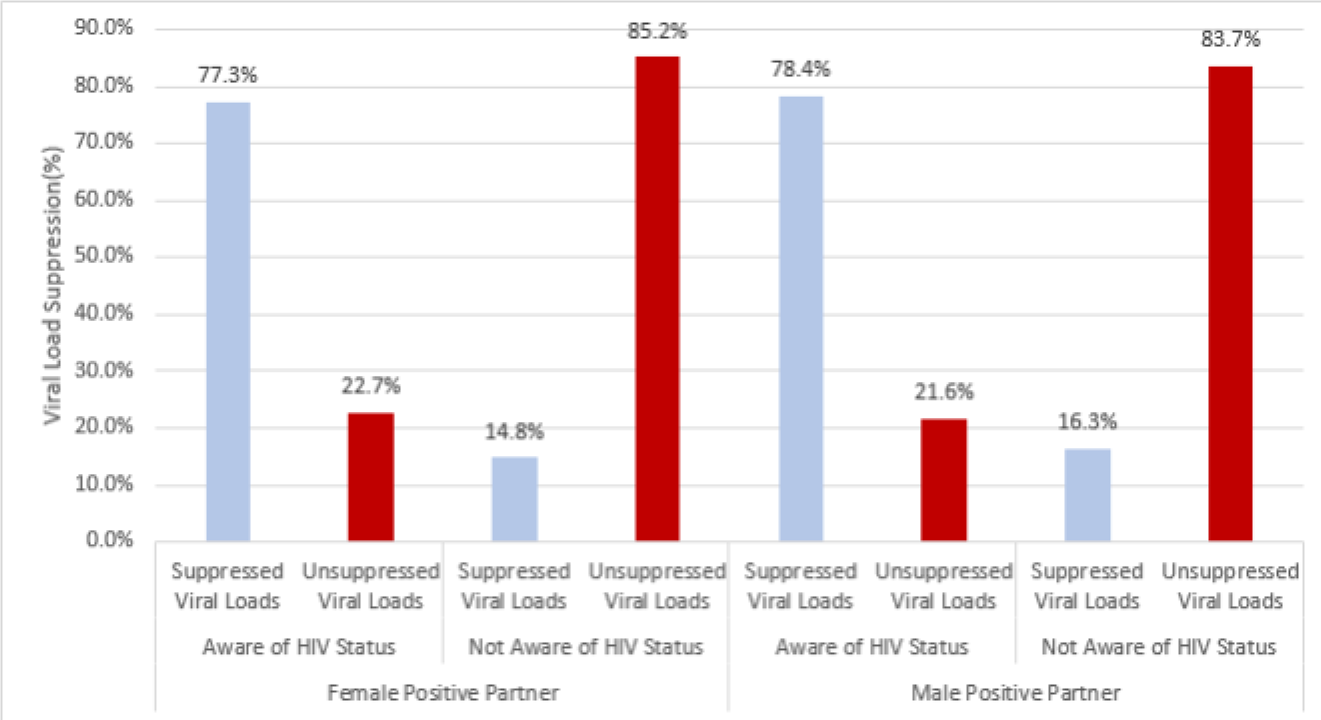

Figure 3. Distribution of Viral Load Suppression Among HIV Positive Partners with Corresponding Awareness of HIV Positive Status in Malawi, Tanzania, Zambia and Eswatini pooled together.