# Intimate partner violence and HIV in African countries: implications for HIV control in women, girls, and infants

**Salome Kuchukhidze, MPH**

Department of Epidemiology, Biostatistics, and Occupational Health
School of Population and Global Health
McGill University
Montréal, Québec, Canada
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# List of Acronyms and Abbreviations

AIDS – Acquired Immunodeficiency Syndrome

AIS – AIDS Indicator Survey

ANC – Antenatal Care

AGYW – Adolescent Girls and Young Women

ART – Antiretroviral Therapy

CDC – Centers for Disease Control and prevention

CI – Confidence Interval

DBS – Dried Blood Spot

DHS – Demographic and Health Surveys

ELISA – Enzyme-Linked Immunosorbent Assay

EMM – Effect Measure Modification

GEE – Generalized Estimating Equations

HAART – Highly Active Antiretroviral Therapy

HR – Hazard Ratio

IPV – Intimate Partner Violence

IMAGE – Intervention with Microfinance for AIDS and Gender Equity

UNAIDS – joint United Nations programme on HIV/AIDS

M-CTS – Modified Conflict Tactics Scale

MTCT – Mother-to-child HIV Transmission

OR – Odds Ratio

PAF – Population Attributable Fraction

PEPFAR – President's Emergency Plan for AIDS Relief

PHIA – Population-based HIV Impact Assessment

PMTCT – Prevention of Mother to Child Transmission of HIV

PR – Prevalence Ratio

PrEP – Pre-Exposure Prophylaxis

PEP – Post-Exposure Prophylaxis

PSU – Primary Sampling Unit

RCT – Randomized Controlled Trials

RD – Risk Difference

RERI – Relative Excess Risk due to Interaction

SABSSM – South African national HIV prevalence, incidence, behaviour and communication survey

SHARE – Safe Homes and Respect for Everyone

SDG – Sustainable Development Goals

UN – United Nations

UI – Uncertainty Interval

UNGA – United Nations General Assembly

VACS – Violence Against Children and Youth Surveys

VLS – Viral Load Suppression

WLHIV – Women Living with HIV

WHO – World Health Organization

# Abstract

Despite significant progress to curb HIV epidemics worldwide, 1.3 million people acquired the virus in 2022, over half of whom lived in African countries. This burden of new infections disproportionately affects women, who account for two thirds of incident HIV in Africa. In 2021, the United Nations adopted new global targets, which commit to reduction to less than 10% the proportion of women who experience intimate partner violence (IPV) – a key structural enabler of the HIV epidemic.

Close to 40% of women in some African countries have experienced physical and/or sexual IPV in their lifetime. Women experiencing IPV may be at increased risk of HIV acquisition. Links between IPV and HIV can be direct, through sexual violence, or indirect via pathways inhibiting women's authority on circumstances around sex. Further, unsuppressed viral load can be detrimental for women's health and leads to onward HIV transmission, including vertical HIV transmission (i.e., from mother to child). Evidence supporting the overlap between IPV and HIV could be strengthened. Previous studies have been single-country and relied on clinic-based samples, which makes it challenging to generalize the results. Few studies have accounted for IPV perpetrator characteristics to understand pathways to women's HIV acquisition. Finally, no study to date has evaluated the impact of IPV on vertical HIV transmission along the full HIV prevention and treatment cascade. To fill these evidence gaps, this manuscript-based thesis examines the overlapping risks of IPV and HIV in African countries.

In my first manuscript, I used a meta-analytic approach to examine the impact of IPV on the entire HIV prevention and care cascade, spanning from recent HIV acquisition to HIV testing, antiretroviral uptake, and ultimately to viral suppression. I pooled individual-level data from up to 57 nationally representative surveys with information on physical or sexual IPV and HIV in 30 countries in Africa (2000-2020). I found that women experiencing past-year IPV were more likely to have a recent HIV infection (prevalence ratio [PR]=3.22, 95% confidence interval [CI]: 1.51-6.85) and less likely to achieve viral suppression (PR=0.91, 95%CI: 0.85-0.98), than those who did not.

To disentangle the pathways between IPV and the increased HIV risk in women, I conducted a multi-country study examining the characteristics of male perpetrators of IPV. I pooled individual-level data among couples from 48 nationally representative, cross-sectional

surveys in 27 countries in Africa. Men who perpetrated IPV were more likely to be living with HIV (PR=1.09; 95%CI: 1.01-1.16). I found that IPV was associated with a slight (3%) increase in young women's risk of living with HIV *beyond the risk* of having an HIV seropositive partner.

The adverse effects of IPV on women's HIV acquisition and viral suppression raise questions on its implications for vertical HIV transmission. In my third manuscript, I developed a probability tree model to quantify the excess risk of vertical transmission attributable to women's experience of IPV in 46 African countries (2000-2022). I used official HIV program statistics from UNAIDS' 2023 Spectrum model files and IPV prevalence estimates from the WHO Global Database on Violence Against Women to parametrize the model. I reviewed the literature for effect size estimates for IPV's impact on HIV indicators. Across all countries, IPV may be responsible for 1 in 8 pediatric infections in 2022 (population attributable fraction=13%; 95% uncertainty interval: 6-23%). IPV had the greatest impact on vertical transmission among adolescent girls and young women.

My thesis' findings have important policy implications for HIV prevention and care delivery in high burden settings. Integrated, women-centered HIV service delivery platforms are crucial to address the unique needs of women experiencing IPV. Elimination of gender-based violence should be considered integral by governments and communities to accelerate progress towards ending AIDS.

# Resumé

Malgré des progrès importants dans la lutte contre l'épidémie de VIH dans le monde, 1,3 million de personnes ont contracté le virus en 2022, dont plus de la moitié vivaient en Afrique subsaharienne. Ce fardeau des nouvelles infections affecte de manière disproportionnée les femmes, qui représentent les deux tiers des cas de VIH en Afrique. En 2021, les Nations Unies ont adopté de nouveaux objectifs mondiaux, qui s'engagent à réduire à moins de 10 % la proportion de femmes qui ont subie de la violence entre partenaires intimes (VPI) –un facteur structurel clé de l'épidémie de VIH.

Près de 40 % des femmes de certains pays d'Afrique subsaharienne ont subies des VPI physiques et/ou sexuelles au cours de leur vie. Les femmes qui subissent de la VPI peuvent courir un risque accru de contracter le VIH. Les liens entre la VPI et le VIH peuvent être directs, par le biais de violences sexuelles, ou indirects, via des voies qui inhibent l'autorité des femmes sur les circonstances liées au sexe. Une charge virale non supprimée peut être préjudiciable à la santé des femmes et conduire à la transmission ultérieure du VIH, y compris la transmission verticale du VIH (c.-à-d., de la mère à l'enfant). Les preuves étayant le chevauchement entre la VPI et le VIH pourraient être renforcées. Les études précédentes portaient sur un seul pays et reposaient sur des échantillons cliniques, ce qui rend difficile la généralisation des résultats. Peu d'études ont pris en compte les caractéristiques des auteurs de VPI pour comprendre les voies menant à l'acquisition du VIH chez les femmes. Enfin, aucune étude n'a évalué l'impact de la VPI sur la transmission verticale du VIH tout au long de la cascade de prévention et de traitement du VIH. Pour combler ces lacunes en matière de données probantes, cette thèse basée sur trois manuscrits examine les risques de VPI et de VIH en Afrique.

Dans mon premier manuscrit, j'ai utilisé une approche méta-analytique pour examiner l'impact de la VPI sur l'ensemble de la cascade de prévention et de soins du VIH, allant de l'acquisition récente du VIH au dépistage du VIH, en passant par l'utilisation des antirétroviraux et, finalement, jusqu'à la suppression virale. J'ai regroupé les données individuelles de 57 enquêtes représentatives au niveau national avec des informations sur la VPI physique ou sexuelle et le VIH dans 30 pays d'Afrique subsaharienne (2000-2020). J'ai découvert que les femmes ayant subi de la VPI au cours de l'année écoulée étaient plus susceptibles d'avoir une infection récente au VIH (PR=3,22; intervalle de confiance [IC] à 95%: 1,51-6,85) et moins

susceptibles d'avoir atteint une suppression de leur charge virale (PR=0,91; IC à 95%: 0,85-0,98), que ceux qui n'en n'ont pas subie.

Pour démêler les liens entre la VPI et le risque accru de VIH chez les femmes, comme le démontre le premier manuscrit, j'ai mené la première étude multi-pays examinant les caractéristiques des auteurs masculins de VPI. J'ai regroupé des données individuelles auprès de couples provenant de 48 enquêtes transversales représentatives au niveau national dans 27 pays d'Afrique. Les hommes infligeant des VPI étaient plus susceptibles de vivre avec le VIH (PR=1,09; IC à 95%: 1,01-1,16). J'ai découvert que la VPI était associée à une légère augmentation (3%) du risque pour les jeunes femmes de vivre avec le VIH, au-delà du risque présent lorsque le partenaire est séropositif.

Les effets néfastes de la VPI sur l'acquisition du VIH et la suppression virale chez les femmes soulèvent des questions sur ses implications pour la transmission verticale du VIH. Dans mon troisième manuscrit, j'ai développé un modèle d'arbre de probabilité innovant pour quantifier le risque excessif de transmission verticale attribuable à l'expérience de la VPI chez les femmes dans 46 pays d'Afrique subsaharienne (2000-2022). J'ai utilisé les statistiques officielles du programme VIH du modèle Spectrum 2023 de l'ONUSIDA et les estimations de la prévalence de la VPI provenant de la base de données mondiale de l'OMS sur la violence à l'égard des femmes pour paramétrer le modèle. J'ai examiné la littérature pour obtenir des estimations de l'ampleur de l'effet de la VPI sur les indicateurs du VIH. Dans tous les pays, le VPI pourrait être responsable d'une infection pédiatrique sur huit en 2022 (PAF=13%; intervalle d'incertitude à 95%: 6-23%). La VPI a eu le plus grand impact sur la transmission verticale chez les adolescentes et les jeunes femmes.

Les résultats de ma thèse ont des implications importantes pour la prévention du VIH et la prestation de soins dans les pays à fardeau élevé de VIH. Les plateformes de prestation de services VIH intégrées et centrées sur les femmes sont essentielles pour répondre aux besoins uniques des femmes subissant des VPI. L'élimination de la violence sexiste devrait être considérée comme primordiale par les gouvernements et les communautés afin d'accélérer les progrès vers la fin du sida.

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I would also like to express gratitude for women who provided data to the surveys which were used in my thesis. The issue of gender-based violence holds great personal significance to me, and I feel honored to have conducted research on this topic. I hope that my work will serve as a modest contribution towards putting an end to violence against women.

My journey to this point would have been incomplete without the support of my friends. Imen, Emma, and Doris have been not just remarkable colleagues to brainstorm ideas with when faced with challenges, but also close friends who have stood by me through thick and thin. Fiona, I'm grateful for our friendship! Enjoying live music, yoga, books, and great food with you has helped me remember to prioritize things that I truly enjoy, beyond my work.

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## Statement of Originality

The work presented in this thesis constitutes original scholarship and provides evidence on the links between intimate partner violence and HIV in African countries. Specifically, Manuscript 1 fills the evidence gaps on the impact of intimate partner violence on the full spectrum of HIV prevention and care cascade in African countries: recent HIV infection, HIV testing in the past year, ART uptake, and viral load suppression. Manuscript 2 describes the characteristics of men perpetrating intimate partner violence and investigates how these impact women's HIV status among cohabiting couples. This was the first multi-country study examining the characteristics of male perpetrators of IPV. Finally, Manuscript 3 uses a mathematical modelling approach to quantify the proportion of excess risk of vertical HIV transmission attributable to women's experience of IPV –a question that has not been quantitatively assessed to date.

In addition to the papers presented in this thesis, I co-authored two articles during my PhD. These are included below for reference:

Schrubbe, L.A., Stöckl, H., Hatcher, A.M., Marston, M., **Kuchukhidze, S.,** Calvert, C. Prevalence and risk factors of unsuppressed viral load among pregnant and breastfeeding women in sub-Saharan Africa: analysis from population-based surveys. 2023, *AIDS*, *37*(4), 659-669. (DOI: 10.1097/QAD.0000000000003459)

Hodgins, C., Stannah, J., **Kuchukhidze, S.,** Zembe, L., Eaton, J.W., Boily, M.C. and Maheu-Giroux, M., 2022. Population sizes, HIV prevalence, and HIV prevention among men who paid for sex in sub-Saharan Africa (2000–2020): A meta-analysis of 87 population-based surveys. *PLoS Medicine*, *19*(1). (DOI: 10.1371/journal.pmed.1003861)

## Contributions of Authors

**Manuscript 1: Kuchukhidze, S.,** Panagiotoglou, D., Boily, M.C., Diabaté, S., Eaton, J.W., Mbofana, F., Sardinha, L., Schrubbe, L., Stöckl, H., Wanyenze, R.K. and Maheu-Giroux, M., 2023. The effects of intimate partner violence on women's risk of HIV acquisition and engagement in the HIV treatment and care cascade: a pooled analysis of nationally representative surveys in sub-Saharan Africa. *The Lancet HIV*, 10(2):e107-117. (DOI: 10.1016/S2352-3018(22)00305-8)

I conceived the study and developed the methodological framework with my supervisor Mathieu-Maheu Giroux. I curated, cleaned, and analyzed all data. Dr. Dimitra Panagiotoglou is my thesis committee member and provided guidance while refining the research question. Drs Boily and Eaton are epidemiologists and modelers who contributed intellectual content through their extensive experience with nationally representative survey analysis. Dr. Diabaté is an epidemiologist focusing on HIV prevention and treatment in Western Africa. Drs Stöckl and Sardinha are social epidemiologists whose expertise on intimate partner violence and its health effects were invaluable in framing the paper. Drs Mbofana and Wanyenze are clinicians with vast experience in infectious diseases research and policy in Mozambique and Uganda respectively; they were able to provide input on the policy and program implications of my work. I wrote the initial draft of the manuscript. All authors contributed to the study methods and to reviewing and editing the manuscript. All authors approved the final version of the manuscript.

**Manuscript 2: Kuchukhidze, S.,** Panagiotoglou, D., Boily, MC., Diabaté, S., Eaton, JW., Stöckl, H., Mbofana, F., Wanyenze, RK., Maheu-Giroux M. 2023. Characteristics of male perpetrators of intimate partner violence and implications for women's HIV status: A pooled analysis of cohabiting couples from 27 countries in Africa (2000–2020). *PLOS Global Public Health*, 3(9):e0002146. (DOI: 10.1371/journal.pgph.0002146)

I conceived the study and developed the methodological framework with my supervisor Mathieu-Maheu Giroux. I curated, cleaned, and analyzed all data. The co-authors' respective contributions were aligned with those presented for Manuscript 1. All authors contributed to the

study methods and to reviewing and editing the manuscript. All authors approved the final version of the manuscript.

**Manuscript 3: Kuchukhidze, S.,** Walters, M., Panagiotoglou, D., Boily, MC., Diabaté, S., Russell, WA., Stöckl, H., Sardinha, L., Mbofana, F., Wanyenze, RK., Imai-Eaton, JW., and Maheu-Giroux M. 2024. The contribution of intimate partner violence to vertical HIV transmission: a modelling analysis of 46 African countries. *Lancet HIV (accepted)*.

I conceived the study and developed the methodological framework with my supervisor Mathieu-Maheu Giroux. I developed and programmed the model. I analyzed the data to obtain the model parameters. I wrote the initial draft of the manuscript. Drs Boily and Eaton, as well as Magdalene Walters are infectious disease modelers who provided crucial feedback during model development. Magdalene Walters reviewed the model code. Dr. Russell is a decision analytic modeler with extensive experience with probability trees. All authors contributed to the study methods and to reviewing and editing the manuscript. All authors reviewed and edited the manuscript, and approved the final version.

# 1. Chapter 1: Introduction

## 1.1 Background

Over the past four decades, significant progress has been made to curb HIV epidemics worldwide. HIV can be treated with consistent use of antiretroviral therapy (ART), which reduces the amount of virus in the blood to achieve viral suppression to undetectable levels. People living with HIV (PLHIV) who are virally suppressed carry no risk of onward HIV transmission.[1] Further, viral suppression in pregnant women is essential to prevent vertical transmission of HIV. Globally ART coverage has increased by over 50%-points since 2010.[2] Still, 1.3 million new HIV infections occurred in 2022, the majority of which were in African countries.[3] In Africa women and girls carry a disproportionate share of HIV burden: women were more than three times as likely to acquire HIV than their male peers in 2022.[2]

The global HIV response is guided by the *Joint United Nations Programme on HIV/AIDS* (UNAIDS) 95-95-95 targets to end AIDS by 2030; an ambitious plan that calls for 95% diagnosis coverage, 95% uptake of ART among those diagnosed, and 95% with viral suppression among those on treatment. Targets further include elimination of vertical HIV transmission to end pediatric AIDS by 2030.[4] UNAIDS has identified addressing structural inequalities such as discriminatory gender and social norms, as key to reaching these goals. As part of this effort, the *2021 United Nations General Assembly* adopted the *Political Declaration on HIV and AIDS* which commits to eliminate all forms of sexual and gender-based violence, including intimate partner violence (IPV).[5]

African countries have among the highest IPV prevalence globally with one in four women having experienced physical and/or sexual IPV in their lifetime.[6] Over two decades of research on IPV and HIV suggests that women experiencing IPV may be more likely to acquire HIV.[7] However, previous studies have generally focused on only one aspect of HIV treatment and prevention.[16] Furthermore, definitions of IPV[17] and the period of measurement (e.g. lifetime versus past year)[18] were often inconsistent.

Pathways between IPV and HIV risk in women may be direct through sexual violence[8] or via male partner characteristics (e.g., concurrency, HIV status, unsuppressed viral load);[8] or indirect via inequitable power dynamics within the relationship which inhibit women's decision-making authority on circumstances around sex. Adverse mental health effects of IPV could

further drive women's poor engagement in HIV treatment.[9] Most studies of mechanisms linking IPV to HIV have focused on women experiencing IPV, with limited research on male partners' characteristics to elucidate pathways between IPV and women's HIV risk.[8,10]

The adverse impact of IPV on ART adherence and subsequent viral suppression[11-13] could extend to pregnant women living with HIV. WLHIV may have lower rates of HIV testing and antenatal care engagement if experiencing IPV reduces access to prevention of vertical transmission of HIV (i.e., from mother to child).[14,15] However, the implications of IPV for HIV vertical transmission at the full spectrum of the prevention of vertical transmission cascade has not yet been studied.

Several nationally representative surveys have used standardized methods to collect data on women's experience of IPV and HIV serostatus. Availability of these sources allows me to fill some of the existing research gaps. To this end, my thesis seeks to shed light on the overlapping risk of women's experience of IPV and HIV risk in African countries.

## 1.2 Organization of this thesis

This manuscript-based thesis is structured around three research objectives as follows:

1) To estimate the effect of past-year physical and/or sexual IPV on four outcomes in African countries: recent HIV infection, HIV testing in the past year, ART uptake, and viral load suppression.
2) To describe the characteristics of men perpetrating physical and/or sexual IPV and investigate how these characteristics impact women's HIV status among cohabiting couples in African countries.
3) To quantify the proportion of excess risk of vertical HIV transmission attributable to women's experience of past-year physical and/or sexual IPV in African countries.

My thesis is structured around 7 chapters. The current Chapter 1 provides background information. Chapter 2 is a literature review of relevant existing evidence and knowledge gaps. Chapter 3 is the overview of methods, including the description of the data sources. Chapters 4, 5, and 6 contain my first, second, and third manuscripts, respectively. Finally, Chapter 7 summarizes and contextualizes the manuscript results, and provides insights into efforts to address IPV and HIV.

# 2. Chapter 2: Literature review

Chapter 2 reviews the HIV epidemic in African countries, followed by the HIV prevention and treatment efforts from a gender lens. Then, I describe the global policy landscape to mitigate HIV's impact. I further summarize the definitions and measurement of various types of intimate partner violence (IPV), its epidemiology in Africa, as well as the pathways between IPV and women's risk of HIV acquisition and engagement in HIV care. Finally, I discuss previous interventions that have addressed IPV and HIV, and the remaining evidence gaps.

## 2.1 HIV epidemics in Africa

### *Origins of HIV*

Despite multiple theories for emergence of HIV, the most likely scenario suggests HIV has originated from the West and Central Africa where it crossed from non-human primates to humans sometime in the early 20th century, likely through hunting.[16] HIV is the causative agent of the Acquired Immunodeficiency Syndrome (AIDS), a spectrum of life-threatening infections resulting from a severe immune system damage caused by the HIV virus. Despite originating on the African continent, AIDS was initially reported in 1981 among gay men in Los Angeles, New York City, and San Francisco.[17] Soon after, in 1983, HIV was officially identified as its causative agent.[18]

AIDS found its way to the United States from Africa between the 1970s and 1980s.[19] At that time the US Centre for Disease Control infamously coined the stigmatizing "*Four Hs*" groups at risk of AIDS: homosexual, heroin users, hemophiliacs, and Haitians.[20] This grouping reflects the modes of HIV transmission (e.g., sexual, injection drug use, blood transfusion) but also how the virus crossed over to North America: from Haitian civil servants working in the Congo after it gained its independence from Belgium in the 1960s.[21] However, it was not until the 1980s when Congolese immigrants to Belgium were diagnosed with AIDS, marking one of the first indications of the disease's spread in Africa.[17] This narrative of HIV's emergence is one most supported by existing evidence, though perfect reconstruction of its complex history is challenging without additional ancient isolates of the virus.[22]

Early epidemiological studies identified cases of HIV in Uganda[23] and South Africa[24] as early as 1982. During most of the decades prior to that, HIV transmission festered unrecognized

at low levels. In the 1980s, HIV prevalence was below 1% at antenatal clinics in South Africa[24] but in the 1990s, HIV started to inflict significant morbidity and mortality. For example, in Swaziland life expectancy declined from 68 in 1990 to 53 years in 2009.[25] In South Africa, HIV contributed to 20% of lives lost in 1997 and over 35% in 2012.[26] Still, HIV burden has been heterogeneous since the early days of the epidemic: Southern and Eastern Africa have had higher HIV prevalence and incidence compared to Western and Central African regions.[2] Even within the regions, HIV epidemics are diverse, with intertwined sub-epidemics among members of key populations that are vulnerable to HIV acquisition and transmission.[27] These include female sex workers, men who have sex with men, transgender people, and people who inject drugs, among others.

*Gender disparities in HIV epidemics in Africa*

In the 1990s, the ratio of HIV prevalence between women and men was generally close to one in Africa (i.e., similar prevalence between men and women).[28] Since then, the ratio increased, and women have experienced higher HIV burden then men. Despite the diversity of epidemics across African countries, a throughline is their gendered nature, with disparities starting during adolescence. Adolescent girls and young women in sub-Saharan Africa accounted for more than 77% of new infections among young people aged 15-24 years in 2022, despite representing only 10% of the population of all women.[29] Progress filling HIV prevention gaps has been slower in women than in men: new infections among adolescent girls and young women in African countries declined by 42% between 2010 and 2021, while among men of the same age, it declined by 56%.[30]

The elevated risk of HIV infection among women in sub-Saharan Africa is driven by biological differences and, importantly, by social determinants. Biologically, receptive penile-vaginal intercourse carries a higher risk of HIV transmission (0.08%) than insertive penile-vaginal intercourse (0.04%). However, women's higher HIV burden is only partly the result of biological differences.[31,32] Sexual behaviors are highly gendered and this drives disparities in HIV burden.

From a social perspective, women's limited financial security and independence due to gender inequities often leads to age-disparate relationships. Older men have higher HIV prevalence (with unsuppressed viral load) which put young women at increased risk of HIV

acquisition.[33] This is compounded by practices like exchanging sexual favors for financial resources and insufficient power to negotiate safe sex behaviors, as well as sexual coercion and violence.[34] Differences in sexual decision-making power, and societal norms dictating acceptable sexual behaviors for men and women play a role in gender-related drivers of HIV as well.[34]

## 2.2 Gender and HIV prevention efforts

The gendered nature of the HIV epidemic is reflected in the utilization and effectiveness of HIV prevention strategies, which often disadvantage women due to the inequitable power dynamics in the relationships.

Condom use is one of the earliest recommended interventions for preventing HIV infection. When used correctly and consistently, male condoms are estimated to reduce the risk of HIV infection by 90%.[35] However, power inequities within the relationship often grant men more control than women over decisions around condom use, increasing women's susceptibility to acquiring HIV.[36] For this reason, other interventions –over which women can have full control– have been proposed.

Relatively recent, female-controlled biomedical interventions (e.g., pre-exposure prophylaxis (PrEP), post-exposure prophylaxis (PEP) and long-acting injectable PrEP) have changed the HIV prevention landscape. Oral PrEP is a combination of two ART drugs in a single pill used to prevent HIV. Taking PrEP every day (to prevent HIV acquisition vaginally or anally) or on demand (to prevent HIV acquisitional anally) is up to 99% effective.[37] Similarly, post-exposure prophylaxis (PEP), a combination ART drug taken withing 72 hours after HIV exposure for a month, can reduce the risk of HIV acquisition by more than 80%.[38] While PrEP is currently being scaled up in Africa, only nine countries had incorporated PrEP as part of their HIV prevention strategy by 2020.[39]

The most recent development, long-acting injectable PrEP, is an intramuscular injectable ART. It could enhance uptake and thus has superior efficacy to oral PrEP. New WHO guidelines recommended its use in 2022,[40] which could be especially beneficial for women, for whom daily PrEP adherence can be difficult if they are hesitant to disclose PrEP use to their male partners.[41] Another discreet, female-initiated, long-acting prevention option is dapivirine vaginal ring (DPV-VR) used for 28 days at a time.[42] Adherence, effectiveness, and safety of dapivirine ring is comparable to oral PrEP.[43]

In addition to biomedical strategies, structural interventions have been shown to bolster HIV prevention efforts. A quasi-experimental study in Botswana demonstrated that additional years of schooling had a large protective effect against HIV risk among women.[44] Conditional cash-transfer programs are another frequently employed strategy, offering monetary incentives to deter behaviors such as unprotected sex, early initiation of sexual activity, and engagement in transactional sex, or to encourage safe sexual behaviors. However, the latter have shown mixed effectiveness.[45] Effectiveness of the above HIV prevention methods necessitates choice-enablement of women, such that women feel empowered to take control of mitigating their own HIV risk.[46]

## 2.3 HIV treatment

There is no cure for HIV and, prior to the emergence of effective HIV treatment strategies, the death toll of AIDS was staggering. As a blood-borne retrovirus, HIV targets the immune system by depleting the CD4 cells – white blood cells essential for the body's defense against pathogens.[47] A major challenge to curing HIV is the virus' ability to "hide" and persist even when it is not being actively transcribed to make new copies.[48] Without treatment, chronic HIV infection lasts 10 years or longer, though in some, HIV could progress faster. CD4 cell count decreases as the virus multiplies, ultimately progressing to the third stage of the infection: AIDS.[47] Since HIV has severely damaged the immune system at this point, the body cannot fight off opportunistic infections such as pneumocystis pneumonia (a fungal infection), kaposi sarcoma (an infection-related cancer), and tuberculosis (a bacterial infection) among others. Without treatment, once a person reaches the clinical stage of AIDS, they typically survive about three years.[47]

Highly Active Antiretroviral Therapy (HAART), also known as ART, was first introduced in 1996 and combined several medications to reduce HIV's viral load and allow for CD4 cells to replenish.[49] The last two decades have witnessed a huge expansion in ART coverage, as well as an evolution in treatment regimens globally. Today, the life expectancy of people who are on ART is almost on par with those without the virus.[50] Importantly, PLHIV on ART who are virally suppressed are not able to transmit the virus onward.[1] Different ART regimens may differ in tolerability, toxicities, convenience, and the potential for drug-drug interactions, all of which can affect the overall adherence and viral suppression.[51] Typically, people start treatment with first-line ART regimens, which per updated 2019 WHO recommendations is Dolutegravir, in

combination with two other ART medications.[52] If first-line ART are not able to control viral replication, patients are switched to second line ART. Factors that contribute to virologic failure include poor adherence to ART or drug resistance.[53]

Recommendations for treatment regimens for pregnant women have varied with time. In the absence of treatment, probabilities of vertical transmission are high, ranging from 15% to 37% depending on the maternal viral load.[54] Among the earliest treatments to prevent vertical HIV transmission was single-dose nevirapine, per WHO guidelines in 2006.[55] Between 2006 and 2015 WHO-recommended regimens included dual prophylaxis, Option A and Option B, each comprising different ART types and eligibility criteria. Since 2015, the standard of care has shifted to Option B+, which entails triple ART (a regimen containing three ART drugs, including Dolutegravir) regardless of CD4 count, as soon as diagnosed, and continued for life.[56] Consistent ART uptake and subsequent viral suppression are essential for prevention of vertical HIV transmission.[57] In December 2021, Botswana became the first country in sub-Saharan Africa to be certified as "Silver Tier" on the path to the elimination of vertical transmission, indicating the achievement of fewer than 500 children per 100,000 births acquiring HIV.[58] Other countries in Africa are still working towards this goal, partially due to the deceleration of ART uptake rates among pregnant WLHIV. Coverage of prevention of vertical transmission programs has plateaued since 2015 at a little over 80%.[3] The COVID-19 pandemic has proven to be an additional impediment to the HIV agenda; between 2019 and 2021, ART coverage among pregnant and breastfeeding WLHIV even declined in some countries.

## 2.4 Current policy and advocacy landscape

The gender disparities in HIV prevention and treatment have been reflected in the policy and advocacy efforts to curb the epidemic. The UNAIDS 95%-95%-95% targets are explicitly anchored in the Sustainable Development Goals (SDG). SDGs were adopted by the 193 United Nations Member States in 2015 and represent a universal call to action to ensure global health, equity and prosperity.[59] At the heart of SDGs are 17 Goals encompassing actionable targets for all countries which address gaps in population health and gender inequality, among other topics.[59]

The central theme of the SDGs is to ensure that no one is being left behind –a core principle currently guiding the HIV response.[3] SDG Goal 3.3 commits to ending AIDS by 2030. However,

achieving this necessitates addressing social disparities and discrimination, particularly gender inequalities, as significant contributors to the HIV epidemic. This is echoed in the SDG Goal 5.2, which calls upon governments and societies to eradicate all forms of violence against women and girls, including IPV. Progress is measured through the "*proportion of ever-partnered women and girls aged 15-49 experiencing physical and/or sexual IPV by a current or former intimate partner in the past year*.[60]"

In line with the SDGs, the *2021 UN General Assembly on HIV and AIDS* identified inequalities as the main threat to the global efforts to stamp out AIDS as a public health threat by 2030.[5] Among the main pillars of action is elimination of sexual and gender-based violence, including IPV, as a key structural driver of the HIV epidemic. The 2025 objectives include, among others, reduction to no more than 10% the number of women and girls who experience sexual and gender-based violence.[5] Among the main areas of action is to address harmful gender stereotypes, negative social norms and to engage men and boys, including male partners, in these efforts.[5] Gaps in pregnant WLHIV's access to ART are emphasized, followed by a commitment to ensure that 95% of women have access to integrated HIV and reproductive healthcare services, including antenatal and maternal care.[5]

To accelerate the above efforts, a Global Alliance was launched in 2022 which aims to eliminate AIDS in children by 2030. Closing the ART treatment gap for pregnant and breastfeeding WLHIV is among the four main pillars of action for the Alliance. Another action point is tackling gender inequities, with IPV being among their most severe manifestations.[4]

## 2.5 Violence against women and HIV: evidence over time

Over the years, a substantial body of evidence has amassed on the intersections between HIV and violence against women. However, the recognition of IPV as a public health issue, beyond solely a judicial and human rights concern, has been gradual. It really started in the late 1990's when the WHO and the *American Medical Association* made statements on the public health importance of violence against women.[61] In a 2002 *Lancet* series on violence against women three major works by Watts,[61] Campbell[62] and Jewkes[63] described the global magnitude, health consequences, and determinants of IPV. Around the same time, the *WHO Multi-Country Study on Women's Health and Domestic Violence* was launched. This was the first large-scale attempt to understand the risk factors and health consequences of IPV.[64] This study was key in starting to uncover the links between IPV and HIV. The resulting report was among the first to

recommend integration of violence against women programs with those for the prevention of HIV/AIDS, spurring further research on intersections between IPV and HIV.[64] Over the years, large-scale cross-sectional studies by Dunkle[65] and Speizer[66] in South Africa have contributed further data, emphasizing the public health importance of IPV. The seminal prospective cohort study by Jewkes in 2010[8] was first to provide strong temporal evidence supporting a causal association between IPV and new HIV acquisitions.[8] This study paved the way for further work in Uganda by Kouyoumdjian (2013), confirming Jewkes' results.[67] Despite Harling (2010)[68] not finding any consistent associations between IPV and HIV seroprevalence in cross-sectional household-based surveys, a more nuanced analysis by Durevall and Lindskog[10] in 2015 showed that women who experience IPV have an increased risk of being HIV positive when compared to women not having ever experienced violence.[10]

## 2.6 Forms of violence against women

Even though the evidence on the intersections between IPV and HIV has been accumulating, determining the internal validity and generalizability of results is challenging. This is because the types, severity, and frequency of IPV, as well as the recall period for IPV measurement (lifetime vs. past-year) and the reference partner (current or most recent vs. any previous partners) in these studies have varied widely, as well as the outcome (HIV prevalence versus incidence). Regardless of these variations, IPV burden is high: worldwide, one in four women has experienced physical or sexual IPV, or both (hereon referred to as physical and/or sexual IPV). IPV is the most prevalent form of gender-based violence[69] and can include physical, sexual or psychological harm during marriage or cohabitation, along with emotional and economic exploitation and controlling behaviors.[70] Still, there is a significant overlap between these different types of IPV.

Dunkle[71] found that among women in South-Africa who reported sexual IPV, 72% also reported physical IPV. Results were similar in the United States where, based on a population-representative sample, 70% of women who experienced sexual IPV had experienced physical IPV as well.[72] Psychological abuse is prevalent too, ranging from 12% to 58% across a pooled analysis of 10 countries globally.[69] Physical IPV is often accompanied by psychological IPV[69] and in one third to one half of the cases, by sexual IPV.[69] Still, uncertainty remains on how to conceptualize, define and measure psychological IPV cross-culturally.[69] Therefore only physical and sexual IPV are included as a metric to evaluate progress towards SDG Target 5.2.

Numerous factors contribute to the global IPV burden, with gender inequality playing a major role. These factors often manifest through male controlling behaviors.[73] Controlling behaviors include jealousy, threats, and attempts to limit a partner's social contact and financial autonomy, and are measured as such in nationally representative, population-based surveys.[74] A study of *Demographic and Health Surveys* from eight countries in Africa showed that male controlling behaviors were highly predictive of the experience of physical, sexual and emotional IPV.[73] Nevertheless, controlling behaviors are not inherently accompanied by physical or sexual IPV.

Most women who are subjected to IPV experience multiple acts of violence over time, creating an atmosphere of chronic violence in the context of an abusive relationship.[69] Over one fifth of women in the United States had experienced 3-5 occurrences of physical IPV in their lifetime with an average duration of physical IPV of 5 years and sexual IPV of 4 years.[75] A systematic review of population-based surveys in African countries [10] further suggests that IPV that is paired with male controlling behaviors might be more strongly indicative of persistent and recurrent violence, as compared to isolated instances of a heated spousal dispute.[10]

## 2.7 IPV measurement

IPV measurement is challenging as it is often entirely based on self-reports. While all IPV is unacceptable and must be eliminated, the severity of physical IPV, measured through the type of violent acts and associated adverse consequences, is an important predictor of morbidity and mortality. Any sexual violence is considered severe,[76] and subscales are used to assess physical IPV of varying severity. The rationale behind this distinction is that acts categorized under the more severe subscale may inflict greater harm.[77] This distinction is based on the United States legal distinction between simple assault and aggravated assault.[77] For example, the consequences of physical violence may range from no visible injuries to those resulting in minor wounds, or even life-threatening situations such as head injuries, knife wounds, or firearm injuries.[78]

The recall period for IPV measurement varies across published literature as well, though most existing studies of the adverse effects of IPV on HIV have used lifetime experience of IPV as an exposure.[8,10,67] When using lifetime IPV, the exact timing of exposure remains ambiguous, implying that some women classified as 'ever-exposed' might have experienced IPV decades ago.

Though no gold standard exists for data collection on IPV, the WHO (leading the landmark research project*: WHO multi-country study on women's health and domestic violence against women* ), Centers for Disease Control and Prevention (conducting the *Violence Against Children and Youth Surveys*; VACS), and the Demographic and Health Surveys (DHS) have agreed upon best practices for IPV data collection.[79] VACS, PHIA, and DHS are nationally representative surveys. VACS focus on violence among adolescents 13-24 years and PHIA focus on HIV indicators among adolescents as well as adults (further detail in Chapter 3).

Survey instruments are based on the modified Conflict Tactics Scale (M-CTS)[80] (further detail in Chapter 3). They ask respondents about their experience and frequency of violent acts in their lifetime or in the past year. M-CTS is among the most used instruments to measure IPV, and psychometrically evaluated and successfully used in many countries, with robust cross-cultural validity and reliability.[81] M-CTS questions as part of population-representative surveys are administered by trained interviewers.[82] Interviewee confidentiality is achieved by conducting the interview only when full privacy is achieved and administering the interview to only one, randomly selected woman in the household, when possible. All participants disclosing IPV are referred to the national social service system.[83]

Despite the methodological rigor with which the IPV module questions are administered, previous researchers[84] have expressed concerns about potential non-comparability of the DHS IPV module across countries and over time due to slight differences in question wordings. However, previous work has demonstrated the approximate measurement invariance of the survey questions across 36 low-resource settings, such that cross-national comparisons are reasonable.[79] Another study comparing the IPV prevalence estimates from the PHIA and VACS surveys suggested that adding a violence module to a larger survey focused on other health issues such as HIV, might underestimate IPV prevalence.[82] The study further suggests that the structure of the IPV questionnaires, specifically the skip patterns and the question sequence, might be important to ensure reliable reporting of IPV. [82]

As with other sensitive, self-reported experiences or behaviors, IPV is prone to underreporting if women conceal IPV in fear of further victimization, if they misinterpret the question, or forget about IPV experience.[85] Given these measurement challenges robust, nationally representative data collection on IPV is crucial to make evidence-based

recommendations on IPV elimination in high-burden settings, and to monitor progress towards SDG Target 5.2.

## 2.8 Epidemiology of IPV in Africa

*Burden and risk factors of IPV in all women*

Even with the risk for underreporting, decades of evidence have consistently shown the universal pervasiveness of IPV. African countries have among the largest prevalence of IPV with lifetime IPV ranging from 27% in Western Africa to 44% in Central Africa; and prevalence of past-year physical and/or sexual IPV ranging from 15% in Western to 32% in Central Africa.[86] Southern Africa, where HIV prevalence is highest, has 27% and 14% lifetime and past-year IPV prevalence respectively.[86]

Adolescent girls and young women aged 15-24 are the most vulnerable to experiencing IPV and this risk diminishes with age.[86] Vulnerability among the youth could be driven by age-disparate relationships, and/or relationships where women are married young and thus have less bargaining power.[87] Lower educational attainment and poverty, which are often the driving force for women's early initiation to marriage and age discrepant partnerships, might lead to the unequal power in intimate relationships, further contributing to young women's vulnerability to IPV.[87] In addition to the experience of IPV, poverty has been linked to IPV perpetration, and this relationship could be mediated by the societal perceptions on masculinity.[63,88] In settings where poverty is not consistent with the socially accepted ideals of "successful manhood", the resulting stress and resentment might trigger violence in the relationship.[64] This is in line with the *relative resource theory* which posits that women who are socioeconomically favored compared to their partner, might be at a higher risk of IPV as this goes against the traditional gender norms and can be perceived to threaten the male role.[89]

Alcohol and other substance use, leading to reduced inhibitions and impairments, has been identified as a strong determinant of IPV perpetration.[64] Finally, discriminatory social norms and justification of gender-based violence are leading drivers of IPV. Intergenerational IPV thrives under the societal approval of IPV, such that men who grew up in families where domestic or child abuse was perpetrated are more likely to perpetrate IPV themselves. Similarly, daughters of women who experienced IPV are also more likely to experience IPV.[63] In addition to witnessing violence, adverse childhood experiences could be associated with IPV perpetration. Two

pathways could link trauma and IPV perpetration: first, children who witness and experience violence may come to accept and internalize it through social learning. Second, abuse and neglect in childhood could impact brain development and personality, subsequently leading to adverse mental health outcomes. Links between men's poor mental health and IPV perpetration are not clear, and most existing studies were conducted in North America. It is likely that poor mental health and substance use overlap in their impacts on IPV perpetration. [90]

In addition to these determinants, major life events, such as pregnancy can increase the risk of IPV or lead to more serious health consequences.

*Burden and risk factors of IPV in pregnant women*

Scholars have suggested that pregnant women might be more at-risk for IPV since they are more likely to be in relationships compared to non-pregnant women.[91] Overall, the prevalence of IPV during pregnancy varied widely from 2% to 57% in a 2011 systematic review of studies from 13 African countries.[91] A 2021 systematic review addressing the same question in 50 countries globally showed that 1 in 10 pregnant women and 1 in 20 women had experienced physical and sexual IPV respectively, with the highest prevalence of both types of IPV estimated in Africa.[92] However, the prevalence of any IPV during pregnancy had a wide range from 2% to 99% in all 118 studies.[92] Experience of IPV prior to pregnancy was the main risk factor for IPV during pregnancy. Other risk factors for violence during pregnancy were aligned with those among all women.[91] The wide range of prevalence estimates, as well as a dearth of longitudinal evidence on IPV (i.e. data on IPV prevalence prior to, during and after pregnancy) make it challenging to identify a single, consistent measure of IPV prevalence during pregnancy.

## 2.9 Pathways between IPV and HIV

*Direct pathways*

Determinants of IPV inform the complex and multifaceted pathways between IPV and HIV acquisition. First, and the most direct pathway from IPV to HIV is infection through sexual assault, where HIV transmission is driven by the genital or anal trauma that can occur during forced sex.[93] From the biological perspective, receptive anal intercourse has the highest probability of HIV transmission (1.4%) among sexual modes of transmission.[32,94] The prevalence of anal intercourse is higher among physically or sexually coercive relationships, predominantly experienced by women.[95,96] While the importance of this mode of HIV transmission cannot be

overlooked, a growing body of evidence suggests that the increased HIV risk at the population level is not primarily attributable to sexual IPV.[93] Further, women who have experienced physical IPV without sexual IPV, still show an increased risk of sexually transmitted infection and HIV acquisition (Figure 2.1).[65]

Male-to-female HIV transmission necessitates male partner to be living with HIV. Thus, a second direct pathway between IPV and women's HIV acquisition could be via higher likelihood of HIV acquisition among male perpetrators of IPV. Previous evidence suggests that men who perpetrate IPV may be more likely to engage in sexual behaviors that increase their HIV acquisition risk.[93] Examples of these behaviors include multiple and concurrent sexual partnerships, inconsistent condom use, engagement in transactional sex and substance use during sex.[93] Previous work further shows that unsuppressed viral load is more frequent among men who perpetrate IPV in crude analyses.[97] Thus male partner characteristics and their HIV risk could subsequently impact women's HIV incidence (Figure 2.1).

At a population level, gender inequity-driven indirect pathways have additional, long-acting impact on women's HIV risk.[8] These pathways operate in the context of chronically abusive relationships, with multiple exposures to IPV over an extended period.[8]

*Indirect pathways*

Third, indirect pathway between IPV and HIV acquisition is related to gender inequities at interpersonal and community levels. For instance, disparities in couple's age, education and earning often accompanying IPV[98], may be associated with women's disempowerment leading to pressure to forego using condoms.[93] Societal gender norms around masculinity and female subordination[99] further merit more acquiescent femininities, male control of reproductive and sexual freedom, and accepting attitudes on IPV, which diminish women's protective powers against HIV acquisition (Figure 2.1).[8]

Fourth indirect pathway between IPV and HIV risk in women is mediated through IPV's long-term impacts on mental health. As a result, women experiencing IPV might engage in sexual behaviors such as multiple and concurrent partnerships, engagement in sex work, or sex while intoxicated.[8,93] Women who have experienced IPV might be less willing to refuse unwanted advances, especially while intoxicated, dissociated or seeking affection, leading to

further IPV.[8,93] This vicious cycle of revictimization amplifies the risk of HIV acquisition and further IPV.[8]

*Potential reversal of association between IPV and HIV*

The relationship between IPV and HIV might be bidirectional, such that women who are living with HIV might be at a higher risk of experiencing IPV after a positive HIV status disclosure.[100] However, evidence is not conclusive and some studies showed that HIV diagnosis was not associated with IPV after disclosure and that levels of IPV were the same irrespective of women's HIV status.[101] Further, prospective cohort studies[8,102] have found links between IPV and HIV incidence, suggesting the salience of the IPV-HIV direction of this relationship.

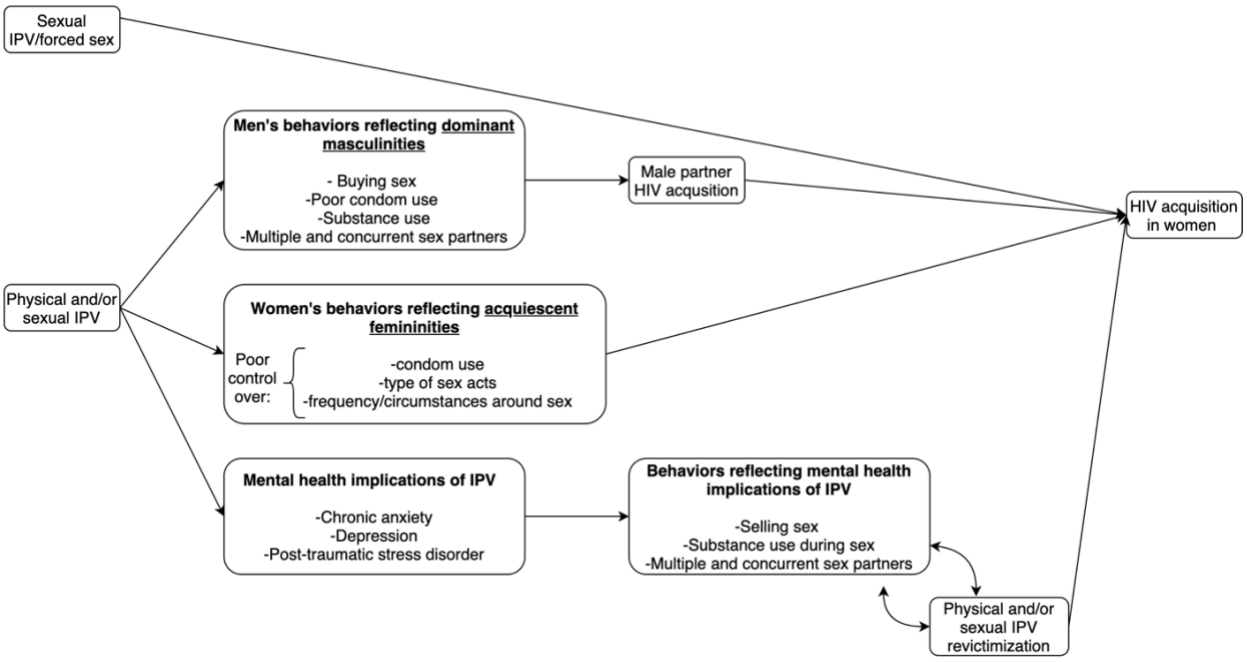


**Figure 2.1**. Conceptual pathways through which physical and/or sexual intimate partner violence might place women at risk of HIV infection.

## 2.10 Pathways between IPV and engagement in the HIV care cascade

In addition to its impact of HIV acquisition, IPV could impact women's engagement in the HIV treatment and care cascade. The care cascade is a public health model that identifies steps from HIV diagnosis to maintaining viral suppression, through ART uptake.

*IPV and HIV testing*

Evidence on the impact of IPV on HIV testing is mixed. A scoping review[11] found that the experience of IPV was associated with reduced HIV testing. This could be explained through women's fear of violent reaction and anticipated stigma from one's partner in the event of a positive HIV test result.[11] Most of the studies in the review focused on specific subgroups such as pregnant women,[103,104] or key populations including women who inject drugs and women who engage in transactional sex.[105-107] Notably, some studies included in the review found that IPV was associated with increased HIV testing. This could be due to higher self-perceived risk of HIV acquisition, which might encourage women experiencing IPV to get tested more frequently.[11]

*IPV and ART uptake and adherence*

Few studies have looked at the effects of IPV on current ART use; those that did, have not observed a relationship between the two.[13] A United States-based study among women who inject drugs found that women who were experiencing IPV were less likely to initiate ART, than those who did not.[108]

Evidence is more extensive on relationships between IPV and ART adherence though most quantitative evidence was generated from the United States.[13] Data show that WLHIV who experience violence are less likely to initiate and adhere to ART.[11,13] This could be explained by the mediating role of adverse mental health effects of IPV. In longitudinal studies, IPV exposure is associated with depression, chronic anxiety and post-traumatic stress disorder.[9] In turn, mental disorders are linked with declines in ART adherence and engagement in HIV care over time.[9]

*IPV and viral load suppression*

Given the adverse role of IPV on ART adherence, it is expected that the experience of IPV adversely affects viral suppression. A 2015 meta-analysis of United States-based studies suggested that women who experience IPV were almost 40% less likely to be virally suppressed than those who do not.[13] Evidence from African countries is sparser. A study among adolescents living with HIV in Zambia suggested a positive association between IPV and viral failure.[12] A South African study among pregnant WLHIV further showed IPV to be associated with elevated viral load postpartum.[109]

## 2.11 Pathways between IPV and vertical HIV transmission

Given IPV's potential impact of women's engagement in HIV care cascade, IPV could increase the risk of vertical HIV transmission. This may be driven by two main pathways: a) elevated risk of HIV acquisition during pregnancy or breastfeeding, and b) women's reduced engagement in prevention of vertical transmission cascade.

There is strong evidence for an elevated risk of HIV acquisition per-condomless sex act during pregnancy and breastfeeding.[110] Prospective cohort studies in Uganda as well as 6 other African countries pointed to increased risk of HIV acquisition in pregnancy, compared to non-pregnancy period.[111,112] IPV might further increase HIV acquisition risk among all women and thus, could compound women's vulnerability to HIV incidence during pregnancy and breastfeeding. This could subsequently increase the risk of vertical HIV transmission due to the initial high viral load seen in the first months after seroconversion.[113] While the risk of HIV acquisition is higher per-condomless-sex act during pregnancy than non-pregnancy, reduction in sexual activity peri-and-postnatally might mitigate this risk.[113] Given the wide variability across Africa in sexual activity patterns during pregnancy/postpartum, higher HIV acquisition risk during pregnancy is plausible.[113]

Links between IPV and pregnant women's engagement in prevention of vertical transmission mirror the adverse effects of IPV among all women. A meta-analysis of 22 DHS surveys in Africa between 2012-2020 found that the experience of IPV was associated with poor timely utilization of ANC.[114] Evidence from another meta-analysis of DHS surveys from 36 countries between 2005-2016 suggested that lifetime experience of any IPV was associated with decreased utilization of four or more ANC visits, on average fewer ANC visits, and poorer utilization of facility care at birth.[115]

Women experiencing IPV are more likely to be nonadherent to infant antiretroviral prophylaxis, to have poor uptake of and adherence to prevention of vertical transmission regimens, and subsequently lower rates of viral suppression.[116,117] These pathways are likely mediated by the adverse mental health effects of IPV.[116] Finally, a South African study found that experience of past-year physical, sexual or psychological IPV among pregnant and postpartum women was associated with reduced odds of viral suppression 12 months after delivery.[109] Thus, IPV may effect pregnant WLHIV's progress in the entire HIV prevention, treatment, and care cascade.

## 2.12 Interventions on IPV and HIV

Empirical evidence on the intersections between IPV and HIV has spurred intervention research to address both issues simultaneously. As summarized in a systematic review of 14 studies,[118] most IPV-HIV intervention studies can be categorized into three main themes: a) prevention efforts focused on *behavioral factors* to decrease HIV acquisition risk among women experiencing IPV, b) prevention efforts focused on *structural factors* to decrease both IPV and HIV risk, and c) prevention efforts focusing on either or both of these factors among vulnerable women (e.g., sex workers, women who use alcohol or other substances, women involved with the criminal justice system).

Most of the existing studies that evaluated interventions were randomized controlled trials, where the intervention was implemented in a group setting. Many of these trials did not include male partners, and their follow-up periods were typically less than 12 weeks.[118] More than two thirds of the interventions provided knowledge on IPV and/or HIV, equipped women with skills for communicating about safer sex, condom use or HIV status disclosure. Most studies tackled structural factors such as women's empowerment, knowledge of sexual rights, and gender norms related to masculinity and femininity.[118]

Few of the reviewed studies provided estimates precise enough to suggest an effect on IPV prevention and biomarker-measured HIV incidence. One of the interventions with the most promising results was *Intervention with Microfinance for AIDS and Gender Equity* (IMAGE).[119] The first part of this initiative offered micro-loans to poor women, fostering growth of women-driven businesses. The second part included a year-long training program covering topics such as cultural beliefs on gender roles, gender and HIV, empowerment and women's work, and IPV. After a two-year follow-up, exposure to IMAGE was associated with a 55% (95% Confidence Interval (CI): 0.23–0.91) reduction in IPV prevalence. However, IMAGE had no effect on community-level HIV incidence (adjusted risk ratio: 1.06, 95%CI: 0.66–1.69), or the risk of unprotected sex (adjusted risk ratio: 1.02, 95%CI: 0.85–1.23).[119]A deeper examination of the mechanisms at play revealed that the addition of the gender-power training curriculum to the microfinance initiative was crucial for the success of IMAGE. Together, these two components amplified the impact by enhancing women's empowerment and diminishing the risk of IPV.[120]

Another effective intervention was the *Safe Homes and Respect for Everyone* (SHARE) project – an integrated program to reduce physical and sexual IPV and HIV incidence.[121]

SHARE was based on the socioecological framework and addressed the drivers of IPV and HIV transmission at individual, relationship, and societal levels.[121] Its first pillar included a youth program, and an intervention for men and boys with the goal of ensuring they understand the importance of gender-equitable relationships. SHARE's second pillar included IPV screening during HIV counselling and testing, as well as ART refill visits.[121] This mitigated the risk factors for HIV acquisition among women experiencing IPV; they further trained the counselors to handle the topic of IPV in a safe and sensitive manner. Finally, SHARE created support groups for WLHIV experiencing IPV, thus fostering a safe, non-judgmental environment for women.[121] Overall, SHARE took a community mobilization approach such that community leaders and members had ownership over its implementation. The study found that women in the intervention groups were 21% less likely (95%CI: 0.67–0.92) to experience physical IPV than women in the control group. At 35 months of follow-up, the intervention was associated with a 33% (95%CI: 0.46–0.97) reduction in HIV incidence, though this reduction was not sustained after the project ended.[121]

The overview of these interventions suggests that the most effective approaches used multi-pronged strategies, which include meaningful involvement of the community to address IPV and HIV. Microfinance interventions, such as IMAGE are among the most frequently implemented in low-resource settings, though the results are conflicting. A systematic review of 10 RCTs on microfinance interventions in low-resource settings found that they were associated with reductions in psychological IPV and controlling behaviors.[122] This could be explained by the relationship's power dynamics that often reflect financial power, which compound patriarchal gender norms.[122] Still, the microfinance interventions did not reduce women's experience of physical and/or sexual IPV.[122] Economic empowerment has been previously linked with increased sexual autonomy in women, including the ability to refuse sex, or to negotiate condom use while having sex. While more sexual agency would reduce women's HIV risk, it might prompt further IPV, as shown in previous work.[123] Context-specific interventions that are conceptualized and implemented in collaboration with women and other community members would ensure that these interventions work as expected.

## 2.13 Gaps in literature

Despite two decades of epidemiological and implementation research on the intersections between IPV and HIV, the evidence base suggesting that IPV and HIV overlap could be strengthened. First, previous studies have recruited select populations such as pregnant women,[116] adolescent girls and young women,[124] female sex workers,[125] or women who use drugs.[106] This makes it difficult to generalize the study results. Further, most multi-country studies have not used biomarker-based outcome measures to describe the full spectrum of the HIV treatment and cascade.[10] Second, male-partner characteristics have not always been accounted for to understand HIV transmission risk to their female partners using a population-representative sample. Finally, quantitative data are sparse on the impact of HIV on vertical HIV transmission. With the increasing ART coverage over time in African countries, obtaining consistent estimates of IPV's impact on vertical HIV transmission is challenging.

# 3. Chapter 3: Methods

My thesis employs various methodologies, encompassing empirical analyses of population-based surveys and mathematical modeling. These diverse methods draw upon several, high-quality data streams. This chapter describes the main types of population-based surveys, sources of HIV estimates, and program data on prevention of vertical HIV transmission. Finally, an overview of my primary methodological approaches is included.

## 3.1 Main data sources

The first two objectives of this thesis leverage population-representative surveys. To identify these surveys, I reviewed all nationally-representative, cross-sectional surveys from African countries over 2000-2020 with individual participant information on IPV and HIV. I searched data catalogs (i.e., the *Global Health Data Exchange* and the *International Household Survey Network*), examined surveys included in the *Global Estimates for Violence Against Women Statistics* systematic review[126], and a previous systematic review of HIV testing and diagnosis coverage.[127]

The third objective, which applies a decision analytic model, was parametrized through systematic reviews of the peer-reviewed literature, population representative surveys, and country-reported program data on prevention of vertical transmission. This was complemented using countries' official demographic and HIV projections derived from the UNAIDS-supported Spectrum mathematical model.

### Demographic and Health Surveys (DHS)

*Survey description*

My thesis relied on the *Demographic and Health Surveys* (DHS) as one of the main data sources. DHS are nationally representative, population-based surveys conducted in over 90 countries globally since 1984. DHS was developed by the *United States Agency for International Development* (USAID) in response to the need for reliable and standardized demographic and health data in low-and-middle income countries. To date, the DHS program is implemented through close partnerships with host countries and implementing organizations.

The original DHS aimed to collect data on fertility, family planning, maternal and child health, nutrition and other key demographic and health indicators. Currently, DHS surveys

comprise three core questionnaires: the Household Questionnaire, the Women's Questionnaire, and the Men's Questionnaire. The household questionnaire collects demographic information on the household members, including their relationship to the head of the household (defined in DHS as the person responsible for the household). The women's questionnaire collects data on socio-demographic characteristics including education, employment, and relationship status. Surveys also include questions on sexual behaviors (e.g., number of sexual partners, engagement in transactional sex), and contraception use (e.g., condom use). The women's module also asks about antenatal and postnatal care, breastfeeding behaviors, and immunization data for children born less than five years before the survey, the latter comprising the Children's Questionnaire. Data on the knowledge of and attitudes on HIV, lifetime and past-year HIV testing are also collected. Women who gave birth in the last two or three years prior to the survey, are asked about HIV testing at the ANC or during delivery. Men's questionnaire contains similar information to women's, excluding questions related to pregnancy and delivery.[128] In the majority of surveys, 15-49 year-old women and 15+ year-old men are eligible to participate, with variations in eligibility age over time.[129]

Countries have the option of including various additional modules to their DHS surveys, depending on national priorities. For example, most DHS surveys include an IPV module administered to a subset of households. Many DHS conducted in African countries also include HIV biomarker data in a subset of households, among consenting and eligible participants.

For simplified analysis, DHS has developed a couples' dataset. It contains data for married or cohabiting men and women who both state to be married (or living together in a union) to each other in individual interviews. This file is the result of linking male and female datasets together based on a partner identifier.

*Sampling methodology*

DHS sampling is based on a stratified, two-stage cluster design. DHS sampling regions are stratified by homogenous geographic regions (often province) and by rural/urban areas within the region. In the first stage of selection, Primary Sampling Units (PSU), forming survey clusters, are selected with the probability proportional to the size of each stratum. PSUs often form a census enumeration area. In the second stage, households are randomly selected from each cluster. The overall selection probability of each household is the probability of selecting a

cluster multiplied by the probability of selecting a household in that cluster.[130] DHS data contain individual sampling weights for men and women.

*HIV testing and biomarker measurement*

Most Women's and Men's DHS questionnaires contain HIV modules. These collect information on the respondents' knowledge of HIV prevention methods, accepting attitudes toward persons living with HIV/AIDS, HIV testing in one's lifetime and in the past 12 months, as well as the receipt of these test results. Women who had delivered in the past two or three years are further asked about HIV testing and counselling at the ANC, and HIV testing immediately prior to and during delivery.

Since the early 2000s, in majority of the DHS surveys conducted in African countries, HIV biomarkers are collected in a subsample of households per cluster. Presence of HIV in blood samples is measured via Dried Blood Spot (DBS) method in most surveys.[131] Additional HIV-related biomarkers such as viral load, presence of ART in the blood and HIV incidence are collected in few select surveys. Viral load testing is conducted using RT-PCR. ART uptake is measured via high-resolution liquid chromatography and tandem mass spectrometry. HIV incidence is measured with an algorithm which includes limiting Antigen Enzyme (Lag-Avidity) immunoassay. The algorithm is used to identify recent infections –those that were acquired less than four to seven months before sample collection[132,133] and accounts for ART biomarkers and viral load suppression to minimize false positives.[134] As of 2023, only two DHS surveys (Lesotho 2014 and Mozambique 2015) had information on biomarker-based viral load, ART uptake, and recent HIV infection measures.[135] DHS data contain HIV biomarker sampling weights.

*IPV measurement*

In 2000, the DHS program added a Domestic Violence module to data collection procedures.[136] The module is administered to only one randomly selected woman per household to maintain confidentiality. Often, only a subset of households is eligible for the IPV module. The interview must be conducted in private, outside of the hearing distance from others. By the end of 2020, 65 countries had administered the domestic violence module at least once and 39 countries had administered it more than once.

In most surveys the IPV module is administered to women who are ever-married, defined as self-reporting as being married, divorced separated or widowed, or living with or having ever lived with a man as if married.[137] The IPV questions are asked about their current or most recent husband/partner.[137] Women are asked about their lifetime experiences of physical and sexual IPV from their current or previous husband/partner, as well as the frequency of IPV acts in the past year. The survey instrument is based on acts-specific, gold-standard modified Conflict Tactics Scale to collect information on IPV.[80,138] Questions across surveys are consistent as listed in Table, though few surveys vary in terms of the question wording. DHS data contain IPV module sampling weights.

In addition to IPV, dating violence and violence during transactional relationships can have detrimental consequences and could contribute to HIV epidemics. However, data on the latter are scarce. DHS generally uses women who report being ever-married or ever living with a man as-if married as the denominator to calculate the proportion of women who experience IPV.[139] This corresponds to the indicator used to measure achievement of SDG 5.2.1: "Proportion of ever-partnered women and girls subjected to physical or sexual violence by a current or former intimate partner in the previous 12 months", where intimate partner is defined as a partner in the context of marriage, cohabitation or any other formal or informal union.[140] In this thesis I used this definition of IPV. Prevalence of violence, and women's risk of HIV acquisition in transactional relationships is likely to be higher than in cohabiting relationships. Further, women who are experiencing dating violence are likely to be younger, which could put them at a higher risk of both, experiencing IPV and acquiring HIV. Thus, the effect estimates for the impact of violence against women on the risk of HIV acquisition are likely to be larger than those observed in studies below, that focused on IPV alone.

**Table 3.1** Questions included in the domestic violence module in Demographic and Health Surveys (DHS). Source: Tanzania 2022 DHS – Final Report.

| A. Did you (last) (husband/partner) ever do any of the following things to you: | | B. How often did this happen during the last 12 months: often, only sometimes, or not at all? | | |
|---|---|---|---|---|
| | Ever | Often | Sometimes | Not in last 12 months |
| a) Push you, shake you, or throw sometime at you? | Yes 1<br>No 2 | 1 | 2 | 3 |
| b) Slap you? | Yes 1<br>No 2 | 1 | 2 | 3 |
| c) Twist your arm or pull your hair? | Yes 1 | 1 | 2 | 3 |

| | | | | | |
|---|---|---|---|---|---|
| | | No 2 | | | |
| d) | Punch you with his fist or with something that could hurt you? | Yes 1<br>No 2 | 1 | 2 | 3 |
| e) | Kick you, drag you, or beast you up? | Yes 1<br>No 2 | 1 | 2 | 3 |
| f) | Try to choke you or burn you on purpose? | Yes 1<br>No 2 | 1 | 2 | 3 |
| g) | Threaten or attack you with a knife, gun, or other weapon? | Yes 1<br>No 2 | 1 | 2 | 3 |
| h) | Physically force you to have sexual intercourse with him when you did not want to? | Yes 1<br>No 2 | 1 | 2 | 3 |
| i) | Physically force you to perform any other sexual acts you did not want to? | Yes 1<br>No 2 | 1 | 2 | 3 |
| j) | Force you with threats or in any other way to perform sexual acts you did not want to? | Yes 1<br>No 2 | 1 | 2 | 3 |

**Population-based HIV Impact Assessment (PHIA)**

Another major data source for my thesis are the *Population-based HIV Impact Assessment* (PHIA) surveys. The PHIA project is sponsored by *the Centers for Disease Control and Prevention* (CDC) and designed to measure the reach and impact of HIV programs in countries supported by the *U.S. President's Emergency Plan for AIDS Relief* (PEPFAR). Since 2015, PHIA surveys have been conducted in 14 countries, mostly in Eastern and Southern Africa.[142]

Sampling design of PHIA surveys is the same as that of the DHS (cross-sectional two-stage, stratified sampling). PHIA contain household and individual questionnaires administrated to all adults (men and women) over the age of 15. Some surveys collect data on children aged 0-14 years. Unlike DHS, PHIA encompass all adults, including those over the age of 59. Most surveys conduct biomarker testing for HIV serostatus, recency of HIV infection, HIV viral load and ART presence in blood. IPV questions are consistent between DHS and PHIA with the difference that PHIA collect information on past-year IPV only (no lifetime IPV measure).[143] DHS and PHIA also differ slightly in terms of their wording of the sexual IPV questions: PHIA ask about partner physically forcing or pressuring women to have sex when they did not want to; in addition to these two, DHS asks about partner physically forcing women to perform sexual acts they did not want to.

**South African National HIV Prevalence, Incidence, Behaviour and Communication Surveys (SABSSM)**

SABSSM, sponsored by the *Human Sciences Research Council*, are the population-based household surveys used to collect nationally representative HIV data in South Africa. The surveys have been conducted every 3-4 years since 2002 and use a multi-stage stratified cluster random sampling design, similar to the DHS and PHIA. Unlike DHS, SABSSM encompasses all adults, including those over the age of 59. It also incorporates a questionnaire for children 12-14 years old.

The IPV module was included only in the last survey wave (2017), which is why only SABSSM 2017 was included in the Manuscript 1. Indicators collected in SABSSM 2017 are aligned with those in PHIA and DHS, including biomarker-based measures for HIV seroprevalence, ART uptake, viral suppression, and recent HIV infection. The IPV module questions are consistent with those in DHS and PHIA with the exception that in SABSSM past-year IPV pertains to physical violence only (i.e., no information on sexual violence).

**Official HIV indicators from the UNAIDS-supported Spectrum model**

My third objective was parametrized through Spectrum – a mathematical model supported by UNAIDS for countries to estimate their HIV epidemic trends from surveillance and survey data.[144] Epidemic projections are obtained at annual, country-led estimation exercises, generating projection files containing a full historical set of estimates. The 2022 projection files (including estimates from the years 2000-2021) were used to parametrize the decision-analytic model in Manuscript 3.

To create the projection files, countries enter national HIV program data in Spectrum program. This includes annual, country-specific prevention of vertical HIV transmission program data such as proportion of women tested for HIV at the ANC, proportion testing positive at ANC, proportion on ART by treatment regimen, proportion of women breastfeeding and duration of breastfeeding, proportion of women retained on ART peri- and postnatally. Projection files also contain a) demographic information including: age-, year- and country-specific fertility rate, as well as rate ratios accounting for the impact of HIV and ART uptake on fertility; b) annual, country-specific HIV information such as HIV prevalence and cumulative HIV incidence over

one year by five-year age group c) HIV transmission probabilities by ART regimen and CD4 count, and distribution of WLHIV in different CD4 count categories.

## 3.2 Methods

*Choice of identification strategy*

The first two manuscripts of this thesis rely on the empirical analyses of survey data. Surveys were pooled to conduct a single-stage, individual participant meta-analysis, wherein individual participant data were combined in one analytical dataset.[145] An alternative approach would be a two-stage meta-analysis, in which individual participant data from *each survey* is analyzed separately to obtain survey-specific effect estimates; then, these are combined by an appropriate fixed-effects or random effects model.[145] A single-stage method was chosen in favor of a two-stage since it often produces more reliable results when few surveys are available (e.g. for our biomarker-based analyses), or when the outcome is rare (e.g. for our HIV incidence analyses) (Manuscript 1). Further, single-stage method allows for adjustment for individual-level confounders.[146]

*Analytical considerations*

To obtain the estimate of the impact of IPV on recent HIV infection, HIV testing, ART uptake and viral suppression (Manuscript 1), I used Poisson regressions based on generalized estimating equations (GEE) with a log-link. I used GEE to account for the correlation between women sampled from the same cluster. GEE models provide a population average (marginal) estimate, which can be interpreted as a change in the outcome across all clusters. Treating across-cluster variation as a 'nuisance' is relevant since my research question seeks to understand the population level impact of IPV. Further, I aimed to provide effect estimates on the relative risk scale (as opposed to the odds ratio scale). If I had used a conditional model (e.g. a random effect model), rather than marginal, I might have faced convergence issues when using a log-link. I estimated prevalence ratios (PR) instead of odds ratios (OR), since PR is easier to interpret as a measure of public health relevance.[147] Finally, in all models I used a survey identifier as a fixed effect which controls for measured and unmeasured country and year-specific confounders. In addition to survey-level fixed effects, I adjusted for other relevant confounders: participant age,

age at sexual debut (HIV recency analysis), urban or rural residency, partnership status, and education.

In Manuscript 2, the analysis was descriptive and sought to understand the relationship-level and male individual characteristics associated with IPV perpetration. Potential characteristics were identified based on previously published risk-factors for IPV. Multivariable models were adjusted for basic socio-demographic variables: age, household wealth quintile, urban or rural residency, and educational attainment.

*Decision analytic models*

Nationally representative survey data provide a valuable tool to answer the first two objectives of my thesis. However, inference about HIV transmission can be challenging. With incidence often unobservable and multiple causal factors impacting HIV transmission, estimating vertical HIV transmission is not feasible based on cross-sectional, population-based surveys. Further, cross sectional studies cannot address the inherent temporal relationships between the experience of IPV, women's HIV acquisition, ART uptake and retention, viral suppression, birth, and breastfeeding and finally, vertical HIV transmission. Cohort studies are lengthy and costly, especially when investigating rare outcomes such as vertical HIV transmission since the ART scale-up in high HIV burden settings. Mathematical modelling approaches can address some of these limitations.

Mathematical models are computer simulations of infectious disease spread that represent transmission through a set of mathematical equations. Mathematical models can be categorized into dynamic and static, among others.[148] Dynamic models allow the force of infection (i.e., the incidence risk) to vary as a function of the number (or prevalence) of infectious contacts at a particular time. Meanwhile, the force of infection in static models is time-invariant and depends on the characteristics of an individual only.[148] HIV status of other women would not impact one's rates of vertical HIV transmission, and the model parameters in Manuscript 3 can be assumed not to vary between the time of IPV experience and vertical HIV transmission. Thus, a static model would be the best analytical choice to address Objective 3.

Decision analytic models are the static mathematical models often used in health economics and outcomes research. They include Markov models, discrete event simulation models, and decision trees with the latter being the simplest and the most commonly used modelling

technique.[149] Decision trees, or probability trees, are a schematic representation of possible states of being (or "decisions") that branch into further, mutually exclusive states (or nodes) with associated probabilities or proportions. Decision analytic models enable the construction of a hypothetical cohort of women who progress through the states (or 'decision' nodes) that represent the evidence-based temporal relationships between IPV and vertical HIV transmission. I was also able to synthesize information from a wide range of data sources, including some longitudinal and country-specific, which account for the time- and setting-dependent variability in ART coverage in Africa.

Decision trees are most appropriate when events occur over a short period and when the evaluation can include intermediate outcomes. This is relevant since the time between IPV experience a year prior to pregnancy, pregnancy and breastfeeding, and vertical HIV transmission is fixed and not of primary interest in my analysis.

## 3.3 Ethics

This thesis leveraged existing data to conduct secondary data analysis. All data obtained was de-identified. Ethics approval was obtained from the McGill Research Ethics board (A12-B95-21B).

# 4. Chapter 4: The effects of intimate partner violence on women's risk of HIV acquisition, and engagement in HIV treatment and care

## 4.1 Preface to Manuscript 1

Compelling evidence on the relationship between the experience of IPV and the full spectrum of the HIV prevention and treatment cascade can promote integration of IPV prevention interventions into HIV programs. I leveraged data from the nationally representative, population-based surveys conducted in sub-Saharan Africa since 2000 to shed light on the associations between IPV and recent HIV acquisition, HIV testing, ART uptake and viral suppression. The resulting article was published in the *Lancet HIV* (February 2023, Volume 10, Issue 2, DOI: 10.1016/S2352-3018(22)00305-8).

## 4.2 Manuscript 1: The effects of intimate partner violence on women's risk of HIV acquisition and engagement in the HIV treatment and care cascade: a pooled analysis of nationally representative surveys in sub-Saharan Africa

Kuchukhidze S[1] MPH, Panagiotoglou D[1] PhD, Boily MC[2] PhD, Diabaté S[3,4,5] MD, Eaton JW[2] PhD, Mbofana F[6] MD, Sardinha L[7] PhD, Schrubbe L[8] MSc, Stöckl H[9] PhD, Wanyenze RK[10] PhD, and Maheu-Giroux M[1,*] ScD

**Affiliations**

1- Department of Epidemiology and Biostatistics, School of Population and Global Health, McGill University, Montréal, Canada
2- Medical Research Council (MRC) Centre for Global Infectious Disease Analysis, School of Public Health, Imperial College London, London, United Kingdom
3- Département de médecine sociale et préventive, Université Laval, Québec, QC Canada
4- Centre de recherche du CHU de Québec, Université Laval, Québec, QC, Canada
5- Université Alassane Ouattara, Bouaké, Côte d'Ivoire
6- Conselho Nacional de Combate ao HIV/Sida, Maputo, Mozambique
7- School for Policy Studies, University of Bristol, Bristol, United Kingdom
8- Department of Population Health, Faculty of Epidemiology and Population Health, London School of Hygiene & Tropical Medicine, London, UK
9- Institute for Medical Information Processing, Biometry, and Epidemiology, Ludwig Maximilian University of Munich, Munich, Germany
10- Department of Disease Control and Environmental Health, School of Public Health, College of Health Sciences, Makerere University, Kampala, Uganda

## Summary

### Background

Achieving the 95-95-95 targets for HIV diagnosis, treatment, and viral load suppression to end the HIV epidemic hinges on eliminating structural inequalities, including intimate partner violence (IPV). Sub-Saharan Africa has among the highest prevalence of IPV and HIV worldwide. We aimed to examine the effects of IPV on recent HIV infection and women's engagement in the HIV care cascade in sub-Saharan Africa.

### Methods

We did a retrospective pooled analysis of data from nationally representative, cross-sectional surveys with information on physical or sexual IPV (or both) and HIV testing, from Jan 1, 2000, to Dec 31, 2020. Relevant surveys were identified from data catalogues and previous large-scale reviews, and included the Demographic and Health Survey, the AIDS Indicator Survey, the Population-based HIV Impact Assessment, and the South Africa National HIV Prevalence, Incidence, Behavior and Communication Survey. Individual-level data on all female respondents who were ever-partnered (currently or formerly married or cohabiting) and aged 15 years or older were included. We used Poisson regression to estimate crude and adjusted prevalence ratios (PRs) for the association between past-year experience of physical or sexual IPV (or both), as the primary exposure, and recent HIV infection (measured with recency assays), as the primary outcome. We also assessed associations of past-year IPV with self-reported HIV testing (also in the past year), and antiretroviral therapy (ART) uptake and viral load suppression at the time of surveying. Models were adjusted for participant age, age at sexual debut (HIV recency analysis), urban or rural residency, partnership status, education, and survey-level fixed effects.

### Findings

57 surveys with data on self-reported HIV testing and past-year physical or sexual IPV were available from 30 countries, encompassing 280,259 ever-partnered women aged 15–64 years. 59 456 (21.2%) women had experienced physical or sexual IPV in the past year. Six surveys had information on recent HIV infection and seven had data on ART uptake and viral load suppression. The crude PR for recent HIV infection among women who had experienced past-

year physical or sexual IPV, versus those who had not, was 3.51 (95% CI 1.64–7.51; n=19 179). The adjusted PR was 3.22 (1.51–6.85). Past-year physical or sexual IPV had minimal effect on self-reported HIV testing in the past year in crude analysis (PR=0.97 [0.96–0.98]; n=274 506) and adjusted analysis (adjusted PR=0.99 [0.98–1.01]). Results were inconclusive for the association of ART uptake with past-year IPV among women living with HIV (crude PR=0.90 [0.85–0.96], adjusted PR=0.96 [0.90–1.02]; n=5 629). Women living with HIV who had experienced physical or sexual IPV in the past year were less likely to achieve viral load suppression than those who had not experienced past-year IPV (crude PR=0.85 [0.79–0.91], adjusted PR=0.91 [0.84–0.98], n=5 627).

**Interpretation**

Past-year physical or sexual IPV was associated with recent HIV acquisition and less frequent viral load suppression. Preventing IPV is inherently imperative but eliminating IPV could contribute to ending the HIV epidemic.

**Funding**

Canadian Institutes of Health Research, the Canada Research Chairs Program, and Fonds de recherche du Québec-Santé.

## Introduction

Despite substantial progress to curb HIV epidemics worldwide, 1.5 million new HIV infections occurred in 2020.[1] This burden of new infections disproportionately affects women. For example in sub-Saharan Africa, women accounted for 63% of new HIV infections in 2020.[1] The global HIV agenda is guided by the 95-95-95 targets to end AIDS by 2030; an ambitious plan that calls for achievement of 95% diagnosis coverage, 95% uptake of antiretroviral therapy (ART) among those diagnosed, and 95% with viral suppression among those on treatment.[1] Reaching these targets partly hinges on addressing structural vulnerabilities such as inequitable gender and social norms and violence against women and girls.

Worldwide, more than one in four women experiences physical or sexual IPV (or both) in their lifetime, with prevalence reaching approximately 40% in central and eastern sub-Saharan Africa.[2] This violence often co-occurs with HIV and could pose barriers to women in preventing HIV acquisition, accessing HIV care, and remaining in care if living with the virus. The 2021 UN General Assembly adopted the Political Declaration on HIV and AIDS with bold new global targets for 2025, including a commitment to eliminate all forms of sexual and gender-based violence, including IPV, as a key enabler of the HIV epidemic.[3] Improving understanding of the relationships between IPV and HIV is essential to meet this commitment.

In sub-Saharan Africa, women being subjected to IPV could be at increased risk of HIV acquisition and adverse HIV outcomes.[4-6] It has been hypothesised that the increased risk of HIV acquisition among women experiencing IPV could be due to partner characteristics (eg, concurrency, HIV prevalence, unsuppressed viral load), be mediated by condom use, or be a direct consequence of sexual violence itself.[7,8] In addition to the potential effect on HIV incidence, IPV could compromise access to the HIV prevention and care cascade: from HIV testing[9], to ART uptake and retention[9,10], to viral suppression.[9,11,12] Adverse mental health effects of IPV, and associated controlling behaviours, could be driving these negative outcomes.[10,13]

Overall, the evidence base suggesting that IPV and HIV interact could be strengthened. Previous studies focused on a single country and recruited specific populations such as pregnant women[10], young people[14], female sex workers[15], or women who use substances.[16] This makes generalisation of the study's results challenging. Previous population-based research from sub-Saharan Africa has provided conflicting evidence[17] or focused on HIV seroprevalence rather than

the full spectrum of how IPV affects women's engagement in HIV care.[4] Furthermore, the definitions of IPV (eg, severity of acts, physical only, sexual only, or both)[18], the period (eg, lifetime or past year)[19], and inclusion criteria (eg, currently partnered or ever-partnered women) have varied, making it difficult to systematically compare effect estimates or generate robust evidence on population-level effects of IPV.[9] Over the past decade, several large, nationally representative, population-based surveys have collected information on IPV and HIV, including data on recency assays, antiretroviral biomarkers, and viral suppression. These surveys use standardised and robust methods, providing researchers with opportunities to overcome some of the limitations of previous studies.

Our aim was to improve understanding around the associations between women's experience of IPV and HIV acquisition, and between IPV and engagement with the HIV prevention and treatment cascade. Using nationally representative surveys from sub-Saharan Africa, we estimated the effect of past-year physical or sexual IPV (or both) on four outcomes: recent HIV infection, HIV testing in the past year, ART uptake, and viral load suppression.

**Research in context**

**Evidence before this study**

We searched PubMed for empirical studies published from database inception to April 8, 2022, without language restrictions, using the terms: HIV AND women AND (violence OR intimate partner OR domestic violence OR GBV OR IPV) AND (Africa* OR sub-Sahara*). Several systematic and scoping reviews have investigated the effects of intimate partner violence (IPV) on HIV with mixed results. Most studies used HIV seropositivity as the outcome. A multicountry study of cross-sectional surveys in sub-Saharan Africa published in 2010 by Harling and colleagues found no association between IPV and HIV serostatus. However, evidence in 2015 suggested that women experiencing IPV are more likely to be living with HIV than a reference group composed of women not experiencing overlapping dimensions of IPV. Longitudinal studies in South Africa and Uganda suggested that women who had experienced IPV were more likely to acquire HIV than those who had not experienced IPV. However, two other prospective cohort studies among young people (in Uganda, Zablotska et al, 2009) and serodiscordant couples (seven countries in east and southern Africa, Were et al, 2011) did not find significant associations. Regarding the effects of IPV on HIV treatment, most included studies in a 2019 scoping review by Leddy and colleagues did not find an association between IPV and HIV testing, although two studies reported a reduction in HIV testing associated with IPV among pregnant and postpartum women. A 2015 meta-analysis of 13 cross-sectional studies, mostly from the USA, found that IPV was associated with reductions in current antiretroviral therapy use, adherence, and viral suppression. Studies from South Africa and Zambia indicated an association between IPV and unsuppressed viral loads among adolescents and postpartum women. Overall, comparison of estimates and outcomes is difficult due to a lack of standardisation in survey instruments, recall period for IPV, outcome measurement, and populations considered (eg, pregnant women, young women, or sex workers).

**Added value of this study**

Our study builds on more than two decades of research on IPV and HIV. Using individual-level data from cross-sectional, population-based surveys, we did a pooled analysis to assess the effects of IPV on HIV in countries across sub-Saharan Africa. Our results generally corroborate previous findings, and we expanded the scope of previous studies by considering the whole continuum of care from HIV acquisition to viral suppression. Furthermore, our use of nationally representative data mitigates some of the challenges associated with the generalisability of clinical samples.

**Implications of all the available evidence**

The 2021 Political Declaration on HIV and AIDS commits to eliminating sexual and gender-based violence, including IPV, by 2025 to combat the HIV epidemic. IPV could lead to HIV acquisition and pose a barrier to viral suppression in sub-Saharan Africa. The overlap between IPV and HIV requires renewed and urgent attention directed towards interventions research and health systems policy.

*Data Sources*

We did a retrospective pooled analysis of surveys following STROBE guidelines (Supplement 4). We reviewed all nationally representative, cross-sectional, population-based surveys of women (aged 15–49 years or 15–64 years) from sub-Saharan Africa that were conducted between Jan 1, 2000 and Dec 31, 2020, with individual participant data on IPV and HIV testing. We searched data catalogues (ie, the Global Health Data Exchange and the International Household Survey Network), examined surveys included in the Global Estimates for Violence Against Women Statistics systematic review[20], and examined a previous review of surveys with information on HIV testing[21] and complemented these with expert knowledge of other available surveys.

The surveys considered for analysis included the Demographic and Health Surveys (DHS), the AIDS Indicator Surveys (AIS; part of The DHS Program), the Population-based HIV Impact Assessment (PHIA), and the South Africa National HIV Prevalence, Incidence, Behavior and Communication Survey (SABSSM), as well as country-specific surveys. The surveys with information on both HIV testing and IPV included in our final analyses were the DHS, AIS, PHIA, and SABSSM. The study population included all female respondents to surveys who had self-reported to be ever-partnered (currently or formerly married or cohabiting) and aged 15 years or older.

All secondary data analyses were done on de-identified and anonymised data. The survey protocols for the DHS and AIS are approved by the Internal Review Board of ICF International (Calverton, MD, USA), and by the relevant country authorities for the PHIA and SABSSM. Ethics approval was obtained from the institutional review board of the Faculty of Medicine and Health Sciences at McGill University (Montréal, QC, Canada; approval number A12-B95–21B).

*Procedures*

In the surveys, information on IPV was collected from one randomly selected woman in each household for PHIA and SABSSM, and from randomly selected women in a fraction of households selected for the domestic violence module in DHS and AIS. The primary exposure of interest in the current analysis was experience of physical or sexual IPV (or both) in the past year (Supplement 1, Table S1). Subsequently we refer to this outcome as physical or sexual IPV. All

surveys used acts-specific instruments based on the modified Conflict Tactics Scale to collect information on IPV.[22]

The secondary exposures were lifetime experience of physical IPV only; lifetime experience of sexual IPV only; lifetime experience of physical or sexual IPV (or both; subsequently referred to as lifetime physical or sexual IPV); lifetime experience of severe physical or sexual IPV (or both; subsequently referred to as lifetime severe physical or sexual IPV); and frequency of physical or sexual IPV (or both) in the past year (with survey response options: not at all, sometimes, or often; Supplement 1, Table S1). Measurements are generally consistent across surveys, although the PHIAs collected information on past-year IPV only (no lifetime measure). In SABSSM, past-year IPV pertains to physical violence only (ie, no information on sexual violence). In the SABSSM and PHIA, frequency of past-year IPV pertains only to physical IPV, while in other surveys this measure pertains to the frequency of physical or sexual IPV. In five DHS the frequencies of IPV categories were created on the basis of a continuous measure of frequency, where "often" was defined as experience of IPV five or more times in the past year; "sometimes" was defined as experience of IPV one to four times in the past year, and "not at all", the reference category, was defined as no experience of any physical or sexual IPV in the past year. Whenever a survey did not collect the information, we extrapolated the frequency of physical IPV to that of physical or sexual IPV based on the strong relationship between both measures.[23] Frequency of sexual IPV was not extrapolated to that of physical or sexual IPV due to sexual IPV more commonly being under-reported. Overall IPV prevalence was presented for sub-Saharan Africa and its subregions (central Africa, western Africa, eastern Africa, and southern Africa; regions as defined by the UN Statistics Division).

Our primary outcome was recent HIV infection (as a proxy for HIV incidence) among women at risk of HIV acquisition (ie, excluding those living with non-recent HIV). Recency of infection was measured via the limiting-antigen avidity assay performed on all participants found to be seropositive for HIV. The recency algorithm used by surveys to identify recent infections (mean duration of recent infection, which was those acquired less than 4–5 months before sample collection[24]) accounted for antiretroviral biomarkers and viral suppression to minimise false positives.

Other outcomes were related to the HIV prevention and treatment cascade (Supplement 1, Table S2). First, we considered self-reported HIV testing histories (lifetime and past-year testing

and receipt of result) among all ever-partnered women. Second, we assessed ART uptake among ever-partnered women living with HIV (on the basis of HIV serostatus, irrespective of self-reported HIV status). ART uptake was defined on the basis of qualitative detection of antiretroviral biomarkers in blood samples complemented by self-report of being on ART at the time of survey administration. Surveys that only collected self-reported ART uptake were excluded. And third, ever-partnered women living with HIV were considered virally suppressed if their HIV RNA load was less than 1000 copies per mL at the time of survey administration. Women with a recent HIV infection were excluded from the ART uptake and viral suppression analyses as we assumed they did not have time to be linked to treatment (Supplement 1, Table S2). For sensitivity analyses, we collected information on testing modality (antenatal care *vs* other) and ART adherence on the basis of self-reported number of missed ART pills in the past 30 days**.**

*Statistical analysis*

Individual-level data from each survey were pooled to calculate crude and adjusted prevalence ratios (PRs) for the association between IPV and recent HIV infection, HIV testing, ART uptake, and viral load suppression. Adjusted PRs were estimated accounting for the potential confounders of participant age (as a continuous variable), residence type (rural or urban), women's current partnership status (in a union or living with a man versus not), women's education (none, primary, secondary, or higher), and survey-level fixed effects (survey country and year). An additional adjustment variable for the HIV recency analysis was age at sexual debut (as a continuous variable). These confounders were reported in the same way in all surveys and have been previously identified as being potentially linked to both IPV and the HIV outcomes of interest.[4,17] The survey-level fixed effects allowed us to control for any measured or unmeasured survey-level confounders. Modified Poisson regression models were used to obtain the crude and adjusted PRs based on generalised estimating equations with robust standard errors that accounted for the sampling design (ie, exchangeable correlation structure with the primary sampling units as the clustering variable). Survey weights were not included in the regression[4,17] as they are often unwarranted to obtain unbiased estimates.[25] We used a complete case analysis given that the overall proportion of missing observations was small for all outcomes (≤4%). Further details including information on the missing observations and the

analyses of potential biases due to missingness, which are unlikely to qualitatively affect our results, are provided in Supplement 2.

With use of the same statistical methods as the main analyses, several sensitivity analyses were done with available survey data. First, we examined the robustness of our results by only including women testing outside of antenatal care for the HIV testing outcome to examine if IPV has a differential effect by HIV testing modality. Second, stratifying the results by year of survey administration (ie, 2000–04, 2005–09, 2010–14, and 2015–19), we estimated the effects of IPV on HIV testing over time to understand whether HIV testing scale-up could affect our results. Third, we explored the effect of IPV on ART adherence by estimating the mean (SD) number of missed ART pills in the past month among women who self-reported being on ART. Additionally, we examined the effect of IPV on ART uptake separately for biomarker-based and self-reported measures of ART use. Fourth, we restricted the analysis of viral suppression to women on ART (ie, conditioning on achieving this step in the cascade). Fifth, to investigate if partner or couple characteristics confound the relationship between IPV and recent HIV infection among women, we linked data for married or cohabiting men and women who both declared to be currently married or cohabiting. To create the analytical dataset, married or cohabiting women were linked to married or cohabiting men with use of a partner identifier. We then summarised data on male partner HIV status, education, age (and corresponding mean partner age discrepancy), and alcohol consumption (never, sometimes, often; in PHIA, survey responses were recoded to match these categories; Supplement 7), and condom use at women's most recent sex, stratified by women's experience of past-year IPV (Supplement 7). Finally, we explored the heterogeneity of effect estimates across surveys for each outcome, using $I^2$ statistics, by calculating survey-specific crude PRs and pooling them using both fixed-effects and random-effect meta-analyses. R software (version 4.0.0) was used for all analyses.

*Role of the funding source*

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

**Results**

We identified 100 nationally representative surveys that included information on HIV testing (the outcome reported in the largest number of surveys), of which 64 had data on IPV (figure 4.1). Seven surveys with no questions on physical IPV, with a high amount of missing data on past-year IPV (>96%), or that did not collect data on IPV and HIV in the same subgroup of women, were excluded. 57 surveys (51 DHS or AIS, five PHIA, and one SABSSM) conducted in 30 countries and 280 259 unique women respondents aged 15–64 years were included (Supplement 5, Table S6). 15 countries had more than one survey included, and the median year of data collection was 2013 (IQR 2010–2015). The majority of surveys were from eastern Africa (29 [50.9%]). Only six (10.5%) surveys had information on recent HIV infection based on recency assays, and seven (12.3%) had data on ART uptake and viral suppression (figure 4.2).

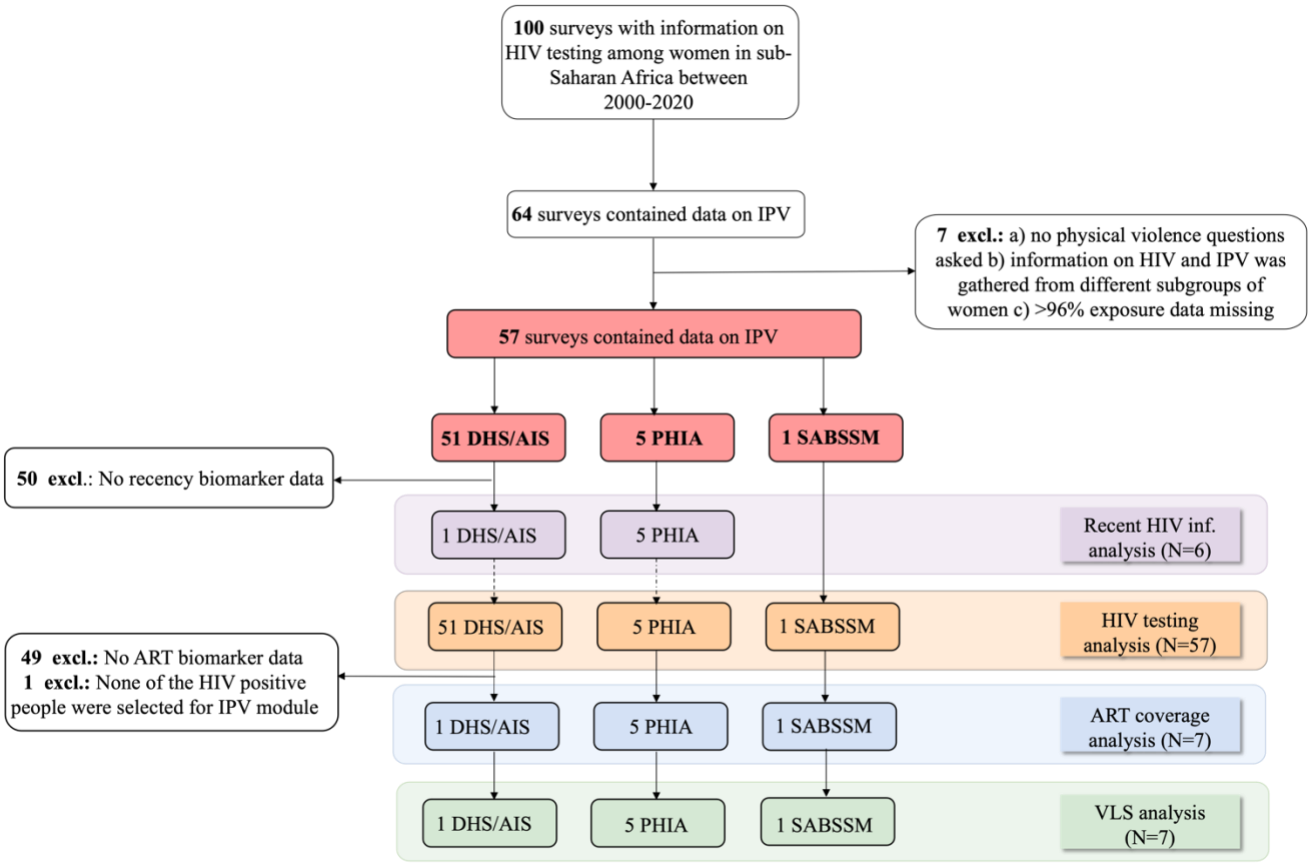


**Figure 4.1.** Flowchart for survey inclusion for each type of analysis.
AIS=AIDS Indicator Survey. ART=antiretroviral therapy. DHS=Demographic and Health Survey. IPV=intimate partner violence. PHIA=Population-based HIV Impact Assessment Survey. SABSSM=South African National HIV Prevalence, Incidence, Behavior and Communication Survey. *In these surveys (Benin DHS 2017 and Cameroon DHS 2011), HIV questions were asked to women whose households were selected for the men's survey, and IPV questions were asked to women whose households were selected for the IPV module. †In the Cote d'Ivoire PHIA 2017 and Cameroon PHIA 2017 surveys, >96% exposure data were missing indicating a possible systematic error in data collection or recording.

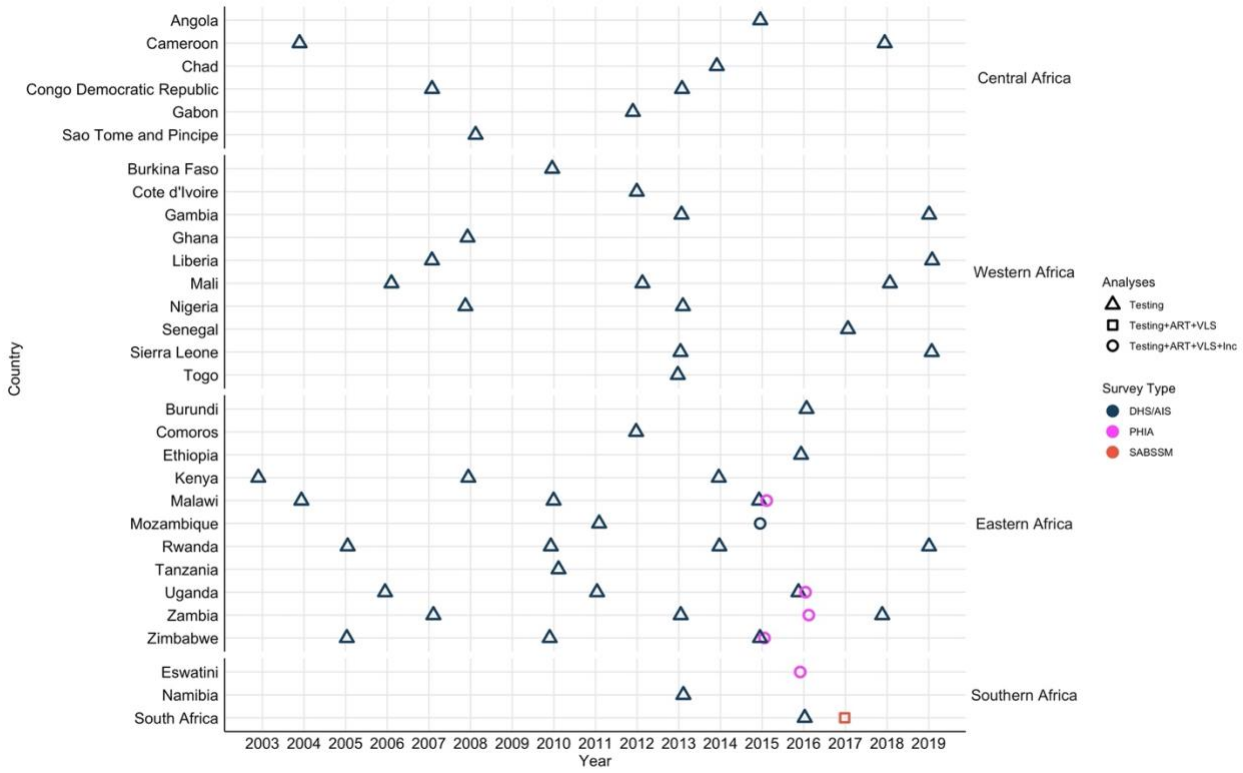


**Figure 4.2.** Surveys in sub-Saharan Africa with questions on HIV and IPV, by country and year, 2000–20. Datapoints represent individual surveys; colours represent the survey type and shapes indicate the type of analyses the surveys were included in (HIV testing only; HIV testing, ART uptake, and viral load suppression; and HIV testing, ART uptake, viral load suppression, and recent HIV infection).

AIS=AIDS Indicator Survey. ART=antiretroviral therapy. DHS=Demographic and Health Survey. IPV=intimate partner violence. PHIA=Population-based HIV Impact Assessment Survey. SABSSM=South African National HIV Prevalence, Incidence, Behavior and Communication Survey.

Overall, 59 456 (21.2%) of 280 259 ever-partnered women had experienced physical or sexual IPV in the past year and 81 555 (29.1%) had experienced it in their lifetime. Central Africa had the highest prevalence of past-year physical or sexual IPV (9552 [29.2%] of 32 759), followed by eastern Africa (31 679 [22.6%] of 139 908), western Africa (17 254 [17.0%] of 101 337), and southern Africa (971 [15.5%] of 6255; Supplement 5, Table S6). Women who had experienced past-year physical or sexual IPV tended to be younger than those who had not (Supplement 6). Among all women included in the HIV testing analysis, 26 901 (45.2%) of 59 456 reporting physical or sexual IPV in the past year had only primary education, compared with 78 326 (36.0%) of 217 646 who did not report IPV (Supplement 6, Table S8).

Among the six surveys with information on recent HIV infections, 45 (0.2%) of 19 935 women respondents had recently acquired HIV (table 4.1). Women not living with HIV who had experienced past-year physical or sexual IPV had a 0.5 percentage point higher proportion of recent HIV infection compared with those who had not experienced past-year physical or sexual IPV (eight [0.7%] of 1158 *vs* 37 [0.2%] of 18 777). We observed similar proportions with and without recent HIV infection for the secondary exposures of lifetime physical IPV, lifetime sexual IPV, and lifetime physical or sexual IPV (table 4.1). The crude PR for recent HIV infection among women who had experienced past-year physical or sexual IPV, versus those who had not, was 3.51 (95% CI 1.64–7.51; six surveys, n=19 179; table 4.2). After adjusting for potential confounders, experience of past-year physical or sexual IPV remained associated with recent HIV infection (adjusted PR=3.22 [95% CI 1.51–6.85]). As a robustness check, we examined the HIV status of cohabiting partners, couple age discrepancy, partner education, partner alcohol consumption, and condom use at women's most recent sex as potential confounders, when partnership data were available for linkage (Supplement 7). We observed differences in partner age discrepancy and partner alcohol consumption between women who had experienced past-year physical or sexual IPV and those who had not. Point estimates of the effect sizes from the main analysis were robust to confounding by these variables, although their uncertainty increased due to the reduced sample size.

**Table 4.1** Number of analyzed surveys and women (unweighted) experiencing different types of IPV for each outcome of interest

| | Past year physical or sexual IPV (or both) | | | Lifetime physical IPV | | | Lifetime sexual IPV | | | Lifetime physical or sexual IPV (or both) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Number of surveys** | **Yes*** | **No†** | **Number of surveys** | **Yes*** | **No†** | **Number of surveys** | **Yes*** | **No†** | **Number of surveys** | **Yes*** | **No†** |
| Recent HIV infection, n (%) | | | | | | | | | | | | |
| Yes | 6 | 8 (0.7%) | 37 (0.2%) | 1 | 2 (0.5%) | 2 (0.1%) | 1 | 0 (0%) | 4 (0.2%) | 1 | 2 (0.5%) | 2 (0.1%) |
| No | - | 1150 (99.3%) | 18 740 (99.8%) | - | 425 (99.5%) | 2,044 (99.9%) | - | 85 (100%) | 2384 (99.8%) | - | 438 (99.5%) | 2,031 (99.9%) |
| Lifetime HIV testing, n (%) | | | | | | | | | | | | |
| Yes | 57 | 31 023 (52.5%) | 113 384 (52.4%) | 52 | 39 531 (53.8%) | 83 757 (46.2%) | 52 | 15 663 (55.2%) | 107 624 (47.6%) | 52 | 43 802 (54.0%) | 79 483 (45.8%) |
| No | - | 28 101 (47.5%) | 102 976 (47.6%) | - | 33 908 (46.2%) | 97 446 (53.8%) | - | 12 704 (44.8%) | 118 614 (52.4%) | - | 37 347 (46.0%) | 93 986 (54.2%) |
| Past year HIV testing, n (%) | | | | | | | | | | | | |
| Yes | 57 | 16 392 (27.8%) | 57 996 (26.9%) | 52 | 20 292 (27.7%) | 43 451 (24.0%) | 52 | 8240 (29.1) | 55 506 (24.6) | 52 | 22 555 (27.9%) | 41 189 (23.8%) |
| No | - | 42 601 (72.2%) | 157 969 (73.1%) | - | 52 993 (72.3%) | 137 456 (76.0%) | - | 20080 (70.9%) | 170 329 (75.4%) | - | 58 429 (72.1%) | 131 995 (76.2%) |
| ART uptake, n (%) | | | | | | | | | | | | |
| Yes | 7 | 416 (64.2%) | 3717 (71.3%) | 2 | 388 (64.8%) | 675 (60.5%) | 2 | 68 (66.7%) | 996 (61.7%) | 2 | 402 (64.9%) | 661 (60.3%) |
| No | - | 232 (35.8%) | 1498 (28.7%) | - | 211 (35.2%) | 441 (39.5%) | - | 34 (33.3%) | 618 (38.3%) | - | 217 (35.1%) | 435 (39.7%) |
| Viral load suppression, n (%) | | | | | | | | | | | | |
| Yes | 7 | 375 (56.7%) | 3506 (67.3%) | 2 | 348 (57.0%) | 645 (57.3%) | 2 | 60 (60.6%) | 934 (57.0%) | 2 | 362 (57.4%) | 631 (57.1%) |
| No | - | 286 (43.3%) | 1700 (32.7%) | - | 262 (43.0%) | 481 (42.7%) | - | 39 (39.4%) | 704 (43.0%) | - | 269 (42.6%) | 474 (42.9%) |

ART=antiretroviral therapy. IPV=intimate partner violence. *Denominators for proportions are the total number of women with each exposure (past-year physical or sexual IPV, lifetime physical IPV, lifetime sexual IPV, lifetime physical or sexual IPV). †Denominators for proportions are the total number of women without each exposure.

**Table 4.2** Crude and adjusted PRs for recent HIV infection among women experiencing past-year physical or sexual IPV.

| Exposures | Number of surveys* | n | Crude PR (95% CI) | Adjusted PR† (95% CI) |
|---|---|---|---|---|
| Past year physical and/or sexual IPV | 6 | 19 179 | 3.51 (1.64, 7.51) | 3.22 (1.51, 6.85) |
| Frequency of past year physical and/or sexual IPV‡ | 6 | 19 178 | - | - |
| Never | - | - | 1 (ref) | 1 (ref) |
| Sometimes | - | - | 3.23 (1.37, 7.62) | 2.95 (1.27, 6.89) |
| Often | - | - | 4.77 (1.16, 19.64) | 4.50 (0.97, 20.8) |

The reference category for all PRs is women who had not experienced physical or sexual IPV in the past year. IPV=intimate partner violence. n=number of individual respondents included in the adjusted analyses without missing data for IPV, the outcome, and the covariates included in the model. PHIA=Population-based HIV Impact Assessment Survey. PR=prevalence ratio.

* Five of six surveys included in the recent HIV infection analysis were PHIAs, which do not collect data on our secondary exposures of interest (lifetime physical IPV, lifetime sexual IPV, lifetime physical or sexual IPV, and lifetime severe IPV).
† Adjusted for age (continuous), age at sexual debut (continuous), residence type (rural or urban), women's current partnership status (in a union or living with a man versus not), women's education (none, primary, secondary, or higher), and survey-level fixed effects.
‡ In PHIA surveys, the frequency of past-year IPV pertains to only recent physical IPV; furthermore, this question asks about perpetration of violence by "someone" which we assumed to be an intimate partner only when the woman had also reported experiencing IPV.

Of 275 484 women respondents, 144 407 (52.4%) reported ever being tested for HIV (table 4.1). Self-reports of HIV testing in the past year were similar between women who had experienced physical or sexual IPV and those who had not. More than a quarter of women in both groups had been tested in the past year: 16 392 (27.8%) of 58 993 women who had experienced past-year physical or sexual IPV and 57 996 (26.9%) of 215 965 women who had not (0.9 percentage point difference). The crude PR for recent HIV testing among women who had experienced past-year physical or sexual IPV, versus those who had not, was 0.97 (95% CI 0.96–0.98; 57 surveys, n=274 506; Supplement 8 Table S15). After adjusting for potential confounders, experience of past-year physical or sexual IPV had no effect on recent HIV testing (adjusted PR=0.99 [95% CI 0.98–1.01]). Women who had experienced physical or sexual IPV in their lifetime were 2% more likely to report lifetime testing (Supplement 8 Table S15). In a sensitivity analysis, experience of lifetime physical or sexual IPV was associated with a small increase in lifetime HIV testing among women who tested outside of antenatal care (Supplement 8 Table S16). A further sensitivity analysis of the effects over time showed that many results

remained robust, although in surveys conducted between 2000 and 2004, lifetime physical IPV was associated with a 16% reduction in recent HIV testing (Supplement 8 Table S20).

Women living with HIV who reported past-year physical or sexual IPV had a lower uptake of ART (416 [64.2%] of 648) than those who did not report past-year IPV (3717 of [71.3%] 5215; 7.1 percentage point difference; table 4.1). The crude PR for ART uptake among women with HIV who had experienced past-year physical or sexual IPV, versus those who had not, was 0.90 (95% CI 0.85–0.96; seven surveys, n=5629; table 4.3). After adjustments, women who had reported past-year IPV were 4% less likely to be on ART, compared with those who had not (adjusted PR =0.96 [0.90–1.02]), although we cannot rule out the possibility of no effect (table 4.3). Effect estimates were similar when only biomarker-based or only self-report measures of ART uptake were used (Supplement 8 Table S21-S22). In a further sensitivity analysis, we examined ART adherence among women who self-reported being on ART. Women reporting physical or sexual IPV in the past year had missed approximately 2.3 times as many pills in the past month as those who had not experienced past-year IPV (Supplement 8 Table S23); however, the absolute difference was less than half a pill per month.

**Table 4.3** Crude and adjusted PRs for ART uptake among women living with HIV experiencing different types of IPV

| Exposures | Number of surveys | n* | Crude PR (95% CI) | Adjusted PR† (95% CI) |
|---|---|---|---|---|
| Past year physical and/or sexual IPV‡ | 7 | 5629 | 0.90 (0.85, 0.96) | 0.96 (0.9, 1.02) |
| Lifetime physical IPV‡ | 2 | 1569 | 1.06 (0.98, 1.14) | 1.00 (0.93, 1.08) |
| Lifetime sexual IPV‡ | 2 | 1570 | 1.08 (0.94, 1.24) | 1.05 (0.91, 1.21) |
| Lifetime physical and/or sexual IPV‡ | 2 | 1569 | 1.06 (0.98, 1.14) | 1.01 (0.94, 1.09) |
| Severe lifetime physical and/or sexual IPV§ | 2 | 1568 | 0.93 (0.83, 1.04) | 0.94 (0.84, 1.05) |
| Frequency of past-year physical and/or sexual IPV‡¶ | 7 | 5629 | - | - |
| Never | - | - | 1 (ref) | 1 (ref) |
| Sometimes | - | - | 0.91 (0.85, 0.97) | 0.96 (0.89, 1.02) |
| Often | - | - | 0.85 (0.72, 1.00) | 0.98 (0.82, 1.16) |

ART=antiretroviral treatment. IPV=intimate partner violence. n=number of individual respondents included in the adjusted analyses without missing data for IPV, the outcome, and the covariates included in the model. PR=prevalence ratio.

* 45 women were excluded because they had a recent HIV infection; we assumed those with a recent infection did not have time to be diagnosed and linked to treatment.

† Adjusted for age (continuous), residence type (rural or urban), women's current partnership status (in a union or living with a man versus not), women's education (none, primary, secondary, or higher), and survey-level fixed effects.

‡ Reference category is women who had not experienced the specific IPV exposure.

§ Reference category includes women who reported non-severe lifetime IPV or no lifetime IPV.

¶ In Population-based HIV Impact Assessment Surveys (five of seven surveys) the frequency of past-year IPV pertains to only recent physical IPV; furthermore, this question asks about perpetration of violence by "someone" which we assumed to be an intimate partner only when the woman had also reported experiencing IPV.

Women living with HIV who had experienced past-year IPV had a lower frequency of viral load suppression (375 [56.7%] of 661) than those who had not experienced past-year IPV (3506 [67.3%] of 5206; 10.6 percentage point difference; table 4.1). The crude PR for viral load suppression among women with HIV who had experienced past-year physical or sexual IPV, versus those who had not, was 0.85 (95% CI 0.79–0.91; seven surveys, n=5627; table 4.4). After adjusting for confounders, women who had experienced past-year physical or sexual IPV were 9% less likely to be virally suppressed than those who had not experienced past-year IPV (adjusted PR=0.91 [95% CI 0.84–0.98]). Lifetime physical or sexual IPV also had an adverse effect on viral suppression, although the adjusted 95% CI included the null effect. The effect size was smaller for the association between past-year IPV and viral suppression among women living with HIV on ART. Women on ART who had experienced past-year physical or sexual IPV were 5% less likely to be virally suppressed than women who had not experienced past-year IPV

(Supplement 8 Table S24). Reporting the frequency of physical or sexual IPV in the past year as "often" was associated with a 14% reduction in the likelihood of viral suppression among women on ART, although the estimate was imprecise.

**Table 4.4** Crude and adjusted PRs for viral load suppression among women living with HIV experiencing different types of IPV

| Exposures | Number of surveys | n* | Crude PR (95% CI) | Adjusted PR† (95% CI) |
|---|---|---|---|---|
| Past year physical and/or sexual IPV‡ | 7 | 5627 | 0.85 (0.79, 0.91) | 0.91 (0.84, 0.98) |
| Lifetime physical IPV‡ | 2 | 1583 | 0.99 (0.91, 1.07) | 0.93 (0.85, 1.01) |
| Lifetime sexual IPV‡ | 2 | 1584 | 1.08 (0.91, 1.27) | 1.04 (0.88, 1.23) |
| Lifetime physical and/or sexual IPV‡ | 2 | 1583 | 1.00 (0.92, 1.08) | 0.94 (0.86, 1.02) |
| Severe lifetime physical and/or sexual IPV§ | 2 | 1582 | 0.99 (0.88, 1.12) | 1.01 (0.90, 1.14) |
| Frequency of past-year physical and/or sexual IPV‡¶ | 7 | 5627 | - | - |
| Never | | | 1 (ref) | 1 (ref) |
| Sometimes | - | - | 0.86 (0.8, 0.93) | 0.91 (0.84, 0.99) |
| Often | - | - | 0.75 (0.62, 0.92) | 0.89 (0.73, 1.10) |

* 45 women were excluded because they had a recent HIV infection; we assumed that those with a recent infection did not have sufficient time to be diagnosed and linked to treatment.
† Adjusted for age (continuous), residence type (rural or urban), women's current partnership status (in a union or living with a man versus not), women's education (none, primary, secondary, or higher), and survey-level fixed effects.
‡ Reference category is women who had not experienced the specific IPV exposure.
§ Reference category is women who reported non-severe lifetime IPV or no lifetime IPV.
¶ In Population-based HIV Impact Assessment Surveys (five of seven surveys) the frequency of past-year IPV pertains to only recent physical IPV; furthermore, this question asks about perpetration of violence by "someone" which we assume to be an intimate partner when the woman had also reported experiencing IPV.

Heterogeneity of the crude effect estimates across surveys was high for the HIV testing and ART uptake outcomes. Heterogeneity was low across the surveys for the viral suppression and recent HIV infection outcomes (Supplement 9 Figure S2-S5).

## Discussion

In our pooled analysis of population-based surveys, after adjusting for potential confounders, women who had experienced physical or sexual IPV in the past year were 3.22 times as likely to acquire a recent HIV infection as those who had not experienced past-year IPV. Although the effect of IPV on ART uptake was inconclusive, women living with HIV who experienced physical or sexual IPV in the past year were 9% less likely to be virally suppressed than those who did not experience past-year IPV. In accordance with the UN 2021 Political

Declaration to end gender inequalities perpetuating the HIV epidemic, the available evidence[5,6] suggests considerable overlap between IPV and HIV epidemics.

Longitudinal studies in South Africa and Uganda reported that women who experienced physical or sexual IPV in their lifetime had a 1.5 times increase in HIV incidence compared with those who had not experienced IPV. [5,6] Our study corroborates these results, although our effect estimates are larger. This discrepancy could be due to a number of reasons affecting cohort studies, including differential risk of loss to follow-up[6], selection of a sample that is different from the target population, and generalisability of effect estimates.[5,6] Other reasons explaining the differences in effect sizes could be discrepancies in the measurements of IPV or reverse causality affecting cross-sectional studies.[4,17-19] Reverse causality could apply to our work, even though we leveraged recent infection assays (in lieu of HIV prevalence), as a proxy for HIV incidence.

Pathways through which IPV can affect HIV acquisition are multifaceted. Although the most direct path is through sexual violence, an increasing body of evidence suggests that, at the population level, structural factors (eg, gender norms and policy environment) surrounding IPV have a larger role than sexual violence.[7] Men who perpetrate IPV might be more likely to have concurrent sexual partners, use condoms inconsistently, and use substances, and thus be more likely to be living with HIV, which in turn could lead to HIV transmission.[7,8,26] In addition, our crude descriptive analyses suggested that partner age discrepancy and partner alcohol consumption were different between women who had experienced IPV and those who had not; however, effect size estimates for the association between IPV and recent HIV acquisition remained robust to confounding by these covariates.

Knowledge of HIV status among women living with HIV, as the first step in the treatment cascade, can be a key bottleneck. In our study, past-year physical or sexual IPV did not affect self-reported HIV testing when adjusting for confounders, even after excluding women who had tested at antenatal care (as HIV testing at antenatal care has been shown to achieve high coverage with time[27]). Overall, evidence regarding the effect of IPV on HIV testing is mixed. Some studies have suggested reduced rates of HIV testing among women who have experienced IPV, due to fear of a violent reaction from their partner if the HIV test is positive. [9,12] Other studies from low-income and middle-income countries have found a positive relationship between IPV and HIV testing, which might be due to an increased self-perceived risk among women experiencing IPV.[9]

Our results suggested an adverse effect of lifetime physical IPV on HIV testing when stratifying to the 2000–04 study period, which could imply that our null overall results might be due to the large scale-up of HIV testing in sub-Saharan Africa in the past decade.[21]

Women who had experienced past-year physical or sexual IPV were less likely to be on ART than those who had not experienced past-year IPV, though our results were inconclusive. Few studies in low-income and middle-income countries have looked at the effects of IPV on current ART use; those that did have not observed a relationship between the two.[12] However, we found that IPV was adversely associated with viral suppression, which could imply that ART adherence is a possible bottleneck in the success of the HIV care cascade in women living with HIV with experience of IPV. Pathways through which IPV affects ART uptake and adherence are complex. Some women might not disclose their HIV status due to fear of their partner's reaction, making it difficult to enrol these women in HIV care and maintain adherence to treatment. [9] Qualitative research has also shown that depression and low self-esteem from experiencing IPV could contribute to poor ART adherence.[12]

Our study has some limitations. First, all surveys depended on self-reports of IPV and might be subject to under-reporting due to the sensitive nature of this topic.[28] The surveys used appropriate measures to ensure confidentiality[22]; however, under-reporting of IPV is still probable, especially in the PHIAs.[29] Compared with the other surveys, the PHIA surveys estimated lower IPV prevalence and probably capture the more severe forms of violence. [29] If so, our effect estimates for the recent HIV infection, ART uptake, and viral suppression analyses, in which most included surveys were PHIAs, could reflect the effect of severe IPV. HIV testing was also self-reported, although evidence shows that self-reported HIV testing histories are generally accurate.[30] Second, some of the included surveys had slight differences in terms of the wording of the IPV questions (eg, in five DHS the frequency of past-year violence was a continuous variable and had to be categorised). Nevertheless, questions were all acts-based and modified from the Conflict Tactics Scales.[22] Third, we did not include psychological violence in the definition of IPV, due to a lack of consensus on how to define, conceptualise, and measure this construct cross-culturally.[31] Fourth, we used cross-sectional survey data and reverse causality remains a possibility. This limitation was partly addressed by restricting our main exposure to IPV in the past year, and examining recent HIV infection, and ART uptake and viral load suppression at the time of the interview. Finally, we cannot rule out residual confounding of the

effect of IPV on recent HIV acquisition. Our descriptive analyses of male partner characteristics were based on a small sample of women who were living with the men, and the number of women who had recently acquired infection was small.

Strengths of our study include a large sample size and a comprehensive analysis of available population-based surveys with information on IPV and HIV. Additionally, we examined the whole prevention and treatment cascade, from HIV acquisition to viral suppression. We also conducted several sensitivity analyses to assess the robustness of our findings.

Our results have important policy implications for HIV prevention and care delivery in high-burden settings. At a service delivery level, health-care provider training should include topics, to allow patients to safely disclose their experience of IPV. This could identify women at increased risk of disengagement from care who can subsequently be linked to HIV services that address the distinct vulnerabilities of women experiencing IPV. Given the role of mental health pathways in the relationship between IPV and women's engagement in HIV care, culturally adapted, trauma-informed interventions could help increase the uptake of and adherence to ART.[32] The emerging patient-focused HIV service delivery platforms, also known as differentiated service delivery models, could incorporate women-only community adherence groups or safe community-based medication pick-up points.[33] Another area to be strengthened is IPV and HIV research, especially work that aims to uncover causal mechanisms linking IPV and worsened HIV outcomes, and intervention research to prevent IPV and support women experiencing it. Violence beyond IPV, such as dating violence among young people, should also be given more attention, given the known HIV-related vulnerabilities of young girls and women.

In conclusion, IPV could have important adverse effects on HIV epidemics by contributing to HIV acquisition risks and decreasing viral load suppression among women living with HIV. The intersecting epidemic of IPV and HIV needs explicit recognition by governments, societies, and communities if violence against women is to be eliminated and women's HIV risk reduced.

**Contributors**

SK and MM-G conceived the study. SK curated and analyzed data. SK and MM-G have accessed and verified the data. All authors contributed to the study methods and to reviewing and editing the manuscript. SK wrote the initial draft of the manuscript. All authors reviewed and

edited the manuscript, and approved the final version. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

**Data sharing**

Deidentified participant data used in the study can be made available for investigators who submit an abstract and a data analysis plan to each platform (Demographic and Health Surveys, https://dhsprogram.com/Data/; Population-based HIV Impact Assessment, https://phia-data.icap.columbia.edu/datasets; and the South Africa National HIV Prevalence, Incidence, Behavior and Communication Survey, http://datacuration.hsrc.ac.za/search/browse/alpha/S). Users are required to create an account and make a data request to gain access. Analysis code that supports the findings of the study are available upon request to the first and corresponding authors (SK, salome.kuchukhidze@mail.mcgill.ca; MM-G, mathieu.maheu-giroux@mcgill.ca).

**Declaration of interests**

MM-G reports an investigator-sponsored research grant from WHO, outside the submitted work. JWE reports research grants from the Bill & Melinda Gates Foundation, the US National Institutes of Health, UNAIDS, WHO, and the United States Agency for International Development (USAID), personal fees from Oxford Policy Management, and support for meeting travel from UNAIDS and SACEMA, all outside the submitted work. All other authors declare no competing interests.

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## 4.4 Manuscript 1: Supplementary materials

### Supplement 1: Operational definitions of intimate partner violence and the outcomes of interest

**Table S1.** Operational definitions of physical and/or sexual intimate partner violence (IPV) and indicators most frequently used in surveys included in this analysis.

| | **Questions used to define the measures in DHS** | **Questions used to define the measures in PHIA** | **Questions used to define the measures in SABSSM** |
|---|---|---|---|
| **Lifetime physical IPV** | Did your (last) (husband/partner) ever do any of the following things to you:[§, ¥]<br>● Push you, shake you, or throw something at you?<br>● Slap you?<br>● Punch you with his fist or with something that could hurt you?<br>● Kick you, drag you, or beat you up?<br>● Choke you or burn you on purpose?<br>● Threaten or attack you with a knife, gun, or other weapon? | Not collected | Did your partner ever do any of the following things to you that could hurt you?[§]<br>● Push you, shake you, or throw something at you?<br>● Slap you?<br>● Punch you with his fist or with something<br>● Kick you, drag you, or beat you up?<br>● Try to choke you or burn you on purpose?<br>● Threaten or attack you with a knife, gun, or other weapon? |
| **Lifetime sexual IPV** | Did your (last) (husband/partner) ever do any of the following things to you:<br>● Physically force you to have sexual intercourse with him when you did not want to?<br>● Physically force you to perform any other sexual acts you did not want to?<br>● Force you with threats or in any other way to perform sexual acts you did not want to? | Not collected | Did your partner ever do any of the following things to you that could hurt you?<br>● Physically force you to have sexual intercourse with him/her when you did not want to<br>● Physically force you to perform any other sexual acts you did not want to<br>● Force you with threats or in any other way |
| **Lifetime physical and/or sexual IPV** | All variables in lifetime physical *and* lifetime sexual violence categories | Not collected | All variables in lifetime physical *and* lifetime sexual violence categories |
| **Severe physical and/or sexual IPV** | Did your (last) (husband/partner) ever do any of the following things to you:[§, ¥]<br>● Punch you with his fist or with something that could hurt you?<br>● Kick you, drag you, or beat you up?<br>● Choke you or burn you on purpose? | Not collected [#] | Did your partner ever do any of the following things to you that could hurt you? [§]<br>● Punch you with his fist or with something?<br>● Kick you, drag you, or beat you up?<br>● Try to choke you or burn you on purpose?<br>● Threaten or attack you with a |

| | | | |
|---|---|---|---|
| | ● Threaten or attack you with a knife, gun, or other weapon?<br>Did your (last) (husband/partner) ever do any of the following things to you:<br>● Physically force you to have sexual intercourse with him when you did not want to?<br>● Physically force you to perform any other sexual acts you did not want to?<br>● Force you with threats or in any other way to perform sexual acts you did not want to? | | knife, gun, or other weapon?<br>Did your partner ever do any of the following things to you that could hurt you?<br>● Physically force you to have sexual intercourse with him/her when you did not want to?<br>● Physically force you to perform any other sexual acts you did not want to<br>● Force you with threats or in any other way? |
| **Past year physical and/or sexual IPV** | How often did this happen during the last 12 months: often, only sometimes, or not at all?[†]<br>*Physical violence*<br>● Push you, shake you, or throw something at you?<br>● Slap you?<br>● Punch you with his fist or with something that could hurt you?<br>● Kick you, drag you, or beat you up?<br>● Choke you or burn you on purpose ?<br>● Threaten or attack you with a knife, gun, or other weapon?<br><br>*Sexual violence*<br>● Physically force you to have sexual intercourse with him when you did not want to?<br>● Physically force you to perform any other sexual acts you did not want to?<br>● Force you with threats or in any other way to perform sexual acts you did not want to? | In the past 12 months, did a partner do any of these things to you?<br>*Physical violence*<br>● Slapped you, threw something at you that could hurt you, pushed you or shoved you?<br>● Punched, kicked, whipped, or beat you with an object?<br>● Choked smothered , tried to drown you, or burned you intentionally?<br>● Used or threatened you with a knife, gun or other weapon?<br>*Sexual violence*<br>● In the past 12 months, did a partner physically force you to have | In the last 12 months, how often has your partner ***physically*** hurt you? [¶] |

| | | | |
|---|---|---|---|
| | | sex?<br>● In the past 12 months, did a partner pressure you to have sex and did succeed? | |
| **Frequency of past year physical and/or sexual IPV** | How often did this happen during the last 12 months: often, only sometimes, or not at all?†<br>*Physical violence*<br>● Push you, shake you, or throw something at you?<br>● Slap you?<br>● Punch you with his fist or with something that could hurt you?<br>● Kick you, drag you, or beat you up?<br>● Choke you or burn you on purpose ?<br>● Threaten or attack you with a knife, gun, or other weapon?<br>*Sexual violence*<br>● Physically force you to have sexual intercourse with him when you did not want to?<br>● Physically force you to perform any other sexual acts you did not want to?<br>● Force you with threats or in any other way | In the past 12 months, how many times did *someone* ‡<br>● Slapped you, threw something at you that could hurt you, pushed you or shoved you?<br>● Punched, kicked, whipped, or beat you with an object?<br>● Choked smothered , tried to drown you, or burned you intentionally?<br>● Used or threatened you with a knife, gun or other weapon? | In the last 12 months, how often has your partner *physically* hurt you? ¶ |

DHS=Demographic and Health Survey; IPV=intimate partner violence; PHIA=Population-based HIV Impact Assessment Survey; SABSSM=South African National HIV Prevalence, Incidence, Behaviour and Communication Survey.

§ Question "(Does/did) your (last) husband/partner ever twist your arm or pull your hair?" was removed from the definition of lifetime physical IPV to align the DHS, PHIA and SABSSM definitions
¥ In 9 surveys, "threatening to attack" and "attack" questions were asked as two separate questions
† In 13 surveys, frequency of past-year IPV was a continuous variable and had to be categorized
‡ In PHIA surveys, the frequency of past-year IPV pertains to only recent physical, not sexual IPV. Furthermore, we assume that "someone" as a perpetrator of violence is an intimate partner only when the woman also reports experiencing IPV.
¶ In SABSSM experience of past year violence, and its frequency pertains to only recent physical, not sexual IPV.

# In PHIA surveys the experience of physical IPV was asked as a single question inquiring about the experience of any of the listed violent acts. This made it impossible to disentangle which women were subjected to severe acts of IPV and which were not.

**Table S2.** Operational definitions and measures of the outcomes used in the analyses.

| Outcome | Numerator | Denominator | Measure |
|---|---|---|---|
| Recent HIV infection | Number of recent HIV infection (past 4-5 months) | Number of *women who are at risk of HIV infection* (i.e., excluding those living with non-recent HIV infections), have been randomly selected for the IPV module and have ever been in a partnership | Algorithm including limiting Antigen Enzyme (LAg-Avidity) Immunoassay, biomarkers for ART in blood, viral load |
| Lifetime/past year HIV testing | Number tested for HIV ever/in the past 12 months and who received the test results | Number of women who have been randomly selected for the IPV module and have ever been in a partnership | Self-reported |
| ART uptake | Number who self-reported current ART intake OR were identified as having ARV biomarkers | Number of *women living with HIV* who have been randomly selected for the IPV module and have ever been in a partnership | High-resolution liquid chromatography & tandem mass spectrometry |
| Viral load suppression | Number with HIV RNA/mL <1000 copies/mL | Number *women living with HIV* who have been randomly selected for the IPV module and have ever been in a partnership | Viral load testing using RT-PCR |

ART=antiretroviral treatment; IPV=intimate partner violence; No.=Number of; RNA=ribonucleic acid; RT-PCR=reverse transcription-polymerase chain reaction.

## Supplement 2. Missing data analysis for past year physical and/or sexual intimate partner violence and recent HIV infection

### Missing data on intimate partner violence and recent HIV infections

We calculated missing observations for past year physical and/or sexual intimate partner violence (IPV) and recent HIV infection, as a percentage of the total sample of eligible women for the HIV recency analysis (Table S3). We *de facto* excluded the Cameroon PHIA 2017 and Côte d'Ivoire PHIA 2017 surveys since they both had more than 95% missing data on past year experience of physical and/or sexual IPV. Overall, missing data on IPV was concentrated in one survey – Eswatini 2016 (43% missing). For recent HIV infection, the Uganda 2016 survey has the least amount of missing data for HIV recency (2%) and Malawi has the most (15%).

**Table S3.** Survey-specific frequencies of missing observations for past year physical and/or sexual IPV and recent HIV infection as a proportion of all eligible women for the HIV recency analysis which includes women at risk of HIV acquisition (i.e., excluding those living with non-recent HIV infections).

| | Exposure: Past year physical and/or sexual IPV | | | Outcome: Recent HIV infection | | |
|---|---|---|---|---|---|---|
| **Survey** | **Missing (N)** | **Non missing (N)** | **Proportion missing (%)** | **Missing (N)** | **Non missing (N)** | **Proportion missing (%)** |
| **Overall** | 728 | 22,515 | 3% | 2,651 | 20,582 | 11% |
| Mozambique 2015 | 10 | 2,782 | 0% | 314 | 2,478 | 11% |
| Malawi 2015 | 37 | 6,308 | 1% | 958 | 5,387 | 15% |
| Zambia 2016 | 66 | 5,552 | 1% | 655 | 4,963 | 12% |
| Uganda 2016 | 10 | 1,119 | 1% | 17 | 1,112 | 2% |
| Eswatini 2016 | 560 | 747 | 43% | 96 | 1,211 | 7% |
| Zimbabwe 2015 | 35 | 6,007 | 1% | 611 | 5,431 | 10% |

IPV=intimate partner violence.

### Justification for a complete case analysis

*Rationale for the proposed missing data mechanism: not missing at random (NMAR)*

Multiple imputation of exposure to past year physical and/or sexual IPV is not warranted for two main reasons. First, if data for past year IPV are not missing at random (NMAR), multiple imputation by chained equations (MICE) would introduce bias in the analysis since MICE assumes missing at random (MAR) or missing completely at random (MCAR).[1] While it is not possible to distinguish between MAR and MNAR based on the available data, evidence has shown that women who have experienced IPV would be less likely to answer survey questions, compared to women not experiencing IPV.[2,3] This could be because women might fear

violence by their abuser, should he find out about the interview. [2,3] Thus, missingness is driven by the covariate with the missing data itself, indicating NMAR. Second, the fact that the bulk of the missing data are concentrated in one survey –Eswatini 2016– indicates that a structural factor might have influenced the way that data were collected or recorded in that survey, further supporting the argument that data are MAR or MCAR. Still, the amount of missing data does not suggest that IPV module implementation was flawed at large (which was the case for Cameroon PHIA 2017 and Côte d'Ivoire PHIA 2017 surveys), thus warranting inclusion of Eswatini 2016 as part of the analysis. Complete cases analysis is the best option when data are NMAR, unless missingness is outcome driven.[1]

*Estimation of whether missingness of past year IPV is outcome (HIV recency) driven*

To understand if missingness in the exposure is outcome driven, we first compared how the proportion of women with a recent HIV infection differs among those with and without IPV data, and how proportion of women experiencing past year physical and/or sexual IPV differed between women with and without HIV recency data (Table S4). Simple tabulations in Table S4 showed that 0.2% of women with both missing and non-missing IPV data had a recent HIV infection.

To investigate the relationship between recent HIV infection and missingness of past year IPV, we ran a logistic regression model with a dummy variable for IPV missingness (0 for missing; 1 for non-missing) as a dependent variable and recent HIV infection as an independent variable. We included survey dummy in the estimation to account for the survey-specific characteristics that might have influenced missingness patterns. This analysis estimated an adjusted odds ratio of 0.73 (95%CI: 0.07-7.14). This effect size estimate is reasonably close to one and, considering the very wide uncertainty, a complete case analysis is warranted.

*Impact of missing data on the estimated relationship between IPV and recent HIV infection*

We investigated exposure to past year IPV among those with missing and non-missing recent HIV infection data: 4.5% of women with missing HIV recency data have experienced past year IPV and this proportion was 5.8% among women with non-missing HIV recency data (Table S4). This indicates that past year IPV are comparable, but slightly higher among women

with non-missing HIV recency data. Because we do not know recent HIV infection rates among women with missing HIV recency data, bias could go toward or away from the null.

**Table S4.** Comparison of the proportions of women with a recent HIV infection among those with and without past year physical and/or sexual IPV data; comparison of the proportion of women experiencing past year IPV among those with and without recent HIV infection data.

| Recent HIV infection | | Past year physical and/or sexual IPV | |
|---|---|---|---|
| **Non-missing IPV, n (%)** | **Missing IPV, n (%)** | **Non-missing recent HIV infection, n (%)** | **Missing recent HIV infection, n (%)** |
| 45/19,935 (0.2%) | 1/647 (0.2%) | 1,158/19,935 (5.8%) | 115/2,580 (4.5%) |

IPV=intimate partner violence.

To investigate the potential relationship between missing HIV recency data and HIV risk, we ran a number of regression analyses of various HIV risk factors as dependent variables and non-missing HIV recency status (0 for missing; 1 for non-missing) as independent variables.[4] All models included survey country and year (survey identifier) as a dummy variable to account for survey-specific missingness patterns as shown in previous research (Table S5).[4]

Women with non-missing HIV recency data were more likely to have earlier sexual debut, had slightly more sexual partners, and were more likely to be currently married (Table S5). Other variables were not associated with the presence of HIV data. Lifetime sexual partners, an earlier sexual debut, and being married might increase the risk of HIV acquisition. Therefore, we suspect that recent HIV infections might be lower among those without HIV recency data. Because past year physical and/or sexual IPV rates are slightly lower among those without recent HIV data than those with non-missing HIV data (Table S4), the estimated relationship between past year IPV and recent HIV infection could be biased downward (i.e., we underestimate the strength of the effect size). However, we state this with caution given that measurement error and unmeasured confounding could also be influencing the direction of bias.

**Table S5.** Association between non-missing recent HIV infection status and potential determinants of acquisitions.

| HIV risk factors | Model type | Estimate | 95%CI |
|---|---|---|---|
| Age at sexual debut | OLS | -0.17 | (-0.29; -0.05) |
| Age | OLS | 0.07 | (-0.39; 0.53) |
| Lifetime number of sexual partners | OLS | 0.1 | (0.01; 0.19) |
| Current marriage status | Logistic | 1.03 | (1.01; 1.04) |
| Mean age difference between couple (male age – female age) * | OLS | -0.02 | (-0.36; 0.33) |

95%CI= 95% confidence interval; OLS=Ordinary least squares regression.

*This analysis was conducted using the linked data for married or cohabiting men and women who both declared to be living with each other

# Supplement 4: STROBE (Strengthening The Reporting of OBservational Studies in Epidemiology) Checklist

**STROBE (Strengthening The Reporting of OBservational Studies in Epidemiology) Checklist**

A checklist of items that should be included in reports of observational studies. You must report the page number in your manuscript where you consider each of the items listed in this checklist. If you have not included this information, either revise your manuscript accordingly before submitting or note N/A.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

| Section and Item | Item No. | Recommendation | Reported on Page No. |
|---|---|---|---|
| **Title and Abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract | 1, 2 |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found | 2 |
| **Introduction** | | | |
| Background/Rationale | 2 | Explain the scientific background and rationale for the investigation being reported | 5 |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | 5-6 |
| **Methods** | | | |
| Study Design | 4 | Present key elements of study design early in the paper | 6 |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | 6 |
| Participants | 6 | (*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up | NA |
| | | *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls | NA |
| | | *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants | 6 |
| | | (*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed | NA |
| | | *Case-control study*—For matched studies, give matching criteria and the number of controls per case | NA |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | 6-7 |

| Section and Item | Item No. | Recommendation | Reported on Page No. |
|---|---|---|---|
| Data Sources/ Measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | 6-7 |
| Bias | 9 | Describe any efforts to address potential sources of bias | 7, Supp 2 |
| Study Size | 10 | Explain how the study size was arrived at | NA |
| Quantitative Variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | 7 |
| Statistical Methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding | 7 |
| | | (*b*) Describe any methods used to examine subgroups and interactions | 7-8 |
| | | (*c*) Explain how missing data were addressed | 7, Supp 2 |
| | | (*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed | NA |
| | | *Case-control study*—If applicable, explain how matching of cases and controls was addressed | NA |
| | | *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy | 7 |
| | | (*e*) Describe any sensitivity analyses | 7-8 |
| **Results** | | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed | Figure 1 |
| | | (b) Give reasons for non-participation at each stage | Figure 1 |
| | | (c) Consider use of a flow diagram | Figure 1 |
| Descriptive Data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | 8; Supp 5 |
| | | (b) Indicate number of participants with missing data for each variable of interest | Supp 2 |
| | | (c) *Cohort study*—Summarise follow-up time (eg, average and total amount) | NA |
| Outcome Data | 15* | *Cohort study*—Report numbers of outcome events or summary measures over time | NA |
| | | *Case-control study*—Report numbers in each exposure category, or summary measures of exposure | NA |
| | | *Cross-sectional study*—Report numbers of outcome events or summary measures | 8, Table 1 |

| Section and Item | Item No. | Recommendation | Reported on Page No. |
|---|---|---|---|
| Main Results | 16 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | 8-9; Tbl 2-5 |
| | | (*b*) Report category boundaries when continuous variables were categorized | NA |
| | | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | NA |
| Other Analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | 8-9 |
| **Discussion** | | | |
| Key Results | 18 | Summarise key results with reference to study objectives | 9 |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | 10 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | 11 |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | 10 |
| **Other Information** | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | 12 |

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Once you have completed this checklist, please save a copy and upload it as part of your submission. DO NOT include this checklist as part of the main manuscript document. It must be uploaded as a separate file.**

## Supplement 5: Survey-specific burden of intimate partner violence

**Table S6.** Distribution of lifetime physical, lifetime sexual, lifetime physical and/or sexual and past year physical and/or sexual intimate partner violence (IPV), stratified by survey and region.

| Country | Survey year | Survey type | Total sample size | Lifetime physical IPV, N (%) | Lifetime sexual IPV, N(%) | Lifetime physical and/or sexual IPV, N (%) | Past year physical and/or sexual IPV, N (%) |
|---|---|---|---|---|---|---|---|
| **Overall** | | | 280,259 | 73,811 (26.3) | 28,499 (10.2) | 81,555 (29.1) | 59,456 (21.2%) |
| **Central Africa** | | | | | | | |
| Angola | 2015 | DHS | 7,669 | 2,466 (32.2) | 601 (7.8) | 2,566 (33.5) | 1,886 (24.6) |
| Cameroon* | 2004 | DHS | 2,184 | 842 (38.6) | 311 (14.2) | 927 (42.4) | 566 (25.9) |
| Cameroon | 2018 | DHS | 4,690 | 1,543 (32.9) | 478 (10.2) | 1,643 (35) | 1,001 (21.3) |
| Chad | 2014 | DHS | 3,812 | 860 (22.6) | 338 (8.9) | 938 (24.6) | 566 (14.8) |
| Congo, Democratic Republic | 2007 | DHS | 2,853 | 1,510 (52.9) | 866 (30.4) | 1,710 (59.9) | 1,589 (55.7) |
| Congo, Democratic Republic | 2013 | DHS | 5,689 | 2,564 (45.1) | 1,448 (25.5) | 2,860 (50.3) | 2,126 (37.4) |
| Gabon | 2012 | DHS | 4,133 | 1,933 (46.8) | 639 (15.5) | 2,031 (49.1) | 1,315 (31.8) |
| Sao Tome and Principe | 2008 | DHS | 1,729 | 501 (29) | 122 (7.1) | 512 (29.6) | 503 (29.1) |
| **Total** | | | 32,759 | **12,219 (37)** | **4,803 (14.6)** | **13,187 (40)** | **9,552 (29.2)** |
| **Western Africa** | | | | | | | |
| Burkina Faso | 2010 | DHS | 10,003 | 1,125 (11.2) | 150 (1.5) | 1,162 (11.6) | 933 (9.3) |
| Côte d'Ivoire | 2012 | DHS | 5,006 | 1,243 (24.8) | 253 (5.1) | 1,279 (25.5) | 1,084 (21.7) |
| Gambia | 2013 | DHS | 3,538 | 772 (21.8) | 103 (2.9) | 797 (22.5) | 296 (8.4) |
| Gambia | 2019 | DHS | 1,953 | 576 (29.5) | 120 (6.1) | 615 (31.5) | 213 (10.9) |
| Ghana | 2008 | DHS | 1,835 | 382 (20.8) | 122 (6.6) | 425 (23.2) | 361 (19.7) |
| Liberia* | 2007 | DHS | 3,839 | 1,402 (36.5) | 426 (11.1) | 1,516 (39.5) | 1,370 (35.7) |
| Liberia | 2019 | DHS | 2,331 | 1,041 (44.7) | 175 (7.5) | 1,064 (45.6) | 820 (35.2) |
| Mali* | 2006 | DHS | 8,922 | 1,580 (17.7) | 326 (3.7) | 1,676 (18.8) | 1,495 (16.8) |
| Mali | 2012 | DHS | 3,120 | 897 (28.7) | 454 (14.6) | 1,069 (34.3) | 816 (26.2) |
| Mali | 2018 | DHS | 3,356 | 1,062 (31.6) | 341 (10.2) | 1,128 (33.6) | 638 (19) |
| Nigeria* | 2008 | DHS | 18,757 | 3,270 (17.4) | 764 (4.1) | 3,431 (18.3) | 2,856 (15.2) |
| Nigeria | 2013 | DHS | 22,279 | 3,347 (15) | 1,190 (5.3) | 3,800 (17.1) | 2,600 (11.7) |
| Senegal | 2017 | DHS | 2,660 | 529 (19.9) | 173 (6.5) | 599 (22.5) | 344 (12.9) |
| Sierra Leone | 2013 | DHS | 4,309 | 1,826 (42.4) | 286 (6.6) | 1,865 (43.3) | 1,201 (27.9) |
| Sierra Leone | 2019 | DHS | 4,055 | 1,920 (47.3) | 311 (7.7) | 1,990 (49.1) | 1,490 (36.7) |
| Togo | 2013 | DHS | 5,374 | 1,169 (21.8) | 434 (8.1) | 1,271 (23.7) | 737 (13.7) |
| **Total** | | | 101,337 | **22,141 (21.8)** | **5,628 (5.5)** | **23,687 (23.3)** | **17,254 (17)** |
| **Eastern Africa** | | | | | | | |
| Burundi | 2016 | DHS | 7,366 | 2,826 (38.4) | 1,884 (25.6) | 3,400 (46.2) | 2,088 (28.3) |
| Comoros | 2012 | DHS | 2,528 | 136 (5.4) | 43 (1.7) | 156 (6.2) | 119 (4.7) |
| Ethiopia | 2016 | DHS | 4,720 | 948 (20.1) | 358 (7.6) | 1,061 (22.5) | 766 (16.2) |
| Kenya* | 2003 | DHS | 4,312 | 1,662 (38.5) | 606 (14.1) | 1,792 (41.6) | 1,200 (27.8) |
| Kenya | 2008 | DHS | 4,901 | 1,767 (36.1) | 716 (14.6) | 1,880 (38.4) | 1,556 (31.7) |
| Kenya | 2014 | DHS | 4,515 | 1,590 (35.2) | 529 (11.7) | 1,689 (37.4) | 1,089 (24.1) |
| Malawi | 2004 | DHS | 8,292 | 1,672 (20.2) | 1,106 (13.3) | 2,202 (26.6) | 1,591 (19.2) |
| Malawi | 2010 | DHS | 3,598 | 776 (21.6) | 616 (17.1) | 1,050 (29.2) | 788 (21.9) |
| Malawi | 2015 | DHS | 5,406 | 1,336 (24.7) | 1,020 (18.9) | 1,787 (33.1) | 1,291 (23.9) |
| Mozambique | 2011 | DHS | 5,824 | 1,829 (31.4) | 457 (7.8) | 1,926 (33.1) | 1,537 (26.4) |
| Mozambique | 2015 | DHS | 3,350 | 622 (18.6) | 133 (4) | 649 (19.4) | 503 (15) |
| Rwanda* | 2005 | DHS | 2,547 | 786 (30.9) | 356 (14) | 888 (34.9) | 525 (20.6) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Rwanda | 2010 | DHS | 3,469 | 1,925 (55.5) | 610 (17.6) | 1,955 (56.4) | 1,576 (45.4) |
| Rwanda | 2015 | DHS | 1,907 | 591 (31) | 221 (11.6) | 648 (34) | 395 (20.7) |
| Rwanda | 2019 | DHS | 1,947 | 708 (36.4) | 297 (15.3) | 778 (40) | 467 (24) |
| Tanzania | 2010 | DHS | 5,689 | 1,917 (33.7) | 731 (12.8) | 2,073 (36.4) | 1,776 (31.2) |
| Uganda | 2006 | DHS | 1,748 | 822 (47) | 542 (31) | 985 (56.4) | 752 (43) |
| Uganda | 2011 | DHS | 1,702 | 703 (41.3) | 457 (26.9) | 835 (49.1) | 555 (32.6) |
| Uganda | 2016 | DHS | 7,536 | 3,088 (41) | 1,710 (22.7) | 3,551 (47.1) | 2,296 (30.5) |
| Zambia | 2007 | DHS | 4,230 | 1,853 (43.8) | 742 (17.5) | 2,000 (47.3) | 1,716 (40.6) |
| Zambia | 2013 | DHS | 9,412 | 3,628 (38.5) | 1,618 (17.2) | 4,040 (42.9) | 2,589 (27.5) |
| Zambia | 2018 | DHS | 7,358 | 2,702 (36.7) | 1,069 (14.5) | 2,962 (40.3) | 1,814 (24.7) |
| Zimbabwe* | 2005 | DHS | 3,788 | 1,148 (30.3) | 524 (13.8) | 1,333 (35.2) | 1,146 (30.3) |
| Zimbabwe | 2010 | DHS | 5,280 | 1,483 (28.1) | 775 (14.7) | 1,795 (34) | 1,383 (26.2) |
| Zimbabwe | 2015 | DHS | 5,800 | 1,726 (29.8) | 679 (11.7) | 1,977 (34.1) | 1,137 (19.6) |
| Malawi§ | 2015 | PHIA | 7,439 | .. | .. | .. | 347 (4.7) |
| Zambia§ | 2016 | PHIA | 6,591 | .. | .. | .. | 259 (3.9) |
| Uganda§ | 2016 | PHIA | 1,179 | .. | .. | .. | 136 (11.5) |
| Zimbabwe§ | 2015 | PHIA | 7,474 | .. | .. | .. | 282 (3.8) |
| **Total** | | | 139,908 | **38,244 (27.3)** | **17,799 (12.7)** | **43,412 (31)** | **31,679 (22.6)** |
| **Southern Africa** | | | | | | | |
| Namibia | 2013 | DHS | 1,448 | 356 (24.6) | 106 (7.3) | 382 (26.4) | 307 (21.2) |
| South Africa | 2016 | DHS | 2,354 | 356 (15.1) | 90 (3.8) | 380 (16.1) | 247 (10.5) |
| Eswatini§ | 2016 | PHIA | 1,221 | .. | .. | .. | 58 (4.8) |
| South Africa | 2017 | DHS | 1,232 | 495 (40.2) | 73 (5.9) | 507 (41.2) | 359 (29.1) |
| **Total** | | | 6,255 | **1,207 (19.3)** | **269 (4.3)** | **1,269 (20.3)** | **971 (15.5)** |

IPV=intimate partner violence.
§ PHIA surveys (5/57) did not collect information on lifetime experience of intimate partner violence (IPV).
* IPV module not administered to widowed women

**Supplement 6: Demographic characteristics of women included in each of the analyses for recent HIV infection, HIV testing, antiretroviral uptake, and viral load suppression**

**Table S7.** Distribution of demographic characteristics among women included in the analysis for recent HIV infection.

| | **Past year physical and/or sexual IPV** | |
|---|---|---|
| | **Yes (N=1,273)** | **No (N=21,242)** |
| Recent HIV infection, n (%) | | |
| Yes | 8 (0.6) | 37 (0.2) |
| No | 1,150 (90.3) | 18,740 (88.2) |
| *Missing* | 115 (9) | 2,465 (11.6) |
| Age, n (%) | | |
| 15-24 | 504 (39.6) | 5,612 (26.4) |
| 25-34 | 443 (34.8) | 7,076 (33.3) |
| 35-44 | 188 (14.8) | 4,308 (20.3) |
| 45-64 | 138 (10.8) | 4,246 (20) |
| *Missing* | .. | .. |
| Education, n (%) | | |
| None | 145 (11.4) | 2,516 (11.8) |
| Primary | 699 (54.9) | 11,041 (52) |
| Secondary | 396 (31.1) | 6,626 (31.2) |
| Higher | 30 (2.4) | 873 (4.1) |
| *Missing* | 3 (0.2) | 186 (0.9) |
| Wealth, n (%) | | |
| 1st | 235 (18.5) | 4,529 (21.3) |
| 2nd | 244 (19.2) | 4,295 (20.2) |
| 3rd | 244 (19.2) | 4,098 (19.3) |
| 4th | 255 (20) | 3,951 (18.6) |
| 5th | 295 (23.2) | 4,349 (20.5) |
| *Missing* | .. | 20 (0.1) |
| Residence type, n(%) | | |
| Urban | 496 (39) | 6,603 (31.1) |
| Rural | 777 (61) | 14,639 (68.9) |
| *Missing* | .. | .. |
| Current partnership status, n (%) | | |
| In a union/living with a man | 1,027 (80.7) | 17,760 (83.6) |
| Not in a union/living with a man | 245 (19.2) | 3,453 (16.3) |
| *Missing* | 1 (0.1) | 29 (0.1) |
| Region, n (%) | | |
| Eastern Africa | 1,247 (98) | 20,521 (96.6) |
| Southern Africa | 26 (2) | 721 (3.4) |
| *Missing* | .. | .. |
| Period, n (%) | | |
| 2015-2019 | 1,273 (100) | 21,242 (100) |
| *Missing* | .. | .. |

IPV=intimate partner violence.

**Table S8**. Distribution of demographic characteristics among women included in the analysis for lifetime and past year HIV testing.

| | Past year physical and/or sexual IPV | |
|---|---|---|
| | **Yes (N=59,456)** | **No (N=217,646)** |
| Lifetime testing for HIV, n(%) | | |
| Yes | 31,023 (52.2) | 113,384 (52.1) |
| No | 28,101 (47.3) | 102,976 (47.3) |
| *Missing* | 332 (0.6) | 1,286 (0.6) |
| Past year HIV testing, n(%) | | |
| Yes | 16,392 (27.6) | 57,996 (26.6) |
| No | 42,601 (71.7) | 157,969 (72.6) |
| *Missing* | 463 (0.8) | 1,681 (0.8) |
| Age, n (%) | | |
| 15-24 | 15,876 (26.7) | 52,458 (24.1) |
| 25-34 | 25,825 (43.4) | 85,515 (39.3) |
| 35-44 | 13,763 (23.1) | 56,359 (25.9) |
| 45-64 | 3,992 (6.7) | 23,314 (10.7) |
| *Missing* | .. | .. |
| Education, n(%) | | |
| None | 17,489 (29.4) | 77,106 (35.4) |
| Primary | 26,901 (45.2) | 78,326 (36) |
| Secondary | 13,896 (23.4) | 52,675 (24.2) |
| Higher | 1,110 (1.9) | 9,156 (4.2) |
| *Missing* | 60 (0.1) | 383 (0.2) |
| Wealth, n(%) | | |
| 1st | 13,966 (23.5) | 47,771 (21.9) |
| 2nd | 12,882 (21.7) | 44,320 (20.4) |
| 3rd | 12,197 (20.5) | 42,453 (19.5) |
| 4th | 11,537 (19.4) | 41,493 (19.1) |
| 5th | 8,515 (14.3) | 40,728 (18.7) |
| *Missing* | 359 (0.6) | 881 (0.4) |
| Residence type, n(%) | | |
| Urban | 18,344 (30.9) | 70,971 (32.6) |
| Rural | 41,112 (69.1) | 146,675 (67.4) |
| *Missing* | .. | .. |
| Current partnership status, n (%) | | |
| In a union/living with a man | 53,099 (89.3) | 193,146 (88.7) |
| Not in a union/living with a man | 6,355 (10.7) | 24,462 (11.2) |
| *Missing* | 2 (0) | 38 (0) |
| Region, n(%) | | |
| Central Africa | 9,552 (16.1) | 22,622 (10.4) |
| Eastern Africa | 31,679 (53.3) | 106,325 (48.9) |
| Southern Africa | 971 (1.6) | 5,259 (2.4) |
| Western Africa | 17,254 (29) | 83,440 (38.3) |
| *Missing* | .. | .. |
| Period, n(%) | | |
| 2000-2004 | 3,357 (5.6) | 9,871 (4.5) |
| 2005-2009 | 13,869 (23.3) | 40,319 (18.5) |
| 2010-2014 | 23,393 (39.3) | 86,731 (39.8) |
| 2015-2019 | 18,837 (31.7) | 80,725 (37.1) |
| *Missing* | .. | .. |

IPV=intimate partner violence.

**Table S9.** Distribution of demographic characteristics among women included in the analysis for antiretroviral (ART) uptake.

| | **Past year physical and/or sexual IPV** | |
|---|---|---|
| | **Yes (N=671)** | **No (N=5,278)** |
| ART uptake, n (%) | | |
| Yes | 416 (62) | 3,717 (70.4) |
| No | 232 (34.6) | 1,498 (28.4) |
| *Missing* | 23 (3.4) | 63 (1.2) |
| Age, n (%) | | |
| 15-24 | 92 (13.7) | 479 (9.1) |
| 25-34 | 270 (40.2) | 1,695 (32.1) |
| 35-44 | 202 (30.1) | 1,788 (33.9) |
| 45-64 | 107 (15.9) | 1,316 (24.9) |
| *Missing* | .. | .. |
| Education, n (%) | | |
| None | 26 (3.9) | 448 (8.5) |
| Primary | 209 (31.1) | 2,257 (42.8) |
| Secondary | 364 (54.2) | 2,184 (41.4) |
| Higher | 20 (3) | 207 (3.9) |
| *Missing* | 52 (7.7) | 182 (3.4) |
| Wealth, n (%) | | |
| 1st | 49 (7.3) | 782 (14.8) |
| 2nd | 36 (5.4) | 735 (13.9) |
| 3rd | 45 (6.7) | 832 (15.8) |
| 4th | 96 (14.3) | 999 (18.9) |
| 5th | 86 (12.8) | 1,069 (20.3) |
| *Missing* | 359 (53.5) | 861 (16.3) |
| Residence type, n (%) | | |
| Urban | 318 (47.4) | 2,245 (42.5) |
| Rural | 353 (52.6) | 3,033 (57.5) |
| *Missing* | .. | .. |
| Current partnership status, n (%) | | |
| In a union/living with a man | 292 (43.5) | 2,945 (55.8) |
| Not in a union/living with a man | 378 (56.3) | 2,324 (44) |
| *Missing* | 1 (0.1) | 9 (0.2) |
| Region, n (%) | | |
| Eastern Africa | 280 (41.7) | 3,979 (75.4) |
| Southern Africa | 391 (58.3) | 1,299 (24.6) |
| *Missing* | .. | .. |
| Period, n (%) | | |
| 2015-2019 | 671 (100) | 5,278 (100) |
| *Missing* | .. | .. |

ART=antiretroviral treatment; IPV=intimate partner violence.

**Table S10.** Distribution of demographic characteristics among women included in the analysis for viral load suppression (VLS).

| | Past year physical and/or sexual IPV | |
|---|---|---|
| | **Yes (N=671)** | **No (N=5,278)** |
| Viral load suppression, n (%) | | |
| Yes | 375 (55.9) | 3,506 (66.4) |
| No | 286 (42.6) | 1,700 (32.2) |
| *Missing* | 10 (1.5) | 72 (1.4) |
| Age, n (%) | | |
| 15-24 | 92 (13.7) | 479 (9.1) |
| 25-34 | 270 (40.2) | 1,695 (32.1) |
| 35-44 | 202 (30.1) | 1,788 (33.9) |
| 45-64 | 107 (15.9) | 1,316 (24.9) |
| *Missing* | .. | .. |
| Education, n (%) | | |
| None | 26 (3.9) | 448 (8.5) |
| Primary | 209 (31.1) | 2,257 (42.8) |
| Secondary | 364 (54.2) | 2,184 (41.4) |
| Higher | 20 (3) | 207 (3.9) |
| *Missing* | 52 (7.7) | 182 (3.4) |
| Wealth, n (%) | | |
| 1st | 49 (7.3) | 782 (14.8) |
| 2nd | 36 (5.4) | 735 (13.9) |
| 3rd | 45 (6.7) | 832 (15.8) |
| 4th | 96 (14.3) | 999 (18.9) |
| 5th | 86 (12.8) | 1,069 (20.3) |
| *Missing* | 359 (53.5) | 861 (16.3) |
| Residence type, n (%) | | |
| Urban | 318 (47.4) | 2,245 (42.5) |
| Rural | 353 (52.6) | 3,033 (57.5) |
| *Missing* | .. | .. |
| Current partnership status, n (%) | | |
| In a union/living with a man | 292 (43.5) | 2,945 (55.8) |
| Not in a union/living with a man | 378 (56.3) | 2,324 (44) |
| *Missing* | 1 (0.1) | 9 (0.2) |
| Region, n (%) | | |
| Eastern Africa | 280 (41.7) | 3,979 (75.4) |
| Southern Africa | 391 (58.3) | 1,299 (24.6) |
| *Missing* | .. | .. |
| Period, n (%) | | |
| 2015-2019 | 671 (100) | 5,278 (100) |
| *Missing* | .. | .. |

IPV=intimate partner violence; VLS=viral load suppression.

**Supplement 7: Analysis of couple and co-habiting male partner characteristics**

We performed robustness checks and examined the characteristics of the women's cohabiting partner as potential confounders of the association between intimate partner violence (IPV) and recent HIV infection in the six surveys included in this analysis. This was achieved by linking women's information to that of their co-habiting partner, which substantially reduced our sample size.

*Partners' HIV status and condom use at last sex*

Despite the small resulting sample size, (only two women were both subjected to past year IPV and had a recent HIV infection), the HIV prevalence among cohabiting partners of women who had experienced past year IPV was similar (16%) to that of partners of women who had not (14%; Table S11). Similarly, proportions of condom use at women's last sex was similar and low between women subjected to (11%) and not subjected to (10%) recent IPV (Table S12).

*Partners' educational levels*

There were no large differences in the partner's education level and IPV. The majority of the male partners of women experiencing IPV in the past year (52%), as well as those not experiencing IPV (48%), had some primary education.

*Couple age discrepancy*

The age discrepancy between partners was slightly larger among women who had not reported past year IPV compared to those who had, though the difference was only 0.6 years. We adjusted for couple age discrepancy in a sensitivity analysis. This did not change the effect estimate though the precision was reduced since the sample size was halved (aPR=3·24, 95%CI: 0·72-14·63, $N_{surv}$=6; Table S11). Furthermore, this analysis includes only currently cohabiting women who mutually declared to be living with their partner.

*Partners' alcohol consumption*

Another potential confounder of the relationship between IPV and HIV acquisition is the alcohol consumption of the male partner (Table S11). We found that the proportion of men

drinking alcohol "*Often*" is higher among women experiencing past year IPV (20%) compared to women not experiencing IPV (15%). Similarly, the proportion of men "*Never*" drinking alcohol is higher among women not subjected to past year IPV (54%) compared to women subjected to IPV (38%). These results are aligned with previous meta-analyses demonstrating that alcohol and IPV perpetration are often associated.[5,6] If there is an association between male alcohol consumption and HIV acquisition among women, this variable might be confounding the IPV-HIV incidence relationship.

We explore this further by examining the distribution of recent HIV infections by male partner's frequency of alcohol consumption. Women whose partners "*Often*" drink have higher proportion of incident HIV (0.11%) compared to women whose partner "*Rarely*" drinks (0.06%) (Table S13). Question remains on pathways through which alcohol consumption effects HIV acquisition. Among the 12 co-habiting women with a recent HIV infection in this sub-sample, half of their male partners ($N_i$=6) are HIV positive and virally unsuppressed. Alcohol use can lead to poor ART adherence and subsequently, poor viral load suppression.[7] In our sample of HIV positive male partners, men who drink "*Often*" are more likely to be virally unsuppressed (51%) compared to other frequency categories. Men who "*Never*" drink are more likely to be virally suppressed (64%) (Table S14).

If male partner's alcohol consumption leads to women HIV's acquisition through poor male ART adherence and viral suppression, it would be sufficient to control for this latter variable to obtain an adjusted effect size estimate for IPV (Figure S1). After doing so in the subset of HIV positive men ($N_i$=1,505) the effect estimate remains robust though the CI is large due to a drastic reduction in the sample size (aPR = 4.87 95%CI: 0.81-29.45).

**Table S11.** Unweighted proportions of couple and male partner characteristics stratified by experience of past year intimate partner violence (IPV), among the six surveys (Mozambique, Malawi, Zambia, Uganda, Eswatini, Zimbabwe) containing information on a recent HIV infection and cohabiting partners.

| | **Experiencing past year physical and/or sexual IPV** | **Not experiencing past year physical and/or sexual IPV** |
|---|---|---|
| Male partner HIV status, n (%)[§] | | |
| Positive | 112 (16.2) | 1,544 (13.6) |
| Negative | 548 (79.3) | 8,735 (77.2) |
| *Missing* | 31 (4.5) | 1,035 (9.1) |
| Male partner education, n (%) | | |

| | | |
|---|---|---|
| None | 30 (4.3) | 612 (5.4) |
| Primary | 358 (51.8) | 5,408 (47.8) |
| Secondary | 256 (37.0) | 4,380 (38.7) |
| Higher | 42 (6.1) | 795 (7.0) |
| *Missing* | 5 (0.7) | 119 (1.1) |
| Couple age discrepancy (man - woman) stratified by women's age, mean (SD)[¥] | | |
| 15-24 | 6.2 (5.6) | 6.3 (4.9) |
| 25-34 | 5.6 (5.1) | 6.2 (5.3) |
| 35-44 | 4.9 (6.0) | 6.2 (6.0) |
| 45-64 | 3.0 (5.6) | 6.0 (6.3) |
| Male partner alcohol consumption, n (%)[‡†] | | |
| Never | 259 (37.5) | 6,145 (54.3) |
| Sometimes | 204 (29.5) | 2,845 (25.1) |
| Often | 139 (20.1) | 1,695 (15.0) |
| *Missing* | 89 (12.9) | 629 (5.6) |

SD=standard deviation; IPV=intimate partner violence.

§ Difference in partner HIV status between women experiencing and not experiencing past year intimate partner violence (IPV) was not statistically significant ($p<0.05$)

‡ Question on the frequency of alcohol consumption was not asked in Uganda 2016 PHIA survey. In PHIA surveys the question about alcohol consumption was asked to the male partner directly; in Mozambique 2015 AIS survey, women were asked about their partners' alcohol consumption frequency.

† In PHIA, the survey responses on alcohol use were recoded to match the "Never", "Sometimes", "Often" response categories in DHS as follows: "Never" (DHS) – "Never" (PHIA); "Sometimes" (DHS) – "Monthly or less" and "2-4 times a month" (PHIA); "Often" (DHS) – "2-3 times a week" and "4 or more times a week" (PHIA)

¥ Difference in the mean couple age discrepancy between women who had not experienced past year physical and/or sexual IPV and women who had was less than one year (0.6 years).

**Table S12.** Unweighted proportion of women who used condoms at last sex, in the last 12 months, stratified by experience of past year physical and/or sexual intimate partner violence (IPV), in the six surveys (Mozambique, Malawi, Zambia, Uganda, Eswatini, Zimbabwe) with available information.

| | **Experiencing past year physical and/or sexual IPV** | **Not experiencing past year physical and/or sexual IPV** |
|---|---|---|
| Condom use at last sex, n (%) | | |
| Use | 77 (11.1) | 1,172 (10.4) |
| No use | 578 (83.6) | 9,166 (81.0) |
| *Missing* | 36 (5.2) | 976 (8.6) |

IPV=intimate partner violence.

**Table S13.** Unweighted proportion of recent HIV infection among women, stratified by male partner alcohol consumption frequency among the six surveys (Mozambique, Malawi, Zambia, Uganda, Eswatini, Zimbabwe) with available information.

| | **Male partner's frequency of alcohol consumption‡** | | |
|---|---|---|---|
| | **Never** | **Sometimes** | **Often** |
| Recent HIV infection, n (%)§ | | | |
| Recent HIV infection | 4 (0.06) | 5 (0.16) | 2 (0.11) |
| Non-recent HIV infection | 962 (14.3) | 489 (15.5) | 260 (13.9) |
| Not living with HIV | 5,207 (77.5) | 2,434 (77.3) | 1,487 (79.4) |
| *Missing* | 543 (8.1) | 221 (7.0) | 123 (6.6) |

§ One woman with incident HIV is removed from the analysis because she had a missing value for male partner alcohol consumption

‡ The denominators in this analysis are the male partners of women (regardless of men's HIV status) who have declared to be in a cohabitating partnership and are at risk of HIV acquisition.

**Table S14.** Unweighted proportion of HIV positive male partners who are virally suppressed stratified by frequency of their alcohol consumption among the six surveys (Mozambique, Malawi, Zambia, Uganda, Eswatini, Zimbabwe) with available information.

| | **Male partner's frequency of alcohol consumption‡** | | |
|---|---|---|---|
| | **Never** | **Sometimes** | **Often** |
| Viral load suppression, n (%) | | | |
| Suppressed | 654 (63.7) | 293 (59.0) | 113 (47.9) |
| Unsuppressed | 365 (35.6) | 196 (39.4) | 121 (51.3) |
| *Missing* | 7 (0.7) | 8 (1.6) | 2 (0.8) |

IPV=intimate partner violence.

‡ The denominators in this analysis are *HIV positive* male partners of women who have declared to be in a cohabitating partnership and are at risk of HIV acquisition.

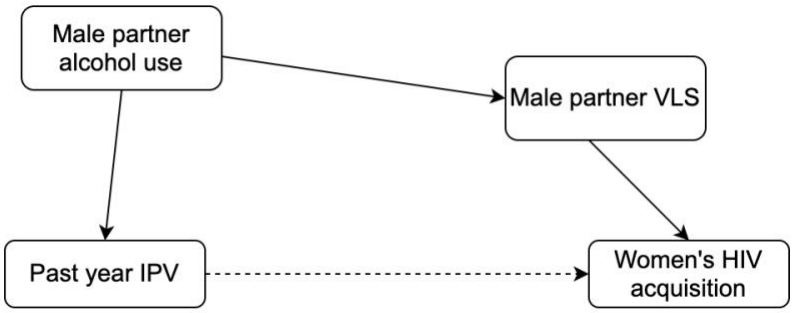


**Figure S1:** Directed Acyclic Graph (DAG) of the proposed relationship between past year IPV and women's HIV acquisition.
*IPV=intimate partner violence; VLS=viral load suppression*

## Supplement 8: Sensitivity analyses

**Table S15.** Crude and adjusted prevalence ratios (PR) of lifetime and past year HIV testing for women experiencing different types of intimate partner violence (IPV) compared to women not experiencing it.

| Exposures | $N_{surv}$ | $N_i$ | Crude PR (95% CI) | Adjusted PR‡ (95% CI) |
|---|---|---|---|---|
| ***Past year HIV testing*** | | | | |
| Past year physical and/or sexual IPV | 57 | 274,506 | 0.97 (0.96, 0.98) | 0.99 (0.98, 1.01) |
| Lifetime physical IPV | 52 | 254,041 | 0.99 (0.97, 1.00) | 1.00 (0.99, 1.01) |
| Lifetime sexual IPV | 52 | 254,005 | 0.99 (0.98, 1.01) | 0.99 (0.97, 1.00) |
| Lifetime physical and/or sexual IPV | 52 | 254,017 | 0.99 (0.98, 1.00) | 0.99 (0.98, 1.01) |
| Severe lifetime physical and/or sexual IPV† | 52 | 253,977 | 0.97 (0.96, 0.99) | 0.98 (0.97, 0.99) |
| Frequency of past-year physical and/or sexual IPV¥ | | | | |
| Never | 57 | 274,505 | Referent | Referent |
| Sometimes | | | 0.98 (0.97, 1.00) | 0.99 (0.98, 1.01) |
| Often | | | 0.94 (0.92, 0.96) | 0.99 (0.96, 1.01) |
| ***Lifetime HIV testing*** | | | | |
| Lifetime physical IPV | 52 | 254,464 | 1.01 (1.00, 1.02) | 1.02 (1.02, 1.03) |
| Lifetime sexual IPV | 52 | 254,428 | 1.00 (0.99, 1.01) | 1.01 (1.00, 1.01) |
| Lifetime physical and/or sexual IPV | 52 | 254,440 | 1.01 (1.01, 1.02) | 1.02 (1.02, 1.03) |
| Severe lifetime physical and/or sexual IPV§ | 52 | 254,399 | 1.00 (0.99, 1.01) | 1.01 (1.00, 1.02) |

95%CI=95% confidence intervals; IPV=intimate partner violence; $N_{surv}$=number of surveys; $N_i$=number of individual observations without any missing data for intimate partner violence (IPV), the outcome and the covariates included in the adjusted models; PR=prevalence ratio.

‡ Adjusted for: age (continuous), residence type (rural/urban), women's current partnership status (in a union/living with a man versus not), women's education (none, primary, secondary, higher), and survey identifier.

¥ In PHIA surveys the frequency of past-year intimate partner violence (IPV) pertains to only recent physical, not sexual IPV. Furthermore, this question asks about perpetration of violence by "someone" which we assume to be an intimate partner only when the woman has also reported experiencing IPV. The referent category for the frequency of past year physical and/or sexual IPV are women who did not experience any past year physical and/or sexual intimate partner violence (IPV).

† Referent category includes women experiencing non-severe lifetime IPV and no lifetime IPV.

**Table S16.** Crude and adjusted prevalence ratios (PR) of lifetime and past year HIV testing among women reporting HIV testing outside of antenatal care (ANC) and experiencing different types of intimate partner violence (IPV) compared to women not experiencing it.

| Exposures | $N_{surv}$ | $N_i$ | Crude PR (95% CI) | Adjusted PR[§] (95% CI) |
|---|---|---|---|---|
| ***Past year HIV testing*** | | | | |
| Past year physical and/or sexual IPV | 57 | 198,979 | 0.96 (0.94, 0.98) | 1.00 (0.98, 1.03) |
| Lifetime physical IPV | 52 | 188,798 | 1.03 (1.01, 1.05) | 1.01 (0.99, 1.03) |
| Lifetime sexual IPV | 52 | 188,769 | 1.05 (1.02, 1.07) | 1.00 (0.97, 1.02) |
| Lifetime physical and/or sexual IPV | 52 | 188,775 | 1.04 (1.02, 1.06) | 1.01 (0.99, 1.03) |
| Severe lifetime physical and/or sexual IPV[†] | 52 | 188,743 | 1.03 (1.01, 1.05) | 1.00 (0.98, 1.02) |
| Frequency of past-year physical and/or sexual IPV[¥] | | | | |
| Never | 57 | 198,979 | Referent | Referent |
| Sometimes | | | 0.97 (0.95, 0.98) | 1.00 (0.98, 1.03) |
| Often | | | 0.95 (0.92, 0.98) | 1.01 (0.97, 1.05) |
| ***Lifetime HIV testing*** | | | | |
| Lifetime physical IPV | 52 | 188,958 | 1.03 (1.02, 1.04) | 1.04 (1.03, 1.05) |
| Lifetime sexual IPV | 52 | 188,928 | 1.03 (1.02, 1.04) | 1.01 (1.00, 1.03) |
| Lifetime physical and/or sexual IPV | 52 | 188,935 | 1.04 (1.03, 1.05) | 1.04 (1.03, 1.05) |
| Severe lifetime physical and/or sexual violence IPV[†] | 52 | 188,902 | 1.02 (1.01, 1.03) | 1.02 (1.00, 1.03) |

95%CI=95% confidence intervals; ANC=antenatal care; IPV=intimate partner violence; $N_{surv}$=number of surveys; $N_i$=number of individual observations without any missing data for intimate partner violence (IPV), the outcome and the covariates included in the adjusted models; PR=prevalence ratio.

§ Adjusted for: age (continuous), residence type (rural/urban), women's current partnership status (in a union/living with a man versus not), women's education (none, primary, secondary, higher), and survey identifier.

¥ In PHIA surveys the frequency of past-year intimate partner violence (IPV) pertains to only recent physical, not sexual IPV. Furthermore, this question asks about perpetration of violence by "someone" which we assume to be an intimate partner only when a woman also reports experiencing IPV. The referent category for the frequency of past year physical and/or sexual IPV are women who did not experience any past year physical and/or sexual intimate partner violence (IPV).

† Referent category includes women experiencing non-severe lifetime IPV and no lifetime IPV.

**Table S17.** Crude and adjusted prevalence ratios (PR) of lifetime and past year HIV testing among women experiencing different types of intimate partner violence (IPV) compared to women not experiencing it, stratified by the 2015-2019 study period.

| Exposures | $N_{surv}$ | $N_i$ | Crude PR (95% CI) | Adjusted PR[§] (95% CI) |
|---|---|---|---|---|
| ***Past year HIV testing*** | | | | |
| Past year physical and/or sexual IPV | 23 | 98,853 | 1.01 (0.99, 1.02) | 1.00 (0.98, 1.02) |
| Lifetime physical IPV | 18 | 75,376 | 0.98 (0.96, 1.00) | 1.00 (0.98, 1.02) |
| Lifetime sexual IPV | 18 | 75,377 | 0.98 (0.96, 1.01) | 0.97 (0.95, 1.00) |
| Lifetime physical and/or sexual IPV | 18 | 75,375 | 0.98 (0.96, 1.00) | 1.00 (0.98, 1.02) |
| Severe lifetime physical and/or sexual IPV[†] | 18 | 75,375 | 0.96 (0.94, 0.98) | 0.97 (0.95, 0.99) |
| Frequency of past-year physical and/or sexual IPV[¥] | | | | |
| Never | 23 | 98,852 | Referent | Referent |
| Sometimes | | | 1.02 (1.00, 1.04) | 1.00 (0.98, 1.02) |
| Often | | | 0.97 (0.94, 1.00) | 0.99 (0.96, 1.02) |
| ***Lifetime HIV testing*** | | | | |
| Lifetime physical IPV | 18 | 75,510 | 1.01 (1.01, 1.02) | 1.03 (1.02, 1.03) |
| Lifetime sexual IPV | 18 | 75,510 | 1.01 (1.00, 1.02) | 1.00 (1.00, 1.01) |
| Lifetime physical and/or sexual IPV | 18 | 75,509 | 1.02 (1.01, 1.02) | 1.02 (1.02, 1.03) |
| Severe lifetime physical and/or sexual violence IPV[†] | 18 | 75,508 | 1.00 (0.99, 1.01) | 1.01 (1.00, 1.02) |

95%CI=95% confidence intervals; ANC=antenatal care; IPV=intimate partner violence; $N_{surv}$=number of surveys; $N_i$=number of individual observations without any missing data for intimate partner violence (IPV), the outcome and the covariates included in the adjusted models; PR=prevalence ratio.

§ Adjusted for: age(continuous), residence type (rural/urban), women's current partnership status (in a union/living with a man versus not), women's education (none, primary, secondary, higher), and survey identifier.

¥ In PHIA surveys the frequency of past-year intimate partner violence (IPV) pertains to only recent physical, not sexual IPV. Furthermore, this question asks about perpetration of violence by "someone" which we assume to be an intimate partner only when a woman also reports experiencing IPV. The referent category for the frequency of past year physical and/or sexual IPV are women who did not experience any past year physical and/or sexual intimate partner violence (IPV).

† Referent category includes women experiencing non-severe lifetime IPV and no lifetime IPV.

**Table S18.** Crude and adjusted prevalence ratios (PR) of lifetime and past year HIV testing among women experiencing different types of intimate partner violence (IPV) compared to women not experiencing it, stratified by the 2010-2014 study period.

| Exposures | $N_{surv}$ | $N_i$ | Crude PR (95% CI) | Adjusted PR[§] (95% CI) |
|---|---|---|---|---|
| ***Past year HIV testing*** | | | | |
| Past year physical and/or sexual IPV | 20 | 108,887 | 1.05 (1.03, 1.08) | 1.00 (0.97, 1.02) |
| Lifetime physical IPV | 20 | 109,436 | 1.02 (1.00, 1.04) | 1.00 (0.98, 1.03) |
| Lifetime sexual IPV | 20 | 109,424 | 1.04 (1.01, 1.07) | 1.01 (0.98, 1.04) |
| Lifetime physical and/or sexual IPV | 20 | 109,432 | 1.02 (1.00, 1.04) | 1.00 (0.98, 1.02) |
| Severe lifetime physical and/or sexual IPV[†] | 20 | 109,415 | 1.02 (1, 1.04) | 0.99 (0.97, 1.02) |
| Frequency of past-year physical and/or sexual IPV[¥] | | | | |
| Never | 20 | 108,887 | Referent | Referent |
| Sometimes | | | 1.08 (1.05, 1.11) | 1.00 (0.97, 1.02) |
| Often | | | 1.00 (0.96, 1.04) | 1.00 (0.96, 1.04) |
| ***Lifetime HIV testing*** | | | | |
| Lifetime physical IPV | 20 | 109,695 | 1.03 (1.02, 1.04) | 1.03 (1.02, 1.04) |
| Lifetime sexual IPV | 20 | 109,684 | 1.03 (1.01, 1.04) | 1.02 (1.00, 1.03) |
| Lifetime physical and/or sexual IPV | 20 | 109,691 | 1.03 (1.02, 1.04) | 1.03 (1.02, 1.04) |
| Severe lifetime physical and/or sexual violence IPV[†] | 20 | 109,674 | 1.02 (1.01, 1.04) | 1.02 (1.01, 1.03) |

95%CI=95% confidence intervals; ANC=antenatal care; IPV=intimate partner violence; $N_{surv}$=number of surveys; $N_i$=number of individual observations without any missing data for intimate partner violence (IPV), the outcome and the covariates included in the adjusted models; PR=prevalence ratio.

§ Adjusted for: age(continuous), residence type (rural/urban), women's current partnership status (in a union/living with a man versus not), women's education (none, primary, secondary, higher), and survey identifier.

¥ In PHIA surveys the frequency of past-year intimate partner violence (IPV) pertains to only recent physical, not sexual IPV. Furthermore, this question asks about perpetration of violence by "someone" which we assume to be an intimate partner only when a woman also reports experiencing IPV. The referent category for the frequency of past year physical and/or sexual IPV are women who did not experience any past year physical and/or sexual intimate partner violence (IPV).

† Referent category includes women experiencing non-severe lifetime IPV and no lifetime IPV.

**Table S19.** Crude and adjusted prevalence ratios (PR) of lifetime and past year HIV testing among women experiencing different types of intimate partner violence (IPV) compared to women not it, stratified by the 2005-2009 study period.

| Exposures | $N_{surv}$ | $N_i$ | Crude PR (95% CI) | Adjusted PR[§] (95% CI) |
|---|---|---|---|---|
| ***Past year HIV testing*** | | | | |
| Past year physical and/or sexual IPV | 11 | 53,579 | 0.95 (0.91, 1.01) | 0.96 (0.91, 1.02) |
| Lifetime physical IPV | 11 | 54,489 | 0.96 (0.91, 1.01) | 0.98 (0.93, 1.04) |
| Lifetime sexual IPV | 11 | 54,466 | 0.97 (0.89, 1.05) | 0.95 (0.88, 1.02) |
| Lifetime physical and/or sexual IPV | 11 | 54,469 | 0.96 (0.91, 1.01) | 0.98 (0.93, 1.03) |
| Severe lifetime physical and/or sexual IPV[†] | 11 | 54,447 | 0.96 (0.90, 1.01) | 0.98 (0.92, 1.04) |
| Frequency of past-year physical and/or sexual IPV[¥] | | | | |
| Never | 11 | 53,579 | Referent | Referent |
| Sometimes | | | 0.94 (0.89, 1.00) | 0.96 (0.90, 1.02) |
| Often | | | 1.00 (0.90, 1.10) | 0.98 (0.89, 1.07) |
| ***Lifetime HIV testing*** | | | | |
| Lifetime physical IPV | 11 | 54,514 | 0.96 (0.93, 0.99) | 0.99 (0.96, 1.02) |
| Lifetime sexual IPV | 11 | 54,491 | 0.94 (0.90, 0.99) | 0.95 (0.91, 0.99) |
| Lifetime physical and/or sexual IPV | 11 | 54,494 | 0.96 (0.93, 0.99) | 0.99 (0.96, 1.02) |
| Severe lifetime physical and/or sexual violence IPV[†] | 11 | 54,472 | 0.94 (0.91, 0.98) | 0.97 (0.94, 1.01) |

95%CI=95% confidence intervals; ANC=antenatal care; IPV=intimate partner violence; $N_{surv}$=number of surveys; $N_i$=number of individual observations without any missing data for intimate partner violence (IPV), the outcome and the covariates included in the adjusted models; PR=prevalence ratio.

§ Adjusted for: age(continuous), residence type (rural/urban), women's current partnership status (in a union/living with a man versus not), women's education (none, primary, secondary, higher), and survey identifier.

¥ In PHIA surveys the frequency of past-year intimate partner violence (IPV) pertains to only recent physical, not sexual IPV. Furthermore, this question asks about perpetration of violence by "someone" which we assume to be an intimate partner only when a woman also reports experiencing IPV. The referent category for the frequency of past year physical and/or sexual IPV are women who did not experience any past year physical and/or sexual intimate partner violence (IPV).

† Referent category includes women experiencing non-severe lifetime IPV and no lifetime IPV.

**Table S20.** Crude and adjusted prevalence ratios (PR) of lifetime and past year HIV testing among women experiencing different types of intimate partner violence (IPV) compared to women not experiencing it, stratified by the 2000-2004 study period.

| Exposures | $N_{surv}$ | $N_i$ | Crude PR (95% CI) | Adjusted PR[§] (95% CI) |
|---|---|---|---|---|
| ***Past year HIV testing*** | | | | |
| Past year physical and/or sexual IPV | 3 | 13,187 | 0.89 (0.76, 1.05) | 0.90 (0.76, 1.06) |
| Lifetime physical IPV | 3 | 14,740 | 0.82 (0.71, 0.96) | 0.84 (0.72, 0.98) |
| Lifetime sexual IPV | 3 | 14,738 | 0.95 (0.78, 1.15) | 0.94 (0.77, 1.15) |
| Lifetime physical and/or sexual IPV | 3 | 14,741 | 0.86 (0.74, 1.00) | 0.87 (0.75, 1.01) |
| Severe lifetime physical and/or sexual IPV[†] | 3 | 14,740 | 0.85 (0.73, 1.00) | 0.88 (0.74, 1.03) |
| Frequency of past-year physical and/or sexual IPV[¥] | | | | |
| Never | 3 | 13,187 | Referent | Referent |
| Sometimes | | | 0.91 (0.76, 1.09) | 0.90 (0.75, 1.08) |
| Often | | | 0.84 (0.63, 1.11) | 0.90 (0.68, 1.20) |
| ***Lifetime HIV testing*** | | | | |
| Lifetime physical IPV | 3 | 14,745 | 0.89 (0.81, 0.98) | 0.91 (0.82, 1.00) |
| Lifetime sexual IPV | 3 | 14,743 | 0.96 (0.85, 1.09) | 0.95 (0.84, 1.08) |
| Lifetime physical and/or sexual IPV | 3 | 14,746 | 0.91 (0.83, 1.00) | 0.92 (0.84, 1.01) |
| Severe lifetime physical and/or sexual violence IPV[†] | 3 | 14,745 | 0.88 (0.79, 0.98) | 0.90 (0.81, 1.00) |

95%CI=95% confidence intervals; ANC=antenatal care; IPV=intimate partner violence; $N_{surv}$=number of surveys; $N_i$=number of individual observations without any missing data for intimate partner violence (IPV), the outcome and the covariates included in the adjusted models; PR=prevalence ratio.

§ Adjusted for: age(continuous), residence type (rural/urban), women's current partnership status (in a union/living with a man versus not), women's education (none, primary, secondary, higher), and survey identifier.

¥ In PHIA surveys the frequency of past-year intimate partner violence (IPV) pertains to only recent physical, not sexual IPV. Furthermore, this question asks about perpetration of violence by "someone" which we assume to be an intimate partner only when a woman also reports experiencing IPV. The referent category for the frequency of past year physical and/or sexual IPV are women who did not experience any past year physical and/or sexual intimate partner violence (IPV).

† Referent category includes women experiencing non-severe lifetime IPV and no lifetime IPV.

**Table S21.** Crude and adjusted prevalence ratios of *self-reported* antiretroviral (ART) uptake among women living with HIV experiencing different types of intimate partner violence (IPV) compared to those not experiencing it.

| **Exposures** | **$N_{surv}$¶** | **$N_i$§** | **Crude PR (95% CI)** | **Adjusted PR‡ (95% CI)** |
|---|---|---|---|---|
| Past year physical and/or sexual IPV | 6 | 3,834 | 0.95 (0.91, 0.99) | 0.95 (0.9, 0.99) |
| Lifetime physical IPV | 2 | 739 | 0.98 (0.93, 1.02) | 0.97 (0.93, 1.02) |
| Lifetime sexual IPV | 2 | 740 | 0.96 (0.86, 1.07) | 0.95 (0.85, 1.07) |
| Lifetime physical and/or sexual IPV | 2 | 739 | 0.98 (0.93, 1.02) | 0.97 (0.93, 1.02) |
| Severe lifetime physical and/or sexual IPV† | 2 | 739 | 0.95 (0.88, 1.02) | 0.96 (0.89, 1.03) |
| Frequency of past-year physical and/or sexual IPV¥ | | | | |
| Never | 6 | 3,834 | Referent | Referent |
| Sometimes | | | 0.95 (0.91, 1) | 0.95 (0.9, 0.99) |
| Often | | | 0.91 (0.81, 1.03) | 0.95 (0.84, 1.08) |

95%CI=95% confidence intervals; ART=antiretroviral treatment; IPV=intimate partner violence; $N_{surv}$=number of surveys; $N_i$=number of individual observations without any missing data for intimate partner violence (IPV), the outcome and the covariates included in the adjusted modesl; PR=prevalence ratio; WLHIV=women living with HIV.

‡ Adjusted for: age (continuous), residence type (rural/urban), women's current partnership status (in a union/living with a man versus not), women's education (none, primary, secondary, higher), and survey identifier.

¥ In PHIA surveys (5/6) the frequency of past-year intimate partner violence (IPV) pertains to only recent physical, not sexual IPV. Furthermore, this question asks about perpetration of violence by "someone" which we assume to be an intimate partner only when the woman has also reported experiencing IPV. The referent category for the frequency of past year physical and/or sexual IPV are women who did not experience any past year physical and/or sexual intimate partner violence (IPV).

§ 0.7% (N=45) of women were removed because they had a recent HIV infection. We assumed that those with a recent infection did not have time to be diagnosed and linked to treatment.

† Referent category includes women experiencing non-severe lifetime IPV and no lifetime IPV.

¶ Includes 6 surveys (instead of 7 as in other ART analyses) since Uganda (PHIA) survey does not collect current, self-reported ART uptake information

**Table S22.** Crude and adjusted prevalence ratios of *biomarker-based* antiretroviral (ART) uptake among women living with HIV experiencing different types of intimate partner violence (IPV) compared to those not experiencing it.

| **Exposures** | **$N_{surv}$** | **$N_i$[§]** | **Crude PR (95% CI)** | **Adjusted PR[‡] (95% CI)** |
|---|---|---|---|---|
| Past year physical and/or sexual IPV | 7 | 5,573 | 0.88 (0.82, 0.94) | 0.95 (0.88, 1.02) |
| Lifetime physical IPV | 2 | 1,536 | 1.05 (0.97, 1.14) | 0.99 (0.91, 1.08) |
| Lifetime sexual IPV | 2 | 1,537 | 1.12 (0.97, 1.3) | 1.07 (0.92, 1.24) |
| Lifetime physical and/or sexual IPV | 2 | 1,536 | 1.06 (0.97, 1.15) | 1.00 (0.92, 1.09) |
| Severe lifetime physical and/or sexual IPV[†] | 2 | 1,535 | 0.94 (0.83, 1.06) | 0.94 (0.83, 1.06) |
| Frequency of past-year physical and/or sexual IPV[¥] | | | | |
| Never | 7 | 5,573 | Referent | Referent |
| Sometimes | | | 0.89 (0.83, 0.95) | 0.94 (0.87, 1.02) |
| Often | | | 0.84 (0.72, 1.00) | 0.98 (0.82, 1.18) |

95%CI=95% confidence intervals; ART=antiretroviral treatment; IPV=intimate partner violence; $N_{surv}$=number of surveys; $N_i$=number of individual observations without any missing data for intimate partner violence (IPV), the outcome and the covariates included in the adjusted models; PR=prevalence ratio; WLHIV=women living with HIV.

‡ Adjusted for: age (continuous), residence type (rural/urban), women's current partnership status (in a union/living with a man versus not), women's education (none, primary, secondary, higher), and survey identifier.

¥ In PHIA surveys (5/7) the frequency of past-year intimate partner violence (IPV) pertains to only recent physical, not sexual IPV. Furthermore, this question asks about perpetration of violence by "someone" which we assume to be an intimate partner only when the woman has also reported experiencing IPV. The referent category for the frequency of past year physical and/or sexual IPV are women who did not experience any past year physical and/or sexual intimate partner violence (IPV).

§ 0.7% (N=45) of women were removed because they had a recent HIV infection. We assumed that those with a recent infection did not have time to be diagnosed and linked to treatment.

† Referent category includes women experiencing non-severe lifetime IPV and no lifetime IPV.

**Table S23.** Mean number of self-reported missed antiretroviral treatment (ART) pills in the past 30 days among women living with HIV who self-reported being on ART. The analysis is stratified by past year experience of intimate partner violence (IPV) and only includes five Population-based HIV Impact Assessment (PHIA) surveys.

| | Past year physical and/or sexual IPV | | |
|---|---|---|---|
| **Self-reported ART adherence** | **Yes ($N_i$= 139)** | **No ($N_i$=2,942)** | **t score (95%CI)** |
| Mean number of missed pills in the past 30 days (mean, sd)† | 0.61 (1.13) | 0.27 (0.74) | -3.4 (-0.54, -0.15) |

ART = antiretroviral treatment; IPV = intimate partner violence; PHIA=Population-based HIV Impact Assessment Survey; SABSSM=South African National HIV Prevalence, Incidence, Behaviour and Communication Survey; sd = standard deviation

† SABSSM was excluded from this analysis because the question "How long were you not taking the (ART) treatment? (Days/Months)" does not pertain to the past 30 days of ART pill missingness

**Table S24.** Crude and adjusted prevalence ratios (PR) of viral suppression among women living with HIV on antiretroviral treatment (ART) experiencing different types of intimate partner violence (IPV) compared to those not experiencing it.

| **Exposures** | **$N_{surv}$** | **$N_i$** | **Crude PR (95% CI)** | **Adjusted PR§ (95% CI)** |
|---|---|---|---|---|
| Past year physical and/or sexual IPV | 7 | 3,932 | 0.91 (0.87, 0.95) | 0.95 (0.90, 1.00) |
| Lifetime physical IPV | 2 | 942 | 0.98 (0.93, 1.05) | 0.94 (0.89, 1.00) |
| Lifetime sexual IPV | 2 | 943 | 1.03 (0.92, 1.15) | 1.01 (0.90, 1.14) |
| Lifetime physical and/or sexual IPV | 2 | 942 | 0.99 (0.93, 1.05) | 0.95 (0.89, 1.01) |
| Severe lifetime physical and/or sexual IPV† | 2 | 942 | 1.04 (0.96, 1.12) | 1.03 (0.95, 1.12) |
| Frequency of past-year physical and/or sexual IPV¥ | | | | |
| Never | 7 | 3,932 | Referent | Referent |
| Sometimes | | | 0.93 (0.89, 0.98) | 0.96 (0.91, 1.01) |
| Often | | | 0.77 (0.64, 0.93) | 0.86 (0.72, 1.03) |

95%CI=95% confidence intervals; ART=antiretroviral treatment; IPV=intimate partner violence; $N_{surv}$=number of surveys; $N_i$=number of individual observations without any missing data for intimate partner violence (IPV), the outcome and the covariates included in the adjusted models; PR=prevalence ratio; WLHIV=women living with HIV.

§ Adjusted for: age(continuous), residence type (rural/urban), women's current partnership status (in a union/living with a man versus not), women's education (none, primary, secondary, higher), and survey identifier.

¥ In PHIA surveys the frequency of past-year intimate partner violence (IPV) pertains to only recent physical, not sexual IPV. Furthermore, this question asks about perpetration of violence by "someone" which we assume to be an intimate partner only when a woman also reports experiencing IPV. The referent category for the frequency of past year physical and/or sexual IPV are women who did not experience any past year physical and/or sexual intimate partner violence (IPV).

† Referent category includes women experiencing non-severe lifetime IPV and no lifetime IPV.

**Supplement 9: Assessment of the heterogeneity of effect size estimates across survey**

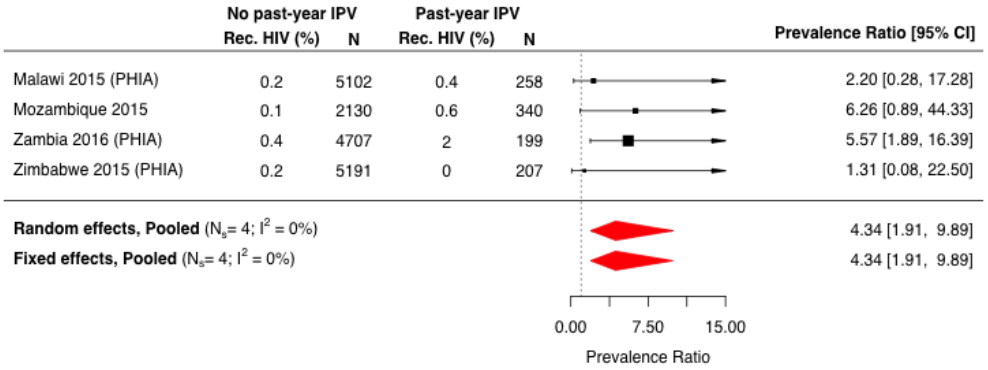


**Figure S2.** Survey-specific and pooled crude prevalence ratios (PR) for recent HIV infection among women who had experienced past year physical and/or sexual intimate partner violence (IPV) compared to women who had not. Two surveys (Uganda 2016 and Eswatini 2016) had to be removed due to low counts. Both fixed and random effects pooled estimates are provided.

95%CI=95% confidence intervals; IPV=intimate partner violence; N= Total number of women who experienced past year IPV or did not experience past year IPV (stratum-specific denominators); $N_s$=number of surveys; Rec.HIV = recent HIV infection

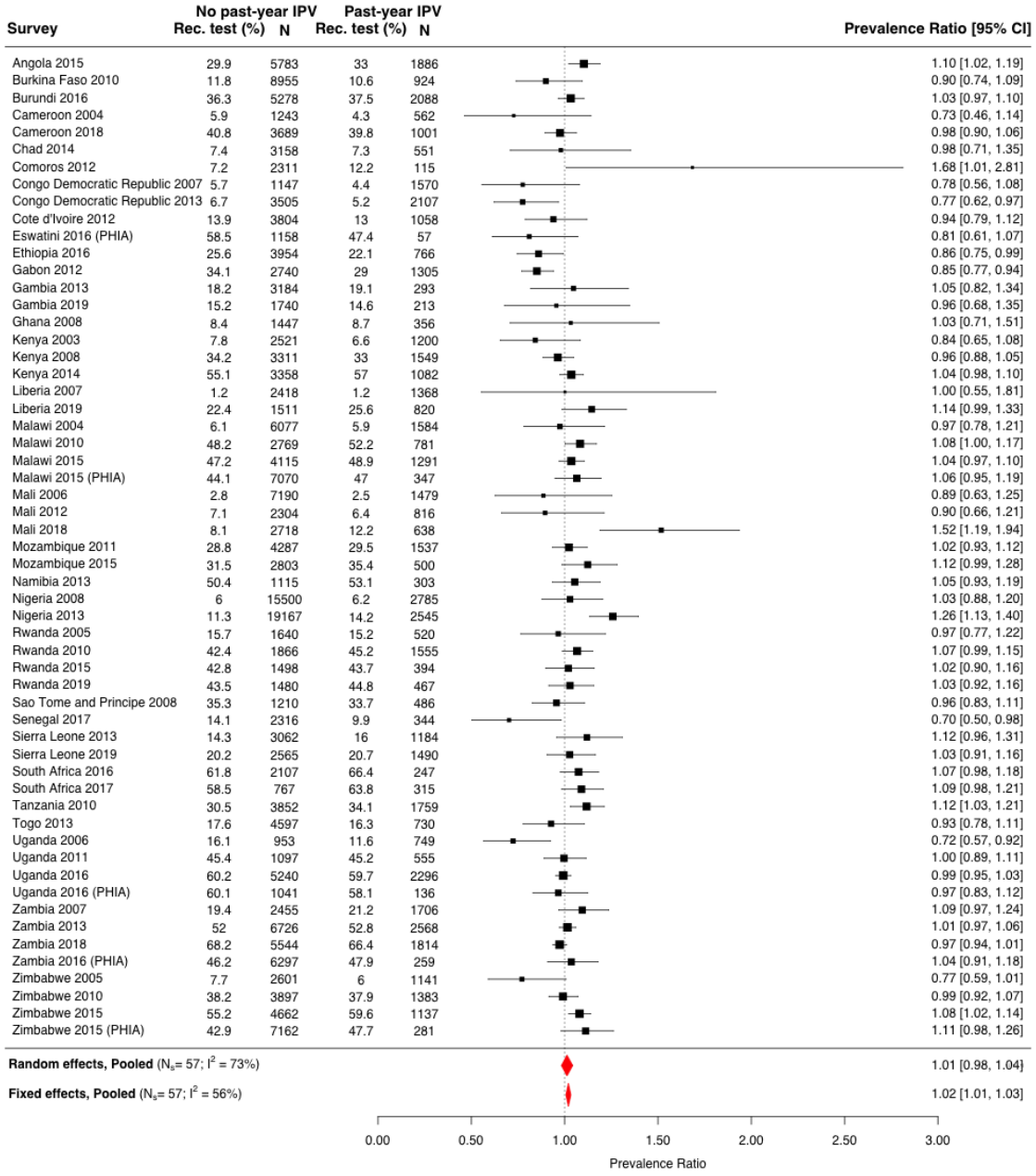


**Figure S3.** Survey-specific and pooled crude prevalence ratios (PR) for past year HIV testing among women who had experienced past year physical and/or sexual intimate partner violence (IPV) compared to women who had not. Both fixed and random effects pooled estimates are provided.

95%CI=95% confidence intervals; IPV=intimate partner violence; N= Total number of women who experienced past year IPV or did not experience past year IPV (stratum-specific denominators); $N_s$=number of surveys; Rec.test = recent HIV testing

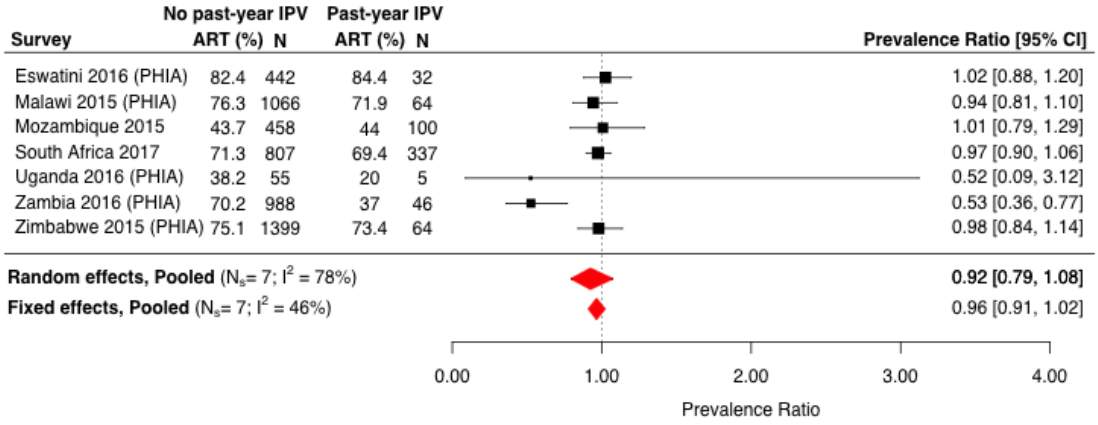


**Figure S4.** Survey-specific and pooled crude prevalence ratios (PR) for ART uptake among women who had experienced physical and/or sexual intimate partner violence (IPV) compared to women who had not. Both fixed and random effects pooled estimates are provided.

95%CI=95% confidence intervals; ART = antiretroviral therapy; IPV=intimate partner violence; N= Total number of women who experienced past year IPV or did not experience past year IPV (stratum-specific denominators); $N_s$=number of surveys

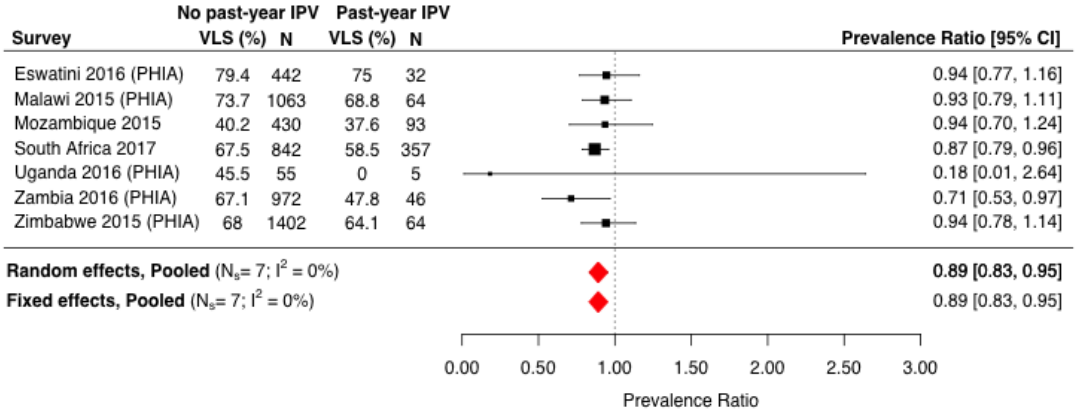


**Figure S5.** Survey-specific and pooled crude prevalence ratios (PR) for viral suppression among women who had experienced past year physical and/or sexual intimate partner violence (IPV) compared to women who had not. Both fixed and random effects pooled estimates are provided.

95%CI=95% confidence intervals; IPV=intimate partner violence; N= Total number of women who experienced past year IPV or did not experience past year IPV (stratum-specific denominators); $N_s$=number of surveys; VLS = Viral Load Suppression

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# 5. Chapter 5: Characteristics of male perpetrators of intimate partner violence and implications for women's HIV status

## 5.1 Preface to Manuscript 2

The impact of IPV on recent HIV infection found in the first manuscript raises questions on the underlying mechanisms. In Manuscript 1, I investigated if partnership characteristics impact IPV-HIV relationship by creating a "couple's" dataset for cohabiting men and women. Given the small sample size of 6 surveys, I only explored crude associations and found no differences in male partner HIV prevalence, condom use, and educational attainment based on whether women experienced IPV in the past year or not. However, there were slight differences in the age gap between the partners, male alcohol use, and viral failure, all of which were higher among men who had perpetrated IPV. To investigate further with a larger sample size (48 surveys), I conducted an analysis of male partner characteristics of women who experienced IPV, and their potential implications for women's HIV status. I also explored whether IPV perpetrators' sexual behaviors and subsequent HIV risk drives women's risk of HIV acquisition. The resulting article was published in the *PLOS Global Public Health* (September 2023, Volume 3, Issue 9, DOI: 10.1371/journal.pgph.0002146).

## 5.2 Manuscript 2: Characteristics of male perpetrators of intimate partner violence and implications for women's HIV status: a pooled analysis of cohabiting couples from 27 countries in Africa (2000-2020)

Salome Kuchukhidze[1], Dimitra Panagiotoglou[1], Marie-Claude Boily[2], Souleymane Diabaté [3,4,5], Jeffrey W Imai-Eaton [2], Heidi Stöckl[7], Francisco Mbofana[8], Rhoda K Wanyenze[9], and Mathieu Maheu-Giroux[1*]

**Affiliations**

1- Department of Epidemiology and Biostatistics, School of Population and Global Health, McGill University, Montréal, QC, Canada
2- MRC Centre for Global Infectious Disease Analysis, School of Public Health, Imperial College London, London, United Kingdom
3- Département de Médecine Sociale et Préventive, Université Laval, Québec, QC, Canada
4- Centre de recherche du CHU de Québec-Université Laval, Québec, QC, Canada
5- Département de Médecine et Spécialités Médicales, Université Alassane Ouattara, Bouaké, Côte d'Ivoire
6- Center for Infectious Disease Dynamics, Department of Epidemiology, Harvard T.H. Chan School of Public Health, Boston, MA, USA
7- Institute for Medical Information Processing, Biometry, and Epidemiology, Medical Faculty, LMU Munich, Germany
8- Conselho Nacional de Combate ao HIV/Sida, Maputo, Mozambique
9- Department of Disease Control and Environmental Health, School of Public Health, College of Health Sciences, Makerere University, Kampala, Uganda

**Abstract**

Intimate partner violence (IPV) may increase women's HIV acquisition risk. Still, knowledge on pathways through which IPV exacerbates HIV burden is emerging. We examined the individual and partnership-level characteristics of male perpetrators of physical and/or sexual IPV and considered their implications for women's HIV status.

We pooled individual-level data from nationally representative, cross-sectional surveys in 27 countries in Africa (2000-2020) with information on past-year physical and/or sexual IPV and HIV serology among cohabiting couples (≥15 years). Current partners of women experiencing past-year IPV were assumed to be IPV perpetrators. We used Poisson regression, based on Generalized Estimating Equations, to estimate prevalence ratios (PR) for male partner and partnership-level factors associated with perpetration of IPV, and men's HIV status. We used marginal standardization to estimate the adjusted risk differences (aRD) quantifying the incremental effect of IPV on women's risk of living with HIV, beyond the risk from their partners' HIV status. Models were adjusted for survey fixed effects and potential confounders.

In the 48 surveys available from 27 countries (N=111,659 couples), one-fifth of women reported that their partner had perpetrated IPV in the past year. Men who perpetrated IPV were more likely to be living with HIV (aPR=1.09; 95%CI: 1.01-1.16). The aRD for living with HIV among women aged 15-24 whose partners were HIV seropositive and perpetrated past-year IPV was 30% (95%CI: 26%-35%), compared to women whose partners were HIV seronegative and did not perpetrate IPV. Compared to the same group, aRD among women whose partner was HIV seropositive without perpetrating IPV was 27% (95%CI: 23%-30%). Men who perpetrated IPV are more likely to be living with HIV.

IPV is associated with a slight increase in young women's risk of living with HIV beyond the risk of having an HIV seropositive partner, which suggests the mutually reinforcing effects of HIV/IPV.

## Introduction

Ending violence against women is a public health priority globally. IPV has serious short and long-term physical and mental health consequences, including injury, depression, anxiety, unwanted pregnancies, and sexually transmitted infections.[1] Several prospective[2,3] and population-based studies [4,5] suggested that intimate partner violence (IPV) also contributes to HIV risk. One in three women between the ages of 15 and 49 in sub-Saharan Africa – the region with the highest HIV burden – have experienced physical and/or sexual IPV in their lifetime.[1] In the same group, 20% of total years of life lost as a result of disability is attributable to HIV.[6] Adolescent girls and young women (AGYW), who are the most vulnerable to IPV, are three times as likely to acquire HIV and twice as likely to be living with HIV than men of the same age.[7] As part of the new strategy to end AIDS, the *2021 United Nations General Assembly (UNGA)* adopted a *Political Declaration on HIV and AIDS* which committed to reducing the proportion of women and girls who experience gender-based violence to less than 10% by 2025.[8,9] Improving understanding of the factors and pathways associated with male-perpetrated IPV and their implications for women's HIV acquisition risk is important to meet this commitment.

Studies that examined links between IPV and HIV have focused on the characteristics of women experiencing IPV.[2-5] However, there is increased evidence that pathways between IPV and HIV are also influenced by male partner characteristics. Distal determinants of HIV acquisition, such as male's concurrent sexual partnerships[10,11], participation in transactional sex[11], and inconsistent condom use [12] could increase men's risk of HIV acquisition and, ultimately, women's risk of acquisition.[13] These sexual behaviors and subsequent HIV risks are shown to be more common among men who perpetrate IPV, which may arise from the underlying, dominant ideals of masculinity.[12,14,15] Proximal determinants such as men's HIV seropositivity, and partnership characteristics could further compound women's risk. For instance, disparities in couples' age, education and earnings, which often disproportionately affect AGYW [16], may inhibit women's decision-making power on circumstances around sex and elevate the risk of HIV acquisition if their male partner has an unsuppressed viral load.

The links between IPV, sexual behaviors, and HIV are rooted in the social norms that perpetuate gender inequality. Studies have shown that masculine norms around virility and

resilience may shape sexual behaviors and subsequent risk of HIV acquisition in men.[17,18] Attitudes on relationship power dynamics, which underly IPV perpetration, limit women's sexual agency, thus contributing to their HIV risk.

Several population-based studies linked women's experience of IPV with HIV. However, few considered their male partners' HIV status, men's engagement in the HIV care cascade, or sexual behaviors.[2,4] Those that do, are cross-sectional and often limited by small sample sizes of cohabiting couples.[5] Conversely, multi-country studies describing characteristics of male perpetrators of IPV have not used an HIV lens and did not seek to understand the transmission risk to their female partner.[19-21] Using information on cohabiting male-female dyads from population-based surveys could help fill these knowledge gaps.

The aim of this study is to describe the characteristics of men perpetrating physical and/or sexual IPV and investigate how these characteristics impact women's HIV status among cohabiting couples in select African countries. We achieve this by leveraging available nationally representative, cross-sectional population-based surveys with information on both IPV and HIV. Specifically, we address three research questions. First, what male partner and partnership-level characteristics are associated with IPV? Second, are men who are reported to perpetrate IPV more likely to report behaviors that increase their risk of HIV acquisition and to be living with HIV? Third, does experiencing IPV increase young women's risk of living with HIV, beyond the risk associated with their male partner's HIV status?

## Methods

*Ethics statement*

Deidentified participant data were used in the study. Ethics approval was obtained from the institutional review board of the Faculty of Medicine and Health Sciences at McGill University (Montréal, QC, Canada; approval number A12-B95–21B).

*Data sources and study population*

We reviewed available nationally representative, cross-sectional surveys conducted in 27 countries in Africa between 2000 and 2020 with available respondent-level data on IPV and HIV testing, as described by Kuchukhidze and colleagues.[5] The included countries were in the geographic region of sub-Saharan Africa; the classification of this region and sub-regions was

aligned with that of the United Nations Statistics Division. [22] The study population comprised currently cohabiting, married or partnered women and men (≥15 years) that participated in the *Demographic and Health Surveys* (DHS), *AIDS Indicator Survey* (AIS), and *Population-based HIV Impact Assessment* (PHIA) surveys. PHIA, DHS and AIS used a stratified, two-stage, household-based cluster sampling design. Survey instruments included household questionnaires, individual questionnaires, and collection of biomarkers. Individual interviews included adult women and men, aged ≥15 years with slight variations in the upper age limit for eligibility across the surveys. [23,24] To create the analytical sample, we used data from survey participants who mutually declared to be married or co-habiting at the time of the survey and in which the female partner completed the IPV survey questionnaire.

In PHIA, data on past-year IPV were collected from one randomly selected woman in each household and, in DHS, from all women in a fraction of households (usually one third). For DHS, we used the couple's dataset; for PHIA, a dataset of cohabiting men and women was linked based on an identifier corresponding to the household member confirmed as the person's partner. All included surveys allowed for this linkage to identify unique, partnered couples.

*Definitions and measurement*

Perpetration of physical and/or sexual IPV over the past year among cohabitating couples was defined based on the women's self-reported experience of IPV, which was defined as the experience of physical and/or sexual violence in the past year by a current or former male intimate partner in the context of marriage or cohabitation. Current partners of women experiencing IPV in the past year were assumed to be perpetrators of IPV.[13,25] From here onwards, when referring to "perpetrators" of IPV, we refer to men whose female partner reported experiencing IPV in the past year.

Perpetration of physical and/or sexual IPV over the past year, as opposed to lifetime, was used for two main reasons. First, it would not be possible to link lifetime reports of IPV to a specific partner since the couple may have ceased cohabiting. Second, past-year reports match the timeframe for sexual behaviors reported in the surveys (e.g., condom use, payment for sex, number of sex partners in the past year). We combined physical and sexual IPV in a single measure given the considerable overlap between the two.[5] All surveys used an acts-specific

instrument, based on the modified Conflict Tactics Scale[26], to collect information on IPV (Table A in S1 Text).

Potential factors correlated with IPV pertained to male individual factors and partnership-level factors. Individual factors included: accepting attitudes on IPV, alcohol use frequency, and polygyny defined as having more than one wife/cohabiting partner. Partnership factors included: couple age disparity, earning disparity, women's say in household decision-making, and household headship (male/female). Couple age disparity was defined as the age difference between the man and the woman in the partnership. Earning disparity measured whether a woman earned more, less than, or the same as her partner, per survey questionnaire. DHS defined household headship as the person considered responsible for the household.[27]

Self-reported factors for men's risk of living with HIV included: payment for sex in the past year, condom use at last sex with the most recent partner in the past year, number of sex partners in the past year, and point-prevalence of concurrency defined as having more than one sexual partnership at a single point in time six months before the interview. Definition of concurrency was aligned with the primary indicator recommended by the UNAIDS Reference Group on Estimates, Modelling and Projections Working Group on Measuring Concurrent Sexual Partnerships. [28] All variables were extracted from individual participant surveys, and survey questions and measurements were generally consistent across the surveys.

HIV seropositivity was measured among consenting male and female participants at the time of survey administration via enzyme-linked immunosorbent assay (ELISA). The Zambia 2013-14 DHS was excluded from all analyses using HIV seropositivity due to concerns about its reliability.[29]

*Data analysis*

To describe characteristics of male IPV perpetrators, individual-level data from each survey were pooled to calculate crude and adjusted prevalence ratios (PR) of the association between the male and partnership-level variables and the IPV outcome. First, univariable Poisson regression models based on Generalized Estimating Equations (GEE) with robust standard errors and clustering by primary sampling unit (PSU) without survey weights[30], were used to calculate crude estimates. Multivariable models were adjusted for basic socio-demographic variables: male age (five-year age groups to account for the non-linear age effect), household wealth

quintile, residence type (rural, urban), and male education (none, primary, secondary, higher). Survey-level fixed effects were included in the adjusted models to account for unmeasured survey-level confounders.

For the second objective, IPV was the primary independent variable since we sought to identify if male perpetrators of IPV were more likely to report selected sexual behaviors (condom use in the past year, payment for sex in the past year, number of sex partners in the past year, concurrency of multiple sexual partners) and to be living with HIV. Here, we treated IPV as an independent variable since male sexual behaviors might be confounded by the underlying, unmeasured patriarchal attitudes that grant men a sexual prerogative.[31] As in the analyses above, multivariable models were adjusted for male demographic characteristics and survey identifier. For the male seropositivity outcome, we additionally adjusted for men's lifetime number of sexual partners (Table B in S1 Text).

For the final objective, we used effect measure modification analysis to assess if IPV modified women's absolute risk of living with HIV. We restricted this analysis to adolescent girls and young women aged 15-24 years for two reasons. First, we aimed to estimate the additional HIV risk due to IPV in the subgroup of women with the highest IPV prevalence and HIV incidence. Second, older women are more likely to have lived with HIV for longer due to higher HIV incidence in younger age groups. Therefore, past-year IPV is more likely to have preceded HIV acquisition among women aged 15-24 years. The analysis on all women is reported in the Text 1 in S1 Text.

We used marginal standardization based on GEE with robust standard errors. Crude and adjusted risk differences between 'doubly exposed' (women whose male partner lived with HIV and perpetrated IPV in the past year) and 'doubly unexposed' (the reference category – women whose male partner did not live with HIV and did not perpetrate IPV) were calculated. Risk differences between 'singly exposed' (women whose partner perpetrated IPV only, or whose partner lived with HIV only) and 'doubly unexposed' were also obtained. We estimated 95% confidence intervals (CIs) calculated via bootstrapping, where the resampling unit was the primary sampling unit. The model was adjusted for female demographic characteristics (linear age effect for analysis specific to 15-24 year-old women, and categorical five-year age groups in all women), household wealth, residence, type of education, women's lifetime number of sex partners (1, 2, $\geq$ 3) and survey-level fixed effects (Table B in S1 Text). Men's sexual behaviors

were not included in the adjustment since they would affect women's HIV risk primarily through male HIV status, which was adjusted for in our analyses.

We calculated the *Relative Excess Risk due to Interaction* (RERI) to understand the presence of additive effect measure modification between male HIV seropositivity and male perpetrated IPV (Table B in S1 Text).[32] To quantify the magnitude of EMM under an additive model, we calculated the difference between the expected joint effect of male HIV status and IPV perpetration (the sum of their unique effects) and their observed joint effects. Further methodological detail and equations are in Text 1 in S1 Text.

Additionally, we estimated the association between past-year IPV perpetration and ART uptake and viral load suppression among HIV seropositive male partners in the small subset of surveys with this information. These analyses were adjusted for male demographic characteristics (five-year age group, wealth quintile, education, residence), male frequency of alcohol consumption (never, sometimes, often) due to its links with both IPV and male engagement in HIV care cascade,[33] and survey identifier.

*Sensitivity analyses*

First, we explored the heterogeneity of effect size estimates across survey for each model by calculating survey-specific crude prevalence ratios and pooling them using both fixed and random-effect meta-analyses. We conducted subgroup (moderator) analyses by survey region and/or year when heterogeneity was moderate (25%-50%) to high (>50%).[34] Second, we also calculated crude and adjusted prevalence ratios stratified by region. Third, we excluded women who had two or more sexual partners in the past year to reduce the likelihood that women's reports of experiencing IPV in the past year referred to someone other than their current, cohabiting partner.

If either men or women respondents declined survey participation, were away from the household at the time of the interview, or if their identification of a cohabiting partner did not match their partner's report, the couple was excluded from the study sample. Survey participation could be associated with both IPV and HIV status in men, leading to selection bias. In a probabilistic sensitivity analysis, we assumed selection probabilities which were assigned to perpetrators and non-perpetrators with and without the outcome of interest (HIV seropositivity) based on the existing literature (Text 2 in S1 Text). We repeatedly resampled these selection

probabilities from a uniform distribution to adjust the observed crude prevalence ratio for potential differential participation.[35] We estimated the median value of the simulations as a bias-corrected crude prevalence ratio and calculated the 95% uncertainty.

**Results**

*Description of included surveys and the study population*

We identified 108 nationally representative surveys with data on HIV, of which 66 also had data on IPV. Eighteen surveys were excluded due to physical IPV questions not being asked, IPV data missingness, or women in couples' dataset not selected for the IPV module, resulting in 48 surveys from 27 countries. These surveys included 1,001,573 female and male participants, 89% from DHS/AIS. Among these, 181,436 men and 422,239 women were cohabiting at the time of the survey. Linking female with male datasets resulted in 157,321 partnerships. Thus, 87% (157,321/181,436) of men were successfully matched to their female partner. Among these couples, 111,659 had been randomly selected for the IPV module and included as the final dataset (Figure 5.1). Since the IPV module was administered to only one randomly selected woman in the household, men in polygynous partnerships were linked to the partner who participated in the IPV module. HIV biomarkers were collected in all five PHIA and 70% (30/43) of DHS surveys; hence 79,325 partnerships were included in HIV analyses. Ten countries had more than one survey. The median year of data collection was 2013. Most surveys were from Eastern Africa (54%) and the least from Southern Africa (6%).

*Characteristics of the study population*

Overall, 21% of women reported that their male partners had perpetrated IPV in the past year, ranging from 25% in Central Africa to 6% in Southern Africa (Table C in S1 Text). Men who perpetrated past-year IPV, and their female partners who experienced it, were younger, more likely to have only primary education, and were less wealthy compared to those who did not (Table 5.1). Among couples where men were reported to perpetrate IPV, women were less likely to have a say in household decision-making (41%) compared to where it was not (47%). Among men who perpetrated IPV, more had accepting attitudes on IPV (34% versus 25%). Men who perpetrated IPV were more likely to consume alcohol "*Often*" (18%) and "*Sometimes*" (29%) compared to those did not (6% and 18%, respectively). Age difference between partners was

comparable between couples where men perpetrated IPV (6.2 years) versus where they did not (6.9 years) (Table 5.1).

Perpetrators of IPV were only slightly more likely to report paying for sex in the past year (3%) compared to non-perpetrators (2%). A higher proportion of perpetrators (21%) had two or more sex partners in the past year compared to non-perpetrators (17%). Women who reported that their partner perpetrated IPV were more likely to have concurrent sex partners (25%) compared to those whose did not (19%). Crude HIV prevalence was comparable between perpetrators (7%) and non-perpetrators of IPV (7%) (Table 5.1).

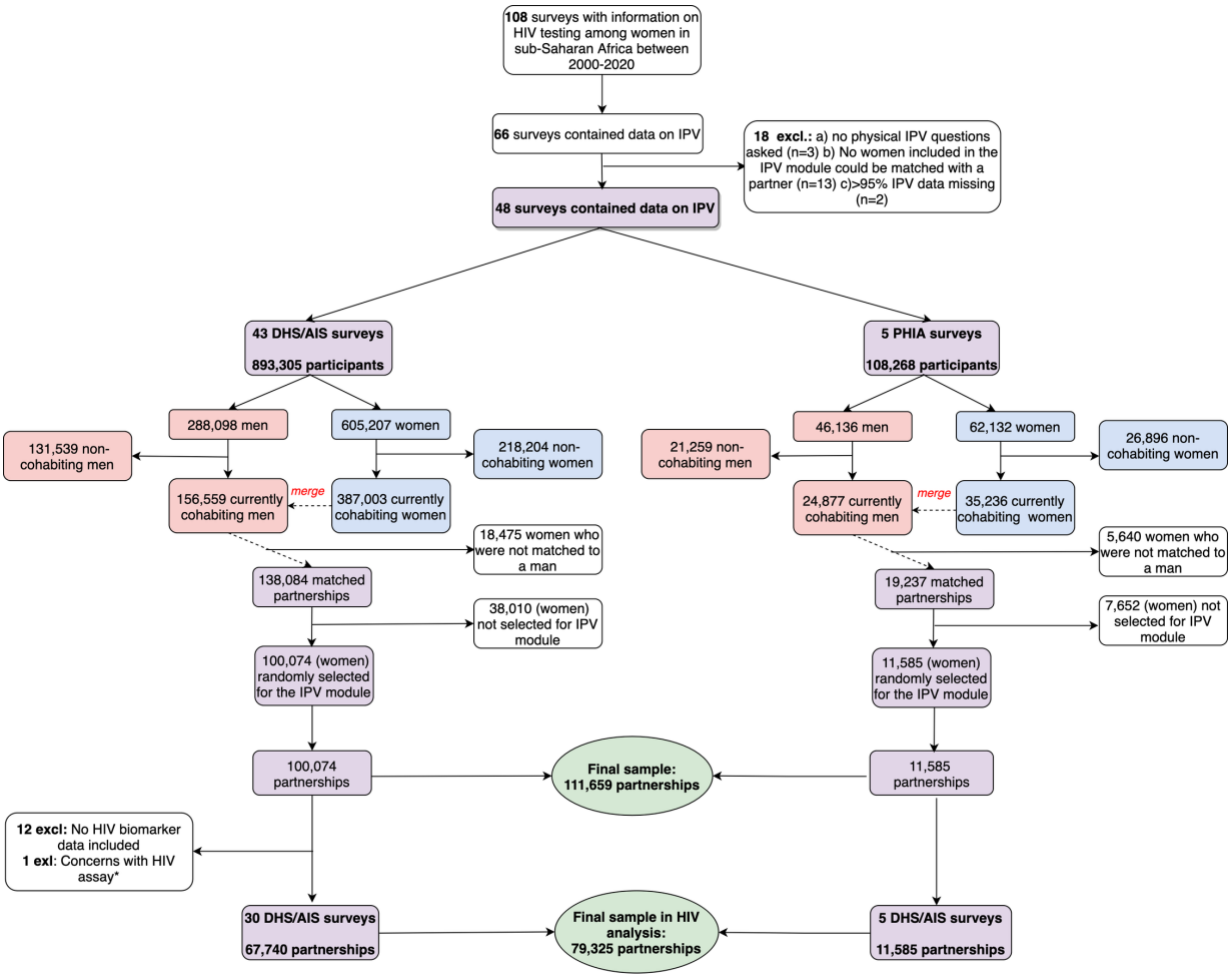


**Figure 5.1. A flowchart describing the steps taken to create the final, analytical sample of cohabiting couples and the number of individuals included in the HIV analyses from each survey type.**

**The Zambia 2013-14 DHS was excluded from the analyses of HIV seropositivity due to concern about the reliability of the HIV testing algorithm assay.* (AIS=AIDS Indicator Survey; DHS=Demographic and Health Survey; Excl.=excluded; IPV=intimate partner violence; PHIA=Population-based HIV Impact Assessment Survey.)

**Table 5.1.** Summary of individual and partnership-level characteristics among men and women who are currently cohabiting, stratified by perpetration or experience of past-year physical and/or sexual intimate partner violence (IPV).

| | | Past year physical and/or sexual IPV, n(%) | | | |
|---|---|---|---|---|---|
| | | **Male** | | **Female** | |
| | **$N_{survey}$** | **Yes ($N_{ind}$=23,777)** | **No ($N_{ind}$=86,596)** | **Yes ($N_{ind}$=23,777)** | **No ($N_{ind}$=86,596)** |
| **Demographic characteristics, n (%)** | | | | | |
| **Age, n (%)** | **48** | | | | |
| 15-24 years | | 1,745 (7.3 %) | 5,490 (6.3 %) | 6,638 (27.9 %) | 23,288 (26.9 %) |
| 25-34 years | | 9,719 (40.9 %) | 30,527 (35.3 %) | 10,943 (46.0 %) | 37,059 (42.8 %) |
| 35-44 years | | 7,976 (33.5 %) | 29,942 (34.6 %) | 5,105 (21.5 %) | 20,347 (23.5 %) |
| 45-64 years | | 4,329 (18.2 %) | 20,106 (23.2 %) | 1,089 (4.6 %) | 5,674 (6.6 %) |
| 65+ years | | 8 (0.0 %) | 531 (0.6 %) | 2 (0.0 %) | 228 (0.3 %) |
| *(Missing)* | | 0 (0 %) | 0 (0 %) | 0 (0 %) | 0 (0 %) |
| **Education, n (%)** | **48** | | | | |
| None | | 4,788 (20.1 %) | 21,158 (24.4 %) | 6,705 (28.2 %) | 28,813 (33.3 %) |
| Primary | | 10,191 (42.9 %) | 31,181 (36.0 %) | 11,062 (46.5 %) | 32,516 (37.5 %) |
| Secondary | | 7,697 (32.4 %) | 26,995 (31.2 %) | 5,594 (23.5 %) | 21,631 (25.0 %) |
| Higher | | 1,100 (4.6 %) | 7,245 (8.4 %) | 412 (1.7 %) | 3,626 (4.2 %) |
| *(Missing)* | | 1 (0.0 %) | 17 (0.0 %) | 4 (0.0 %) | 10 (0.0 %) |
| **Recent employment, n (%)** | **48** | | | | |
| Employed | | 22,665 (95.3 %) | 78,603 (90.8 %) | 16,751 (70.5 %) | 52,736 (60.9 %) |
| Unemployed | | 1,108 (4.7 %) | 7,972 (9.2 %) | 7,021 (29.5 %) | 33,836 (39.1 %) |
| *(Missing)* | | 4 (0.0 %) | 21 (0.0 %) | 5 (0.0 %) | 24 (0.0 %) |
| **Household characteristics, n (%)** | | **Yes ($N_{ind}$=23,777)** | | **No ($N_{ind}$=86,596)** | |
| **Wealth quintile, n (%)**** | **48** | | | | |
| Lowest | | 5,531 (23.3 %) | | 18,970 (21.9 %) | |
| Second lowest | | 5,380 (22.6 %) | | 18,161 (21.0 %) | |
| Middle | | 5,064 (21.3 %) | | 17,213 (19.9 %) | |
| Second highest | | 4,626 (19.5 %) | | 16,417 (19.0 %) | |
| Highest | | 3,176 (13.4 %) | | 15,815 (18.3 %) | |
| *(Missing)* | | 0 (0.0 %) | | 20 (0.0 %) | |
| **Residence type, n (%)**** | **48** | | | | |
| Rural | | 17,049 (71.7 %) | | 60,504 (69.9 %) | |
| Urban | | 6,728 (28.3 %) | | 26,092 (30.1 %) | |
| *(Missing)* | | 0 (0%) | | 0 (0%) | |
| **HIV and behavioral risk factors, n (%)** | | | | | |
| **HIV prevalence, n (%)** | **35** | **Yes ($N_{ind}$=16,364)** | **No ($N_{ind}$=55,745)** | **Yes ($N_{ind}$=16,364)** | **No ($N_{ind}$=55,745)** |
| Yes | | 1,137 (6.9%) | 4,082 (7.3%) | 1,221 (7.5%) | 4,115 (7.4%) |
| No | | 13,666 (83.5%) | 46,267 (83.0%) | 14,146 (86.4%) | 47,749 (85.7%) |
| *(Missing)* | | 1,561 (9.5%) | 5,396 (9.7%) | 997 (6.1%) | 3,881 (7.0%)0 |
| **Condom use at last sex with most recent partner in the past 12 months, n (%)** | **48** | **Yes ($N_{ind}$=23,777)** | **No ($N_{ind}$=86,596)** | **Yes ($N_{ind}$=23,777)** | **No ($N_{ind}$=86,596)** |
| Yes | | 1,977 (8.3%) | 6,856 (7.9%) | 1,102 (4.6%) | 4,238 (4.9%) |
| No | | 21,241 (89.3%) | 76,409 (88.2%) | 21,848 (91.9%) | 78,473 (90.6%) |

| | | | | | |
|---|---|---|---|---|---|
| *(Missing)* | | 559 (2.4%) | 3,331 (3.8%) | 827 (3.5%) | 3,885 (4.5%) |
| **Number of sex partners in the past 12 months, n (%)** | **47** | **Yes ($N_{ind}$=23,391)** | **No ($N_{ind}$=85,704)** | **Yes ($N_{ind}$=23,391)** | **No ($N_{ind}$=85,704)** |
| 1 | | 18,411 (78.7%) | 70,465 (82.2%) | 22,920 (98.0%) | 84,494 (98.6%) |
| 2+ | | 4,809 (20.6%) | 14,260 (16.6%) | 357 (1.5%) | 582 (0.7%) |
| *(Missing)* | | 171 (0.7%) | 979 (1.1%) | 114 (0.5%) | 628 (0.7%) |
| **Point prevalence of concurrency,¤ n (%)** | **47** | **Yes ($N_{ind}$=4,809)** | **Yes ($N_{ind}$=14,260)** | **Yes ($N_{ind}$=357)** | **Yes ($N_{ind}$=582)** |
| Yes | | 1,878 (39.1%) | 6,771 (47.5%) | 89 (24.9%) | 113 (19.4%) |
| No | | 2,931 (60.9%) | 7,489 (52.5%) | 268 (75.1%) | 469 (80.6%) |
| *(Missing)* | | 0 (0.0 %) | (0.0 %) | (0.0 %) | (0.0 %) |
| **Male payment for sex in past 12 months, n (%)*** | **43** | **Yes ($N_{ind}$=22,216)** | **No ($N_{ind}$=81,929)** | | |
| Yes | | 621 (2.8%) | 1,592 (1.9%) | - | - |
| No | | 21,276 (95.8%) | 78,001 (95.2%) | - | - |
| *(Missing)* | | 319 (1.4%) | 2,336 (2.9%) | - | - |
| **Male individual predictors of IPV, n (%)** | | | | | |
| **Man has more than one cohabiting partner, n (%)** | **48** | **Yes ($N_{ind}$=23,777)** | **No ($N_{ind}$=86,596)** | | |
| Yes | | 2,974 (12.5 %) | 10,580 (12.2 %) | - | - |
| No | | 20,791 (87.4 %) | 75,986 (87.7 %) | - | - |
| *(Missing)* | | 12 (0.1 %) | 30 (0.0 %) | - | - |
| **Male accepting attitudes on IPV, n (%)‡** | **43** | **Yes ($N_{ind}$=23,093)** | **No ($N_{ind}$=77,549)** | - | - |
| Yes | | 7,758 (33.6 %) | 18,982 (24.5 %) | - | - |
| No | | 15,066 (65.2 %) | 57,646 (74.3 %) | - | - |
| *(Missing)* | | 269 (1.2 %) | 921 (1.2 %) | - | - |
| **Male alcohol use frequency, n (%)§** | **46** | **Yes ($N_{ind}$=22,480)** | **No ($N_{ind}$=84,834)** | - | - |
| Never | | 11,744 (52.2 %) | 62,948 (74.2 %) | - | - |
| Sometimes | | 6,619 (29.4 %) | 15,574 (18.4 %) | - | - |
| Often | | 4,063 (18.1 %) | 4,814 (5.7 %) | - | - |
| *(Missing)* | | 54 (0.2 %) | 1,498 (1.8 %) | - | - |
| **Partnership predictors of IPV** | | | | | |
| **Couple earning disparity, n (%)**** | **43** | **Yes ($N_{ind}$=23,229)** | | **No ($N_{ind}$=76,026)** | |
| Woman less than man | | 7,303 (31.4 %) | | 24,620 (32.4 %) | |
| About the same | | 1,362 (5.9 %) | | 4,097 (5.4 %) | |
| Woman more than man | | 966 (4.2 %) | | 2,471 (3.3 %) | |
| Woman not received cash earnings in the past year | | 12,630 (54.4 %) | | 41,602 (54.7 %) | |
| *(Missing)* | | 968 (4.2 %) | | 3,236 (4.3 %) | |
| **Couple age disparity, mean(sd)**** | **48** | 6.19 (5.48) | | 6.94 (5.66) | |
| **Woman has a say in household decision-making, n (%)†**** | **48** | **Yes ($N_{ind}$=23,777)** | | **No ($N_{ind}$=86,596)** | |

| | | | |
|---|---|---|---|
| Yes | | 9,779 (41.1 %) | 40,244 (46.5 %) |
| No | | 13,977 (58.8 %) | 46,264 (53.4 %) |
| *(Missing)* | | 21 (0.1 %) | 88 (0.1 %) |
| **Household head, n (%)**** | **48** | **Yes ($N_{ind}$=23,777)** | **No ($N_{ind}$=86,596)** |
| Female | | 1,114 (4.7 %) | 4,480 (5.2 %) |
| Male | | 22,663 (95.3 %) | 82,116 (94.8 %) |

*IPV = Intimate Partner Violence; $N_{survey}$ = Number of surveys; $N_{ind}$ = Number of individuals; sd = standard deviation.*

† In PHIA surveys the indicator on household decision making is comprised of two variables: *healthcare decision making* and *decision making on household spending*. To harmonize the definitions between PHIA and DHS (comprised of *healthcare decision making*, *decision making on visits to family/relatives* and *decision making on large household purchases*), we removed *household spending* from the definition of the composite covariate in PHIA surveys. Thus, in PHIA the indicator on household decision making is only reflective of women's *healthcare decision-making*.

‡ In PHIA surveys included in this analysis, the definition of "accepting attitudes on IPV" indicator does not include a question on whether they agree or disagree that *wife-beating is justified if wife burns food.*

§ The denominator for Zimbabwe DHS 2005 survey includes only women who had ever experienced IPV, hence those who had not, would be coded as missing. Furthermore, in PHIA surveys this question is asked to the individual respondents (both men and women) while it is asked to women in reference to their male partner in DHS surveys.

¤ Denominator includes women and men who had two or more sexual partners in the past year. Study sample in Gambia 2013 DHS survey included women who only had one or no sex partners in the past year which is why this survey was not included for concurrency summary estimate among women. This explains different denominators among men and women.

* Not collected in the women's survey

** Partnership/household level characteristics, thus the same for both men and women

### *Variables correlated with past-year physical and/or sexual intimate partner violence perpetration*

In adjusted analyses, male accepting attitudes on IPV (aPR=1.24; 95%CI: 1.21-1.27), frequent alcohol use (aPR=2.90; 95%CI: 2.81-2.99), and being in a polygynous partnership (aPR=1.17; 95%CI: 1.13-1.21) were associated with IPV perpetration in the past year (Table 5.2).

In partnerships where women earned more than men, women were 12% more likely to report experiencing IPV (aPR=1.12; 95%CI: 1.06-1.18), though when women had decision-making power in the household, men were less likely to perpetrate IPV (aPR=0.82; 95%CI: 0.80-0.84). In households headed by women, IPV perpetration was 4% lower compared to those headed by men (aPR=0.96; 95%CI: 0.91-1.01). Generally, these results were consistent in the region-stratified analysis; though in Western Africa, men in female-headed households were less likely to perpetrate IPV, and in Central Africa earning disparity was not associated with IPV perpetration (Table D-G in S1 Text).

**Table 5.2.** Crude and adjusted prevalence ratios of the association between partnership and male individual characteristics and perpetration of past year physical and/or sexual intimate partner violence.

| Partnership characteristics | $N_{survey}$ | $N_{ind}$ | Crude prevalence ratio (95%CI) | Adjusted prevalence ratio (95%CI)† |
|---|---|---|---|---|
| **Couple earning disparity** | 43 | 95,051 | | |
| Less than him | | | Referent | Referent |
| Same | | | 0.98 (0.93, 1.04) | 0.89 (0.84, 0.93) |
| More than him | | | 1.14 (1.07, 1.21) | 1.12 (1.06, 1.18) |
| Woman not paid in cash/kind | | | 0.98 (0.96, 1.01) | 0.91 (0.89, 0.94) |
| **Couple age disparity** | 48 | 110,373 | 0.99 (0.99, 0.99) | 1.00 (1.00, 1.00) |
| **Woman has a say in household decision-making** | 48 | 110,264 | | |
| Yes | | | 0.78 (0.76, 0.80) | 0.82 (0.80, 0.84) |
| No | | | Referent | Referent |
| **Household head** | 48 | 110,373 | | |
| Female | | | 0.87 (0.82, 0.93) | 0.96 (0.91, 1.01) |
| Male | | | Referent | Referent |
| **Partnership predictors of IPV** | | | | |
| **Male accepting attitudes on IPV** | 43 | 99,452 | | |
| Yes | | | 1.33 (1.3, 1.37) | 1.24 (1.21, 1.27) |
| No | | | Referent | Referent |
| **Man has more than one wife/cohabiting partner** | 48 | 110,331 | | |
| Yes | | | 1.11 (1.07, 1.15) | 1.17 (1.13, 1.21) |
| No | | | Referent | Referent |
| **Male alcohol use frequency** | | | | |
| Never | 46 | 105,762 | Referent | Referent |
| Sometimes | | | 1.80 (1.74, 1.85) | 1.77 (1.72, 1.82) |
| Often | | | 2.81 (2.72, 2.90) | 2.90 (2.81, 2.99) |

*IPV= intimate partner violence; $N_{ind}$ = Number of individuals in the adjusted analyses; $N_{survey}$ = Number of surveys in the adjusted analyses; PR = Prevalence Ratio.*

† All models are adjusted for male age (five-year age groups), male education (none, primary, secondary, higher), wealth quantile, residence type (rural, urban), survey identifier.

*Association of past-year physical and/or sexual intimate partner violence with men's sexual behaviors and HIV seropositivity*

After adjustments, men who perpetrated IPV in the past year were 37% more likely to have paid for sex in the past year (aPR=1.37; 95%CI: 1.25-1.51) and 26% more likely to have had two or more sexual partners in the past year (aPR=1.26; 95%CI: 1.22-1.29). Men who perpetrated IPV were 9% (aPR=1.09; 95%CI: 1.01-1.16) more likely to be living with HIV (Table 5.3).

Heterogeneity of the crude PRs across surveys were small for concurrency ($I^2$=8%; Fig E in S1 Text) and HIV status ($I^2$=15%; Fig D in S1 Text) moderate for payment for sex ($I^2$=27%; Fig B in S1 Text) and men's past year condom use ($I^2$=43%; Fig A in S1 Text); and high for number of sex partners ($I^2$=66%; Fig C in S1 Text). In sensitivity analyses we found that survey region and survey year combined explained 78% and 79% of the heterogeneity across studies for the number of sex partners and payment for sex, respectively. Survey regions alone accounted for 67% of heterogeneity for past year condom use.

Our sensitivity analysis (Text 2 in S1 Text) did not indicate a notable impact of selection bias on the association between past year perpetration of IPV and male HIV seroprevalence.

*The role of male-perpetrated physical and/or sexual intimate partner violence in adolescent girls and young women's risk of HIV seroprevalence*

Among AGYW living with HIV, 50% ($N_{ind}$=435/873) of male partners were also HIV seropositive. Crudely, this proportion did not vary by IPV perpetration status. 49% percent ($N_{ind}$=128/261) of male IPV perpetrators were living with HIV, compared to 50% ($N_{ind}$=300/599) to non-perpetrators (Table H in S1 Text).

**Table 5.3:** Crude and adjusted prevalence ratios of the association between past-year perpetration of physical and/or sexual intimate partner violence and behavioral risk factors for HIV acquisition, and HIV seropositivity among male partners.

| Outcome | $N_{survey}$ | $N_{ind}$ | Crude prevalence ratio (95% CI) | Adjusted prevalence ratio (95% CI) |
|---|---|---|---|---|
| **Man living with HIV[§]** | 31 | 53,613 | | |
| Yes | | | 0.94 (0.89, 1) | 1.09 (1.01, 1.16) |
| No | | | Referent | Referent |
| **Male reported condom use at last sex with the most recent partner in past 12 months[¥]** | 48 | 106,452 | 1.00 (0.96, 1.05) | 1.04 (0.99, 1.09) |
| Yes | | | Referent | Referent |
| No | | | | |
| **Male reported number of sex partners in the past 12 months[¥]** | 47 | 107,909 | | |
| 2+ | | | 1.23 (1.2, 1.27) | 1.26 (1.22, 1.29) |
| 1 | | | Referent | Referent |
| **Male reported point-prevalence of concurrency[*¥]** | 47 | 19,066 | | |
| Yes | | | 0.89 (0.86, 0.92) | 1.01 (0.97, 1.04) |
| No | | | Referent | Referent |
| **Male reported payment for sex in the past 12 months[¥]** | 43 | 101,460 | | |
| Yes | | | 1.38 (1.26, 1.52) | 1.37 (1.25, 1.51) |
| No | | | Referent | Referent |

[¥]Adjusted for male age (five-year age groups), wealth quintile, male education (none, primary, secondary, higher), residence type (rural, urban), survey identifier.
[§]Adjusted for male age (five-year age groups), wealth quintile, male education (none, primary, secondary, higher), residence (rural, urban), survey identifier, men's lifetime number of sex partners (1, 2, ≥ 3).
*$N_{ind}$ = Number of individuals in adjusted analyses; $N_{survey}$ = Number of surveys in adjusted analyses.*
*Denominator includes men who had two or more sexual partners in the past year.

Compared to AGYW whose partner was not living with HIV and was not perpetrating IPV, our adjusted effect modification analysis suggests AGYW whose partner was living with HIV had a 26.6% higher risk of being HIV seropositive on an absolute scale (aRD=26.6%; 95%CI: 23.0-30.4%). Compared to the same reference group, AGYW whose male partner perpetrated IPV *in addition to living with HIV* had a 30.1% higher risk of HIV seropositivity (aRD=30.1%; 95%CI: 25.6-34.7%; Figure 5.2, Table I-J Text 1 in S1 Text).

The results from the EMM analyses suggest that the *expected* joint effect of male HIV status and IPV perpetration on AGYW's HIV status was 27 excess women living with HIV per 100. That is, the sum of the unique effects of IPV (0.4%) and male HIV status (26.6%) (Figure 5.2). However, the *observed* joint effect (30.1%) indicates that HIV risk in AGYW whose IPV

perpetrating partner lives with HIV exceeds by 3 cases per 100 women the *expected* joint effect (27.0%) of male HIV status and IPV. This is derived as the difference between expected and observed effects: 30.1% minus 27.0%, and indicates a small additive effect measure modification between IPV perpetration and male HIV seropositivity among AGYW. The RERI was 1.03 (95% CI: 0.99-1.08) indicating an additive EMM. When performing this analysis on all women 15 years or older, we found no added effect of IPV (Table K Text 1 in S1 Text). Further details on these calculations are available in Text 1 in S1 Text.

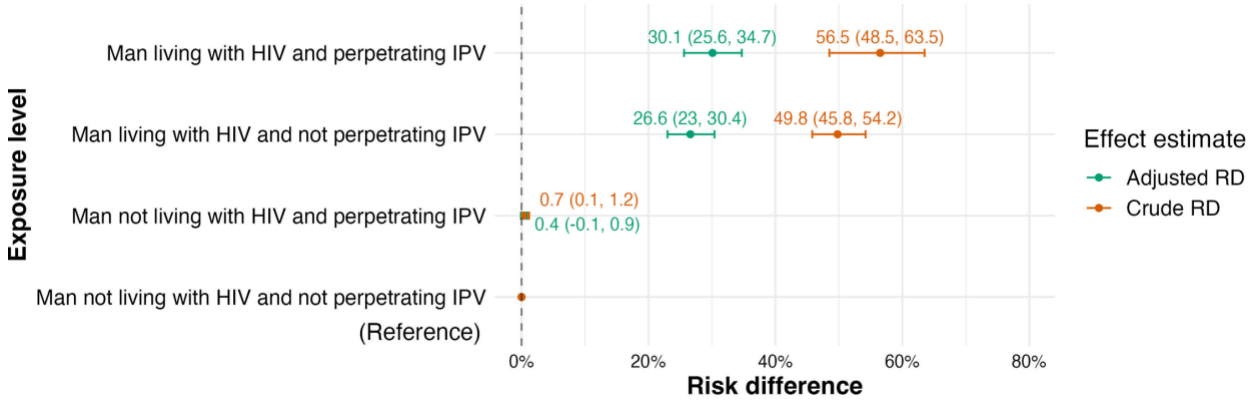


**Figure 5.2:** Unique and joint contributions of male partner HIV status and male partner perpetrated physical and/or sexual intimate partner violence to HIV status among adolescent girls and young women. We present crude and adjusted risk differences. Adjusted for women's age (continuous), wealth quintile, women's education (none, primary, secondary, higher), residence type (rural, urban), women's lifetime number of sexual partners (1, 2, ≥ 3), survey identifier. *IPV = Intimate Partner Violence; RD = Risk Difference.*

Among men living with HIV, a lower proportion of male perpetrators of IPV were on ART (47%; $N_{ind}$=52/111) and virally suppressed (42%; $N_{ind}$=47/111) compared to those who were non-perpetrators (65% for ART [$N_{ind}$=996/1,541] and 60% [$N_{ind}$=919/1,541] for viral suppression, respectively). However, the adjusted analyses of IPV's effects on ART uptake (cPR= 0.73; 95%CI: 0.60-0.89; aPR=0.88; 95%CI: 0.72-1.07; $N_{ind}$=1,595) and viral load suppression (cPR= 0.73; 95%CI: 0.58-0.90; aPR = 0.84; 95%CI: 0.68-1.04; $N_{ind}$=1,594) were imprecise due to the small sample size.

Sensitivity analyses showed that the removal of women who had two or more sex partners in the past year from our analyses did not change our estimates of the contribution of IPV in AGYW's risk of HIV seroprevalence (Table L Text 1 in S1 Text).

**Discussion**

Pooling data on up to 111,600 couples from 48 surveys from 27 countries in Africa, we found that men whose partners reported that they perpetrate IPV were more likely to share behaviors that increased men's risk of HIV acquisition and transmission than those who do not. These men were also more likely to be living with HIV. Further, AGYW whose male partners perpetrated IPV had a small (3%) added risk of living with HIV in addition to the risk entailed solely by their partners' HIV status.

A few factors could explain the small additional risk of living with HIV arising from IPV. First, IPV perpetrators may be less likely to be in HIV care than non-perpetrators and have unsuppressed viral load which can increase HIV transmission risk to their female partners. Previous work has shown that unsuppressed viral load, though not ART interruptions, are more frequent among men who perpetrate IPV in crude analyses.[36] This is aligned with our study, though our sample size was insufficient to precisely estimate the association between men's engagement in care and IPV. Second, IPV could have adverse mental health effects on women which can influence subsequent sexual behaviors, such as concurrency, substance use during sex and participation in transactional sex.[14] Our crude analysis found that among all women who have experienced past-year IPV, more had concurrent sex partners (though we did not explore the directionality of this relationship). Third, type of sex act, information which was not available in our surveys, could explain the IPV-HIV relationship among women. Coerced sex may lead to frequent anal intercourse[37,38], often more common in IPV perpetrators[13], and mucosal lesions

which increase women's risk of HIV acquisition.[39] Among all women, IPV did not add to the risk of HIV seropositivity beyond the one resulting from male partners' HIV status. This could be explained by the overall lower HIV incidence in older women and declining prevalence of past year IPV with age.[1]

Our results align with previous research showing that IPV perpetrators are more likely to engage in sexual behaviors that increase their HIV acquisition risk and may be more likely to be living with HIV.[19,40] Previous work has suggested that IPV perpetration and behaviors increasing men's HIV risk could have a common root in a unifying ideal of masculinity which emphasizes heterosexual performance and dominance over women.[41,42] The latter is compatible with our analysis of the correlates of IPV perpetration, where we show that variables reflecting women's power within the relationship are correlated with IPV perpetration. Women who have a decision-making capacity in the household are less likely to experience IPV. However, women who earn more than their partner were more likely to experience IPV in our sample. Relative resource theory posits that when women are socioeconomically favored compared to their partner, they are at a higher risk of IPV as this goes against the traditional gender norms and can be perceived to threaten the male role.[43-45] Also, economic empowerment has been previously linked with increased sexual autonomy in women, including the ability to refuse sex, or to negotiate condom use while having sex. [46,47] While more sexual agency would reduce women's HIV risk, it might prompt further IPV, as shown in previous work.[48,49]

Finally, male accepting attitudes on IPV as well as frequent alcohol use were also correlated with IPV perpetration.[50] These factors diminish women's ability to control the timing of and circumstances around sex, especially during adolescence and youth, which could contribute to the spike in the risk of HIV acquisition among AGYW, as suggested by our results. Our findings align with previous work suggesting men's rationalization of IPV may increase the risk of IPV perpetration, and is linked with gender norms around masculinity and female subordination.[51]

Our results should be interpreted considering their limitations. First, we assumed that the male partners of women who reported past-year IPV and are currently in a partnership, were the perpetrators of IPV. This is especially relevant given the reported discordance between cohabiting couple's reports of violence.[52] Due to the challenges of gathering accurate information from men about their enactment of this type of violence[53], we believe this is the

most accurate measure of IPV perpetration. Previous studies have also used this method to identify perpetrators of IPV.[13,54] Further, while both men and women might underreport IPV, men tend to underreport both victimization and perpetration more frequently compared to women.[52,55] Finally, only 0.7% of women in our sample had two or more sex partners in the past year and the removal of this group in the sensitivity analyses did not change our results. Second, we used HIV seropositivity data which makes it difficult to identify the direction and timing of HIV acquisition/transmission in the analysis of male HIV seropositivity. It remains possible that men acquired HIV from their female partners as opposed to outside this relationship, which could subsequently result in IPV. However, since men's sexual behaviors pointed towards their higher HIV acquisition risk among IPV perpetrators compared to non-perpetrators, this is less likely. Third, in our analysis that uncovers IPV's role as an effect modifier, IPV could have taken place after women's HIV acquisition. This risk was reduced by restricting our analysis to younger women. Still, bias remains possible since we are not able to precisely disentangle the temporality between IPV and HIV. Similarly, the relationship between the IPV and male behaviors could be bidirectional; for example, alcohol consumption has been found to be associated with IPV.[50] However, our analysis is restricted to male sexual behaviors which are more likely to be subsequent to IPV given the underlying gender attitudes. Fourth, IPV and sexual behaviors were self-reported and might be subject to under-reporting due to their sensitive nature, which could dilute the association between the two.[70] However, the surveys took measures to ensure confidentiality; for example DHS does not administer the survey unless complete privacy is achieved.[56,57] Additionally only one participant per household (per fraction of households in some DHS surveys) was selected for the domestic violence module such that other household members were not aware of what was being discussed during the interview.[56,57] Fifth, heterogeneity of effect size measures across surveys in univariate analyses was sometimes moderate to high, depending on the outcome. However, controlling for survey-level fixed effects helps account for measured and unmeasured differences by country and survey year and our subgroup analyses suggest that region and survey year accounted for a notable part of this heterogeneity.

Our study also has several strengths. First, we conducted a comprehensive analysis of the HIV status of male partners, their engagement in HIV care and sexual behaviors to elucidate the pathways between IPV and women's HIV acquisition. Second, our large sample size of

cohabiting male-female dyads from population-based surveys, which includes detailed information on more than 111,600 couples, allowed us to estimate IPV's added effect on women's absolute risk of living with HIV. Finally, we conducted a multitude of sensitivity analyses to ensure the robustness of our results.

Ending IPV may not single-handedly eliminate HIV acquisition in women since the added risk of living with HIV due to IPV, beyond the risk entailed solely in their partners' HIV status could be small. Still, experiencing IPV adds to AGYW's risk of living with HIV, which demonstrates the mutually reinforcing effects of HIV/IPV and the importance of addressing both issues simultaneously. Women's empowerment-based HIV/IPV prevention interventions are crucial and should focus on AGYW, who are at the highest risk of both IPV and HIV acquisition. [58]. The UNGA Political Declaration on HIV/AIDS commits to the delivery of integrated services for HIV prevention, focused on strengthening economic independence, sexual agency and challenging gender stereotypes[58]. Meaningful involvement of both men and women in the development of these multi-pronged services tailored to the needs of women of all ages is important to develop effective approaches for IPV prevention.[59] Community-based efforts that foster women's agency and combat negative social norms in men may be key in dislodging the well-established gender inequalities driving both IPV and HIV.[59] However, gender-based discrimination in social norms, practices and laws varies widely across the countries included in our study. [60] These local and regional variations should be accounted for in the development of services for HIV and IPV prevention. So far, existing population-based surveys have understandably focused on women and their reported experience of IPV. Despite the methodological challenges with gathering information from and about men on their own use of violence, collecting data on IPV perpetrators is crucial to devise methods for IPV and HIV prevention in women. Longitudinal studies are needed to further disentangle causal pathways between male-perpetrated IPV and HIV acquisition in women, to subsequently inform IPV and HIV prevention interventions. Violence beyond IPV, such as non-partner sexual violence and violence among transactional relationships are equally concerning and have implications for HIV acquisition risk. The impacts of violence and HIV are profound and have long-lasting effects on the well-being of millions of women and girls globally. Actions to eliminate violence and end AIDS must be accelerated.

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**Data Availability:** Deidentified participant data used in the study can be made available for investigators who submit an abstract and a data analysis plan to each platform (Demographic and Health Surveys, https://dhsprogram.com/data/; Population-based HIV Impact Assessment, https://phia-data.icap.columbia.edu/datasets). Users are required to create an account and make a data request to gain access. Analysis code that supports the findings are available at https://github.com/pop-health-mod/IPV_HIV/tree/main.

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## 5.4 Manuscript 2: Supplementary materials

**Table A in S1 Text.** Operational definitions of past year physical and/or sexual intimate partner violence and indicators most frequently used in surveys included in this analysis.

| | Questions used to define the measures in DHS[¥§] | Questions used to define the measures in PHIA |
|---|---|---|
| **Past year physical and/or sexual IPV** | Did your (last) (husband/partner) ever do any of the following things to you?<br>If the respondent answers "Yes":<br>How often did this happen during the last 12 months: often, only sometimes, or not at all?<br>*Physical violence*<br>● Push you, shake you, or throw something at you?<br>● Slap you?<br>● Punch you with his fist or with something that could hurt you?<br>● Kick you, drag you, or beat you up?<br>● Choke you or burn you on purpose ?<br>● Threaten or attack you with a knife, gun, or other weapon?<br>*Sexual violence*<br>● Physically force you to have sexual intercourse with him when you did not want to?<br>● Physically force you to perform any other sexual acts you did not want to?<br>● Force you with threats or in any other way to perform sexual acts you did not want to? | In the past 12 months, did a partner do any of these things to you? By partner, I mean a life-in partner, whether or not you were married at the time.<br>*Physical violence*<br>● Slapped you, threw something at you that could hurt you, pushed you or shoved you?<br>● Punched, kicked, whipped, or beat you with an object?<br>● Choked smothered, tried to drown you, or burned you intentionally?<br>● Used or threatened you with a knife, gun or other weapon?<br>*Sexual violence*<br>● In the past 12 months, did a partner physically force you to have sex?<br>● In the past 12 months, did a partner pressure you to have sex and did succeed? |

§ Question "(Does/did) your (last) husband/partner ever twist your arm or pull your hair?" was removed from the definition of past year physical IPV to align the DHS and PHIA definitions.

¥ In $N_s$= 9 DHS surveys "threatening to attack" and "attack" questions were asked as two separate questions.

*DHS=Demographic and Health Survey; IPV=intimate partner violence; PHIA=Population-based HIV Impact Assessment Survey.*

**Table B in S1 Text.** The summary of exposures, outcomes and covariates included in the analyses of each of the three research questions.

| Research question | Exposure(s) | Outcome | Adjustment variables |
|---|---|---|---|
| a) What male partner and partnership-level characteristics are associated with IPV? | Individual<br>• Male accepting attitudes on IPV<br>• Man has more than one wife/cohabiting partner<br>• Male alcohol use frequency<br>Partnership<br>• Couple age disparity<br>• Couple earning disparity<br>• Women has a say in household decision-making<br>• Household headship (male/female) | Perpetration of physical and/or sexual IPV in the past 12 months | Male age (five-year age group), household wealth quintile, male education (none, primary, secondary, higher) residence type (rural, urban), survey identifier. |
| b) Are men who are reported to perpetrate IPV more likely to report behaviors that increase their risk of HIV acquisition and to be living with HIV? | Perpetration of physical and/or sexual IPV in the past 12 months | Condom use at last sex with the most recent partner in the last 12 months | Male age (five-year age group), household wealth quintile, male education (none, primary, secondary, higher) residence type (rural, urban), and survey identifier |
| | | Number of sex partners in the past 12 months | |
| | | Male reported point-prevalence of concurrency (having more than one sexual partnership at a single point in time six months before the interview) | |
| | | Payment for sex in the past 12 months | |
| | | Male HIV status | Male age (five-year age group), household wealth quintile, male education (none, primary, secondary, higher) residence type (rural, urban), men's lifetime sex partners (1, 2, ≥ 3), survey identifier. |
| c) Does experiencing IPV increase young women's risk of living with HIV, beyond the risk entailed by their male partner's HIV status? | Male HIV status | Female HIV status | Female age (five-year age group or continuous), household wealth quintile, female education (none, primary, secondary, higher) residence type (rural, urban), women's lifetime sex partners (1, 2, ≥ 3), survey identifier, and a product term between |

| | | | |
|---|---|---|---|
| | | | male HIV status and past year IPV perpetration |

*ART= antiretroviral treatment; IPV = intimate partner violence; VLS= viral load suppression; ELISA = enzyme-linked immunosorbent assay.*

**Table C in S1 Text.** Distribution of past year physical and/or sexual intimate partner violence (IPV) stratified by surveys and regions.

| Country | Survey year | Survey type | Total sample size | Past year physical and/or sexual IPV, N (%) |
|---|---|---|---|---|
| **Overall** | | | 111,659 | 23,777 (21.3) |
| **Central Africa** | | | | |
| Angola | 2015 | DHS | 2,034 | 532 (26.2%) |
| Cameroon | 2018 | DHS | 904 | 207 (22.9%) |
| Gabon | 2012 | DHS | 1,513 | 512 (33.8%) |
| Sao Tome and Principe | 2008 | DHS | 823 | 250 (30.4%) |
| Tchad | 2014 | DHS | 2,350 | 375 (16.0%) |
| **Total** | | | 7,624 | 1,876 (24.6) |
| **Western Africa** | | | | |
| Burkina Faso | 2010 | DHS | 3,728 | 388 (10.4%) |
| Cote d'Ivoire | 2012 | DHS | 1,574 | 352 (22.4%) |
| Ghana | 2008 | DHS | 1,042 | 194 (18.6%) |
| Gambia | 2013 | DHS | 762 | 76 (10.0%) |
| Gambia | 2019 | DHS | 901 | 133 (14.8%) |
| Liberia | 2007 | DHS | 2,235 | 816 (36.5%) |
| Liberia | 2019 | DHS | 1,436 | 530 (36.9%) |
| Mali | 2006 | DHS | 1,935 | 302 (15.6%) |
| Mali | 2012 | DHS | 2,059 | 566 (27.5%) |
| Mali | 2018 | DHS | 2,337 | 479 (20.5%) |
| Nigeria | 2008 | DHS | 6,751 | 966 (14.3%) |
| Nigeria | 2013 | DHS | 6,961 | 778 (11.2%) |
| Nigeria | 2018 | DHS | 6,386 | 947 (14.8%) |
| Sierra Leone | 2019 | DHS | 2,652 | 1,026 (38.7%) |
| Togo | 2013 | DHS | 1,752 | 265 (15.1%) |
| **Total** | | | 42,511 | 7,818 (18.4) |
| **Eastern Africa** | | | | |
| Burundi | 2016 | DHS | 1,481 | 481 (32.5%) |
| Ethiopia | 2016 | DHS | 2,687 | 463 (17.2%) |
| Kenya | 2003 | DHS | 1,190 | 336 (28.2%) |

| | | | | |
|---|---|---|---|---|
| Kenya | 2008 | DHS | 1,251 | 403 (32.2%) |
| Kenya | 2014 | DHS | 2,283 | 582 (25.5%) |
| Comoros | 2012 | DHS | 594 | 24 (4.0%) |
| Malawi | 2004 | DHS | 1,709 | 336 (19.7%) |
| Malawi | 2010 | DHS | 3,365 | 740 (22.0%) |
| Malawi | 2015 | DHS | 3,379 | 823 (24.4%) |
| Malawi | 2015 | PHIA | 3,300 | 166 (5.0%) |
| Mozambique | 2015 | AIS | 1,158 | 170 (14.7%) |
| Rwanda | 2005 | DHS | 1,887 | 425 (22.5%) |
| Rwanda | 2010 | DHS | 2,450 | 1,219 (49.8%) |
| Rwanda | 2015 | DHS | 1,377 | 306 (22.2%) |
| Rwanda | 2019 | DHS | 1,387 | 350 (25.2%) |
| Tanzania | 2010 | DHS | 978 | 296 (30.3%) |
| Tanzania | 2015 | DHS | 1,278 | 386 (30.2%) |
| Uganda | 2016 | PHIA | 613 | 78 (12.7%) |
| Zambia | 2007 | DHS | 2,689 | 1,113 (41.4%) |
| Zambia* | 2013 | DHS | 6,095 | 1,748 (28.7%) |
| Zambia | 2016 | PHIA | 3,205 | 122 (3.8%) |
| Zambia | 2018 | DHS | 4,629 | 1,203 (26%) |
| Zambia | 2005 | DHS | 2,132 | 709 (33.3%) |
| Zimbabwe | 2010 | DHS | 2,479 | 731 (29.5%) |
| Zimbabwe | 2015 | DHS | 2,966 | 638 (21.5%) |
| Zimbabwe | 2015 | PHIA | 3,543 | 154 (4.3%) |
| **Total** | | | 60,105 | 14,002 (23.3%) |
| **Southern Africa** | | | | |
| Eswatini | 2016 | PHIA | 924 | 28 (3.0%) |
| South Africa | 2016 | DHS | 495 | 53 (10.7%) |
| **Total** | | | 1,419 | 81 (5.7%) |

*DHS = Demographic and Health Surveys; IPV=intimate partner violence; PHIA = Population-based HIV Impact Assessment Survey.*

*Removed from the HIV seroprevalence analyses.

**Table D in S1 Text.** Crude and adjusted prevalence ratios of the association between partnership and male individual characteristics and perpetration of past year physical and/or sexual intimate partner violence in Central Africa.

| | $N_{survey}$ | $N_{ind}$ | Crude prevalence ratio (95%CI) | Adjusted prevalence ratio (95%CI)† |
|---|---|---|---|---|
| **Partnership characteristics** | | | | |
| **Couple earning disparity** | 5 | 7,215 | | |
| Less than him | | | Referent | Referent |
| Same | | | 0.88 (0.71, 1.08) | 0.86 (0.7, 1.05) |
| More than him | | | 1.12 (0.91, 1.38) | 1.08 (0.88, 1.31) |
| Woman not paid in cash/kind | | | 0.92 (0.84, 1.01) | 0.93 (0.85, 1.02) |
| **Mean couple age disparity** | 5 | 7,573 | 0.98 (0.97, 0.99) | 0.99 (0.98, 1.00) |
| **Woman has a say in household decision-making** | 5 | 7,551 | | |
| Yes | | | 0.93 (0.85, 1.02) | 0.86 (0.78, 0.94) |
| No | | | Referent | Referent |
| **Household head** | 5 | 7,573 | | |
| Female | | | 1.08 (0.91, 1.29) | 1.01 (0.85, 1.19) |
| Male | | | Referent | Referent |
| **Male individual characteristics** | | | | |
| **Male accepting attitudes on IPV** | 5 | 7,435 | | |
| Yes | | | 1.24 (1.13, 1.35) | 1.26 (1.15, 1.38) |
| No | | | Referent | Referent |
| **Man has more than one wife/cohabiting partner** | 5 | 7,573 | | |
| Yes | | | 0.98 (0.89, 1.09) | 1.18 (1.06, 1.32) |
| No | | | Referent | Referent |
| **Male alcohol use frequency** | | | | |
| Never | 5 | 7,558 | Referent | Referent |
| Sometimes | | | 2.06 (1.85, 2.28) | 1.92 (1.74, 2.13) |
| Often | | | 3.22 (2.93, 3.54) | 3.13 (2.84, 3.45) |

*IPV= intimate partner violence; $N_{ind}$ = Number of individuals in the adjusted analyses; $N_{survey}$ = Number of surveys in the adjusted analyses.*

† All models are adjusted for male age (five-year age groups), male education (none, primary, secondary, higher) wealth quantile, residence type (rural, urban), survey identifier.

**Table E in S1 Text.** Crude and adjusted prevalence ratios of the association between partnership and male individual characteristics and perpetration of past year physical and/or sexual intimate partner violence in Western Africa.

| Partnership characteristics | $N_{survey}$ | $N_{ind}$ | Crude prevalence ratio (95%CI) | Adjusted prevalence ratio (95%CI)† |
|---|---|---|---|---|
| **Couple earning disparity** | 15 | 40,347 | | |
| Less than him | | | Referent | Referent |
| Same | | | 0.94 (0.84, 1.06) | 0.86 (0.77, 0.96) |
| More than him | | | 1.19 (1.06, 1.33) | 1.14 (1.02, 1.27) |
| Woman not paid in cash/kind | | | 1.05 (1.01, 1.10) | 0.95 (0.91, 1.00) |
| **Mean couple age disparity** | 15 | 42,289 | 0.99 (0.99, 1.00) | 1.00 (1.00, 1.01) |
| **Woman has a say in household decision-making** | 15 | 42,229 | | |
| Yes | | | 0.94 (0.89, 0.98) | 0.86 (0.82, 0.90) |
| No | | | Referent | Referent |
| **Household head** | 15 | 42,289 | | |
| Female | | | 1.09 (0.97, 1.23) | 0.89 (0.80, 0.98) |
| Male | | | Referent | Referent |
| **Male individual characteristics** | | | | |
| **Male accepting attitudes on IPV** | 14 | 39,886 | | |
| Yes | | | 1.25 (1.20, 1.31) | 1.21 (1.16, 1.26) |
| No | | | Referent | Referent |
| **Man has more than one wife/cohabiting partner** | 15 | 42,260 | | |
| Yes | | | 1.01 (0.97, 1.06) | 1.10 (1.04, 1.16) |
| No | | | Referent | Referent |
| **Male alcohol use frequency** | | | | |
| Never | 15 | 42,221 | Referent | Referent |
| Sometimes | | | 2.02 (1.92, 2.13) | 2.0 (1.90, 2.11) |
| Often | | | 2.97 (2.79, 3.16) | 2.96 (2.78, 3.16) |

*IPV= intimate partner violence; $N_{ind}$ = Number of individuals in the adjusted analyses; $N_{survey}$ = Number of surveys in the adjusted analyses.*

† All models are adjusted for male age (five-year age groups), male education (none, primary, secondary, higher) wealth quantile, residence type (rural, urban), survey identifier.

**Table F in S1 Text**. Crude and adjusted prevalence ratios of the association between partnership and male individual characteristics and perpetration of past year physical and/or sexual intimate partner violence in Eastern Africa.

| Partnership characteristics | $N_{survey}$ | $N_{ind}$ | Crude prevalence ratio (95%CI) | Adjusted prevalence ratio (95%CI)† |
|---|---|---|---|---|
| **Couple earning disparity** | 22 | 47,023 | | |
| Less than him | | | Referent | Referent |
| Same | | | 0.91 (0.85, 0.97) | 0.88 (0.83, 0.94) |
| More than him | | | 1.02 (0.95, 1.10) | 1.10 (1.02, 1.18) |
| Woman not paid in cash/kind | | | 0.87 (0.84, 0.91) | 0.88 (0.85, 0.91) |
| **Mean couple age disparity** | 26 | 59,486 | 0.99 (0.98, 0.99) | 1.00 (0.99, 1.00) |
| **Woman has a say in household decision-making** | 26 | 59,459 | | |
| Yes | | | 0.68 (0.66, 0.71) | 0.79 (0.76, 0.81) |
| No | | | Referent | Referent |
| **Household head** | 26 | 59,486 | | |
| Female | | | 0.77 (0.71, 0.83) | 0.98 (0.92, 1.05) |
| Male | | | Referent | Referent |
| **Male individual characteristics** | | | | |
| **Male accepting attitudes on IPV** | 23 | 51,641 | | |
| Yes | | | 1.44 (1.39, 1.48) | 1.26 (1.22, 1.3) |
| No | | | Referent | Referent |
| **Man has more than one wife/cohabiting partner** | 26 | 59,473 | | |
| Yes | | | 1.31 (1.24, 1.38) | 1.27 (1.21, 1.33) |
| No | | | Referent | Referent |
| **Male alcohol use frequency** | | | | |
| Never | 24 | 54,962 | Referent | Referent |
| Sometimes | | | 1.71 (1.64, 1.77) | 1.65 (1.60, 1.71) |
| Often | | | 2.72 (2.61, 2.84) | 2.79 (2.69, 2.90) |

*IPV= intimate partner violence; $N_{ind}$ = Number of individuals in the adjusted analyses; $N_{survey}$ = Number of surveys in the adjusted analyses.*

† All models are adjusted for male age (five-year age groups), male education (none, primary, secondary, higher) wealth quantile, residence type (rural, urban), survey identifier.

**Table G in S1 Text.** Crude and adjusted prevalence ratios of the association between partnership and male individual characteristics and perpetration of past year physical and/or sexual intimate partner violence in Southern Africa.

| Partnership characteristics[¥] | $N_{survey}$ | $N_{ind}$ | Crude prevalence ratio (95%CI) | Adjusted prevalence ratio (95%CI)[†] |
|---|---|---|---|---|
| **Mean couple age disparity** | 2 | 1,025 | 0.97 (0.92, 1.02) | 1.00 (0.95, 1.05) |
| **Woman has a say in household decision-making** | 2 | 1,025 | | |
| Yes | | | 0.69 (0.41, 1.15) | 0.66 (0.40, 1.08) |
| No | | | Referent | Referent |
| **Household head** | 2 | 1,025 | | |
| Female | | | 1.08 (0.59, 1.96) | 1.25 (0.70, 2.22) |
| Male | | | Referent | Referent |
| **Male individual characteristics** | | | | |
| **Man has more than one wife/cohabiting partner** | 2 | 1,025 | | |
| Yes | | | 1.25 (0.63, 2.50) | 1.2 (0.58, 2.50) |
| No | | | Referent | Referent |
| **Male alcohol use frequency** | 2 | 1,021 | | |
| Never | | | Referent | Referent |
| Sometimes | | | 1.74 (1.07, 2.83) | 1.74 (1.07, 2.83) |
| Often | | | 2.81 (1.60, 4.94) | 2.63 (1.56, 4.42) |

*IPV= intimate partner violence; $N_{ind}$ = Number of individuals in the adjusted analyses; $N_{survey}$ = Number of surveys in the adjusted analyses.*

† All models are adjusted for male age (five-year age groups), male education (none, primary, secondary, higher) wealth quantile, residence type (rural, urban), survey identifier.

¥ Male accepting attitudes on IPV and couple earning disparity were not collected in Swaziland 2016 PHIA survey; to allow for adjustment by survey identifier these variables were not included in the fully adjusted models.

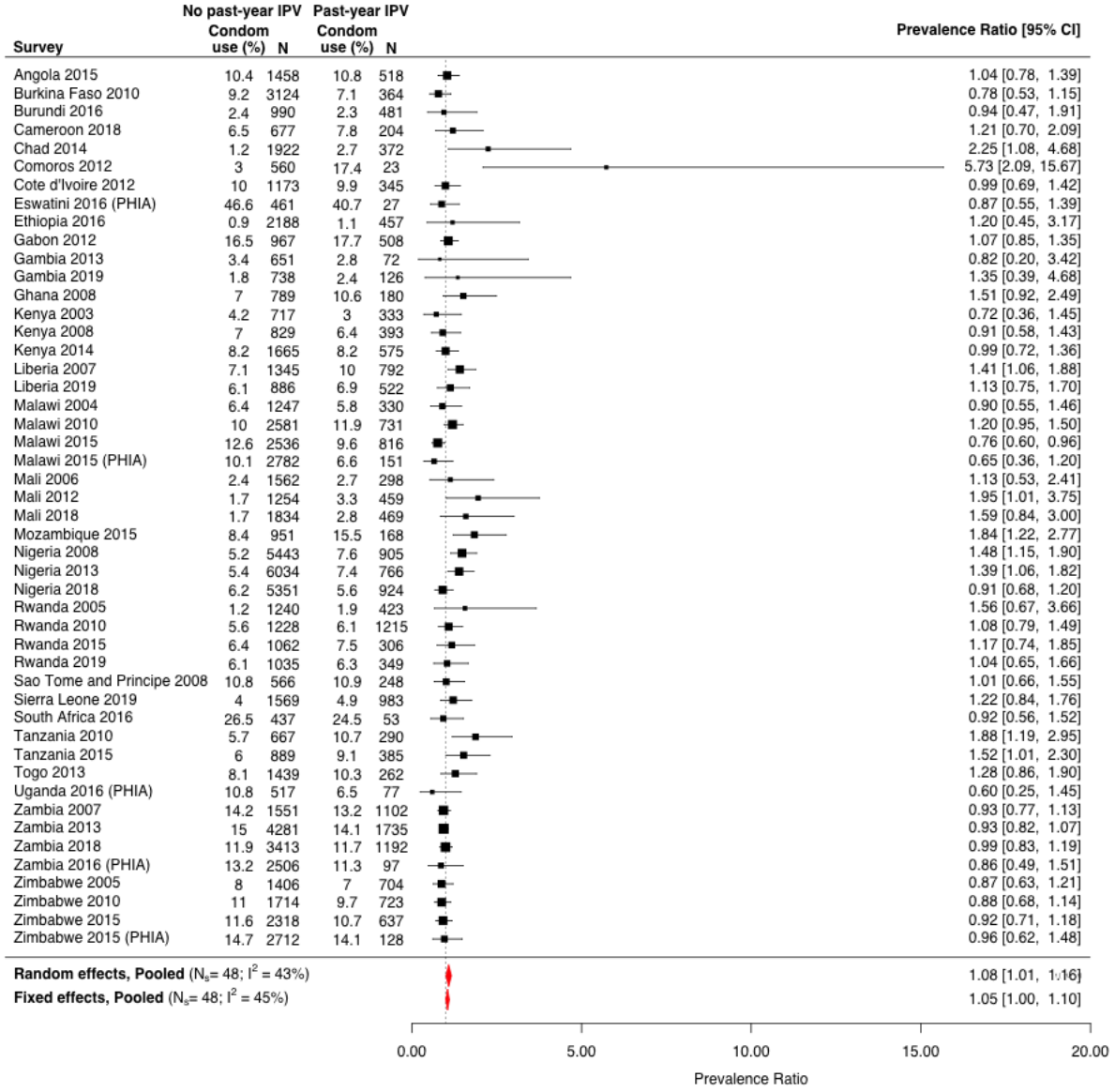


**Figure A in S1 Text.** Survey-specific and pooled crude prevalence ratios (PR) for past year condom use at last sex with the most recent partner among men who had perpetrated past year physical and/or sexual intimate partner violence (IPV) compared to men who had not. Both fixed and random effects pooled estimates are provided. After accounting for the moderating effects of survey region in the random effects analysis, $I^2$= 33%.

95%CI=95% confidence intervals; IPV=intimate partner violence; N= Total number of men who had perpetrated past year IPV or did not perpetrate past year IPV (stratum-specific denominators); $N_s$=number of surveys.

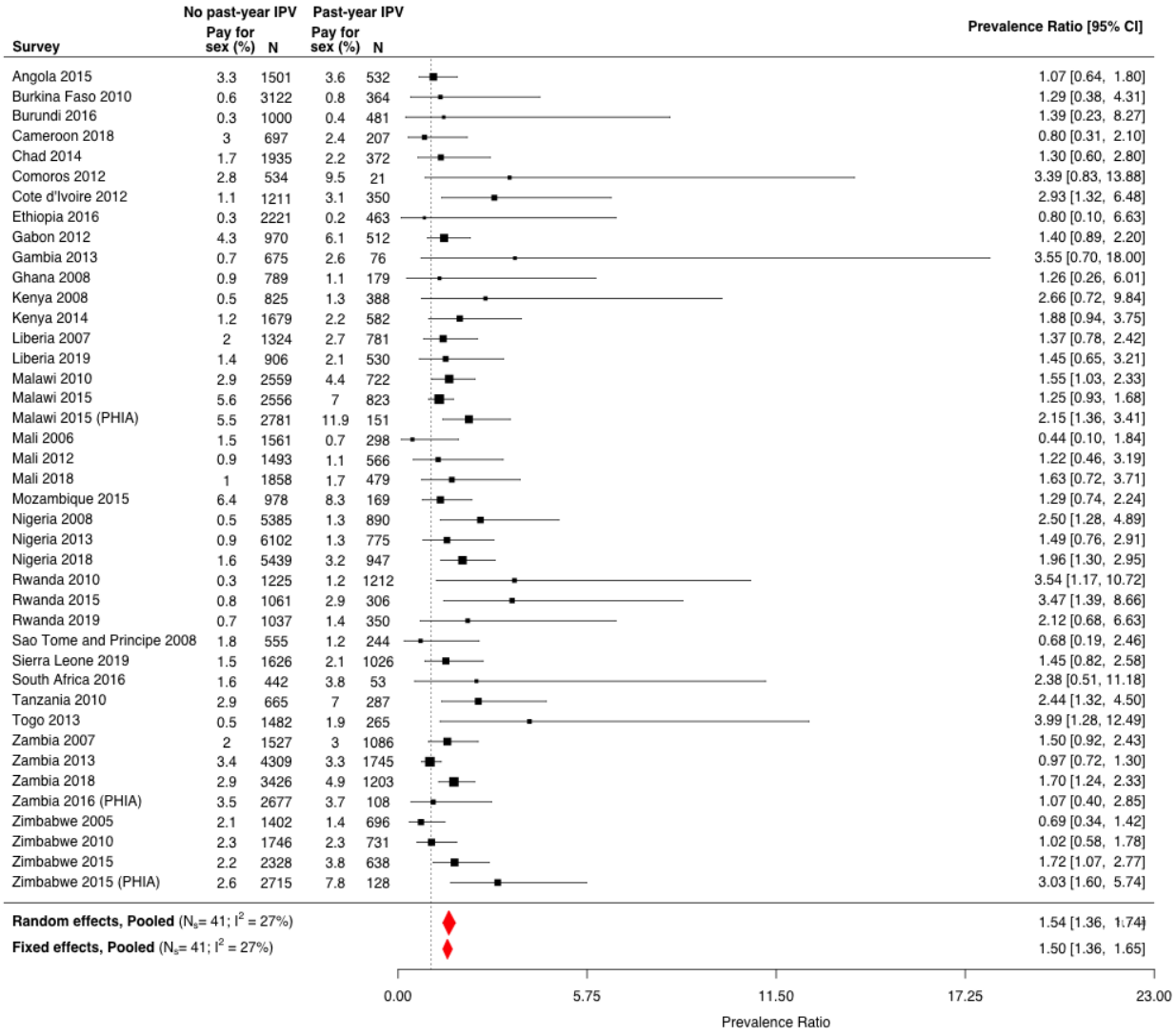


**Figure B in S1 Text.** Survey-specific and pooled crude prevalence ratios (PR) for past year payment for sex among men who had perpetrated past year physical and/or sexual intimate partner violence (IPV) compared to men who had not. Both fixed and random effects pooled estimates are provided. After accounting for the moderating effects of survey region and survey year in the random effects analysis, $I^2$= 21%.

95%CI=95% confidence intervals; IPV=intimate partner violence; N= Total number of men who had perpetrated past year IPV or did not perpetrate past year IPV (stratum-specific denominators); $N_s$=number of surveys.

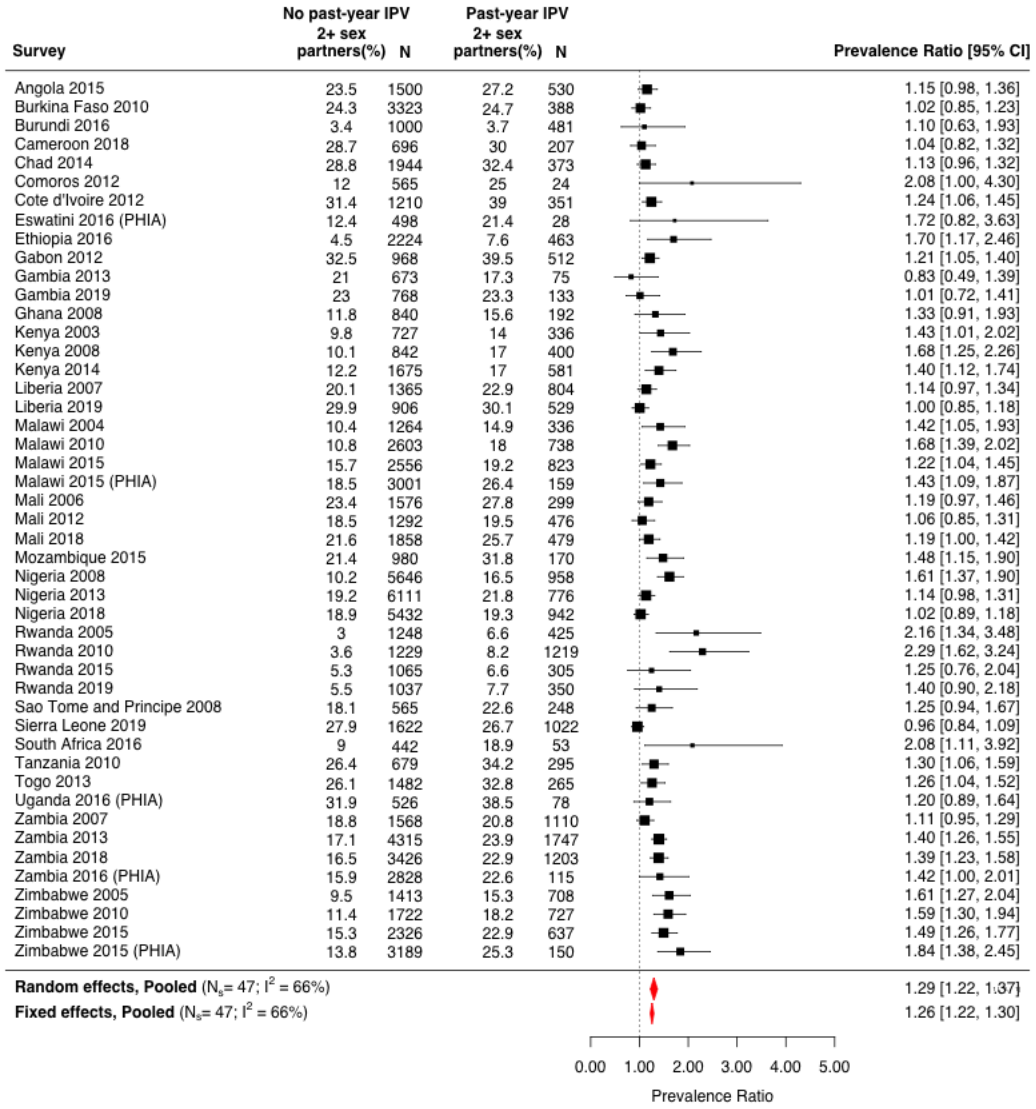


**Figure C in S1 Text.** Survey-specific and pooled crude prevalence ratios (PR) for two or more sex partners in the past year among men who had perpetrated past year physical and/or sexual intimate partner violence (IPV) compared to men who had not. Both fixed and random effects pooled estimates are provided. After accounting for the moderating effects of survey region and survey year in the random effects analysis, $I^2$= 22%.

95%CI=95% confidence intervals; IPV=intimate partner violence; N= Total number of men who had perpetrated past year IPV or did not perpetrate past year IPV (stratum-specific denominators); $N_s$=number of surveys.

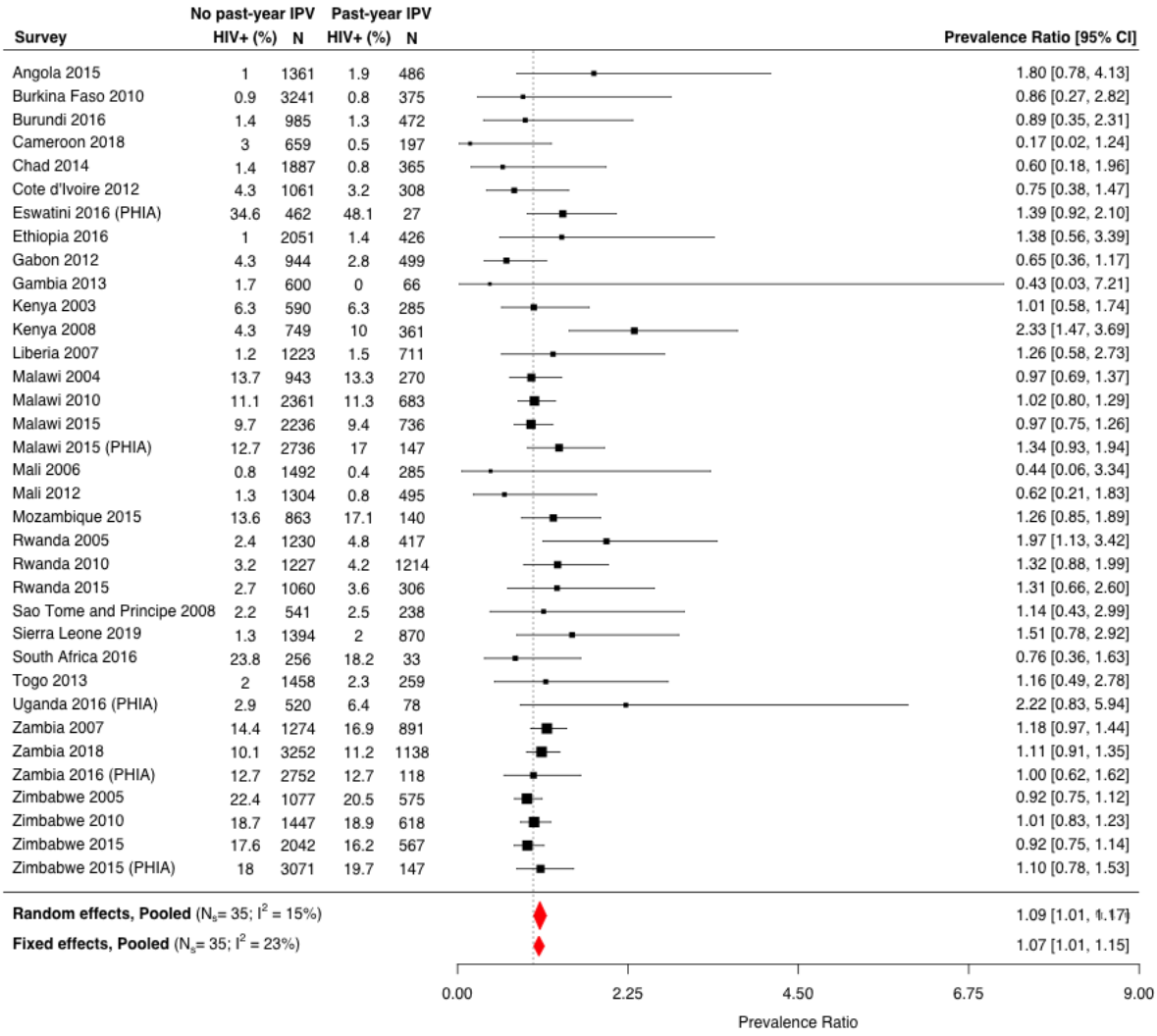


**Figure D in S1 Text.** Survey-specific and pooled crude prevalence ratios (PR) for HIV prevalence among men who had perpetrated past year physical and/or sexual intimate partner violence (IPV) compared to men who had not. Both fixed and random effects pooled estimates are provided. Zambia 2013 DHS survey has been removed from this analysis.

95%CI=95% confidence intervals; IPV=intimate partner violence; N= Total number of men who had perpetrated past year IPV or did not perpetrate past year IPV (stratum-specific denominators); $N_s$=number of surveys.

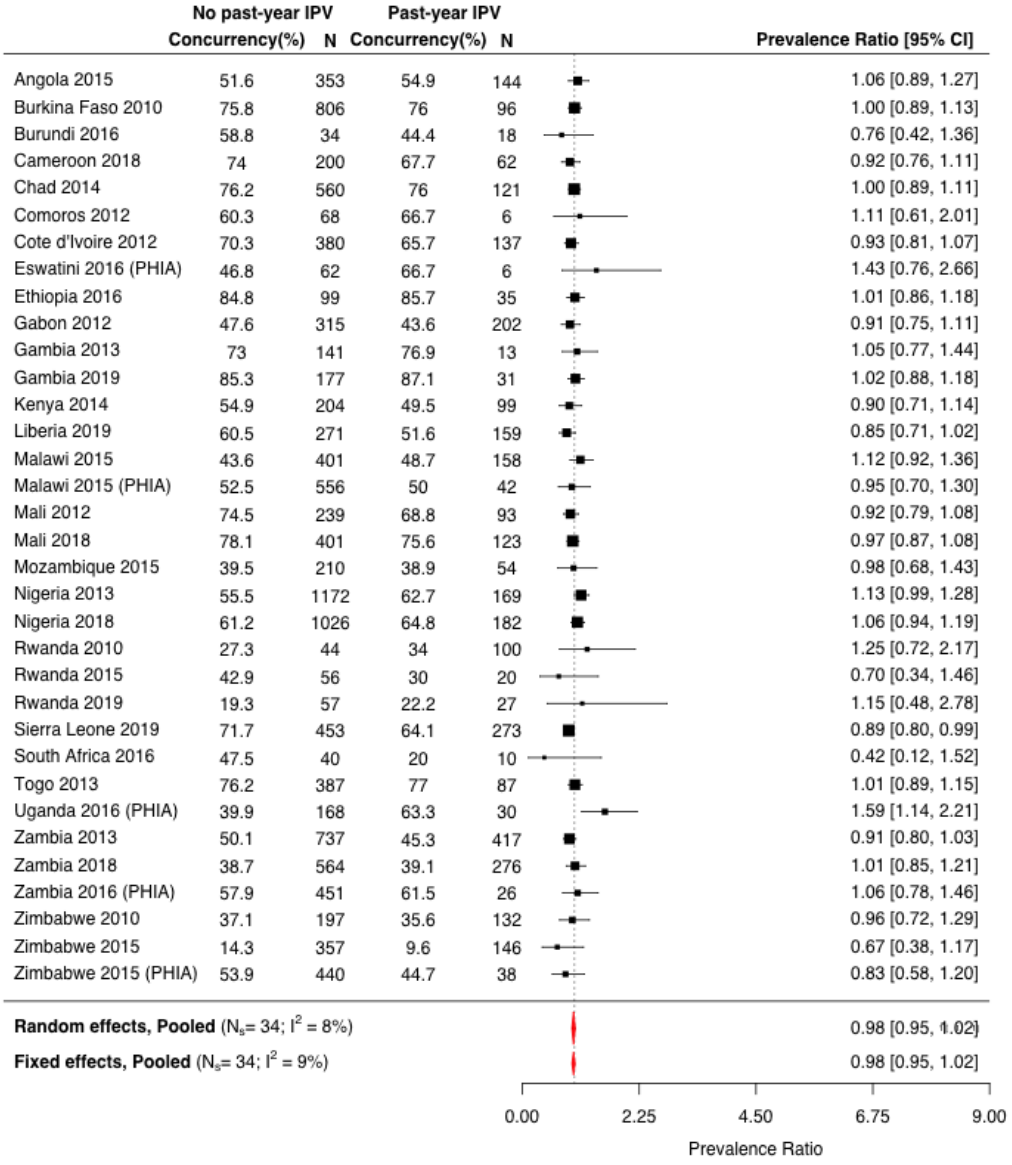


**Figure E in S1 Text.** Survey-specific and pooled crude prevalence ratios (PR) for concurrency among men who had perpetrated past year physical and/or sexual intimate partner violence (IPV) compared to men who had not. Both fixed and random effects pooled estimates are provided. 13 surveys were removed since no men had concurrent sexual partners.

95%CI=95% confidence intervals; IPV=intimate partner violence; N= Total number of men who had perpetrated past year IPV or did not perpetrate past year IPV (stratum-specific denominators); $N_s$=number of surveys.

**Table H in S1 Text.** HIV seroprevalence among male partners of adolescent girls and young women living with HIV. The proportions are stratified by perpetration/experience of physical and/or sexual intimate partner violence in the past year.

| | **Past year physical and/or sexual IPV, n (%)** | | |
|---|---|---|---|
| | **Yes** ($N_{ind}$= 261) | **No** ($N_{ind}$=599) | **Overall*** ($N_{ind}$= 873) |
| Male partner HIV prevalence | | | |
| Male living with HIV | 128 (49.0 %) | 300 (50.1 %) | 435 (49.8 %) |
| Male not living with HIV | 99 (37.9 %) | 238 (39.7 %) | 343 (39.3 %) |
| *(Missing)* | 34 (13.0 %) | 61 (10.2 %) | 95 (10.9 %) |

$N_{ind}$ = *number of adolescent girls and young women living with HIV.*

*Male partner HIV prevalence among adolescent girls and young women living with HIV irrespective of male perpetration of IPV in the past year. $N_{ind}$ = 13 women have missing data for the experience of physical and/or sexual violence in the past year.

**Text 1. Detailed methodology and the results for the analysis of the role of male-perpetrated physical and/or sexual intimate partner violence in women's risk of HIV seroprevalence**

**Methods:**

First, we calculate the absolute risk of living with HIV among adolescent girls and young women (AGYW) who a) have HIV seropositive male partner who perpetrated IPV in the past year b) have HIV seropositive male partner who did not perpetrate IPV in the past year c) have HIV seronegative male partner who perpetrated IPV in the past year. We also calculate baseline risk among women whose partner is HIV seronegative and did not perpetrate IPV in the past year. (Table I in S1 Text).

Using the baseline risk among women whose partner is HIV seronegative and does not perpetrate IPV in Table A as the reference category, we calculate the adjusted and crude risk differences (RD) for the unique and joint contributions of male partner HIV status and male partner perpetrated IPV to HIV status among AGYW (Table J in S1 Text). To calculate the risks and subsequent risk [1] differences we use marginal standardization based on GEE model with robust standard errors (Formula 1).

$$P(Y_{ij} = 1 \mid IPV = ipv_{ij}, HIV = hiv_{ij}) = \sum_c P(Y_{ij} = 1 \mid IPV_{ij} = ipv_{ij},\ HIV_{ij} = hiv_{ij},\ C_{ij} = c_{ij}) * P(C_{ij} = c_{ij}).$$ (Formula 1)

In Formula 1, $\boldsymbol{Y_{ij}}$ is the marginally standardized probability of living with HIV for a woman *i* in primary sampling unit (PSU) *j,* where every observation in the population is set/fixed to have a given combination of exposure levels: [ ($ipv_{ij}$= 1, $hiv_{ij}$ = 1); ($ipv_{ij}$= 1, $hiv_{ij}$ = 0); ($ipv_{ij}$= 0, $hiv_{ij}$ = 1); ($ipv_{ij}$= 0, $hiv_{ij}$ = 0)]

$\boldsymbol{[IPV = ipv_{ij}, HIV = hiv_{ij}]}$ reflects forcing all observations to a single combination of the above exposure levels. $\boldsymbol{C_{ij} = c_{ij}}$ refers to a combination of observed values for a confounder vector $\mathbf{C}_{ij}$. The predicted probability of living with HIV for women *i* in PSU *j*, given each exposure combination is weighted by the relative frequency of $c_{ij}$ and summed over each covariate pattern (combination of categorical covariates).

To calculate the estimates and associated 95% CI we used bootstrapping, where the resampling unit was the PSU.

## Results

**Table I in S1 Text.** Crude and adjusted *absolute risks* of living with HIV among AGYW who have HIV seropositive male partner perpetrating IPV, who have HIV seropositive partner not perpetrating IPV, who have HIV seronegative partner perpetrating IPV, and who have HIV seronegative partner not perpetrating IPV.

| | $N_{exp}/N_t$ | Crude risk (95% CI) | Adjusted risk (95% CI) | $N_{exp}/N_t$ | Crude risk (95% CI) | Adjusted risk (95% CI) |
|---|---|---|---|---|---|---|
| **Female HIV prevalence** | **No past year IPV** | | | **Past year IPV** | | |
| **Male HIV$^-$** | 13,003/ 17,834 | 1.9% (1.6%, 2.1%) | **1.8% (1.6%, 2.1%)** | 3,987/ 17,834 | 2.6% (2.1%, 3.0%) | **2.3% (1.8%, 2.7%** |
| **Male HIV$^+$** | 614/ 17,834 | 51.7% (47.8%, 56%) | **28.4 % (24.9%, 32.1%)** | 230/ 17,834 | 58.4% (50.3%, 65.4%) | **31.9% (27.6 %, 36.5 %)** |

*AGYW = adolescent girls and young women; $N_{exp}$ = Number of individuals in each exposure category; $N_t$ = total number of individuals in the denominator.*

**Table J in S1 Text.** Unique and joint contributions of male partner HIV status and male partner perpetrated physical and/or sexual IPV to HIV status among adolescent girls and young women. We present crude and adjusted risk differences.

| | $N_{exp}/N_t$ | Crude risk difference (95% CI) | Adjusted risk difference* (95% CI) | $N_{exp}/N_t$ | Crude risk difference (95% CI) | Adjusted risk difference* (95% CI) |
|---|---|---|---|---|---|---|
| **Female HIV prevalence** | **No past year IPV** | | | **Past year IPV** | | |
| **Male HIV$^-$** | 13,003/ 17,834 | Referent | Referent | 3,987/ 17,834 | 0.7% (0.1%, 1.2%) | **0.4 %**** **(-0.1%, 0.9%)** |
| **Male HIV$^+$** | 614/ 17,834 | 49.8% (45.8%, 54.2%) | **26.6 % (23.0%, 30.4%)** | 230/ 17,834 | 56.5% (48.5%, 63.5%) | **30.1 % (25.6%, 34.7%)** |

* Adjusted for women's age (continuous), wealth quintile, women's education (none, primary, secondary, higher), residence type (rural, urban), women's lifetime number of sexual partners (1, 2, ≥ 3), survey identifier.

** Does not add up to 0.5% [2.3% minus 1.8%] due to rounding (Table J)

*$N_{exp}$ = Number of individuals in each exposure category; $N_t$ = total number of individuals in the denominator.*

Based on Table J in S1 Text:

- The expected joint effect under an additive model: $E(RD_{expected}) = 26.6\% + 0.4\% = 27.0\%$
- The observed joint effect under an additive model: $E(RD_{observed}) = 30.1\%$

- The difference between the expected and observed effects: $E(RD_{observed}) - E(RD_{expected}) = 3.1\%$

Therefore, HIV risk in AGYW whose IPV perpetrator partner lives with HIV exceeds by 3 cases (per 100 women) the sum of unique effects of male HIV status and IPV, indicating the presence of a small additive effect measure modification.

To further check for the presence of additive effect measure modification, we calculate the Relative Excess Risk due to Interaction (RERI): $RERI= RD_{11}-RD_{01}-RD_{01}+1 = 0.301 -0.266 - 0.004+1 = 1.03$

Same methodology as above was used to conduct the sensitivity analysis among women of all ages (Table K in S1 Text) and excluding those AGYW who had two or more sex partners in the past year (Table L in S1 Text).

**Table K in S1 Text.** Unique and joint contributions of male partner HIV status and male partner perpetrated IPV to female HIV status among all women over the age of 15. We present crude and adjusted risk differences.

| | $N_{exp}/N_t$ | Crude risk difference (95% CI) | Adjusted risk difference* (95% CI) | $N_{exp}/N_t$ | Crude risk difference (95% CI) | Adjusted risk difference* (95% CI) |
|---|---|---|---|---|---|---|
| **Female HIV prevalence** | **No past year IPV** | | | **Past year IPV** | | |
| **Male HIV$^-$** | 46,267/ 65,152 | Referent | Referent | 13,666/ 65,152 | 0.6% (0.1%, 1.1%) | **0.4 % (0%, 0.9%)** |
| **Male HIV$^+$** | 4,082/ 65,152 | 48.5% (45.1%, 52.5%) | **22.1% (18.7%, 25.5%)** | 1,137/ 65,152 | 48.8% (41.8%, 56.0%) | **19.4% (15.0%, 24.1%)** |

* Adjusted for women's age (five-year age groups), wealth quintile, women's education (none, primary, secondary, higher), residence type (rural, urban), women's lifetime number of sexual partners (1, 2, ≥ 3), survey identifier.

*$N_{exp}$ = Number of individuals in each exposure category; $N_t$ = total number of individuals in the denominator.*

**Table L in S1 Text.** Unique and joint contributions of male partner HIV status and male partner perpetrated physical and/or sexual IPV to HIV status among adolescent girls and young women, *excluding women who had two or more sexual partners in the past year*. We present crude and adjusted risk differences.

| | $N_{exp}/N_t$ | Crude risk difference (95% CI) | Adjusted risk difference* (95% CI) | $N_{exp}/N_t$ | Crude risk difference (95% CI) | Adjusted risk difference* (95% CI) |
|---|---|---|---|---|---|---|

| Female HIV prevalence | No past year IPV | | | Past year IPV | | |
|---|---|---|---|---|---|---|
| **Male HIV$^-$** | 12,779/ 17,493 | Referent | Referent | 3,891/ 17,493 | 0.7% (0.2%, 1.3%) | **0.5 % (-0.1%, 1%)** |
| **Male HIV$^+$** | 598/ 17,493 | 49.5% (45.7%, 53.2%) | **26.7 % (23.0%, 30.7%)** | 225/ 17,493 | 56.7% (49.8%, 63.6%) | **30.2 % (25.2%, 35.4%)** |

* Adjusted for women's age (continuous), wealth quintile, women's education (none, primary, secondary, higher), residence type (rural, urban), women's lifetime number of sexual partners (1, 2, ≥ 3), survey identifier.

*$N_{exp}$ = Number of individuals in each exposure category; $N_t$ = total number of individuals in the denominator.*

## Text 2. Sensitivity analysis for the effects of selection bias on male HIV seroprevalence analysis.

### Methods

We conducted probabilistic sensitivity analysis to estimate the effects of selection bias on the association between the perpetration of past year IPV and male HIV prevalence. We followed the steps below per Lash et al. [2]

1. Identify the selection probabilities ($\alpha$, $\beta$, $\gamma$ and $\delta$) based on the published literature (Table M in S1 Text).

As the baseline bias parameter among men who are HIV negative and do not perpetrate IPV *($\delta$),* we used the mean HIV testing response rates since all participants would have to have consented to HIV testing to be included in this analysis. This value is similar to the median HIV testing response rates among men (male response rate: 77.1%).[3] For the bias parameter for men who are HIV negative and do perpetrate IPV ($\gamma$), we assumed a 5% reduction in response rate. A paper by Barnighausen shows that those who are living with HIV were four times as likely to refuse participation in HIV testing, compared to those who were HIV negative, suggesting that nonparticipation is associated with HIV status.[4] Therefore, we scaled down the bias parameters for men living with HIV ($\alpha$, $\beta$) by four compared to the respective bias parameters among men not living with HIV ($\gamma$, $\delta$)

**Table M in S1 Text.** Bias parameter values and data sources used for the selection bias sensitivity analysis.

| Observed data | Bias parameter | Population | Bias parameter value | Bias parameter value data source |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| A° | $\alpha$ | IPV$^+$, HIV$^+$ | 0.190 | Postulate that men living with HIV are four times less likely to participate in HIV testing, compared to those not living with HIV ($\gamma/4$)[4] |
| B° | $\beta$ | IPV$^-$, HIV$^+$ | 0.199 | Postulate that men living with HIV are four times less likely to participate in HIV testing, compared to those not living with HIV ($\delta/4$) [4] |
| C° | $\gamma$ | IPV$^+$, HIV$^-$ | 0.758 | Assume a 5% reduction in response rates as compared to $\delta$ |
| D° | $\delta$ | IPV$^-$, HIV$^-$ | 0.798 | Average HIV testing response rate[5] |

*IPV$^+$ = Perpetrated IPV in the past year; IPV$^-$ = Did not perpetrate IPV in the past year.*

*HIV$^+$ = living with HIV; HIV$^-$ = not living with HIV.*

2. Continuously resample a random value from a uniform probability distribution built around these bias parameters. The distribution bounds were built by increasing or decreasing the selection probabilities by 15%.

3. Use simple bias analysis to correct the prevalence ratio using the formula (1) where $\alpha$, $\beta$, $\gamma$ and $\delta$ are selection probabilities and A°, B°, C°, D° are observed data. This gives us a systematic error-corrected estimate. [6]

   $$PR_{corrected} = \frac{(A°/\alpha)}{(A°/\alpha + C°/\gamma)} / \frac{(B°/\beta)}{(B°/\beta + D°/\delta)} \quad (1)$$

4. To simulate an additional random error, choose a random standard normal deviate and multiply it by the standard error from the estimate of crude association between IPV and male HIV prevalence based on the observed data.

5. For each simulation combine the systematic and random error as follows:

   $$Estimate_{total} = estimate_{systematic} - random_{0,1} * ste_{observed}$$

   Here $estimate_{total}$ is a single simulated estimate of association that incorporates both systematic and random error, $estimate_{systematic}$ is a single simulated estimate corrected for only systematic error (from step 3), $random_{0,1}$ is a random standard normal deviate, and $ste_{observed}$ is a standard error from observed data.

   As the "$estimate_{systematic}$" is the ratio measure of association, we take its natural log and exponentiate formula (1) to get the final formula (2)

   $$Estimate_{total} = e^{\log(estimate_{systematic}) - random_{0,1} * ste_{observed}} \quad (2)$$

6. Pool and summarize the estimates by calculating the median value. Calculate the 95% uncertainty intervals.

**Results:**

Based on the analysis above, the observed crude PR ($cPR_{obs}$) = 0.98, while the bias corrected value is $cPR_{corrected}$= 0.983 (95%CI: 0.757-1.260).

Given the similarity between the crude and bias corrected values, we do not anticipate a qualitatively significant impact of selection bias on the association between past year IPV perpetration and men's HIV prevalence. However, we state this with caution given that our bias analysis is conditional on the provided bias parameters.

Keeping the bias parameters among men not living with HIV constant (γ and δ) and varying the proportion of survey participation among men living with HIV (α and β) we show that, for the observed cPR to be an overestimate ($cPR_{obs}$= 0.98), the survey response rates should be higher among IPV perpetrators than in IPV non-perpetrators (α > β) which is unlikely (Table N in S1 Text).[7]

**Table N in S1 Text.** Effect of various bias parameter values on corrected crude prevalence ratio.

| Bias parameters | | $cPR_{corrected}$ |
|---|---|---|
| **$IPV^+$, $HIV^+$ (*α*)** | **$IPV^-$, $HIV^+$ (*β*)** | |
| 0.253 | 0.199 | 0.79 |
| 0.217 | 0.199 | 0.89 |
| 0.200 | 0.199 | 0.95 |
| 0.150 | 0.199 | 1.16 |
| 0.190 | 0.267 | 1.22 |
| 0.190 | 0.228 | 1.08 |
| 0.190 | 0.218 | 1.04 |
| 0.190 | 0.200 | 0.98 |

*$IPV^+$ = Perpetrated IPV in the past year; $IPV^{-+}$ = Did not perpetrate IPV in the past year.*

*$HIV^+$ = living with HIV; $HIV^-$ = is not living with HIV*

## Text 3: STROBE Statement—checklist of items that should be included in reports of observational studies

| | Item No. | Recommendation | Page No. | Relevant text from manuscript |
|---|---|---|---|---|
| **Title and abstract** | 1 | (*a*) Indicate the study's design with a commonly used term in the title or the abstract | 2 | "We pooled individual-level data from nationally representative, cross-sectional surveys from 27 countries in Africa (2000-2020)." |
| | | (*b*) Provide in the abstract an informative and balanced summary of what was done and what was found | 2 | Abstract, Paragraph 2-3 |
| **Introduction** | | | | |
| Background/rationale | 2 | Explain the scientific background and rationale for the investigation being reported | 5<br>4 | **Rationale:** "Improving understanding of the factors and pathways associated with male-perpetrated IPV and their implications for women's HIV acquisition risk is important to meet this commitment"; Introduction, Paragraph 1<br>**Scientific background**: Introduction, Paragraph 2 and 3. |
| Objectives | 3 | State specific objectives, including any prespecified hypotheses | 5 | "The aim of this study is to describe the characteristics of men perpetrating physical and/or sexual IPV and investigate how these characteristics impact women's HIV status among cohabiting couples in […] Specifically, we address three research questions. First, what male partner and partnership-level characteristics are associated with IPV? Second, are men who are reported to perpetrate IPV more likely to report behaviors that increase their risk of HIV acquisition and to be living with HIV? Third, does experiencing IPV increase young women's risk of living with HIV, beyond the risk associated with their male partner's HIV status? " |
| **Methods** | | | | |
| Study design | 4 | Present key elements of study design early in the paper | 6 | "We reviewed available nationally representative, cross-sectional surveys conducted in 27 countries in Africa between 2000 and 2020 with available respondent-level data on IPV and HIV." |
| Setting | 5 | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | 6 | **Setting and timeline:** Methods, Paragraph 1 |
| Participants | 6 | (*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up | 6 | **Eligibility and sampling:** "The study population comprised currently cohabiting, married or partnered women and men (≥15 years) that participated in the *Demographic and Health Surveys* (DHS), *AIDS Indicator Survey* (AIS), and *Population-based HIV Impact Assessment* (PHIA) surveys. […] In PHIA, data on past-year IPV were collected from one randomly selected woman in each household and, in DHS, from all women in a fraction of households (usually one third)." |

| | | | | |
|---|---|---|---|---|
| | | *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls<br>*Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants | | |
| | | (*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed<br>*Case-control study*—For matched studies, give matching criteria and the number of controls per case | NA | - |
| Variables | 7 | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | 6-7<br>8-9 | **Exposures:** Perpetration of physical and/or sexual IPV over the past year among cohabitating couples was defined based on the women's self-reported experience of IPV, which was defined as the experience of physical and/or sexual violence in the past year by a current or former male intimate partner in the context of marriage or cohabitation. Current partners of women experiencing IPV in the past year were assumed to be perpetrators of IPV.<br><br>**Predictors:** "Potential factors correlated with IPV pertained to male individual factors and partnership-level factors. Individual factors included: accepting attitudes on IPV, alcohol use frequency, polygyny defined as having more than one wife/cohabiting partner. Partnership factors included: couple age and earning disparity, women's say in household decision-making, and household headship (male/female) [….] Self-reported factors for men's risk of living with HIV include: payment for sex in the past year, condom use at last sex with the most recent partner in the past year, number of sex partners in the past year, and point-prevalence of concurrency defined as having more than one sexual partnership at a single point in time six months before the interview. Definition of concurrency was aligned with the primary indicator recommended by the UNAIDS Reference Group on Estimates, Modelling and Projections Working Group on Measuring Concurrent Sexual Partnerships.<br><br>**Outcomes:** "HIV seropositivity was measured among consenting male and female participants at the time of survey administration via enzyme-linked immunosorbent assay (ELISA). The Zambia 2013- |

| | | | | |
|---|---|---|---|---|
| | | | | 14 DHS was excluded from all analyses using HIV seropositivity due to a concern about the reliability of the HIV testing algorithm assay."<br>**Potential confounders:** "Multivariable models were adjusted for basic socio-demographic variables: male age (five-year age groups to account for the non-linear age effect), household wealth quintiles and residence type (rural, urban), and male education (none, primary, secondary, higher). Survey-level fixed effects were included in the adjusted models to account for unmeasured survey-level confounders."<br>"[…] The model was adjusted for female demographic characteristics (linear age effect for analysis specific to 15-24 year-old women, and five-year age groups in all women), household wealth and residence, education, women's lifetime number of sex partners (1, 2, 3+) and survey-level fixed effects." |
| Data sources/ measurement | 8* | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | 6-7 | **Exposure measurement:** "Current partners of women experiencing IPV in the past year were assumed to be perpetrators of IPV. From here onwards, when referring to "perpetrators" of IPV, we refer to men whose female partner reported experiencing IPV in the past year."<br>**Outcome measurement:** "HIV seropositivity was measured among consenting male and female participants at the time of survey administration via enzyme-linked immunosorbent assay (ELISA). The Zambia 2013-14 DHS was excluded from all analyses using HIV seropositivity due to a concern about the reliability of the HIV testing algorithm assay." |
| Bias | 9 | Describe any efforts to address potential sources of bias | 11<br>25 | **Sensitivity analyses:** "Survey participation could be associated with both IPV and HIV status in men, leading to selection bias. In a probabilistic sensitivity analysis, we assumed selection probabilities which were assigned to perpetrators and non-perpetrators with and without the outcome of interest (HIV seropositivity) based on the existing literature."<br>**Limitations:** Discussion, Paragraph 4 |
| Study size | 10 | Explain how the study size was arrived at | NA | Existing survey data with a fixed sample size were used |

Continued on next page

| | | | | |
|---|---|---|---|---|
| Quantitative variables | 11 | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | 8-9 | **Groupings for continuous variables:**<br>Number of sex partners: "[…] women's lifetime number of sex partners (1, 2, 3+) […]"<br>Age: "[…] male age (five-year age groups to account for the non-linear age effect) […]" |
| Statistical methods | 12 | (*a*) Describe all statistical methods, including those used to control for confounding | 8-9 | **Adjustment for potential confounders:** "Multivariable models were adjusted for basic socio-demographic variables: male age (five-year age groups to account for the non-linear age effect), household wealth quintiles and residence type (rural, urban), and male education (none, primary, secondary, higher). Survey-level fixed effects were included in the adjusted models to account for unmeasured survey-level confounders."<br>"The model was adjusted for female demographic characteristics (linear age effect for analysis specific to 15-24 year-old women, and five-year age groups in all women), household wealth and residence, education, women's lifetime number of sex partners (1, 2, 3+) and survey-level fixed effects"<br>**Statistical models used**: "We used univariable Poisson regression models based on Generalized Estimating Equations (GEE) with robust standard errors and clustering by primary sampling unit (PSU)."<br>"We used marginal standardization based on GEE with robust standard errors." |
| | | (*b*) Describe any methods used to examine subgroups and interactions | 9 | **Subgroup analysis and justification:** "We restricted this analysis to adolescent girls and young women aged 15-24 years for two reasons. First, we aimed to estimate the additional HIV risk due to IPV in the subgroup of women with the highest IPV prevalence and HIV incidence. Second, older women are more likely to have lived with HIV for longer due to higher HIV incidence in younger age groups. Therefore, past-year IPV is more likely to have preceded HIV acquisition among women aged 15-24 years."<br>**Addressing effect measure modification:** "To quantify the magnitude of EMM under an additive model, we calculated the difference between the expected joint effect of male HIV status and IPV perpetration (the sum of their unique effects) and their observed joint effects." |
| | | (*c*) Explain how missing data were addressed | 12 | "Eighteen surveys were excluded due to physical IPV questions not asked, IPV data missingness, or women in couples' dataset not selected for the IPV module." |
| | | (*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed<br>*Case-control study*—If applicable, explain how matching of cases and controls was addressed<br>*Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy | 8 | "We used Generalized Estimating Equations (GEE) with robust standard errors and clustering by primary sampling unit (PSU), without survey weights." |
| | | (*e*) Describe any sensitivity analyses | 10-11 | **Sensitivity analyses:** "First, we explored the heterogeneity of effect size estimates across survey for each model by calculating survey-specific crude prevalence ratios and pooling them using both fixed and random-effect meta-analyses. We conducted subgroup (moderator) analyses by survey region and/or year when heterogeneity was moderate (25%-50%) to high (>50%). Second, we also calculated |

| | | | | |
|---|---|---|---|---|
| | | | | crude and adjusted prevalence ratios stratified by region. Third, we excluded women who had two or more sexual partners in the past year to reduce the likelihood that women's reports of experiencing IPV in the past year refers to someone other than their current, cohabiting partner." |
| **Results** | | | | |
| Participants | 13* | (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analyzed | 11 | **Description of included surveys and the study population**: Results, Paragraph 1 |
| | | (b) Give reasons for non-participation at each stage | 14 | Figure 1 |
| | | (c) Consider use of a flow diagram | 14 | Figure 1 |
| Descriptive data | 14* | (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders | 12 | **Characteristics of the study population:** Results, Paragraph 2 and 3 |
| | | (b) Indicate number of participants with missing data for each variable of interest | 15 | Table 1 |
| | | (c) *Cohort study*—Summarise follow-up time (eg, average and total amount) | NA | - |
| Outcome data | 15* | *Cohort study*—Report numbers of outcome events or summary measures over time | NA | - |
| | | *Case-control study*—Report numbers in each exposure category, or summary measures of exposure | NA | - |
| | | *Cross-sectional study*—Report numbers of outcome events or summary measures | 12-13 | Results, Paragraph 2 and 3 |
| Main results | 16 | (*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included | | Table 2, Table 3, Figure 2<br>We report both unadjusted and adjusted estimates with relevant confidence intervals throughout the Results section. Table 1 and 2 footnotes include a full list of confounders that were adjusted for. |

| | | | |
|---|---|---|---|
| | (*b*) Report category boundaries when continuous variables were categorized | 9<br>8 | Number of sex partners: "[…] women's lifetime number of sex partners (1, 2, 3+) […]"<br>Age: "[…] male age (five-year age groups to account for the non-linear age effect) […]" |
| | (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period | 19, 20,21 | **The role of male-perpetrated physical and/or sexual intimate partner violence in adolescent girls and young women's risk of HIV seroprevalence:** Throughout our third objective we are using absolute (risk difference), as opposed to relative measures. |

Continued on next page

| | | | | |
|---|---|---|---|---|
| Other analyses | 17 | Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses | 19<br>22 | "Sensitivity analysis (Text 2, S1 Appendix) does not indicate a noteworthy impact of selection bias on the association between past year perpetration of IPV and male HIV seroprevalence."<br><br>"Sensitivity analyses show that the removal of women who had two or more sex partners in the past year from our analyses does not change our estimates of the contribution of IPV in AGYW's risk of HIV seroprevalence (Table L, S1 Appendix)." |
| **Discussion** | | | | |
| Key results | 18 | Summarise key results with reference to study objectives | 23 | "Pooling data from 48 surveys from 27 countries in Africa, including up to 111,600 couples, we found that men whose partners reported that they perpetrate IPV are more likely to share behaviors that increased their risk of HIV acquisition and transmission than men who do not. They are also more likely to be living with HIV. Further, AGYW whose male partners perpetrate IPV have a small (3%) added risk of living with HIV in addition to the risk entailed solely by their partners' HIV status." |
| Limitations | 19 | Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias | 24-25 | Discussion, paragraph 4 |
| Interpretation | 20 | Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence | 26 | "Ending IPV may not single-handedly eliminate HIV acquisition in women since the added risk of living with HIV due to IPV, beyond the risk entailed solely in their partners' HIV status could be small. Still, experiencing IPV adds to AGYW's risk of living with HIV, which demonstrates the mutually reinforcing effects of HIV/IPV and the importance of addressing both issues simultaneously." |
| Generalisability | 21 | Discuss the generalisability (external validity) of the study results | 26-27 | Discussion, final paragraph |
| **Other information** | | | | |
| Funding | 22 | Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based | NA | We have included the funding information in the "Sources of funding" section of the manuscript submission form. |

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at

http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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# 6. Chapter 6: The contribution of intimate partner violence to vertical HIV transmission

## 6.1 Preface to Manuscript 3

The impact of IPV on viral suppression observed in Manuscript 1, a crucial factor for prevention of vertical HIV transmission, raises questions on the implications of IPV for vertical transmission of HIV. Manuscript 1 highlighted the adverse effects of IPV on HIV acquisition which, if occurring during pregnancy, could further raise the risk of vertical HIV transmission. Understanding the full impact of IPV on vertical HIV transmission is essential for reaching vertical HIV transmission eliminations goals, thereby contributing to ending HIV as a public health challenge. To shed light on the impact of IPV on pediatric HIV, I used a decision analytic modelling approach to estimate the contribution of IPV in vertical HIV transmission in my 3rd manuscript. The resulting article is accepted for publication in The Lancet HIV.

## 6.2 Manuscript 3: The contribution of intimate partner violence to vertical HIV transmission: a modelling analysis of 46 African countries

Salome Kuchukhidze, MPH[1], Magdalene K Walters, MPH[2], Dimitra Panagiotoglou, PhD[1], Prof Marie-Claude Boily, PhD[2], Souleymane Diabaté, PhD[3,4], W Alton Russell, PhD[1], Prof Heidi Stöckl, PhD[5], Lynnmarie Sardinha, PhD[6], Francisco Mbofana, MD[7], Prof. Rhoda K Wanyenze [8], Jeffrey W Imai-Eaton, PhD[2,9], and Mathieu Maheu-Giroux, ScD[1*]

1- Department of Epidemiology and Biostatistics, School of Population and Global Health, McGill University, Montréal, Canada.
2- MRC Centre for Global Infectious Disease Analysis, School of Public Health, Imperial College London, London, United Kingdom.
3- Département de médecine sociale et préventive, Université Laval, Québec, QC, Canada.
4- Centre de recherche du CHU de Québec-Université Laval, Québec, QC, Canada.
5- Institute for Medical Information Processing, Biometry, and Epidemiology, Medical Faculty, LMU Munich, Germany.
6- The UNDP-UNFPA-UNICEF-WHO-World Bank Special Programme of Research, Development and Research Training in Human Reproduction (HRP), Department of Sexual and Reproductive Health and Research, World Health Organization, Geneva, Switzerland.
7- Conselho Nacional de Combate ao HIV/Sida, Maputo, Mozambique.
8- Department of Disease Control and Environmental Health, School of Public Health, College of Health Sciences, Makerere University, Kampala, Uganda
9- Center for Infectious Disease Dynamics, Department of Epidemiology, Harvard T.H. Chan School of Public Health, Boston, MA, USA.

**Summary**

**Background** Addressing gender inequities could be key to the elimination of vertical transmission of HIV. Women experiencing intimate partner violence (IPV) might be at an increased risk of vertical transmission due to their vulnerability to HIV acquisition and barriers to access and retention in care. Sub-Saharan Africa, where IPV burden is among the highest globally, accounts for most new paediatric HIV infections. We aimed to examine the proportion of excess vertical transmission attributable to IPV in this region.

**Methods** In this modelling analysis, we created a probability tree model of vertical HIV transmission among women aged 15–49 years in 46 African countries. We estimated the proportion of vertical transmission attributable to past-year physical or sexual IPV, or both, as an age-standardised population attributable fraction (PAF) and as excess vertical transmission risk per 1000 births among women experiencing IPV. We incorporated perinatal and postnatal vertical transmission among women who acquired HIV before pregnancy, during pregnancy, and during breastfeeding. Fertility, HIV prevalence, HIV incidence, ART uptake, and ART retention varied in the model by women's IPV experience. The model was parameterised using UNAIDS' 2023 Spectrum model data, WHO's Global Database on Violence Against Women, and the peer-reviewed literature. Uncertainty intervals (95% UI) were calculated through 1000 Monte Carlo simulations.

**Findings** Across 46 countries 13% (95% UI 6–21) of paediatric HIV infections in 2022 were attributed to IPV, corresponding to over 22 000 paediatric infections. The PAF ranged from 4% (2–7) in Niger to 28% (13–43) in Uganda. The PAF was highest among women and girls aged 15–19 years (20%, 8–33) and lowest among women aged 45–49 years (6%, 3–9). In southern Africa, where women's HIV prevalence is highest (23%), IPV led to 11 (5–20) additional infections per 1000 births among women experiencing it.

**Interpretation** IPV might be responsible for one in eight paediatric HIV infections in sub-Saharan Africa. Ending IPV could accelerate vertical transmission elimination, especially among young women who bear the highest burden of violence.

**Funding** Canadian Institutes of Health Research, Canada Research Chair, and Fonds de recherche du Québec-Santé.
**Word count:** 299

**Keywords:** Intimate partner violence, vertical HIV transmission, probability tree model, sub-Saharan Africa.

## Research in Context

### Evidence before this study

We searched PubMed for empirical and modelling studies (November 23, 2023), without language restrictions using the terms: (vertical HIV transmission OR MTCT OR mother-to-child HIV transmission) AND women AND (violence OR intimate partner OR domestic violence OR GBV OR IPV OR marital violence) AND (Africa* OR sub-Sahara*).

Most existing studies are qualitative and focus on the impact of IPV on prevention of mother-to-child HIV transmission (PMTCT). Empirical studies from Ethiopia, Tanzania, and Mozambique have shown that women who experience IPV have lower rates of HIV testing and antenatal care engagement compared to those who do not. Systematic reviews of the adverse effects of IPV on pregnant women living with HIV (WLHIV) in sub-Saharan Africa demonstrate poor uptake of and adherence barriers to PMTCT interventions among women experiencing IPV. A South African study suggests IPV's association with elevated viral load postpartum.

A 2023 meta-analysis of six population-based surveys in sub-Saharan Africa found that women experiencing IPV are at an increased risk of HIV acquisition. This, combined with a cohort study in Uganda showing an added risk of HIV acquisition among pregnant compared to non-pregnant women suggests that IPV may exacerbate the risk of HIV acquisition, and subsequent vertical transmission among pregnant women.

Despite this evidence on pathways linking IPV and pediatric HIV, a comprehensive analysis of the contribution of IPV to vertical HIV transmission rates incorporating the full PMTCT cascade has not been undertaken. Empirical estimation of this phenomenon is methodologically difficult due to the relative rarity of vertical transmission (i.e., low power), as well as time- and setting-dependent variability in PMTCT program coverage.

### Added value of this study

To our knowledge, our study provides the first comprehensive analysis of past-year physical or sexual (or both) IPV's contribution to vertical HIV transmission in sub-Saharan Africa, along the full HIV prevention and treatment cascade. We used country-reported PMTCT program data and estimates of key HIV indicators from 46 countries, as well as meta-analyses of population-representative surveys, and community-based cohort studies to parametrize our model. Our custom application of a detailed probability tree model accounts for the temporal relationships between IPV and vertical transmission of HIV. We found that in sub-Saharan Africa, one out of eight new pediatric HIV acquisitions could have been averted through elimination of IPV, with the greatest impact on adolescent girls and young women.

### The implications of all the available evidence

The *2022 Global Alliance to End AIDS in Children* stakeholders commit to eliminating vertical transmission of HIV by 2030, with a directed focus on gender inequities and structural drivers of HIV. Experience of IPV could exacerbate risks of vertical HIV transmission, especially in adolescent girls and young women where the IPV burden and HIV incidence is the highest. Progress in reducing new pediatric HIV acquisitions must be paired with reductions in IPV to accelerate vertical HIV transmission elimination goals.

## Introduction

New pediatric infections from vertical HIV transmission have declined by 58% since 2010.[3] Still, 130 000 children acquired HIV in 2022 globally.[3] Most (85%) of these infections occurred in sub-Saharan Africa.[3] Reductions in vertical transmission are largely attributed to increased coverage of HIV testing and antiretroviral treatment (ART) among women living with HIV (WLHIV).[3] However, ART coverage among pregnant WLHIV has recently plateaued at a little over 80%.[3] The *2022 Global Alliance to End AIDS in Children* aims to close the prevention and treatment gaps to eliminate vertical transmission by 2030. It recognizes that structural drivers of HIV are key to achieving this goal. The *United Nations Political Declaration on HIV and AIDS* further identifies gender-based violence, including intimate partner violence (IPV), among these drivers and commits to reducing its global burden from 27%[86] to less than 10% by 2025.[5] Shedding light on relationships between IPV and vertical HIV transmission is key to inform vertical transmission elimination strategies.

Sub-Saharan Africa has among the highest IPV prevalence globally, with over 1 in 5 women having experienced IPV in the past year.[86] IPV could contribute to increasing vertical transmission risk in several ways. Women subjected to IPV are more likely to acquire HIV,[7] mainly through indirect pathways driven by interpersonal and societal gender inequities.[8] In the context of prevention of vertical HIV transmission programs: women experiencing IPV have lower rates of HIV testing and antenatal care (ANC) engagement[115], lower uptake of prevention of vertical HIV transmission programs[15], and poorer viral suppression.[7] Some forms of IPV, such as forced sex and reproductive coercion, may also contribute to increases in pregnancies.[150] Adverse effects of IPV may compound the hormonal and immunological drivers of the heightened risk of HIV acquisition among pregnant compared to non-pregnant women.[111] Women who acquire HIV during pregnancy or breastfeeding may have a higher rate of vertical transmission due to the initial high viral load following seroconversion.[151] Finally, adolescent girls and young women may be at higher vertical HIV transmission risk, since they are the most vulnerable to IPV[86] and have lower rates of viral suppression than older women.[152]

A comprehensive analysis of the contribution of IPV to vertical HIV transmission, along the full prevention and treatment cascade has not been undertaken. Empirical studies exploring

the adverse impact of IPV on the prevention of vertical HIV transmission cascade have either been inconclusive, focused on a single setting,[153] were qualitative,[154] or only studied one component of the care continuum.[109] prevention of vertical HIV transmission program scale-up has reduced the number of pediatric HIV infections, making it challenging to empirically estimate vertical transmission.[3] Finding a common effect size for IPV-vertical HIV transmission relationships is further complicated by the time and setting-dependent variability in prevention of vertical HIV transmission program coverage and uptake, which lie on the pathway between IPV and vertical HIV transmission.

The goal of this study was to estimate the contribution of past-year physical or sexual IPV, or both, on vertical transmission of HIV. We aimed to quantify the annual proportion of excess risk of vertical transmission attributable to women's experience of past-year physical or sexual IPV, or both by age in sub-Saharan Africa. To achieve this, we developed a probability tree model, parameterized through literature reviews and data from programs for prevention of vertical HIV transmission.

## Methods

### Study design

A probability tree model for women (15-49 years), stratified by five-year age groups, was developed for the period 2014-2022 (Figure 6.1).[155] The model was based on the pediatric HIV module of the *Spectrum AIDS Impact Model* (AIM) (v6.28),[155] used by the *Joint United Nations Programme on HIV/AIDS* (UNAIDS) to estimate HIV trends from surveillance and survey data.[155]

Our model considers vertical HIV transmission during the perinatal and postnatal periods. It assumed that women's fertility rate varies by IPV, HIV status, ART uptake, and CD4 cell counts. Women not already living with HIV before conception can acquire it during pregnancy or breastfeeding, considering the additional risk of HIV acquisition during these periods (compared to non-pregnancy or non-breastfeeding). This departs slightly from Spectrum's assumption that women have the same incidence regardless of pregnancy status. While HIV acquisition risk is higher per-condomless-coital act during pregnancy than non-pregnancy,

reduction in sexual activity perinatally might mitigate this risk.[113] Given the heterogeneity in sexual activity patterns, we adhered to the assumption of higher risk by $2.16^{111}$ and $1.16^{111}$ for pregnancy and postpartum periods, respectively.[113]

Women acquiring HIV during pregnancy/breastfeeding will not be diagnosed and enrolled on ART.[156] For WLHIV before conception, the model incorporates HIV testing at ANC and ART regimens for pregnant women. Women may not receive ART either by not testing for HIV at (or attending) ANC or by testing but not enrolling in care. The country-specific proportion of breastfeeding WLHIV reduces over time, up to 36 months. The probability of vertical HIV transmission varies by CD4 cell counts, ART regimen, and perinatal/postnatal transmission period.

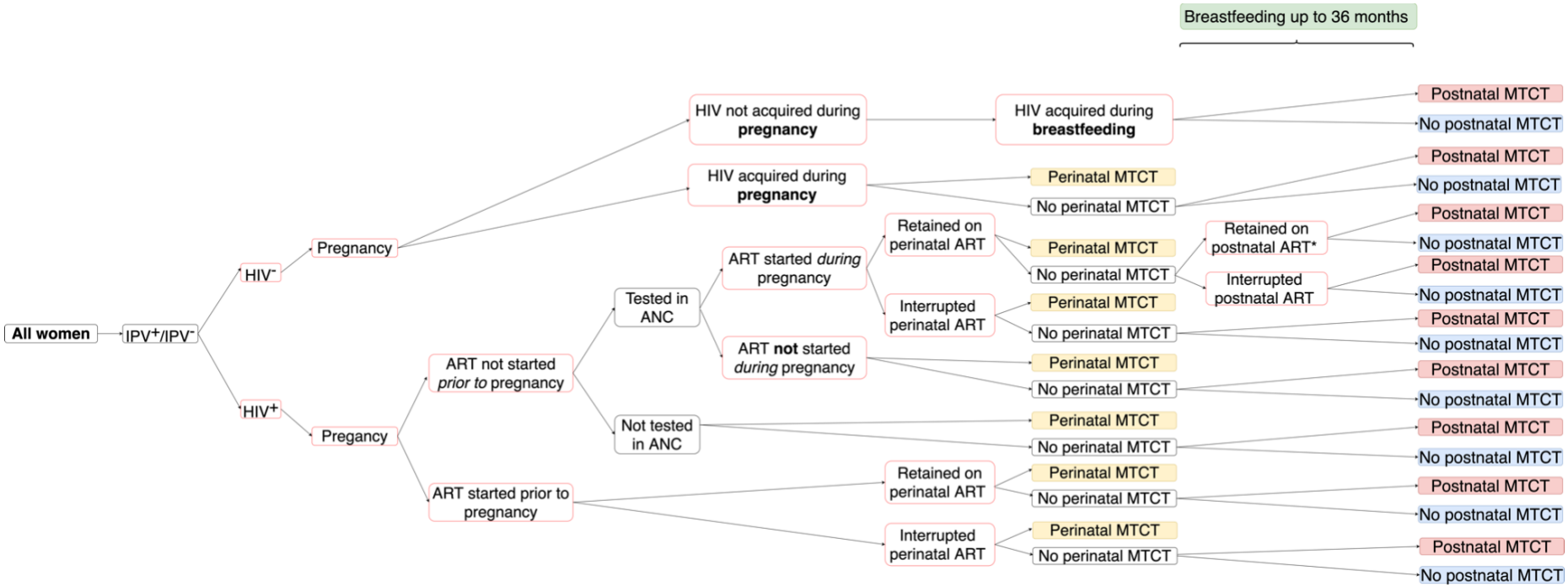


**Figure 6.1.** Flowchart of the structure of the probability tree model of the impact of intimate partner violence (IPV) on vertical transmission of HIV. The model includes women who acquire HIV before pregnancy, during pregnancy and during breastfeeding. Parameters in red boxes are impacted by IPV. ART regimens that women can be enrolled on during pregnancy include: single dose nevirapine, dual prophylaxis, Option A, Option B, Option B+ (>4 weeks or <4 weeks before delivery). Further detail on these regimens can be found in Table S6. Perinatal ART retention, representing the proportion of women retained in ART at delivery, is incorporated for women on Option B+ (>4 or <4 weeks before delivery) and women on ART before pregnancy. Postnatal ART retention, representing monthly postnatal dropout rate, is incorporated for women on Option A, B, B+ (>4 weeks or <4 weeks before delivery). *ANC = antenatal care; ART = antiretroviral treatment; HIV+ = living with HIV; HIV- = not living with HIV; IPV+ = experiencing past-year physical and/or sexual intimate partner violence; IPV- = not experiencing past-year physical and/or sexual intimate partner violence; MTCT = mother-to-child HIV transmission*

## Procedures

*Demographic parameters, prevention of vertical HIV transmission program data, and HIV projection outputs*

Model parameters relied on country-reported prevention of vertical HIV transmission program data and demographic projections from publicly available 2023 Spectrum projection files.[156] For Djibouti, Mauritius and Nigeria, the 2023 files were unavailable and their 2022 Spectrum files (2014-2021) were used instead. ANC testing data in South Africa was extracted from the proportion of pregnant women tested for HIV at ANC used in Thembisa 4.7.[157] Demographic parameters include age-, year- and country-specific fertility rate, as well as rate ratios accounting for the impact of HIV and ART uptake on fertility. Annual, country-specific prevention of vertical HIV transmission program data were extracted from Spectrum files: proportion tested for HIV at ANC, proportion on ART by regimen ("ART uptake" hereon), proportion breastfeeding and duration (up to 36 months postnatally), and proportion retained on ART peri- and postnatally. HIV transmission probabilities varied by ART regimen and transmission period (perinatal or postnatal), and CD4 cell counts (<200, 200-350, >350 cells per μL). Annual, country-specific HIV prevalence and cumulative HIV incidence over one year were extracted for women by five-year age group (Table S2; pp 15-16).

*Prevalence of past-year physical or sexual (or both) intimate partner violence*

Estimates of past-year physical or sexual IPV (or both; subsequently referred to as physical or sexual IPV) prevalence in 2018 were obtained for each country by five-year age group from the *Global Database on the Prevalence of Violence Against Women*.[86] We restricted our analysis to four years before and after 2018 (2014-2022) to ensure the validity of the IPV prevalence estimates from 2018. This prevalence was assumed to be constant over time.[86] Experience of past-year IPV, as opposed to lifetime, was the preferred exposure since recent IPV experiences have a more direct causal link with model parameters. We excluded psychological violence from the IPV definition, due to a lack of agreement on how to universally define and quantify it cross-culturally.[69] The model conservatively assumes that pregnancy does not affect the risk of experiencing IPV.

*Impact of intimate partner violence on vertical transmission of HIV*

Fertility rate, ART uptake, ART retention, cumulative HIV incidence and HIV prevalence varied by past-year IPV experience, using estimates from meta-analyses of nationally representative surveys (Table 6.1). Hazard ratio for IPV's impact on fertility was based on a meta-analysis of 29 population-representative surveys in low-and-middle-income countries (Table 6.1).[111] Prevalence ratios for the effect of past-year IPV on cumulative HIV incidence, ART uptake and ART retention among WLHIV were informed by a meta-analysis of six nationally representative surveys in sub-Saharan Africa.[7] The odds ratio for the relationship between lifetime IPV and HIV prevalence was obtained from a meta-analysis of 12 Demographic and Health Surveys (DHS).[10]

To understand the impact of past-year IPV on HIV testing at the ANC, we analyzed 29 DHS surveys with information on IPV, HIV testing and HIV biomarkers among WLHIV who gave birth in the past year. We did not find evidence that IPV impacted ANC testing, consistent with previous work.[7] Therefore, HIV testing at ANC does not vary by IPV in our model (Table S3 (pp 19-20)).

**Table 6.1.** Effect size estimates for the relationship between past-year physical or sexual intimate partner violence and model parameters relevant to vertical transmission of HIV.

| Model parameters affected by intimate partner violence | Adjusted effect estimate (95% CI)* | Source |
|---|---|---|
| **Effect of intimate partner violence on model parameters** | | |
| ART uptake before and during pregnancy (%)§ | aPR = 0·96 (0·90-1·02) | Kuchukhidze et al. 2023[4] |
| ART retention peri- and postnatally among WLHIV on ART‡ (%) | aPR = 0·95 (0·90-1·00) | Kuchukhidze et al. 2023[4] |
| Cumulative HIV incidence over one year† | aPR = 3·22 (1·51-6·85) | Kuchukhidze et al. 2023[4] |
| HIV prevalence (%)¶ | aOR = 1·10 (1·01-1·21) | Durevall et al. 2010[20] |
| Fertility rate** | aHR = 1·13 (1·07-1·20) | Maxwell et al. 2017[8] |

*A full version of this table, including adjustment variables for the effect estimates is available in Table S3 (pp 19-20).

§We assume that ART uptake for WLHIV on each ART regimen during pregnancy and before pregnancy is the same as ART uptake among all WLHIV.

‡aPR for viral suppression among WLHIV by IPV status is used as a proxy estimate for the effect of IPV on perinatal and postnatal ART retention among pregnant WLHIV. Since postnatal ART retention is reported as monthly postnatal ART dropout rate in Spectrum, we operationalized this aPR as an aHR.

†aPR for recent HIV infection by IPV status is used as a proxy estimate for the effect of IPV on cumulative HIV incidence over one year. Measurement of recent infection is based on a Lag-avidity assay.

¶aOR represents the effect of lifetime IPV on HIV prevalence to account for the fact that women might have seroconverted prior to experiencing past-year IPV.
**aHR represents the effect of any IPV on the probability of incident pregnancy.
*ART= antiretroviral therapy; CI = confidence interval; aHR = adjusted hazard ratio; IPV = intimate partner violence; aPR = adjusted prevalence ratio; aOR = adjusted odds ratio; WLHIV = women living with HIV*

*Outcomes*

The primary outcome was the risk of vertical HIV transmission by experience of IPV. From this, we estimated the population attributable fraction (PAF) or fraction of all vertical transmission caused by IPV. Risk difference (RD) was estimated as the number of vertical transmission cases that would be averted per 1000 births among the exposed if the effect of IPV was eliminated.

*Statistical analyses*

The usual denominator for vertical transmission rate calculation is births among women with HIV. However, IPV increases the risk of women acquiring HIV[4] during the pregnancy and postpartum.[9] This added risk does not apply to women with HIV before conception. To address this issue, we used all births as the denominator.

To account for confounding of the IPV–vertical transmission relationship by age when using risks, we calculated age-standardised RD and PAF. The standard population was all births for RD by country and year from Spectrum's demographic projections, and vertical transmissions for PAF by country and year from the probability tree.[21]

PAFs and RDs were calculated for each country and year (2014–22). We also calculated PAFs and RDs across the four subregions (central, eastern, southern and western sub-Saharan Africa) and overall. In Nigeria, Djibouti, and Mauritius the most recent available data was carried over to 2022; this was 2020 for Nigeria and 2021 for Djibouti and Mauritius. We present PAFs stratified by perinatal versus postpartum period and by women with prevalent versus incident HIV.

Two sources of uncertainty were incorporated into the model. First, uncertainty related to the effect size estimates for the effect of IPV on model parameters. Second, uncertainty related to perinatal and postnatal vertical transmission probabilities (appendix p 26). 95% uncertainty intervals (UI) were estimated via 1000 Monte Carlo simulations, where effect size

estimates were resampled from lognormal distributions and transmission probabilities from logit-normal distributions.

*Sensitivity analyses*

We conducted a sensitivity analysis for the effect of specific parameters on the annual PAF**.** Adjusting for IPV, we calculated partial correlation coefficients (*r*) between the annual PAF and ART uptake, ART retention, cumulative HIV incidence, HIV prevalence, and fertility rate. Furthermore, we conducted a scenario analysis where we set the effect estimates for the relationship between IPV and the model parameters to null (eg, prevalence ratio=1) one at a time and assessed the change in the overall PAF in 2022. Finally, we assumed the absence of added risk of HIV acquisition during pregnancy and breastfeeding.

**Role of the funding source**

The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

## Results

A total of 46 countries in sub-Saharan Africa had available data. Regionally aggregated results are only presented for calendar years when data were available for at least 50% of the total population in the region (i.e., 2014 onwards for Southern Africa, 2016 for Central Africa, and 2017 onwards for Eastern, Western and all sub-Saharan Africa).

Aggregating data from 46 countries in 2022, 13% (95%UI: 6-21%) of pediatric infections may have been attributable to IPV. PAF ranged from 4% (95%UI: 2-7%) in Niger to 28% (95%UI: 13-43%) in Uganda (Figure 6.2A). The lowest PAF in Niger was consistent with a combination of low IPV prevalence (13%) and low ART uptake before pregnancy (12%) in 2022 (Figure 6.2B-6.2C).

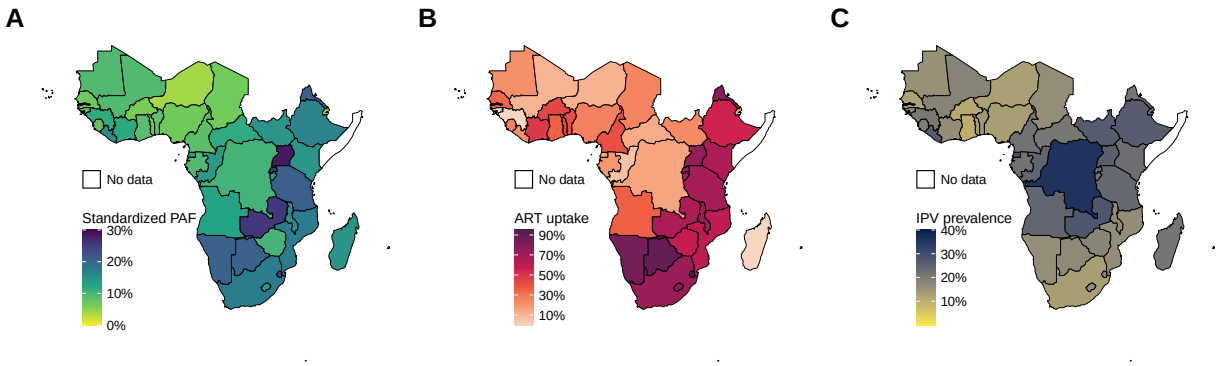


**Figure 6.2.** A) Age-standardized population attributable fraction (PAF) of past-year physical or sexual intimate partner violence (IPV) in sub-Saharan Africa in 2022 in each country. B) Overall (non-IPV stratified) antiretroviral treatment uptake prior to pregnancy among women in sub-Saharan Africa in 2022 in each country. C) Past-year physical or sexual intimate partner violence prevalence in sub-Saharan Africa in 2018 as reported in the *Global Database on Violence Against Women*. In Nigeria, Djibouti, and Mauritius we carried over the most recent available data (obtained from Spectrum 2022 projection files) to 2022. This was 2020 for Nigeria and 2021 for the latter two countries. *ART=antiretroviral treatment; IPV=intimate partner violence; PAF= population attributable fraction.*

In 2022, PAF were largest in Eastern (19%; 95%UI:9-29%) and Southern Africa (18%; 95%UI: 8-30%) where almost one fifth of all vertical HIV transmission was attributable to IPV (Figure S1A). The highest PAF in Southern and Eastern Africa was consistent with the highest ART uptake (73% and 65% respectively), in addition to the high prevalence (24%) of past-year IPV[86] in Eastern Africa (Figure S1B-S1C, pp 2). This could suggest that a portion of IPV's effect on vertical transmission acts through ART uptake: in regions with the highest ART uptake, IPV elimination would be expected to prevent the largest percentage difference in failure to uptake and remain on ART, with subsequent impacts on vertical HIV transmission. In contrast, regions with lower ART uptake would experience a relatively smaller impact from IPV elimination.

In 2022, PAF was the lowest in Western Africa with 8% (95%UI:3-13%) of all vertical transmission due to IPV (Figure S1A, pp 2). IPV prevalence (15%; 95%UI: 11-19%)[86] and ART uptake prior to pregnancy (30%) were also low in this region (Figure S1B-S1C, pp 2).

We did not observe major temporal trends in PAF (Figure S2, pp 3), likely due to the plateau in ART uptake among pregnant WLHIV in recent years. Southern Africa was the exception and, for instance, PAF increased from 10% (95%UI:5-16%) in 2014 to 21% (95%UI:10-32%) in 2022

for Botswana (Figure S2, pp 3). These changes parallel the increased ART uptake before pregnancy in Southern Africa (Figure S3, pp 4). Between 2014 and 2022, ART uptake increased from 43% to 88% in Botswana.

Pooling data from 2022 in sub-Saharan Africa, the RD was 2·4 (95% UI 1·1–3·9) paediatric infections averted per 1000 births among women experiencing IPV. Averted vertical transmission varies proportionally to HIV prevalence ($r$=0·9). In Eswatini, where HIV prevalence among women 15-49 years was 35% in 2022, 14·7 (6·9–24·4) infections per 1000 births could be averted by ending IPV among women experiencing it. This compares with only 0·02 (0·01–0·03) in Comoros, where HIV prevalence is less than 1% (figure 3). For 2022, the largest RD was found for southern Africa, the region with the highest HIV prevalence (23%), with 11·1 (4·8–19·5) infections per 1000 births among women experiencing IPV that could be averted by elimination of violence (Figure S4, pp 5).

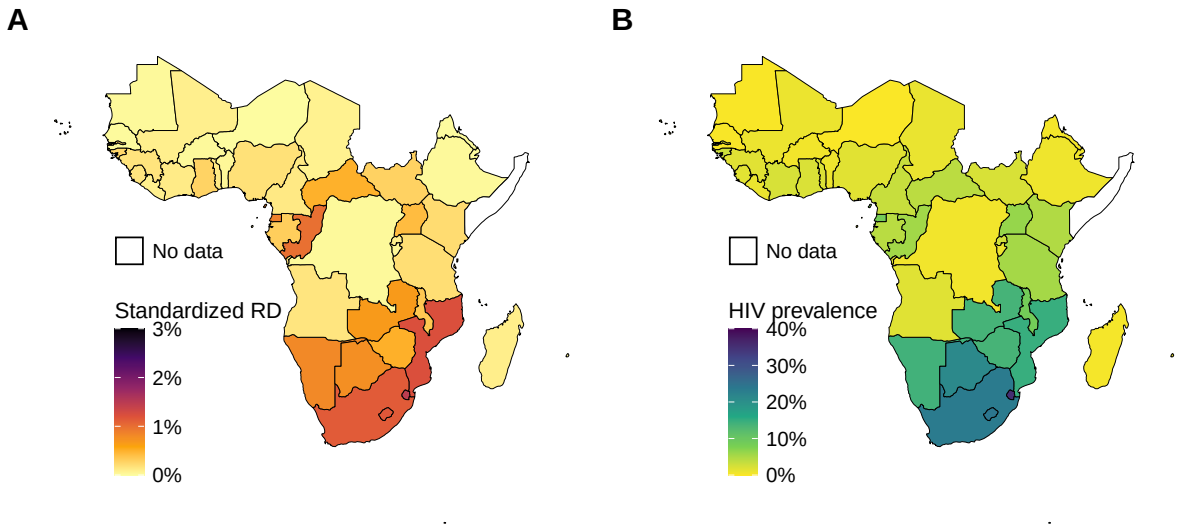


**Figure 6.3** A) Age-standardized risk difference (RD) for the effect of past-year physical or sexual intimate partner violence (IPV) on vertical transmission of HIV in sub-Saharan Africa in 2022. B) Overall (non-IPV stratified) HIV prevalence among women in sub-Saharan Africa in 2022. In Nigeria, Djibouti, and Mauritius we carried over the most recent available data (obtained from Spectrum 2022 projection files) to 2022. This was 2020 for Nigeria and 2021 for the latter two countries. *IPV=intimate partner violence; RD=risk difference.*

Across all subregions the highest PAFs were estimated for adolescent girls and young women who experienced the highest levels of past-year IPV[86] (Figure 6.4). In sub-Saharan Africa in 2022, PAF was highest among 15-19-year-old women (20%; 95%UI:8-33%) and lowest among 45-49-year-olds (6%; 95%UI:3-9%). Country-specific analysis confirms the highest PAF among the youngest age groups (Figure S5, pp 6).

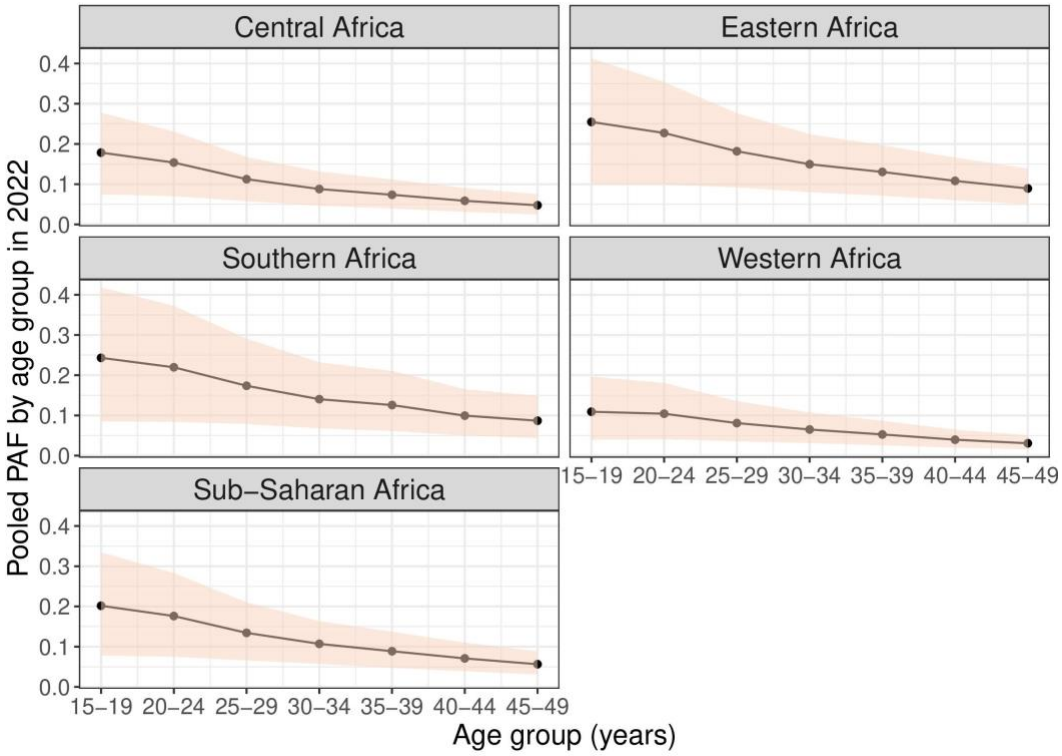


**Figure 6.4.** Age-stratified population attributable fraction overall (sub-Saharan Africa), by subregion and age group (years) in 2022. The shaded area refers to the 95% uncertainty intervals. *PAF=population attributable fraction.*

Stratified PAF showed that twice as much vertical HIV transmission was attributable to IPV during the postnatal (18%, 95%UI:7-29%) than during the perinatal period (10%, 95%UI:5-14%) (Figure 6.5). Smaller fractions of women can transmit HIV perinatally than postnatally because the former occurs among WLHIV before pregnancy and during pregnancy. Meanwhile postnatal transmission occurs among both groups, *plus* women who acquire HIV during breastfeeding. The added risk of HIV acquisition and vertical transmission due to IPV from women with incident HIV contributes to the high PAF postnatally. PAF is not impacted by the nine-month and 36-month time horizons for pregnancy and breastfeeding respectively since these periods do not vary by IPV in our model.

Women's higher risk of HIV acquisition due to IPV during pregnancy and breastfeeding compared to non-pregnancy and non-breastfeeding could explain that, among women with prevalent HIV, only 3% (95%UI:1-5%) of pediatric infections were due to IPV, while among those with incident HIV 32% (95%UI:11-54%) were attributable to IPV (Figure 6.5). Country-specific analyses confirm these observations (Figure S6-S9, pp 7-10).

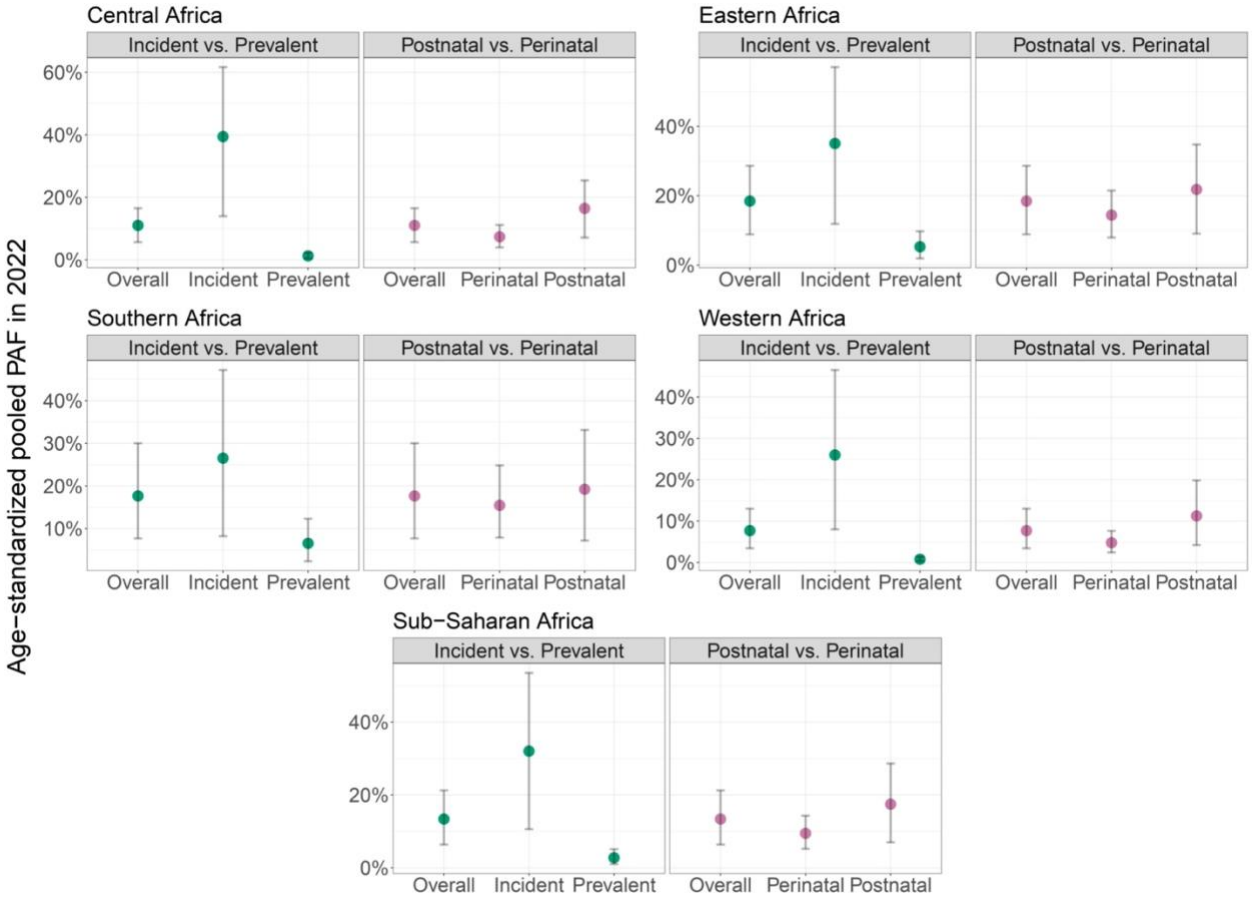


**Figure 6.5.** Pooled proportion of vertical HIV transmission attributable to past-year physical or sexual intimate partner violence (IPV) stratified by perinatal versus breastfeeding periods and by the timing of HIV acquisition in women, in 2022. The error bars refer to the 95% uncertainty interval. In Nigeria, Djibouti, and Mauritius we carried over the most recent available data (obtained from Spectrum 2022 projection files) to 2022. This was 2020 for Nigeria and 2021 for the latter two countries. *IPV= intimate partner violence; PAF=population attributable fraction.*

Controlling for IPV prevalence, ART uptake prior to pregnancy was most correlated with PAF (r=0·8), followed by ART uptake during pregnancy (r=0·6) (Figure S10, pp11). When setting the effect estimates for IPV's impact on model parameters to a null value one by one (compared to no change in the parameter), the strength of association between IPV and HIV incidence in women had the largest impact (a 10% reduction in PAF) (Figure S11, pp12). Setting the effect estimate for the relationship between pregnancy and HIV acquisition risk to a null decreased PAF by 2%.

## Discussion

Using data from 46 African countries, our probability tree model estimated that over 1 in 8 pediatric HIV infections would have been averted through elimination of IPV in 2022. This corresponds to over 22,000 pediatric infections averted if IPV was eliminated. The proportion of vertical HIV transmissions attributable to IPV varied widely. IPV has the greatest impact among adolescent girls and young women.

The high PAF for IPV in Eastern Africa is driven by the high prevalence of past-year IPV.[86] This was similar in age stratified analysis: adolescent girls and young women have the highest PAF across all sub-regions which is due to the high burden of past-year IPV in the youngest age groups. More than one in six girls aged 15-19 years have experienced IPV in the past year.[86]

Southern Africa has the lowest IPV burden with 15% of women experiencing past-year IPV[86], but the second highest PAF in our study. Two pathways through which IPV affects vertical transmission can explain this finding. First, via reducing ART uptake before pregnancy among WLHIV. Second, via HIV acquisition among pregnant and breastfeeding women. In regions with high ART uptake, IPV could lead to a larger absolute reduction in ART uptake, and a subsequent rise in vertical transmission. Conversely, where ART uptake is low, the added benefit of eliminating IPV in preventing vertical HIV transmission would be relatively smaller. Our sensitivity analyses confirm the importance of ART uptake prior to pregnancy in explaining country variations in PAF.

In high ART uptake settings such as Eastern and Southern sub-Saharan Africa, HIV incidence is also higher, which can affect the second pathway between IPV and vertical HIV transmission. High incidence contributes to PAF by amplifying the role of IPV in women's risk of HIV acquisition and vertical transmission during pregnancy and breastfeeding. Indeed, stratifying PAF by the timing of women's HIV acquisition shows that the proportion of pediatric infections from IPV is much larger among women with incident HIV compared to those already living with HIV at conception. Modelling studies corroborate that vertical HIV transmission among women who seroconvert during pregnancy accounts for a big portion of all HIV transmissions, despite representing only a small proportion of all pregnant WLHIV.[158] Combined effect of the high initial viral load after seroconversion and increased risk of HIV acquisition

during pregnancy could contribute to the higher vertical HIV transmission risk among women with incident HIV. This risk is especially pronounced in young women, who in sub-Saharan Africa account for almost four in five new acquisitions in youth.[3]

Other pathways between IPV and vertical HIV transmission could also play a role, though the correlation between ART uptake *during* pregnancy and PAF is weaker than the one for ART uptake *before* pregnancy. This is consistent with evidence suggesting that women who begin their treatment early have the lowest rates of vertical transmission, due to achieving viral suppression sooner.[159]

Our study has several limitations. First, PAF assumes a causal relationship between the IPV and vertical transmission. The estimates of IPV's impact on model parameters are derived from observational studies whose methods might still lead to residual biases. Thus, we explored the impact of key parameters in sensitivity analyses. However, our model outcomes are likely conservative, since they do not capture averted vertical transmission with the elimination of *lifetime* experience of IPV. Second, PAF interpretation relies on the complete elimination of the exposure. While there are no silver bullets to fully eliminate IPV, several interventions to tackle gender-based violence have been effective.[119] It is imperative for the global advocacy and research agenda to be guided by IPV elimination goals. IPV is a fundamental human rights violation, with tolerant and condoning attitudes standing out as major risk factors. Third, our model may be subject to structural misspecification and may not capture all features of vertical transmission. For example, we assume that women who acquire HIV during pregnancy are not engaged in prevention of vertical HIV transmission programs. Although some women might be identified and enrolled in prevention of vertical HIV transmission programs, this assumption is supported by existing literature on low rates of HIV retesting at ANC.[160] Further, we did not incorporate the impact of IPV on breastfeeding initiation and duration because previous conflicting evidence from population-based surveys.[161] Fourth, the most recent estimates of IPV prevalence date from 2018, thus not accounting for longitudinal trends in IPV, including COVID-19. We present data for years proximate to 2018, and IPV prevalence declined by a small average annual rate of 0.2% between 2000-2021 in low-and-middle income countries.[162] Finally, our model used estimates of past-year IPV among all women and not specifically

pregnant women. However, estimates of IPV prevalence during pregnancy vary widely[92], and the evidence is sparce on variation in levels of IPV before, during and after pregnancy.[91]

Strengths of our study include our novel application of probability tree models to account for the temporal relationships between IPV and vertical HIV transmission. We used country-reported HIV program data and estimates of key HIV indicators from the UNAIDS-supported Spectrum model. These were complemented with meta-analyses, secondary analyses of population-representative surveys, and community-based cohort studies to parametrize our model. We conducted multiple sensitivity analyses to understand the mechanisms through which IPV effects vertical HIV transmission.

Our results have important policy implications for achieving vertical transmission elimination. Improving ART coverage among pregnant WLHIV which is still lagging in high HIV burden settings, should be prioritized. Repeated HIV testing in late pregnancy or breastfeeding would identify recently infected women and expedite their enrollment in prevention of vertical HIV transmission programs. Concomitantly, identifying women experiencing IPV and supporting them to remain in care is important. Differentiated service delivery models could help fill treatment gaps.[163] In settings where ART uptake is already high, reduction in IPV could be an important, final hurdle to accelerate vertical HIV transmission elimination. Interventions could have the largest population-level impact on vertical transmission by focusing on younger age groups, given that adolescent girls and young women carry a disproportionate burden of IPV and HIV acquisition.

Progress in reducing new HIV infections in sub-Saharan Africa must be accompanied with the corresponding reduction in IPV to achieve vertical HIV transmission elimination. Reaching this goal requires addressing structural vulnerabilities affecting women beyond IPV, such as poverty and educational attainment. Repercussions of the overlap between IPV and HIV have long-lasting effects on hundreds of thousands of infants globally.

**Contributions**

Contributors SK and MM-G conceived the study. SK developed and programed the model. SK analyzed the data to obtain the model parameters. SK and MM-G have accessed and verified

Spectrum projection files. All authors contributed to the study methods and to reviewing and editing the manuscript. SK wrote the initial draft of the manuscript. All authors reviewed and edited the manuscript and approved the final version. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

**Declaration of interests**

MM-G reports contractual arrangements from WHO and UNAIDS. JWE-I reports research grants from the Bill & Melinda Gates Foundation, the US National Institutes of Health, UNAIDS, WHO, and the United States Agency for International Development (USAID), personal fees from Oxford Policy Management, and support for meeting travel from UNAIDS, BAO Systems, International AIDS Society and SACEMA, all outside the submitted work. M-CB declares HPTN Modelling Centre, which is funded by the U.S. National Institutes of Health (NIH UM1 AI068617) through HPTN. SK reports contractual arrangements from the UNAIDS. SD reports a grant from the Canadian Institutes of Health Research, outside the submitted work. WAR reports funding from Canadian Blood Services, Fonds de recherche du Québec, the AABB Foundation, Canadian Institutes of Health Research, Urgencé Santé, and Natural Sciences and Engineering Research Council of Canada, all outside the submitted work. All other authors declare no competing interests.

**Data sharing**

Projection files (.PJNZ) from Spectrum are publicly available via UNAIDS AIDS Data Repository after user registration, data request and approval (https://hivtools.unaids.org/spectrum-file-request/ ). Analysis code that supports the findings of the study are available upon request to the first and corresponding authors (SK, salome.kuchukhidze@mail.mcgill.ca; MM-G, mathieu.maheu-giroux@mcgill.ca).

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## 6.4 Manuscript 3: Supplementary results

**Supplement 1**: Regionally pooled, age-standardized population attributable fraction in 2022.

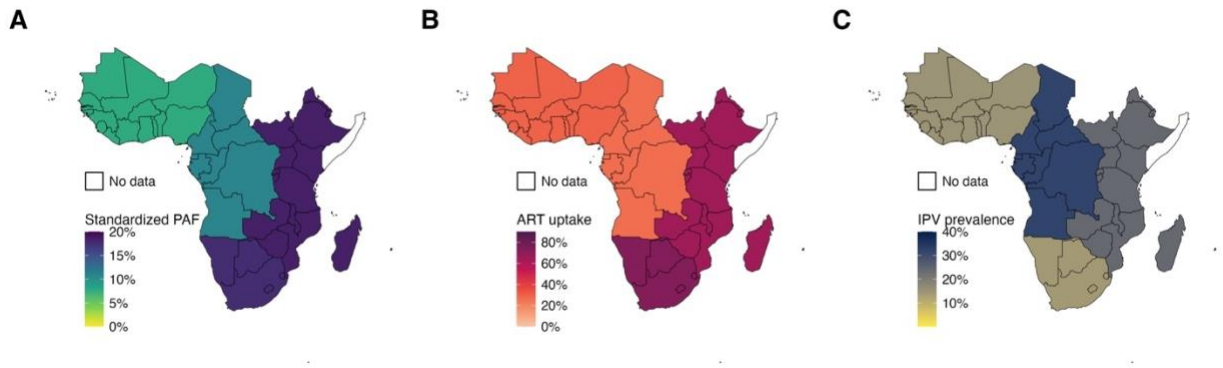


**Figure S1.** A) Age-standardized population attributable fraction of past-year physical and/or sexual intimate partner violence in 46 African countries in 2022 in each subregion (central, eastern, western and southern Africa). B) Overall (non-IPV stratified) antiretroviral treatment uptake prior to pregnancy among women in 46 African countries in 2022 in each subregion. C) Past-year physical and/or sexual intimate partner violence prevalence in 46 African countries in 2018 as reported in the *Global Database on Violence Against Women*. In Nigeria, Djibouti, and Mauritius we carried over the most recent available data (obtained from Spectrum 2023 projection files) to 2022. This was 2020 for Nigeria and 2021 for the latter two countries. *ART=antiretroviral treatment; IPV=intimate partner violence; PAF= population attributable fraction.*

**Supplement 2**: Country-specific, age-standardized population attributable fraction over time.

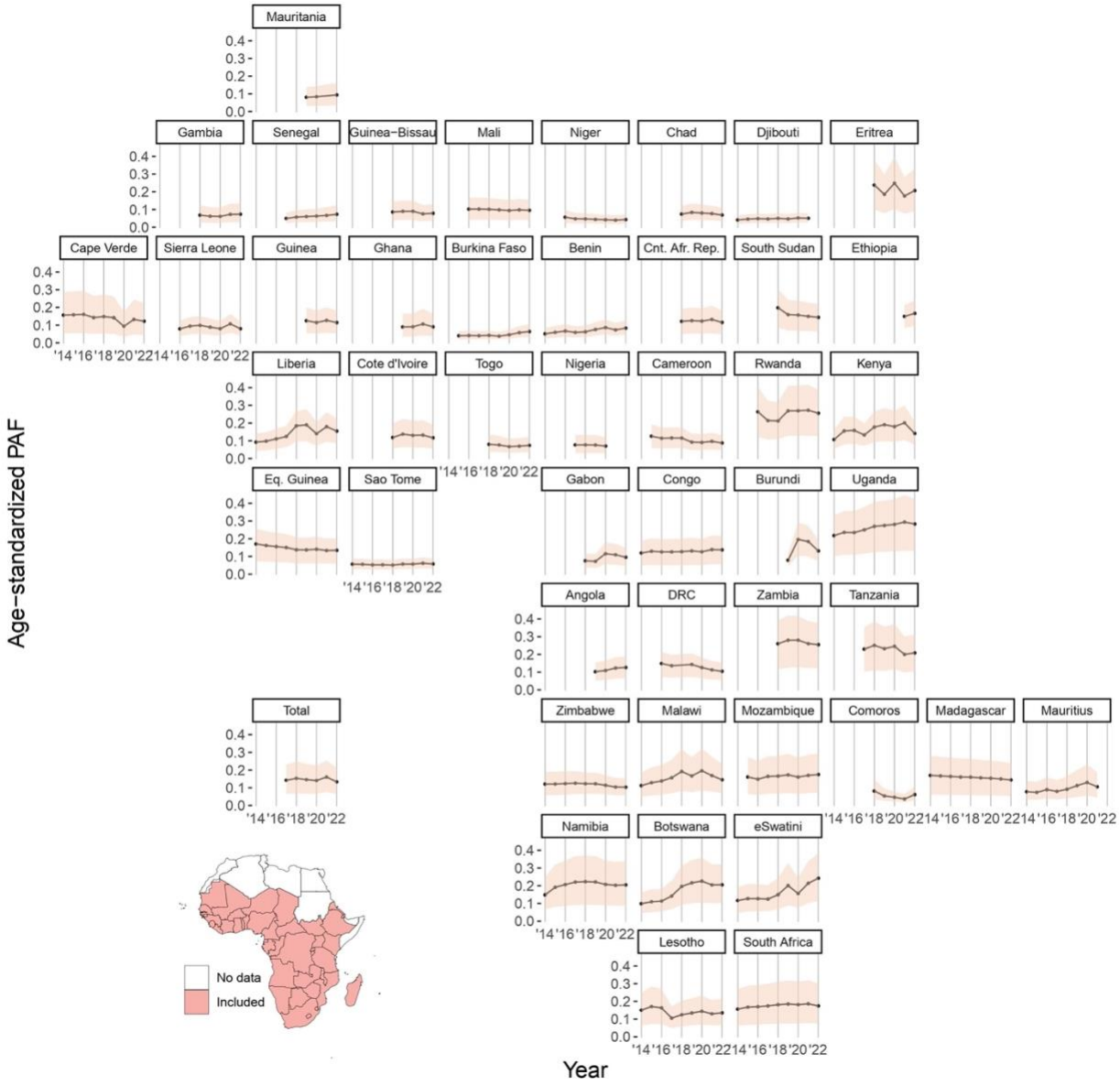


**Figure S2.** Proportion of vertical transmission of HIV attributable to past-year physical and/or sexual intimate partner violence in 46 African countries between 2014-2022. Somalia had no publicly available projection file in Spectrum in 2022 or 2023. The shaded area refers to the 95% uncertainty interval. *PAF=population attributable fraction*

**Supplement 3**: Regionally pooled descriptive summary of model parameters over time.

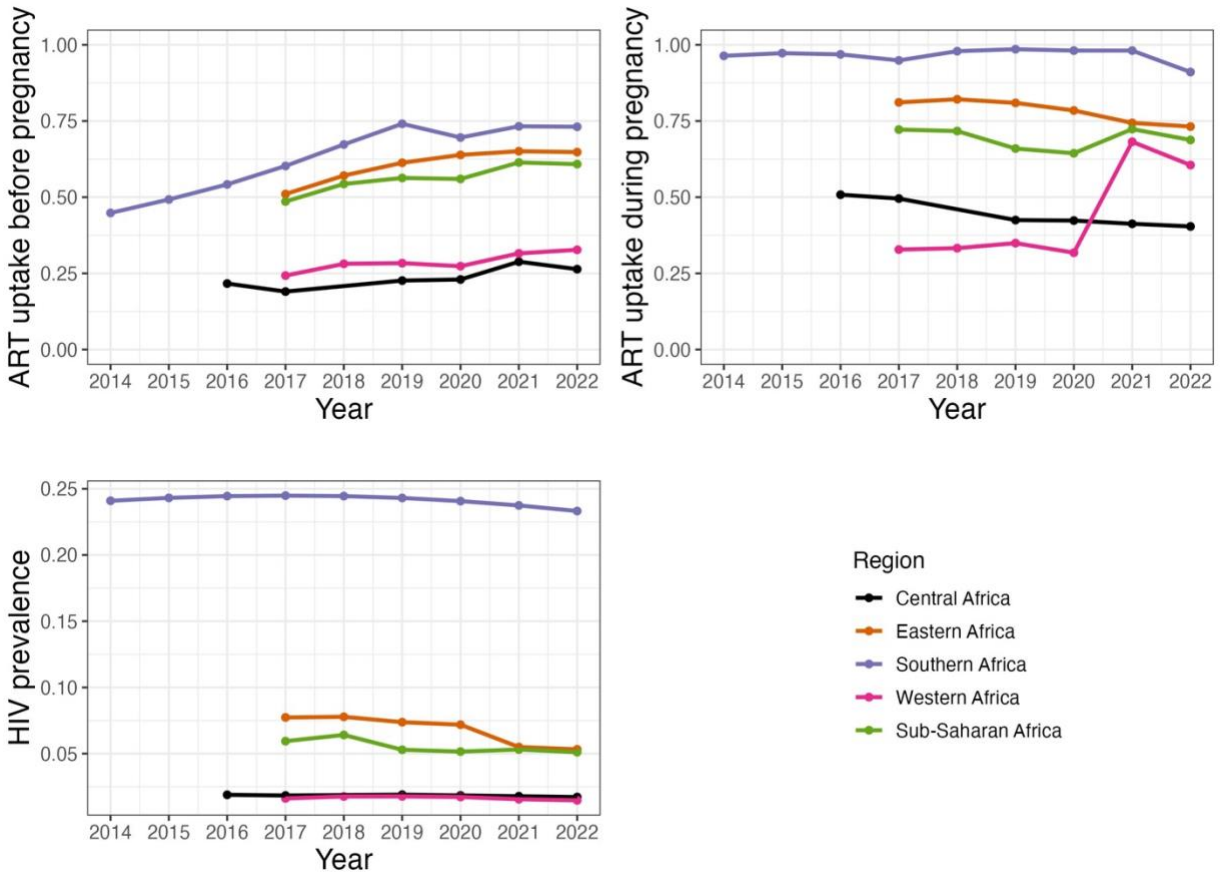


**Figure S3.** Longitudinal summary of antiretroviral treatment (ART) uptake prior to pregnancy, ART uptake during pregnancy, and HIV prevalence among women (15-49 years) in central Africa (2016-2022), eastern Africa (2017-2022), southern Africa (2014-2022), western Africa (2017-2022) and overall, 46 African countries (2017-2022). We present results for calendar years where we have data for at least 50% of the total population in the subregion. In Nigeria, Djibouti, and Mauritius we carried over the most recent available data (obtained from Spectrum 2023 projection files) to 2022. This was 2020 for Nigeria and 2021 for the latter two countries.
*ART = antiretroviral treatment.*

**Supplement 4**: Regionally pooled, age-standardized risk difference in 2022.

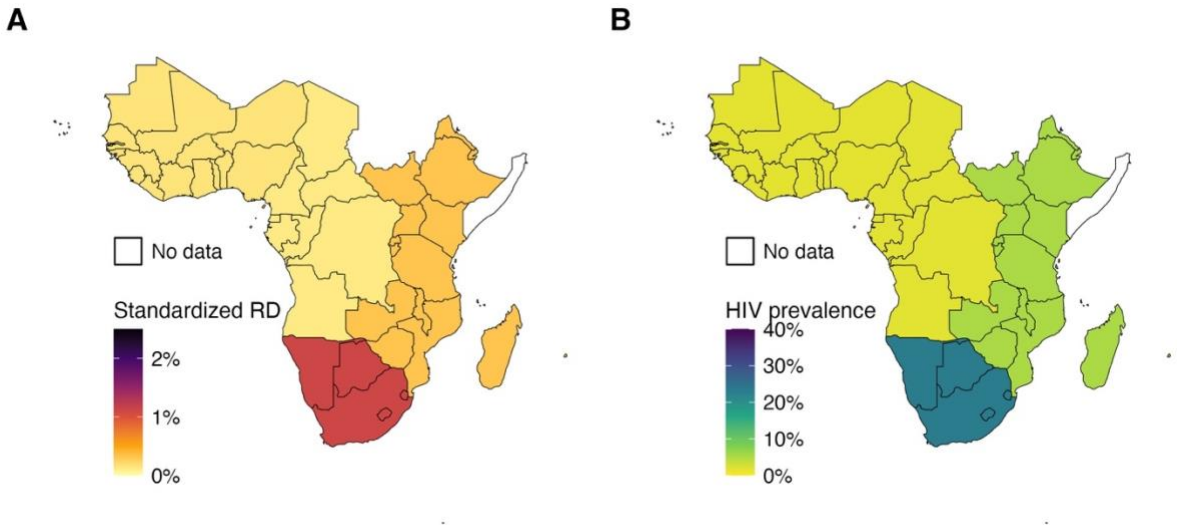


**Figure S4.** A) Age-standardized risk difference (RD) for the effect of past-year physical and/or sexual intimate partner violence on vertical HIV transmission in 46 African countries in 2022. B) HIV prevalence (non-IPV stratified) among women (15-49 years old) in 46 African countries in 2022. In Nigeria, Djibouti, and Mauritius we carried over the most recent available data (obtained from Spectrum 2023 projection files) to 2022. This was 2020 for Nigeria and 2021 for the latter two countries. *RD=risk difference*.

**Supplement 5**: Age-specific population attributable fraction in 2022.

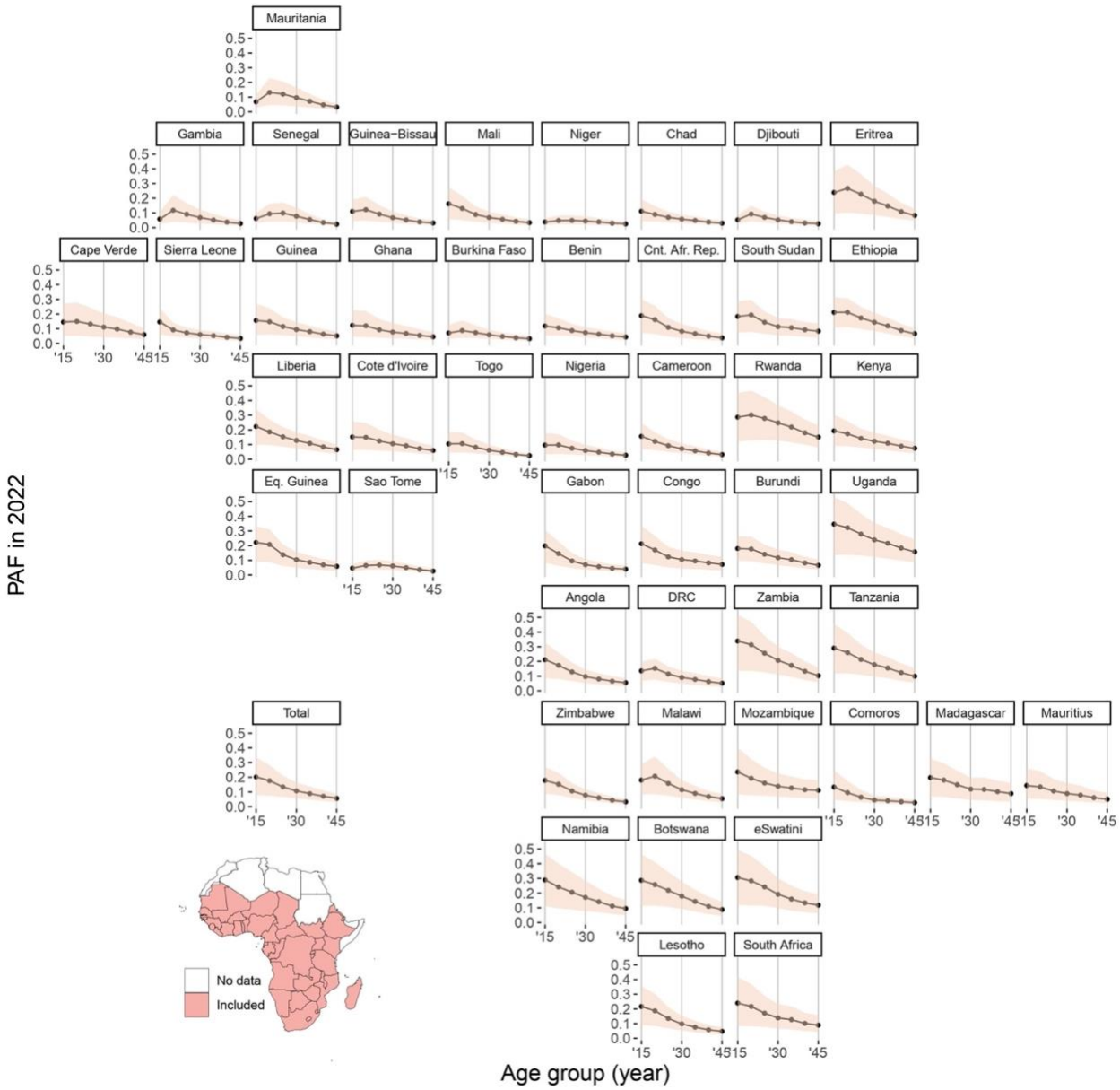


**Figure S5.** Age-specific population attributable fraction (PAF) of past-year physical and/or sexual intimate partner violence in 46 African countries in 2022. Somalia had no publicly available projection file in Spectrum in 2022 or 2023. The shaded area refers to the 95% uncertainty interval. *PAF=population attributable fraction*

**Supplement 6**: Stratified population attributable fraction in 2022.

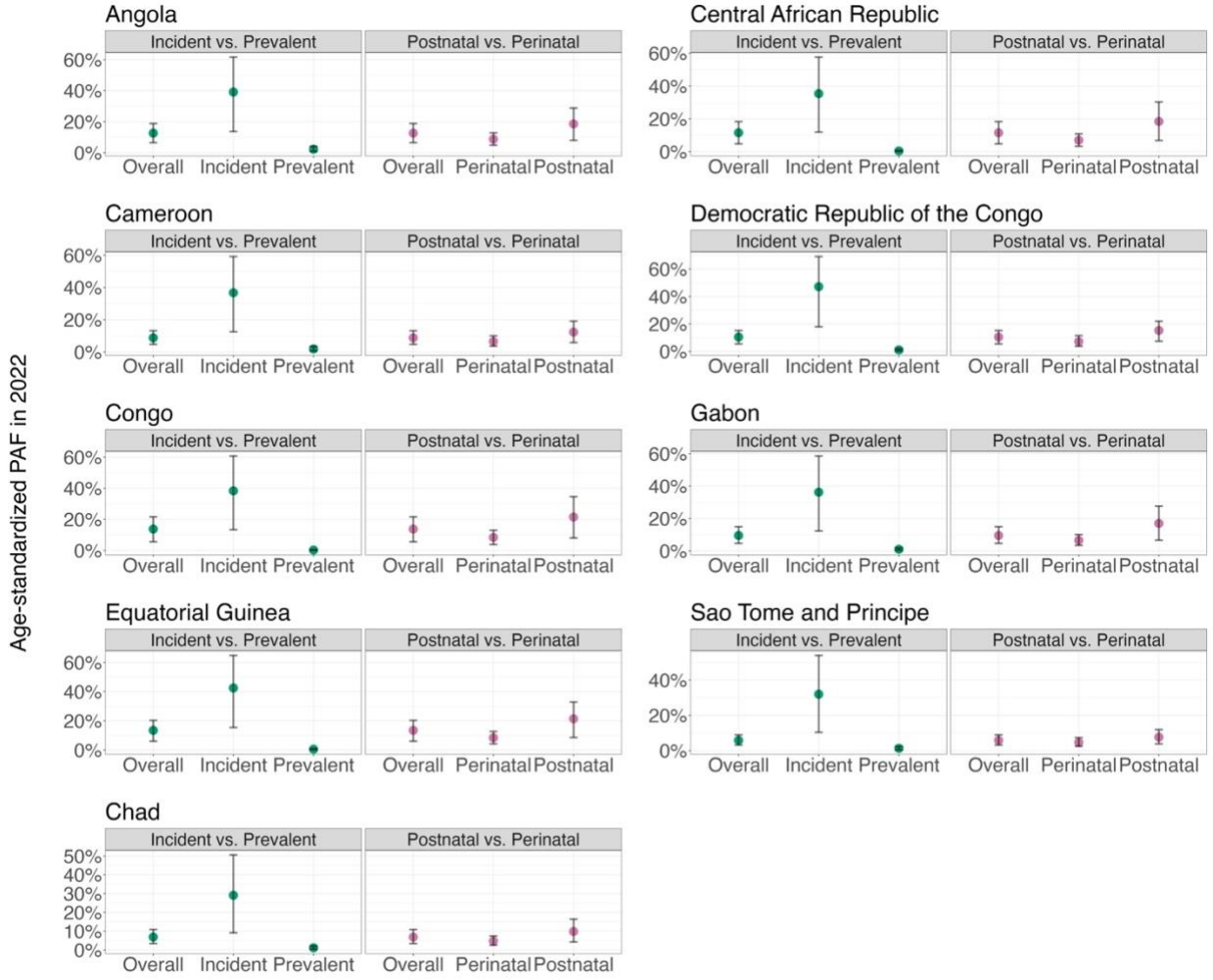


**Figure S6**. Age-standardized proportion of vertical HIV transmission attributable to past-year physical and/or sexual intimate partner violence stratified by perinatal versus breastfeeding periods and by the timing of HIV acquisition in women, in 2022 in central Africa. The error-bars refer to the 95% uncertainty intervals. *PAF=population attributable fraction*.

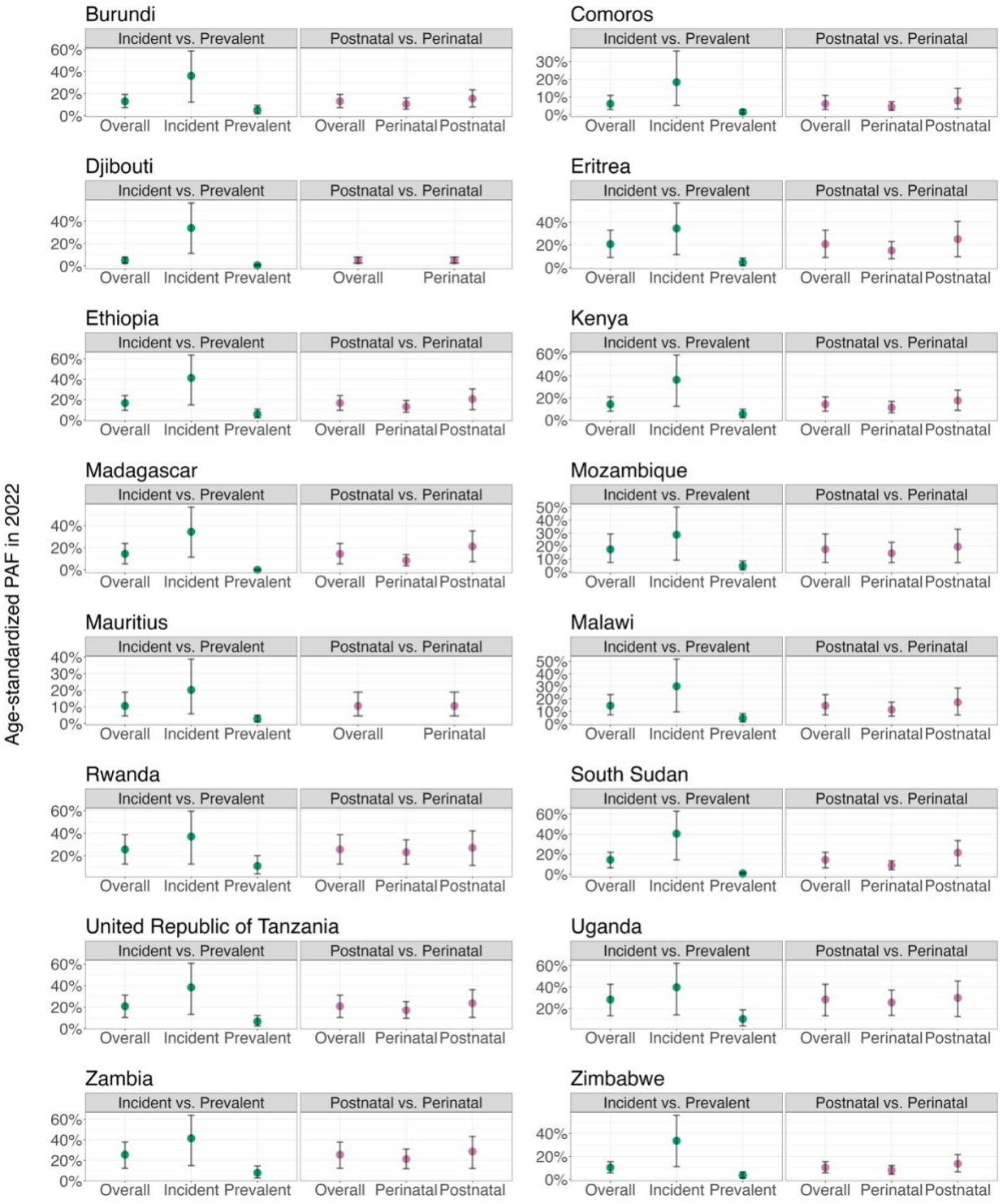


**Figure S7**. Age-standardized proportion of vertical HIV transmission attributable to past year physical and/or sexual intimate partner violence stratified by perinatal versus breastfeeding periods and by the timing of HIV acquisition in women in 2022 in eastern Africa. Data for Djibouti and Mauritius were carried over to 2022 from 2021. The error-bars refer to the 95% uncertainty intervals. *PAF=population attributable fraction*.

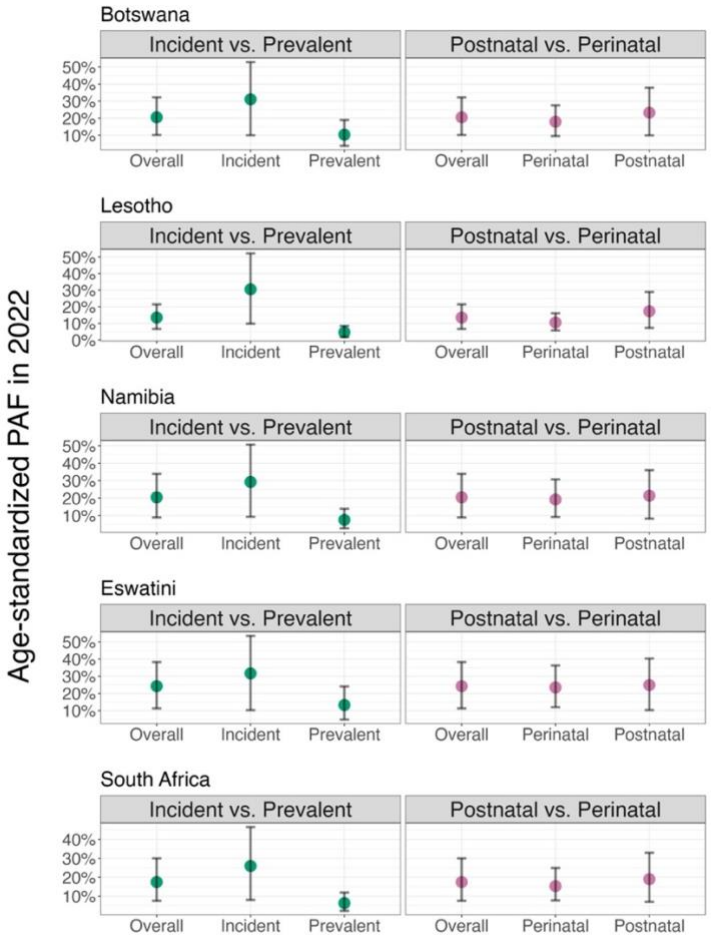


**Figure S8**. Age-standardized proportion of vertical HIV transmission attributable to past-year physical and/or sexual intimate partner violence stratified by perinatal versus breastfeeding periods and by the timing of HIV acquisition in women, in 2022 in southern Africa. The error-bars refer to the 95% uncertainty intervals. *PAF=population attributable fraction*.

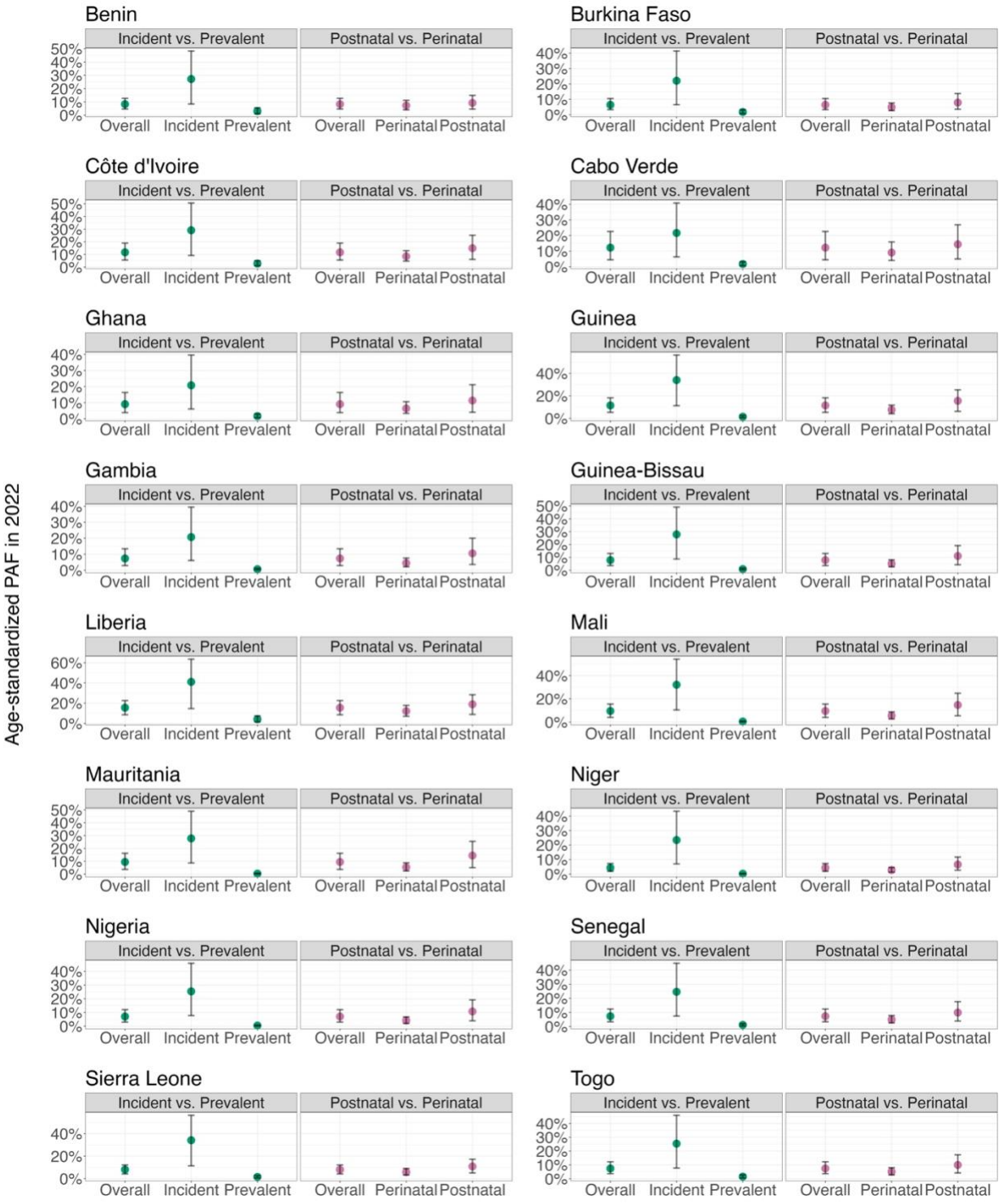


**Figure S9**. Age-standardized proportion of vertical HIV transmission attributable to past-year physical and/or sexual intimate partner violence stratified by perinatal versus breastfeeding periods and by the timing of HIV acquisition in women, in 2022 in western Africa. Data for Nigeria was carried forward from 2020 to 2022. The error-bars refer to the 95% uncertainty intervals. *PAF=population attributable fraction*.

**Supplement 7**: Sensitivity analyses.

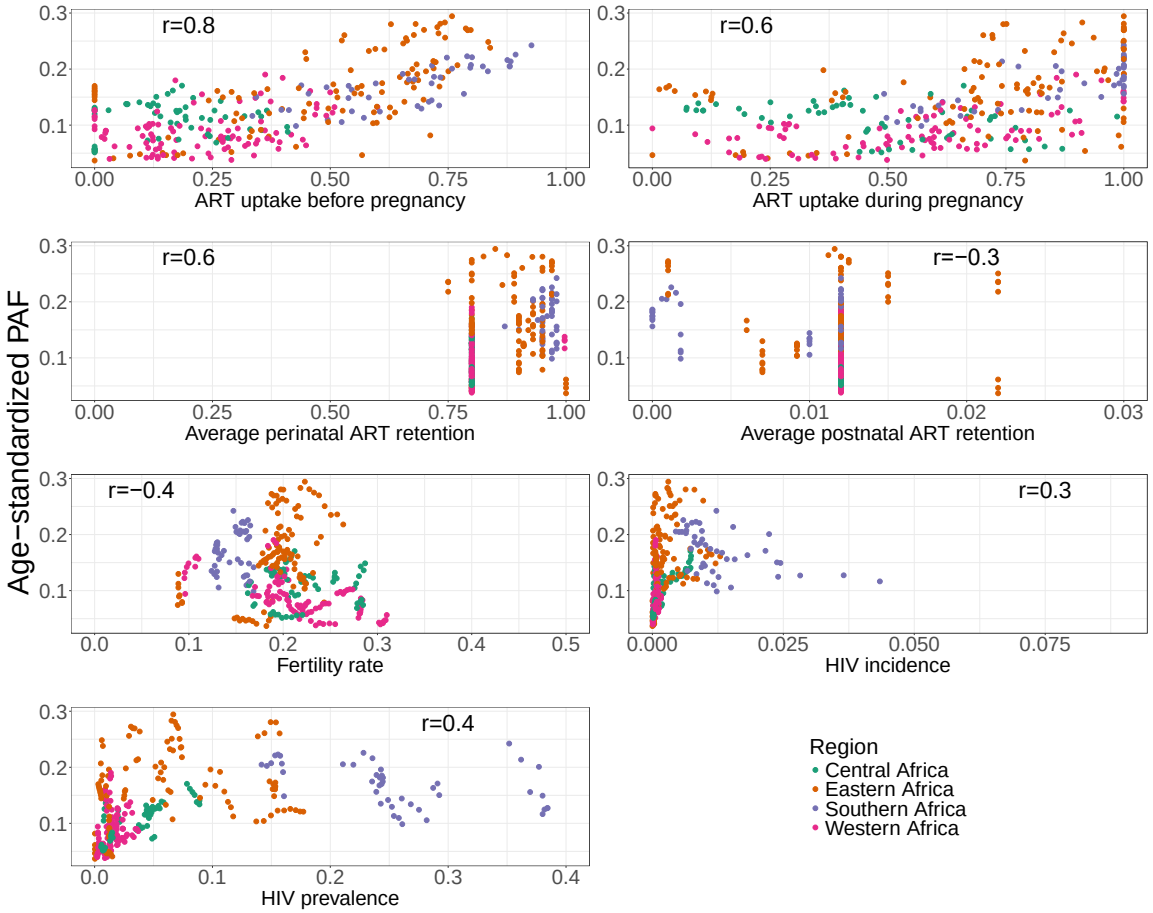


**Figure S10.** Country-level correlation between the model parameters impacted by intimate partner violence and the age-standardized population attributable fraction. Data points represent each country and year, colored by region. The x-axis indicates the parameter value, and the y-axis is the PAF. Models to calculate partial correlation coefficients (*r*) were adjusted for county-specific prevalence of past-year physical and/or sexual IPV. *ART = antiretroviral treatment; IPV = intimate partner violence; PAF = population attributable fraction*

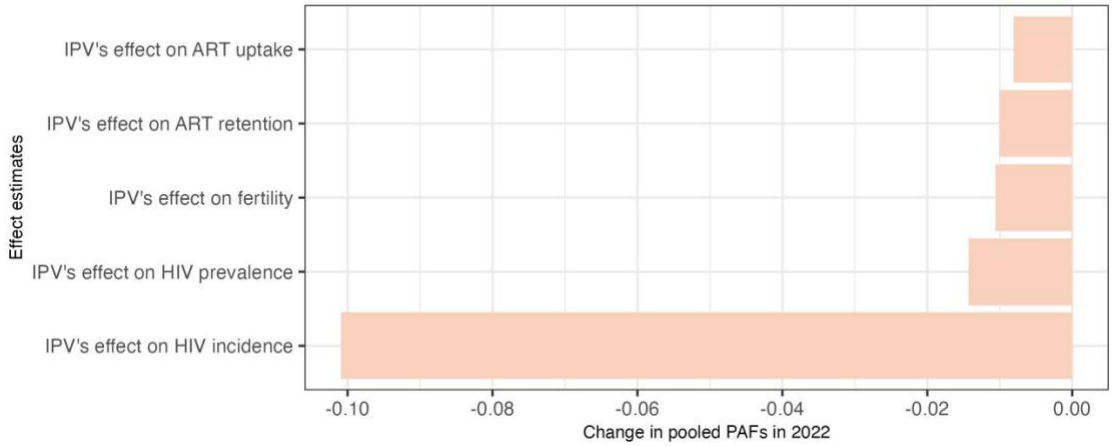


**Figure S11.** The absolute impact of the effect estimates for the association between past-year physical and/or sexual intimate partner violence and model parameters on the age-standardized population attributable fraction (PAF) in 2022, aggregated across 46 African countries. We set the effect estimates to a null one at a time and calculated the resulting change in percentage-points of the age-standardized population attributable fraction. *ART = antiretroviral treatment; IPV = intimate partner violence; PAF = population attributable fraction.*

## 6.5 Manuscript 3: Supplementary methods

**Table S1.** The dictionary for the notation used in the Supplemental Methods.

| Subscript / Superscript | Variables that the notation represent |
|---|---|
| *a* | Five-year age group categories (15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49) |
| *c* | Countries (N=46) |
| *d* | Subregions in 46 African countries (central, eastern, southern, western Africa) |
| *h* | HIV status |
| *i* | Intimate partner violence experience (Yes/No) |
| *k* | CD4 count categories (<50, 50-99, 100-199, 200-249, 250-349, 350-499, >500) |
| *m* | ART regimens (single dose nevirapine, dual prophylaxis, Option A, Option B, Option B+ <4 week prior to delivery, Option B+ >4 weeks prior to delivery, ART prior to pregnancy and overall ART treatment status (Yes/No) |
| *n* | Number of months of breastfeeding (n=36) |
| *t* | Year (2014-2022) |

# Spectrum parameters

## 1a. Spectrum parameters and assumptions

To parametrize the model, we used the latest 2023 projection files from 46 countries in Africa (Table S2), included in Spectrum (version 6.28). Projection files are generated annually at country-led estimation workshops. These estimates are publicly available via the *UNAIDS AIDS Data Repository* pending user registration, data request and approval (https://hivtools.unaids.org/spectrum-file-request/). We list the definitions of extracted parameters, relevant assumptions, and the notation used to represent the parameters in this Supplemental Methods, when applicable (Table S3). Spectrum did not contain data for HIV testing at the antenatal care (ANC) for South Africa. We used the assumed proportions of HIV testing among pregnant women at the ANC in South Africa used in Thembisa version 4.7.[157]

**Table S2**. 46 countries in Africa included in our analysis.

| Region | Country |
|---|---|
| Central Africa | Angola, Cameroon, Central African Republic, Chad, Congo, Democratic Republic of Congo, Equatorial Guinea, Gabon, São Tomé and Príncipe |
| Eastern Africa | Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, South Sudan, Uganda, United Republic of Tanzania, Zambia, Zimbabwe |
| Western Africa | Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo |
| Southern Africa | Botswana, Eswatini, Lesotho, Namibia, South Africa |

**Table S3.** Parameters used in the probability tree model with relevant assumptions and notation used in the Supplemental Methods.

| Parameter definition | Assumptions and remarks | Notation used in the supplement |
|---|---|---|
| **Programmatic data** | | |
| Proportion of women attending and receiving at least one HIV test at ANC among all women giving birth by country (*c*) and year (*t*). | Rounded down to one (100%) in countries where proportion of HIV testing at ANC was greater than 100%. This could happen when women receive repeat HIV tests in different health facilities, thus are counted more than once in prevention of vertical HIV transmission program data. We assumed that the probability of testing during ANC is the same for women not living with HIV and those living with the virus. Aligned with this, Thembisa 4.7 reports assumed ANC testing proportion among all pregnant women. | $\delta_t^c$ |
| Proportion of women breastfeeding at each month (*n*) of postpartum period (up to 36 months) by ART uptake status (*m, Yes/No*). | Breastfeeding proportions were recorded for up to 36 months of postpartum period per Spectrum data editor. The proportion of women breastfeeding reduces over time. | $P_{t,n}{}^{mc}$ |
| Total number of births among WLHIV. | Used as a denominator to calculate ART uptake proportion among pregnant WLHIV. | - |
| Total number of pregnant WLHIV on ART. | Used as a denominator to calculate ART uptake proportion among pregnant WLHIV when the number of births among WLHIV reported in Spectrum was less than the number of pregnant WLHIV receiving ART. | - |
| Proportion of women receiving Option B+ before pregnancy among all WLHIV ("ART uptake" hereon) | In countries where the number of pregnant WLHIV was less than number of pregnant WLHIV receiving ART, we used the total number of pregnant WLHIV receiving any ART as the denominator in ART uptake calculations. The number of pregnant WLHIV could be less than the number of pregnant WLHIV on ART due to potential underreporting of HIV-positive women or overreporting of pregnant women on ART in Spectrum prevention of vertical HIV transmission module. | $\varphi_t^c$ |
| Proportion of women receiving ART during pregnancy (by ART regimen type, *m*) among all WLHIV ("ART uptake" hereon). | | $\eta_t^{mc}$ |
| Proportion of women retained in ART during the *perinatal* period (at delivery) by ART regimen type. | Relevant for women on Option B+ in Spectrum. | $r_t^{mc}$ |
| Proportion of women retained in ART during the *postnatal* period by ART regimen type. | Relevant for women on Option A, B, B+ in Spectrum. Data in Spectrum were reported as monthly dropout rate from ART. | $\lambda_t^{mc}$ |
| **HIV projection outputs** | | |
| Total number of women by five-year age group *(a),* living with and without HIV *(h).* | - | $N_{t,h}{}^{ac}$ |
| HIV prevalence by five-year age group. | - | $H_t^{ac}$ |
| Cumulative HIV incidence over one year in women by five-year age group. | - | $I_t^{ac}$ |
| **Demographic parameters** | | |

| | | |
|---|---|---|
| Fertility multiplier by five-year age group for WLHIV by ART uptake status (*m,Yes/No*). | - | $FA^{acm}$ |
| Ratio of fertility rate among WLHIV to the fertility rate of women not living with HIV by CD4 cell count category (*k*). | - | $FR^{kc}$ |
| Fertility multiplier by location. | Local adjustment factor which is fitted to HIV prevalence data from ANC clinics to ensure that estimates of HIV prevalence among pregnant women match empirical data. | $FC^{c}$ |
| Proportion of WLHIV in each CD4 count category (<200, 200-350, >350 cells per μL) by ART uptake status (*m,Yes/No*). | These parameters were used to calculate the vertical HIV transmission rate among women not on ART. We assumed that the CD4 count distribution of pregnant WLHIV not on ART did not differ from the distribution of CD4 count for all untreated WLHIV. | $C_t^{kcm}$ |
| Total number of births among all women. | Used only as a denominator to calculate the proportion of HIV testing at the ANC. | - |
| Percentage of total births in each five-year age group. | Used to calculate age specific fertility rate. | $PRF_t^{ac}$ |
| Total fertility rate. | - | $TFR_t^c$ |
| HIV transmission probabilities during perinatal (*peri)* and breastfeeding periods (*bf*), by ART regimen, among women who acquired HIV before pregnancy. | - | $\beta_{bf}^{m}$<br>$\beta_{peri}^{m}$ |
| HIV transmission probabilities during perinatal (*peri)* and breastfeeding (*bf*) periods among women who acquire HIV during pregnancy or breastfeeding (*incident*). | - | $\beta_{bf}^{incident}$<br>$\beta_{peri}^{incident}$ |

*ANC = antenatal care; ART= antiretroviral treatment; ASFR = age-specific fertility rate; WLHIV = women living with HIV.*

# IPV's impact on model parameters

## 2a. Pathways between intimate partner violence and vertical HIV transmission

To estimate the effect of intimate partner violence (IPV) on vertical HIV transmission, the model needs to specify the multiple pathways by which women's experience of past-year IPV could influence vertical HIV transmission. To guide which parameters need to vary by IPV, we first reviewed the literature to understand the impact of IPV on each step in the prevention of vertical HIV transmission program cascade. We found that women experiencing IPV are more likely to acquire and to be living with HIV[7], less likely to adhere to antiretroviral treatment (ART)[164] and be virally suppressed.[7] This is true in the context of prevention of vertical HIV transmission programs as well: women experiencing IPV might have lower rates of antenatal care (ANC) engagement,[104,165,166] lower uptake of and retention in ART regimens,[14,15] and lower rates of viral suppression.[109]

## 2b. Review of effect size estimates

To stratify model parameters, we obtained the effect size estimates for the relationship between IPV and the intermediate outcomes of interest (e.g., ART uptake). To obtain these effect size estimates we identified peer-reviewed meta-analyses of population-representative surveys, and community-based cohort studies that examined the impact of past-year physical and/or sexual IPV on each step of the prevention of vertical HIV transmission program cascade. When effect estimates were not available in the published literature, we conducted *de novo* analyses of relevant surveys.

The prevalence ratios for the effect of past-year IPV on cumulative HIV incidence over one year, ART uptake and ART retention were extracted from a meta-analysis of nationally representative surveys (2000-2021) in six African countries.[7] Effect estimate for viral suppression among WLHIV by IPV status was used as a proxy for the effect of IPV on perinatal and postnatal ART retention among pregnant WLHIV. Prevalence ratio for *recent HIV infection* by IPV status was used as a proxy estimate for the effect of IPV on cumulative HIV incidence

over one year. Recent HIV infection measurement was based on a Lag-avidity assay. Viral suppression and ART uptake measurement were biomarker-based.

The odds ratio for the relationship between IPV and HIV prevalence was extracted from a meta-analysis of 12 Demographic and Health Surveys (DHS) surveys from 10 countries in Africa.[10] This estimate reflects the effect of lifetime physical and/or sexual IPV, instead of the past-year IPV on HIV prevalence (biomarker-based measure), to account for the fact that women might have seroconverted prior to experiencing past-year IPV.

A meta-analysis of 22 DHS in African countries between 2012-2020 found that the experience of IPV was associated with poor timely utilization of ANC.[114] Evidence from another meta-analysis of DHS surveys from 36 countries between 2005-2016 suggested that lifetime experience of any IPV is associated with decreased utilization of four or more ANC visits, fewer ANC visits, and poorer utilization of facility care at birth.[115] However, both studies used lifetime IPV which included emotional violence, as their exposure which is different from our exposure definition. Further, they focused on ANC attendance, rather than HIV testing at the ANC as their outcome. Since we did not find any multi-country reports on the impact of past-year physical/or sexual IPV on HIV testing at the ANC, we conducted a *de novo* analysis of 29 DHS surveys that collected information on past-year experience of IPV, HIV testing and HIV biomarkers among women who had given birth in the past year (Table S5). Our adjusted analysis showed no impact (aPR=1.00; 95% confidence intervals: 0.96-1.08). Therefore, we did not vary HIV testing at the ANC by IPV. This is aligned with the existing evidence from 57 DHS surveys showing that the past-year physical and/or sexual IPV does not affect self-reported HIV testing in the past year.[7]

Regardless of IPV, HIV acquisition risk may be higher among pregnant and breastfeeding women compared to non-pregnant/non-breastfeeding women, which was also accounted for while calculating the HIV incidence measure for women who acquire HIV during pregnancy or breastfeeding. Incidence rate ratio for the increased risk of incident HIV during pregnancy and breastfeeding, compared to non-pregnancy/non-breastfeeding period was obtained from a community-based prospective cohort study of over 5,500 pregnant or lactating women in Uganda.[111] Here we depart from Spectrum assumptions where pregnant women are assumed to have the same HIV incidence as non-pregnant. The latter is based on evidence suggesting that

while the risk of HIV acquisition is higher per-condomless-coital act during pregnancy than non-pregnancy, reduction in sexual activity peri-and-postnatally might mitigate this increased risk.[113] However given the wide variability across African countries in sexual activity patterns during pregnancy/postpartum, we adhered to the assumption of higher risk.[113] In our sensitivity analyses we explored the impact of removing this assumption.

Finally, women who experience IPV might have a higher fertility. IPV perpetration frequently coincides with male controlling behaviors, such as exertion of control over women's fertility and impediment to their ability to negotiate safe sexual practices. Sexual violence might also directly lead to unwanted pregnancies.[150] Hazard ratio for pregnancy among women who ever-experienced any type of IPV compared to those who never did was obtained from a two-stage random effects meta-analyses of 29 nationally-representative surveys in low-and-middle-income countries.[150] Given that hazard ratio (a rate-based measure) is small (HR=1.13), we used it as an approximation of a prevalence ratio (a risk-based measure).

**Table S4. Effect size estimates for the relationship between past-year physical or sexual intimate partner violence and model parameters relevant to vertical transmission of HIV.**

| Parameters | Adjusted effect size estimate (95% CI) | Adjustment variables | Sources | Assumptions and remarks |
|---|---|---|---|---|
| Prevalence ratio for ART uptake among WLHIV who experienced physical and/or sexual IPV in the past year compared to those who did not. | PR=0.96 (0.90-1.02) | Age, urban or rural residency, marital status, education, and survey-level fixed effects. | Kuchukhidze *et al.* 2023[167] | We assumed that ART uptake for each ART regimen among pregnant WLHIV is the same as ART uptake among all WLHIV. ART uptake was defined based on qualitative detection of antiretroviral biomarkers in blood samples complemented by self-report of being on ART at the time of survey administration. |
| Incidence rate ratio for HIV acquisition during pregnancy compared to the nonpregnant, non-breastfeeding period.* | IRR=2.16 (1.39-3.37) | Age, education, marital status, number of sex partners, genital ulcer disease, and condom use. | Gray *et al.* 2005[111] | |
| Incidence rate ratio for HIV acquisition during breastfeeding compared to the nonpregnant, non-breastfeeding period.* | IRR=1.16 (0.82-1.63) | Age, education, marital status, number of sex partners, genital ulcer disease, and condom use. | Gray *et al.* 2005[111] | |
| Prevalence ratio for recent HIV infection among women who experienced physical and/or sexual IPV in the past year compared to those who did not. | PR=3.22 (1.51-6.85) | Age, urban or rural residency, marital status, education, age at sexual debut, and survey-level fixed effects. | Kuchukhidze *et al.* 2023[167] | Recent HIV infection measurement was based on a Lag-avidity assay. This effect size estimate was used as a proxy for IPV's effect on cumulative HIV incidence over one year. |
| Odds ratio for living with HIV among women who ever-experienced physical and/or sexual IPV compared to those who never experienced any type of physical and/or sexual IPV. | OR=1.10 (1.00-1.20) | Age, education, marital status, occupation, religion, wealth, urban or rural residency, and survey-level fixed effects. | Durevall *et al.* 2010[10] | HIV seroprevalence measurement was based on HIV biomarkers in blood. Lifetime experience of IPV was used as an exposure (instead of past-year) to account for the fact that women might have seroconverted prior to experiencing past-year IPV. |
| Prevalence of any breastfeeding of the last-born child among women not living with HIV. | 0.98 (0.97-0.98) | - | 32 DHS surveys (2000-2023) that collected information on past year experience of physical and/or sexual IPV, HIV | This estimate was used to obtain cumulative HIV incidence measure among breastfeeding women who acquire HIV during breastfeeding. |

| | | | | |
|---|---|---|---|---|
| | | | testing, and HIV biomarkers. | |
| Hazard ratio for incident pregnancy among women who ever-experienced any type of IPV compared to those who never did. | HR=1.13 (1.07-1.20) | Age, education, marital status, partner's education, wealth, urban or rural residency. | Maxwell *et al.* 2017[150] | Hazard ratio for incident pregnancy was used as a proxy for IPV's effect on age specific fertility rate. Given that hazard ratio (a rate-based measure) is small it can approximate a prevalence ratio (a risk-based measure). |
| Prevalence ratio for viral load suppression among *WLHIV on ART* who experienced IPV in the past year compared to those who did not. | PR=0.95 (0.91-1.00) | Age, urban or rural residency, marital status, education, and survey-level fixed effects. | Kuchukhidze *et al.* 2023[167] | Prevalence ratio for viral suppression was used as a proxy for the effect of IPV on perinatal and postnatal ART retention among pregnant WLHIV. |

*ANC = antenatal care; ART = antiretroviral treatment; DHS = demographic and health surveys; HR = hazard ratio; IPV = intimate partner violence; IRR = incidence rate ratio; PR = prevalence ratio; OR = odds ratio; WLHIV= women living with HIV.*

* Incidence rate ratios for HIV acquisition during pregnancy and breastfeeding compared to non-pregnancy and non-breastfeeding periods do not reflect the impact of IPV on vertical HIV transmission. Rather these parameters were used to modify HIV incidence measure to account for the added risk of HIV acquisition during pregnancy and breastfeeding period compared to non-pregnancy and non-breastfeeding period.

**Table S5**. Twenty-nine demographic and health surveys included in the analysis for IPV's impact on HIV testing at the antenatal care

| Region | Survey country, survey year |
|---|---|
| Central Africa | Angola 2015, Cameroon 2018, Chad 2014, Gabon 2012, Gabon 2019, São Tomé and Príncipe 2008 |
| Eastern Africa | Burundi 2016, Ethiopia 2016, Kenya 2008, Malawi 2010, Malawi 2015, Mozambique 2015, Rwanda 2005, Rwanda 2010, Rwanda 2015, Zambia 2007, Zambia 2013, Zambia 2018, Zimbabwe 2005, Zimbabwe 2010, Zimbabwe 2015 |
| Western Africa | Burkina Faso 2010, Côte d'Ivoire 2012, Gambia 2013, Mali 2006, Mali 2012, Sierra Leone 2019, Togo 2013 |
| Southern Africa | South Africa 2016 |

### 2c. Calculation of stratified model parameters when the effect size estimate is a prevalence ratio

We obtained overall population estimates – those that are not stratified by IPV– for several quantities in the model. These are weighted averages of IPV-stratified estimates. For example, overall ART uptake ($\varphi_t^c$) is a weighted average of ART uptake among women who did not experience IPV and those who experienced it. Here, the weights are the proportion of women who have experienced IPV ($IPV_{t=2018}^{ac}$) and have not experienced IPV in the past year (1-$IPV_{t=2018}^{ac}$). Hence, when the effect estimate was a PR, we calculated IPV-specific ART uptake using the following set of equations where X and Y are the ART uptake in IPV-exposed and unexposed women respectively. In rare cases when the overall ART uptake was 100% per Spectrum, we assumed that the ART uptake was overestimated and assigned a maximum uptake of 100% to women *not* experiencing IPV.

$$\frac{X}{Y} = PR$$

$$\varphi_t^c = IPV_{t=2018}^{ac} \times X + (1 - IPV_{t=2018}^{ac}) \times Y$$

For parameters where stratification was needed by pregnancy or breastfeeding status (e.g., HIV incidence), the proportion of pregnant (based on ASFR) and breastfeeding women were used respectively as weights, instead of the proportion of women exposed and unexposed to IPV.

Median past-year physical and/or sexual IPV prevalence in 2018, by five-year age groups, was obtained from the *Global Database on the Prevalence of Violence Against Women*.[86] This prevalence was assumed to be constant over time.[86] This assumption was reliable since recent evidence from 53 low income and middle income countries showed that IPV prevalence

declined by a small average annual rate of 0.2% between 2000-2021.[162] To justify this assumption, we present our results for 2014-2022: the four years proximate to 2018, the year for which IPV prevalence data are available.

### 2d. Calculation of stratified model parameters when the effect size estimate is an odds ratio

When the effect estimate is an OR, the weights to calculate IPV-specific estimates are not simply the proportion of women who experienced IPV and who did not. This is because OR is defined as: (the odds that a WLHIV had experienced IPV) / (the odds that a woman *not living with HIV* had experienced IPV). Thus, we derived two-by-two cell counts from the contingency table margins (the prevalence of the exposure and the prevalence of the outcome) and the odds ratio for the association between IPV and HIV (Table S6).

**Table S6.** A sample set-up for a two-by-two table to derive the components of the table based on the table margins and the overall odds ratio.

| | **Outcome** | | |
|---|---|---|---|
| **Exposure** | HIV+ | HIV- | Overall |
| IPV+ | a | b | Pr(E) |
| IPV- | c | d | 1- Pr(E) |
| Overall | Pr(O) | 1-Pr(O) | |

*Pr(O) = prevalence of the outcome; Pr(E)= prevalence of the exposure*

$$a + b = Pr(E)$$
$$a + c = Pr(O)$$
$$a + b + c + d = 1$$
$$ad/bc = OR$$

In Table S6, *Pr(O)* is the prevalence of the outcome and *Pr(E)* is the prevalence of the exposure. The above set of 4 equations contain 4 unknowns (*a*, *b*, *c*, *d*) and can be expressed as a single quadratic equation below. We solved this equation for one valid solution for *a*, determined by non-negative coefficients. We subsequently solved for the remaining components of the 2x2 table and calculated IPV-stratified HIV prevalence as *a/(a+b)* and *c/(c+d)* (Table S6).

$$(OR - 1)a^2 + \left[\left(Pr(E) + Pr(O)\right) \times (1 - OR) - 1\right] \times a + OR \times Pr(E) \times Pr(O) = 0$$

# Number of incident HIV among pregnant women not living with HIV before pregnancy

*3a. Births among women not living with HIV*

To calculate the expected number of births occurring among women who were not living with HIV ($B^{aic}_{h=0,t}$), we first obtained the number of women not living with HIV ($N^{aic}_{h=0,t}$) from Spectrum and multiplied it by the appropriate age-specific fertility rate ($ASFR^{ac}_{t}$). To calculate $ASFR^{aic}_{t}$ we normalized the percentage of total births among women in each five-year age group ($PFR^{ac}_{t}$) and then multiplied it by the total fertility rate ($TFR^{c}_{t}$). $ASFR^{aic}_{t}$ was stratified by women's experience of IPV in the past year.

$$B^{aic}_{h=0,t} = N^{aic}_{h=0,t} \times ASFR^{aic}_{t}$$

*3b. HIV incidence during pregnancy*

From this expected number of births among women not living with HIV, a proportion acquired HIV during the perinatal ($N^{aic}_{\text{perinatal,t}}$) and breastfeeding ($N^{aic}_{\text{breastfeeding,t}}$) period, as a function of cumulative HIV incidence over one year. Cumulative HIV incidence during pregnancy and breastfeeding varied to account for the different incidence rate ratios for the risk of HIV acquisition during pregnancy and breastfeeding periods (Table S4).

The number of new births by five-year age group, IPV experience, and year ($B^{aic}_{h=0,t}$) was used to calculate the number of women with incident HIV during pregnancy ($N^{aic}_{\text{perinatal,t}}$). During pregnancy, age- and IPV-specific cumulative HIV incidence during the perinatal period ($I^{aic}_{\text{perinatal,t}}$) was scaled for the 9-month at-risk period during pregnancy.

$$N^{aic}_{\text{perinatal,t}} = B^{aic}_{h=0,t} \times I^{aic}_{\text{perinatal,t}} \times {}^{9}/_{12}$$

*3c. HIV incidence during breastfeeding*

Women who did not acquire HIV during pregnancy ($B^{aic}_{h=0,t} - N^{aic}_{\text{perinatal,t}}$) might have acquired it during breastfeeding. HIV incidence was calculated cumulatively at each time point during the 0-36 months (*n*) of the breastfeeding period after birth. To calculate the number of women who acquired HIV during breastfeeding ($N^{aic}_{\text{breastfeeding,t}}$), we used IPV-specific cumulative HIV incidence estimate during postnatal period ($I^{aic}_{breastfeeding,t}$) as well as

proportion of women who were breastfeeding and not on ART at each month (n=36) of breastfeeding ($P_{\mathrm{t,n}}^{m=0,c}$). The proportion of women breastfeeding decreased over the 36 months.

$$N_{\mathrm{breastfeeding,t}}^{aic} = (B_{h=0,t}^{aic} - N_{\mathrm{perinatal,t}}^{aic}) \times \sum_{n=1}^{36}(\frac{I_{breastfeeding,t}^{aic}}{12} \times P_{\mathrm{t,n}}^{m=0,c})$$

# Number of births among women living with HIV before pregnancy

*4a. Calculation of fertility rate reduction due to HIV*

Generally, fertility is lower among HIV-positive women than HIV-negative women. This could be linked to HIV-associated morbidity or death of a male partner, reduced ability to conceive and higher risk of adverse pregnancy outcomes due to sexually transmitted infections concurrent to HIV.[168] Women without clinical symptoms of HIV might also experience lower fertility, possibly due to higher levels of amenorrhea or the increased use of contraception. At the population level, awareness of high HIV risk might overlap with reduced fertility due to older age at sexual debut and increased use of contraception.[168]

To calculate fertility rate reduction due to HIV we calculated the fertility rate reduction for a) WLHIV on ART and b) WLHIV not on ART. Then, these were weighed by the distribution of WLHIV in seven CD4 count categories (<50, 50-99, 100-199, 200-249, 250-349, 350-499, >500) by a) and b).

To calculate the fertility reduction for WLHIV *on ART* we multiplied the fertility multiplier by age for WLHIV *on ART* ($\mathrm{FA}^{ac,m=1}$) by the local adjustment factor. Local adjustment factor is fitted to HIV prevalence data from ANC clinics so that estimates of HIV prevalence among pregnant women match empirical data ($\mathrm{FC}^{c}$).

$$\mathrm{FRR}^{ac,m=1} = \mathrm{FA}^{ac,m=1} \times \mathrm{FC}^{c}$$

To calculate the fertility reduction for WLHIV *not on ART* we used the fertility multiplier by age for WLHIV *off ART* ($\mathrm{FA}^{ac,m=0}$), the ratio of fertility among WLHIV to the fertility of HIV negative women by CD4 count category ($\mathrm{FR}^{\mathrm{kc}}$), and the local adjustment factor ($\mathrm{FC}^{c}$).

$$\mathrm{FRR}^{akc,m=0} = \mathrm{FA}^{ac,m=0} \times \mathrm{FC}^{c} \times \mathrm{FR}^{\mathrm{kc}}$$

CD4 count distributions by ART status in Spectrum files were not stratified by age groups ($C_t^{kcm}$). They only provided the total number of WLHIV on ART and not on ART in seven CD4 count categories (*k*). To calculate CD4 count distribution by ART status, as well as by age, we simulated the model using the "first90release"[169] package in R and extracted the number of women in each CD4 count category stratified by age and ART status ($C_t^{akcm}$). We then calculated the *proportion of women* in each of the seven CD4 count (*k*) and five age groups (*a*) by ART status (*m*) as:

- Number of women *not on ART* in each CD4 count and age group in each year divided by all WLHIV *not on ART* in each year:

$$C_t^{akc,m=0} \Big/ \sum_a^7 \sum_k^7 N_{h=1,t}^{akc,m=0}$$

- Number of women *on ART* in each CD4 count and age group in each year divided by all WLHIV *on ART* in each year:

$$C_t^{akc,m=1} \Big/ \sum_a^7 \sum_k^7 N_{h=1,t}^{akc,m=1}$$

We then applied the above age stratified proportions to the crude number of women in each CD4 count category by ART uptake from Spectrum output files to obtain the final distribution of women in CD4 count categories by age and ART uptake ($C_t^{akcm}$).

Finally, we weighted the distribution of WLHIV in CD4 count categories by ART uptake ($C_t^{akcm}$) by $\text{FRR}^{ac,m=1}$ and $\text{FRR}^{akc,m=0}$ as follows:

$$FRR_t^{ac} = \frac{\sum_k^7 [C_t^{akc,m=0} * \text{FRR}^{akc,m=0}] + \sum_k^7 [C_t^{akc,m=1} * \text{FRR}^{ac,m=1}]}{\sum_k^7 \left[C_t^{akc,m=0}\right] + \sum_k^7 \left[C_t^{akc,m=1}\right]}$$

*4b. Births among women who were living with HIV before pregnancy*

Births among WLHIV ($B_{h=1,t}^{aic}$) were calculated using the total number of WLHIV ($N_{h=1,t}^{aic}$) and fertility rate ($ASFR_t^{aic}$). The latter was adjusted for the effects of HIV infection using fertility rate reduction ($FRR_t^{ac}$) calculated in 4a and HIV prevalence ($H_t^{ac}$).

$$B_{h=1,t}^{aic} = N_{h=1,t}^{aic} \times ASFR_t^{aic} \times FRR_t^{ac} / [FRR_t^{ac} \times H_t^{ac} + (1 - H_t^{ac})]$$

# HIV transmission probabilities used in the calculation of vertical transmission

We used the same vertical transmission probabilities as the ones from Spectrum, which varied by perinatal versus postnatal period and ART regimen (Table S7; Table S8). These probabilities were identified via systematic reviews of peer-reviewed and grey literature by the UNAIDS Reference Group on Estimates, Modelling, and Projections. They are updated periodically, and Spectrum uses the most recent available estimates.[144] Postnatal transmission probabilities were monthly and varied by CD4 count, except for women with incident HIV. Monthly transmission probability was not estimated for breastfeeding women with incident infection, as the high risk of vertical transmission due to high viral load initially after seroconversion might only be present for one or two months. Therefore, Rollins et al. considered it inappropriate to apply an average monthly probability over the duration of breastfeeding.[170] For women not on ART, both perinatal and postnatal transmission probabilities were weighted by the proportion of women in three CD4 count categories: CD4 <200 cells per µL, CD4 200-350 cells per µL and CD4 >350 cells per µL.

We assumed that women receiving Option A and B had CD4 >350 cells per µL. However, if the combined uptake of Option A and B was greater than the proportion of WLHIV with CD4 >350 cells per µL, we let the excess women have CD4 <350 cells per µL. Option A and B may be less effective for women with CD4 <350 cells per µL, so we scaled the perinatal transmission probability by multiplying the transmission probability by the excess ratio (ER) where:

$$ER = \frac{PR_A + PR_B}{Pr_{CD4>350} - 1}$$

$PR_A$and $PR_B$ above are the proportion of WLHIV receiving Option A or B, and $Pr_{CD4>350}$is the proportion of WLHIV with CD4 count >350 cells per µL.

The scaled perinatal HIV transmission probability for Option A ($\beta_{peri}^{m=A'}$) was the product of the excess ratio and the original HIV transmission probability ($\beta_{peri}^{m=A}$):

$$\beta_{peri}^{m=A'} = \beta_{peri}^{m=A} \times ER$$

The scaled postnatal transmission probability ($\beta_{bf}^{m=A'}$) for Option A (and B) was calculated using the excess proportion (*EP*) where *EP* was the difference between the combined uptake of Option A and B and the proportion of WLHIV with CD4 >350 cells per µL.

$$EP = (PR_A + PR_B) - \mathrm{PR}_{CD4>350}$$

$$\beta_{bf}^{m=A'} = \beta_{bf}^{m=A} * PR_{CD>350} + EP * \left(\frac{1.45}{0.46}\right) * \frac{\beta_{bf}^{m=A}}{[\mathrm{PR}_{CD4>350} + \mathrm{EP}]}$$

**Table S7**. Vertical HIV transmission probabilities extracted from Spectrum (version 6.28). Uncertainty around these estimates was calculated based on the standard deviation proportional to the point estimate by the scale factor of 0.05 per Spectrum (Further detail in *Uncertainty Analyses*, p 32).

| **ART regimens** | **Perinatal** | **Breastfeeding (per month)** | |
|---|---|---|---|
| | | **CD4 <350** cells per µL | **CD4 ≥350** cells per µL |
| **No prophylaxis** | | | |
| **Existing infections** | | | |
| CD4 <200 cells per µL | 37.00% | 0.89% | |
| CD4 200-350 cells per µL | 27.00% | 0.81% | |
| CD4 >350 cells per µL | | | 0.51% |
| **Incident infection** | 18.10% | 26.90%* | 26.90% |
| **Single dose nevirapine**‡ | 7.50% | | |
| **WHO 2006 dual ARV regimen**‡ | 2.20% | | |
| **Option A**§ | 4.10% | | 0.20% |
| **Option B**§ | | | 0.13% |
| **Option B+**† | | | |
| Started before pregnancy | 0.26% | 0.02% | |
| Started during pregnancy >4 weeks | 1.40% | 0.11% | |
| Started during pregnancy <4 weeks | 8.20% | 0.20% | |

*For incident infections the breastfeeding transmission rates are cumulative, not monthly.

‡Single dose nevirapine and dual prophylaxis do not have a postnatal component.

§Option A and B are only suggested for women with CD4 > 350 cells per µL.

†We are assuming that women on Option B+ have CD4 < 350 cells per µL.

**Table S8**. ART regimens included in the probability tree model based on the WHO 2004, 2006 and 2012 ART recommendations for women and infants.

| | **Woman receives** | | **Infant receives** |
|---|---|---|---|
| | **CD4 count ≤350** cells per µL | **CD4 count >350** cells per µL | |
| **Single dose nevirapine**[55,171] | *Intrapartum:* at onset of labor, sdNVP | | sdNVP to the infant < 72 hours postpartum |
| **WHO 2006 dual ART regimen**[172] | | *Antepartum:* AZT starting as early as 28 weeks gestation<br>*Intrapartum:* at onset of | Daily sdNVP and AZT from birth through 1 week |

| | | | |
|---|---|---|---|
| | | labour, sdNVP and first dose of AZT/3TC<br>*Postpartum:* daily AZT/3TC through 7 days postpartum | |
| **Option A**[*173] | Triple ARTs starting as soon as diagnosed, continued for life | *Antepartum:* AZT starting as early as 14 weeks gestation<br>*Intrapartum:* at onset of labour, sdNVP and first dose of AZT/3TC<br>*Postpartum:* daily AZT/3TC through 7 days postpartum | Daily NVP from birth through 1 week beyond complete cessation of breastfeeding; or, if not breastfeeding or if mother is on treatment, through age 4–6 weeks |
| **Option B**[173] | Same initial ARTs for both[‡]: | | Daily NVP or AZT from birth through age 4–6 weeks regardless of infant feeding method |
| | Triple ARTs starting as soon as diagnosed, continued for life | Triple ARTs starting as early as 14 weeks gestation and continued intrapartum and through childbirth if not breastfeeding or until 1 week after cessation of all breastfeeding | |
| **Option B+**[173] | Same for treatment and prophylaxis[‡]: | | |
| | Regardless of CD4 count, triple ART starting as soon as diagnosed§, continued for life | | Daily NVP or AZT from birth through age 4–6 weeks regardless of infant feeding method |

Note: "Triple ARTs" refers to the use of one of the recommended three-drug fully suppressive treatment options.
* Recommended in WHO 2010 guidelines
‡ True only for EFV-based first-line ART; NVP-based ART not recommended for prophylaxis (CD4 >350 cells per μL)
§ Formal recommendations for Option B+ have not been made, but presumably ART would start at diagnosis.
*ART = antiretroviral treatment; AZT =zidovudine; EFV = efavirenz; sdNVP = single dose nevirapine; WHO= world health organization; 3TC = lamivudine.*

# Calculation of vertical transmission of HIV

## 5a. Number of women living with HIV prior to pregnancy on different ART regimens

First, we calculated the number of women on each ART regimen (*m*), by five-year age group (*a*), IPV (*i*), year (*t*) and country (*c*) among women who were living with HIV before pregnancy ($N_t^{aicm}$). To do so we multiplied the overall number of births ($B_{h=1,t}^{aic}$) among women living with HIV by the proportion of women who were tested for HIV at the ANC and received each ART regimen ($\delta_t^{ic} \times \eta_t^{mic}$), and the proportion of those who were on ART prior to pregnancy ($\varphi_t^{ic}$). We multiplied the proportion of women on ART during pregnancy and on ART before pregnancy by the perinatal ART retention rate ($r_t^{mic}$). Perinatal ART retention was defined as retention at delivery.

$$N_t^{aicm}=B_{h=1,t}^{aic} \times (\varphi_t^{ic} \times r_t^{mic} + \delta_t^{ic} \times \eta_t^{mic} \times r_t^{mic})$$

We calculated number of women not on any ART regimen ($N_t^{aicm=0}$) as a sum of a) proportion of women who were not HIV tested (or did not attend) at the ANC, and b) women who got HIV tested at the ANC but did not get ART. All women who were not retained in ART perinatally were added to the number of women not on any ART.

$$N_t^{aicm=0} = B_{h=1,t}^{aic} \times[(1 - \delta_t^{ic} - \varphi_t^{ic}) + \sum_m^7[\delta_t^{ic} \times (1 - \eta_t^{mic})] +$$

$$B_{h=1,t}^{aic} \times [\varphi_t^{ic} \times (1 - r_t^{mic}) + \sum_m^7[\delta_t^{ic} \times \eta_t^{mic} \times \left(1 - r_t^{mic}\right) ]$$

## 5b. Perinatal vertical transmission among women who were living with HIV prior to pregnancy

Next, we calculated the number of babies who acquired HIV during the perinatal period ($MTCT_{prevalent,peri}^{aic}$) among women with prevalent HIV. To do so we multiplied the number of women on ART ($N_t^{aicm}$) and not on ART ($N_t^{aicm=0}$) calculated above by relevant perinatal transmission probabilities ($\beta_{peri}^{m}$). Transmission probabilities for women *not on treatment* varied over time because they were weighted by the proportion of women in seven CD4 count categories which also varied over time ($\beta_{peri,t}^{m=0}$ ). Below, the number of women who

transmitted HIV to the baby is represented as the sum of transmission from women on each ART regimen (N=7) and women not on any ART (HIV tested at ANC but not on treatment and not tested at ANC).

$$MTCT^{aic}_{prevalent,peri,t} = \sum_m^7 (N_t^{aicm} \times \beta_{peri}^{m=1}) + N_t^{aicm=0} \times \beta_{peri,t}^{m=0}$$

## 5c. Perinatal vertical transmission among women who acquire HIV during pregnancy

To calculate the number of vertical HIV transmissions from women who acquire HIV during pregnancy, we multiplied the number of women who acquired HIV during pregnancy ($N^{aic}_{perinatal,t}$) by the perinatal transmission probability in women who got HIV during pregnancy ($\beta^{incident}_{peri}$).

$$MTCT^{aic}_{incident,peri,t} = N^{aic}_{perinatal,t} \times \beta^{incident}_{peri}$$

## 5d. Postnatal vertical transmission among women who were living with HIV prior to pregnancy

We calculated the vertical HIV transmission during the postnatal period (0-36 months) using a set of difference equations with monthly time steps. A certain proportion of all women started breastfeeding. This proportion reduced over time, up to 36 months. We used difference equations to calculate the cumulative risk of vertical transmission during the breastfeeding period while accounting for the competing risks such as dropout from breastfeeding and retention in postnatal ART. Postnatal ART retention was defined as the proportion of monthly postnatal ART dropout, which is how we operationalized it in the model (Figure S12). Postnatal dropout rate differed between the first 12 months of breastfeeding versus 12-36 months of breastfeeding, per Spectrum. Breastfeeding dropout was calculated as the difference between the proportion breastfeeding at a current (*t*) and the previous time (*t-1*) point.

The calculation included five groups of women: number of women who were breastfeeding and on treatment for each ART regimen (*m*) ($P_t^{aicm}$), number of women breastfeeding and not on any treatment ($P_t^{aicm=0}$), women not breastfeeding ($L$), number of vertical transmissions among women breastfeeding and on treatment for each ART regimen ($M_t^{aicm}$), number of vertical transmissions among women breastfeeding and *not on* any treatment

($M_t^{aicm=0}$) (Figure S12). Women moved through these compartments using the following rates: postnatal ART dropout during breastfeeding ($\lambda_t^{icm}$) which varied by IPV and ART regimen (and was referred to above as postnatal ART retention), breastfeeding dropout ($\gamma^{m=1}/\gamma^{m=0}$) which varied by ART uptake (*Yes/No*), and postnatal vertical transmission probability for women on ART ($\beta_{bf}^{m=1}$) and not on ART ($\beta_{bf}^{m=0}$).

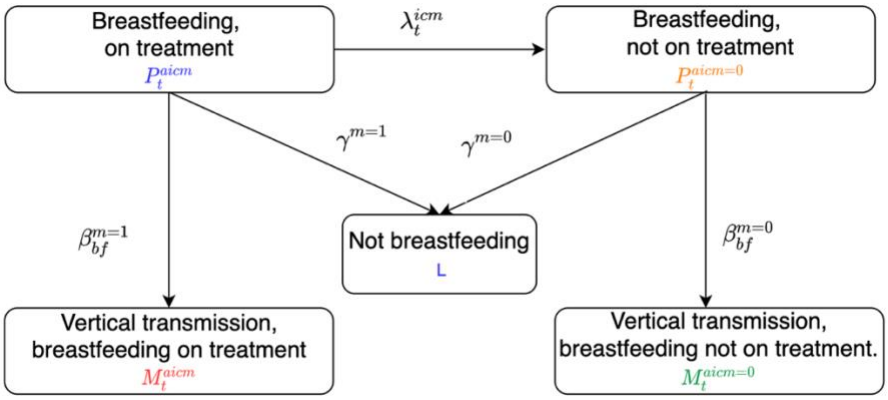


**Figure S12**: Compartments used to develop a set of difference equations to calculate vertical transmission of HIV during the 36 months of postnatal period among women who were living with HIV before pregnancy.

At the first month after delivery (*n=1*) the number of women at risk of transmitting HIV to the baby by age (*a*), IPV status (*i*), country (*c*), ART regimen (*m*) (or on no ART at all, *m=0*) are women who did not transmit HIV during perinatal period in each ART regimen, and initiated breastfeeding.

The following set of difference equations (with monthly time steps) were used to calculate the vertical HIV transmission during postnatal period:

$$\mathrm{P}_{t+1}^{aicm} = \mathrm{P}_t^{aicm} + \left(-\left(\lambda_t^{icm} + \gamma^{m=1} + \beta_{bf}^{m=1}\right) \times \mathrm{P}_t^{aicm}\right)$$

$$\mathrm{P}_{t+1}^{aicm=0} = \mathrm{P}_t^{aicm=0} + \left(\lambda_t^{icm} \times \mathrm{P}_t^{aicm} - (\gamma^{m=0} + \beta_{bf}^{m=0}) \times \mathrm{P}_t^{aicm=0}\right)$$

$$L_{t+1} = L_t + \gamma^{m=1} \times \mathrm{P}_t^{aicm} + \gamma^{m=0} \times \mathrm{P}_t^{aicm=0}$$

$$M_{t+1}^{aicm} = M_t^{aicm} + \beta_{bf}^{m=1} \times \mathrm{P}_t^{aicm}$$

$$M_{t+1}^{aicm=0} = M_t^{aicm=0} + \beta_{bf}^{m=0} \times \mathrm{P}_t^{aicm=0}$$

Finally, the total number of babies who acquired HIV during breastfeeding from women who were living with HIV before pregnancy was calculated as the sum of the number transmitted from women on ART ($\sum_m^7 M_{t+1}^{aicm}$) and not on ART ($M_{t+1}^{aicm=0}$).

$$MTCT_{prevalent,bf,t}^{aic} = \sum_m^7 M_{t+1}^{aicm} + M_{t+1}^{aicm=0}$$

### 5e. Postnatal vertical transmission among women who acquired HIV during pregnancy or breastfeeding

HIV transmission probability during breastfeeding for women who acquire HIV during pregnancy is cumulative, not monthly. Therefore to obtain the number of vertical transmissions from women who acquired HIV during pregnancy, we simply multiplied the postnatal transmission probability for women with incident HIV ($\beta_{bf}^{incincdent}$) by the number of women who did *not transmit* HIV during the perinatal period ($N_{perinatal,t}^{aic}$- $MTCT_{incident,peri,t}^{aic}$).

Finally, to calculate vertical HIV transmission among women who acquired HIV during breastfeeding we multiplied the number of women who acquired HIV during breastfeeding ($N_{breastfeeding,t}^{aic}$) by the postnatal transmission probability.

$$MTCT_{incident,bf,t}^{aic} = (N_{perinatal,t}^{aic} - MTCT_{incident,peri,t}^{aic}) \times \beta_{bf}^{incident} + N_{breastfeeding,t}^{aic} \times \beta_{bf}^{incident}$$

## Calculation of the model outcomes

Since pediatric HIV infections can be acquired from women who were living with HIV before conception and those that acquired HIV after, we used all births as our denominator. This ensures comparability of transmission risk when the IPV exposure itself affects the number of HIV-exposed infants. IPV-stratified risks of vertical HIV transmission were calculated as:

$$\frac{MTCT_{prevalent,peri,t}^{aic} + MTCT_{incident,peri,t}^{aic} + MTCT_{prevalent,bf,t}^{aic} + MTCT_{incident,bf,t}^{aic}}{B_{h=0,t}^{aic} + B_{h=1,t}^{aic}}$$

## 6a. Country-specific analyses

We used standardization to account for the confounding effect of age when pooling risks across age groups. For each country (*c*), and year (*t*) the standardized risk differences (*RD*) were calculated as:

$$RD_t^{std,c} = \frac{\sum_{a=1}^{7} w_t^{ac}\, RD_t^{ac}}{\sum_{a=1}^{7} w_t^{ac}}$$

where the weights were the proportion of births in each age group by country and year:

$$w_t^{ac} = \frac{B_t^{ac}}{\sum_{a=1}^{7} B_t^{ac}}$$

Similarly, the standardized population attributable fractions (PAF) were calculated as:

$$PAF_t^{std,c} = \frac{\sum_{a=1}^{7} w_t^{ac}\, PAF_t^{ac}}{\sum_{a=1}^{7} w_t^{ac}}$$

where the weights were the proportion of cases of vertical HIV transmission in each age group per Benichou 2001[174] and Masters 2019[175]:

$$w_t^{ac} = \frac{MTCT_t^{ac}}{\sum_{a=1}^{7} MTCT_t^{ac}}$$

The age-specific PAF used in the formula above was calculated as the difference between the overall risk of vertical transmission ($R_t^{ac}$) and the risk in the unexposed ($R_t^{a,i=0,c}$), divided by the overall risk.[176]

$$PAF_t^{ac} = \frac{R_t^{ac} - R_t^{a,i=0,c}}{R_t^{ac}}$$

The age specific RD used in the formula above was the difference between the exposed and the unexposed risk of vertical HIV transmission:

$$RD_t^{ac} = R_t^{a,i=1,c} - R_t^{a,i=0,c}$$

## 6b. Regionally aggregated analyses

When conducting aggregated analyses across the regions (*d*) we calculated age-standardized RD similarly to above. However, in addition to standardization by age, we standardized by country to account for differential distribution of HIV prevalence (thus vertical transmission) and IPV prevalence by country.

For each region, we first calculated the most RD in most granular strata by age (*a*), country (*c*), region (*d*) and year (*t*) as follows:

$$RD_t^{acd} = \frac{MTCT_t^{acd,i=1}}{B_t^{acd,i=1}} - \frac{MTCT_t^{acd,i=0}}{B_t^{acd,i=0}}$$

To aggregate by region, weights were calculated as the number of births in each age group, country, subregion, and year as a proportion of all births in all countries in region *(d)*, year *(t).* For example, in southern Africa where we have five countries in the analysis (Botswana, Namibia, Lesotho, South Africa and Eswatini), the weights were calculated as:

$$w_t^{acd} = \frac{B_t^{acd}}{\sum_{c=1}^{5}\sum_{a=1}^{7} B_t^{acd}}$$

Pooled RD by region and year would thus be:

$$RD_{pool,t}^{d} = \frac{\sum_{c=1}^{5}\sum_{a=1}^{7} w_t^{acd} * RD_t^{acd}}{\sum_{c=1}^{5}\sum_{a=1}^{7} w_t^{acd}}$$

Pooled PAF by region and year was calculated similarly with weights representing the number of vertical HIV transmission cases in each age group, country, subregion, and year as a proportion of all vertical transmission in all countries in region (*d*), year (*t*).

## Uncertainty analyses

We have two main sources of uncertainty: effect estimates for the relationship between IPV and the model parameters (Table S4) and vertical HIV transmission probabilities (Table S7). Effect estimates in our analysis were PR, OR, HR and IRR (Table S4) which were resampled from a lognormal distribution where the mean was the log of the effect estimate and standard deviation (σ) was calculated from their confidence intervals as follows: (Ln (upper limit) – Ln (lower limit))/ (2 x 1.96) or (Ln (upper limit) – Ln (OR))/1.96 (for OR)[177].

The distributions were truncated at one as we assumed that IPV cannot have a positive effect on our outcomes. For instance, for the prevalence ratios we had:

$$PR|[0,1] \sim e^{N(\log(E[PR]),\sigma)}$$

HIV transmission probabilities were resampled from a logit-normal distribution. We approximated the standard deviation on the logit scale using the delta method[178]($\sigma$). Standard deviation is proportional to the expectation of the function by the scale factor of 0.05, per Spectrum. Here, we deviate from Spectrum methodologies where probabilities are resampled from a normal distribution. The uncertainty around these transmission probabilities has not been formally quantified in Spectrum.

$$\beta \sim Logitnormal\ (logit(E[\beta]), \sigma)$$

We used 1,000 Monte Carlo simulations to calculate 95% uncertainty intervals. To calculate uncertainty intervals around the regionally pooled estimates, we aggregated each of the simulated datasets and calculated the 2.5$^{th}$ and 97.5$^{th}$ percentiles of the 1,000 resampled datasets.

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# 7. Chapter 7: Implications and Conclusions

## 7.1 Summary of findings

Elimination of violence against women and girls is central to achieving the Sustainable Development Goals (SDG). Intimate partner violence (IPV), in addition to being a grave human rights violation, has adverse physical and mental health effects.[179] Previous work has shown that IPV increases the risk of developing anxiety and depression, diabetes, engaging in substance abuse, developing chronic pain, and acquiring sexually transmitted infections, including HIV.[179] To address the latter, the 2021 UN General Assembly on HIV and AIDS committed to reducing to no more than 10% the proportion of women and girls who experience sexual and gender-based violence.[5] My thesis strengthens the evidence base supporting interventions to address IPV as part of the global efforts to end AIDS by 2030.

In Manuscript 1, I estimated the impact of IPV on women's risk of HIV acquisition and engagement in HIV treatment in African countries. I found that women experiencing past-year IPV were over 3 times more likely to have a recent HIV infection and 9% less likely to achieve viral suppression than those who did not. The results showed no impact of IPV on HIV testing in the past year and ART uptake among women living with HIV. This work was innovative for its use of available biomarker-based outcome-measures to address IPV's impact on the full HIV treatment and care cascade. Poor viral suppression among women experiencing IPV might suggest the importance of ART adherence due to the adverse mental health consequences of IPV.[9] However, data on mental health is not consistently collected in most population-representative surveys. Thus, questions remain on how mental health pathways between IPV and HIV outcomes operate, creating opportunities for future research directions.

To disentangle indirect pathways between IPV and the increased HIV risk for women, I described the characteristics of IPV perpetrators and their implications for women's HIV risk in my 2nd manuscript. I found that men who perpetrated IPV were 9% more likely to be living with HIV. They were also 37% more likely to have paid for sex in the past year and 26% more likely to have had two or more sexual partners in the past year. These alone imply that the characteristics of male perpetrators of IPV could confound the relationship between IPV and HIV acquisition. However, I found that IPV was associated with a slight (3%) increase in young women's risk of living with HIV *beyond the risk* of having an HIV seropositive partner. Thus, IPV by itself may increase the risk of HIV acquisition, but this raises further questions about the

specific mechanisms leading to this outcome. These could include adverse mental health effects of IPV and types of sex acts, e.g. anal sex, which tends to be more common among IPV perpetrators, or among intimate relationships with inequitable power dynamics. Information on neither type of sex acts, nor mental health is available in the DHS, offering avenues for further data collection and study.

The adverse effects of IPV on women's HIV acquisition and viral suppression prompted my investigation into its implications for vertical HIV transmission. I address this in Manuscript 3 and quantify the excess risk of vertical HIV transmission attributable to women's experience of IPV. Across all countries in Africa, IPV may be responsible for 1 in 7 pediatric infections in 2021. In absolute numbers, this corresponds to over 75,000 pediatric infections averted over one year if IPV was eliminated. IPV had the greatest impact on vertical transmission among adolescent girls and young women. These results suggest the importance of IPV for reaching the WHO vertical HIV transmission elimination goal of ≤50 cases per 100,000 live births. Countries working towards vertical HIV transmission elimination should prioritize tackling gender-based violence as a barrier towards reducing vertical transmission.

## 7.2 Strengths and limitations

*Limitations*

My thesis' results should be interpreted considering several limitations. First, residual confounding of the effect of IPV on recent HIV acquisition might have impacted the results of the Manuscript 1. For example, I was not able to account for male partner characteristics due to sample size limitations. However, crude analyses did not demonstrate major differences between perpetrators and non-perpetrators in terms of male partner HIV status, condom use, educational attainment, and couple age discrepancy.

Second, there are limitations to biomarker-based outcome measures such as recent HIV infection. To mitigate the false positivity rate in the population-based surveys featured in my thesis, a widely adopted strategy incorporates a viral load threshold (based on RT-PCR) and ART exposure (based on liquid-based chromatography) in HIV recency assays.[180] Still I cannot exclude the possibility of some remaining false positives, especially among people on ART for longer, or early in their infection.[180] However, false recency rate was shown to be 0.2% with the LAg-Avidity assay, thus this is unlikely to have greatly affected our results.[181]

Third, despite the measures taken in household-based surveys to minimize IPV underreporting, it remains a possibility. Further, these surveys likely capture the more severe forms of violence.[29] If so, our effect estimates for the recent HIV infection, for example, could reflect the effect of more severe IPV. Differential underreporting of IPV, however, could bias our inferences in either direction. For instance, if sensitivity of the IPV questionnaire is higher among women *without the outcome*, the observed effect estimate is *underestimating* the truth. When sensitivity is higher among women *with the outcome*, the observed estimate would *overestimate* the truth.

Fourth, due to the absence of mental health data in nationally representative surveys, I was unable to explore mental health pathways between IPV and women's engagement in the HIV care cascade. Collection of quantitative data on mental health experiences in large, population-based surveys would open new research avenues moving forward. Further, quantitative data should be accompanied by qualitative research in a small sample of women to investigate in-depth the 'hows' and the 'whys' of gender-based violence.

Fifth, analyses of survey data from multiple countries inevitably involve combining data from different social contexts and diverse HIV epidemics. Thus, generalizing the results across different settings could be problematic. In manuscripts where I used nationally representative survey data, I quantified and explored heterogeneity by country and found that this does not impact my most salient results (Chapter 4, Figure S2-S5; Chapter 5, Figure A-E).

Sixth, due to sample size limitations I was only able to explore the role of the male partner HIV status in the relationship between IPV and recent HIV acquisition in crude, sensitivity analyses in Manuscript 1. More surveys that collect HIV recency data would address this limitation, however even in relatively high-burden countries, the sample sizes required for a national HIV incidence estimates can be prohibitively large for population-based surveys.[180]

Seventh, my modelling strategy in Manuscript 3 is parametric and assumes that all effect size estimates for the impact of IPV and model parameters are causal. Though there is no guarantee that this is true since all data sources were observational studies. However, the selected studies were of high quality and control for important confounders. Yet, they could still be subjected to bias. Further, lack of reliable, longitudinal data on IPV experience during women's life course, including before, during, and after pregnancy prevented me from exploring the role of IPV *during* pregnancy on vertical HIV transmission prevention.

Finally, lockdowns and stay-at home orders during COVID-19 pandemic might have increased IPV prevalence globally and thus, impacted the results of my Manuscript 3.[183] However, the impact is unlikely to be large since recent evidence from low-and-middle income countries shows that IPV prevalence declined by a small average annual rate of 0.2% between 2000-2021.[162] Further, we restricted the analysis to the 4 years proximate to 2018 (2014-2022) to ensure the legitimacy of using the IPV prevalence from 2018 as constant across the years.

*Strengths*

Despite the above limitations, my thesis' strengths are the use of robust data sources and applied methodologies. The surveys used for Manuscript 1 and 2 comprised all available population-representative surveys containing information on IPV and HIV among adults in African countries. Key advantages of these surveys include high response rates and national coverage, which allowed for generalization of the study results at a population level. The interviewers undergo robust training, and the data collection procedures are standardized and consistent across countries. Further, some surveys collect biomarker data at the time of survey administration which allows for a robust estimation of the impact of past-year experience of IPV and women's engagement in the full spectrum of the HIV care cascade. Additionally, PHIA and DHS contain a partner identifier variable which I used to link cohabiting partners. Thus, I was able to describe the characteristics of IPV perpetrators and explore the implications of their traits for their female partners' HIV status. In terms of methodologies, the individual participant meta-analysis used in in Manuscripts 1 and 2, provided me with a large sample size and subsequent number of events to estimate the links between IPV and HIV outcomes, while accounting for relevant individual- and survey-level confounders.

## 7.3 Implications

My thesis holds implications for the development of interventions mitigating the impact of IPV on HIV. The most effective integrated HIV/IPV interventions[119,121,184] address drivers of IPV and HIV transmission on multiple fronts, focusing on individual, interpersonal, community and structural determinants of IPV and HIV risk.[121] Below I describe the implications of my work at each of these levels of intervention.

Given the impact of IPV on HIV acquisition in women (Manuscript 1), HIV prevention interventions focusing on individual-level factors should be informed by women's risk of

experiencing IPV. First, female-controlled HIV prevention methods, such as PrEP and long-acting injectable PrEP, offer discreet HIV prevention strategies for women at risk of experiencing IPV, allowing them to protect themselves without their male partners' knowledge. Second, IPV's adverse impact on viral suppression suggests that ART adherence might be a key bottleneck in women's success in HIV treatment and care cascade. Focusing on mental health within the HIV treatment and care programs is an important pathway for reducing the risk of poor ART adherence among those who are on treatment. This is especially important given the severe mental health resource gaps: the African region has 1.4 mental health workers per 100,000 people, compared with a global average of 9.0 per 100,000.[185] Thus, significant innovation in implementation research will be necessary to establish the effectiveness of services delivered by non-specialist mental health practitioners.[186]

To address the interpersonal determinants of IPV, interventions must include young boys and men given the role of male IPV perpetrators and their HIV risk in women's vulnerability to HIV acquisition (Manuscript 2). Early access to education that tackles gender inequities and dismantles practices perpetuating male control over women should be made available to boys to challenge traditional notions of masculinity from an early age. These could reduce men's accepting attitudes towards IPV, and increase women's decision-making power – both determinants of IPV (Manuscript 2). A rigorous global evidence review to evaluate what works to prevent IPV has demonstrated the effectiveness of school-based interventions to reduce peer violence, and dating violence, which could have trickle down effects to reduce IPV.[187] Couple-based interventions that focus on transforming gendered-power dynamics, substance use and condom use have also been shown to reduce IPV.[187]

At a community level, using feminist theories to reshape gender attitudes is key for all interventions addressing IPV and HIV. Interventions focused on community activism to shift harmful gender attitudes and social norms have been shown to create an enabling environment for sustained change, at scale.[187] Creating support groups providing safe spaces for women to share their experiences of IPV could contribute to denormalization of gender-based violence in families and communities, and empower others in the process. Ultimately, impacting attitude shifts within one generation is key to breaking the cycle of intergenerational continuity of gender-based violence, a challenge that has impeded program developers from moving the needle on ending IPV.

As countries work towards achieving the 2030 goals, addressing the structural enablers of HIV, such as gender inequities are important to ensure the success of HIV interventions beyond 2030.[188] Policy environments that protect women against violence, ensure survivors receive suitable support, and that they can achieve legal redress against perpetrators are key to achieve the sustainability of HIV programs for years to come.[188]

Efforts to address IPV at each of these individual, interpersonal, community and structural levels must be developed with the experiences and perspectives of women and girls in mind. Though young women are most vulnerable to both IPV and HIV, gender-transformative and economic interventions have been impactful to address IPV and HIV among older women, not adolescents and youth.[189] This could be due to the absence of their meaningful involvement, one which goes beyond the simplistic user testing or consultation of targeted groups, in the design of these interventions.[189] Meaningful involvement includes, but is not limited to co-development of interventions where women and girls involved in interventions are those who design them with practitioners' support.[189] This pertains to research as well as implementation. Given the embeddedness of IPV in various societal layers, and the ethical considerations of studying this topic in the first place, partnering with communities where research is conducted is critical. IPV interventions based on community-based participatory research, intervention design and implementation are important to ensure their effectiveness and sustainability.

## 7.4 Conclusions

Elimination of HIV as a public health threat hinges on addressing structural factors, such as gender inequities. In my thesis, I found that women who had experienced IPV were more likely to acquire a recent HIV infection and have unsuppressed viral load. This applies to pregnant WLHIV as well, consequently elevating the risk of vertical HIV transmission, especially among adolescent girls and young women. Finally, I showed that IPV by itself can increase women's risk of HIV acquisition, beyond the risk associated with their male partner HIV status. The intersecting epidemic of IPV and HIV demands recognition by governments, societies, and communities if gender-based violence is to be eliminated and women's and infants' HIV risk reduced.

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