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Armed Conflicts, HIV Testing, HIV Prevalence, and High-Risk Sexual Behaviors: An Epidemiologic Analysis

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ARMED CONFLICTS, HIV TESTING, HIV PREVALENCE, AND HIGH-RISK SEXUAL BEHAVIORS: AN EPIDEMIOLOGIC ANALYSIS

By

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1.0 Abstract

Armed conflicts have a wide array of consequences on health and behavior possibly serving a role in the spread of HIV, yet there is limited research on the quantitative association between armed conflicts and HIV. To address this gap in the literature, we evaluated the effect of armed conflicts on HIV testing, HIV prevalence, and high-risk sexual behaviors, using Demographic and Health Surveys data from 11 countries in Sub-Saharan Africa (years 2010 to 2018) and the Armed Conflict Location & Event Data. We hypothesized that armed conflicts, measured using number of conflict days, fatalities, or distance to nearest conflict, would be associated with reduced likelihoods of HIV testing, higher likelihoods of HIV prevalence, and higher occurrences of high-risk sexual behaviors. We developed three specific aims to 1) compare HIV testing, HIV prevalence, HIV knowledge and attitudes, and high-risk sexual behaviors between conflict and non-conflict areas, 2) determine the association between armed conflicts, HIV testing, and HIV prevalence and 3) determine the association between armed conflicts and high-risk sexual behaviors. We utilized a cross-sectional ecologic study, descriptive statistics such as maps, plots and two-sample T tests for the first aim and generalized linear mixed effects models with spatial random effects while adjusting for common confounders for subsequent aims. For these analyses, we used data from 168 administrative regions. Of these, 79 experienced conflict with an average of 87 days spent in conflict and 200 fatalities. In Aim 1, we found significantly lower HIV prevalence, stigma, previous HIV testing, and HIV knowledge in conflict areas. In Aim 2, armed conflicts were significantly associated with lower rates of HIV prevalence but not with previous HIV testing. In Aim 3, number of days and fatalities were significantly associated with increased rates of high-risk sexual behaviors but close proximity to an area of conflict was significantly associated with lower rates of high-risk sexual behaviors. Our findings illustrate that the relationship between armed conflicts and HIV measures is complex and is influenced by conflict duration, intensity, and proximity. Future studies should consider accounting for temporality and utilizing different populations exposed to higher intensity conflicts.

1.1 Specific Aims

The presence of armed conflict in a community or a country has wide-ranging consequences for health and behavior beyond the conflict itself. Studies have found that factors such as sexual violence, widespread movements of refugees and internally displaced people, a higher prevalence of HIV/AIDS amongst soldiers, and limited/destroyed access to health care services propagate the spread of HIV in regions with war [1-3]. However, many previous studies evaluating armed conflicts and HIV incidence have focused on country-level estimates [1-4] or have focused on a single country [5]. Understanding the predictors of HIV testing and high-risk sexual behavior (e.g., multiple partners, lack of condom use) in the context of armed conflicts might be one solution to ending the HIV epidemic. Often rocked by armed conflict, Sub-Saharan Africa (SSA) is the region with the highest number of refugees and internally displaced people in the world [6]. With armed conflicts possibly playing a role in the spread of HIV [1], [7], [8] whether protective [2], [3], [9] or propagative [4], [7], [8] it is crucial to better understand this factor when evaluating differences in HIV testing uptake and high-risk sexual behavior within and across countries in SSA.

According to UNAIDS, as of 2018, about 64% of people living with HIV (PLWH) in West and Central Africa and 85% in East and Southern Africa [10] are aware of their status of the estimated 25.6 million PLWH residing across Africa [10]. In an effort to end the HIV epidemic, the Joint United Nations Programme on HIV/AIDS (UNAIDS) developed the 90-90-90 goals [11]. These goals entailed that by 2020, 90% of all people living with HIV should know their HIV status, 90% of all people with diagnosed HIV infection should receive sustained antiretroviral therapy, and 90% of all people receiving antiretroviral therapy should achieve viral suppression [11]. Despite some progress made towards reaching the first of the 90-90-90 goal, it is crucial to continue investigating factors that make an individual willing to test for HIV if we are to properly develop prevention strategies to reach this target. Another pivotal area to consider is reducing high-risk sexual behaviors, as these can serve as significant drivers of the epidemic [12-14]. Strategies aimed at improving HIV testing uptake and reducing high-risk sexual behavior have the potential to decrease HIV transmission rates; however, the role of armed conflict is often overlooked. Moreover, previous studies evaluating the spread of HIV at various stages of armed conflict show conflicting results and have significant limitations [1]. To our knowledge, no study to date has combined detailed geographic data on armed conflict events with HIV risk behaviors, testing, and prevalence.

To better understand how armed conflicts impact our ability to end the global HIV pandemic, the proposed study will focus on the role of armed conflicts on HIV testing and high-risk sexual behavior among individuals living in different administrative regions in SSA. We hypothesized that armed conflicts were associated with a decrease in HIV testing uptake and increase in HIV prevalence and high-risk sexual behaviors. We controlled for well-known confounders such as urban/rural residence, religion, marital status, education, and poverty.

To test these hypotheses, demographic and health surveys (DHS) data including geographic data, from 11 countries in SSA from 2010 to 2018 and the Armed Conflict Location & Event Data Project (ACLED) data spanning from 2005 to 2018 were used with HIV testing, HIV prevalence, and high-risk sexual behaviors as the outcomes of interest. Using data spanning 13 years allowed us to evaluate longer-term trends and made it feasible to ascertain the effects of armed conflict on the outcomes and allow for more effective interventions to decrease the spread of HIV even in armed conflict areas. With armed conflict serving as the main exposure of interest in each aim, CEA level geographic information was used to approximate each cluster's distance to the nearest armed conflict location. Aim 1 evaluated at the spatial variation in different indicators of HIV in the context of conflicts, aim 2 evaluated the association between conflicts, HIV testing and HIV prevalence, and aim 3 focused on the association between high-risk sexual behaviors and conflicts.

1.1.1 Aim 1

Specific Aim 1: Evaluated previous HIV testing, HIV prevalence, HIV knowledge and attitudes, high-risk sexual behavior, and different measures of armed conflict of the administrative regions in the DHS dataset, using descriptive statistics such as maps, graphs, and tables. This approach helped us assess preliminary differences between conflict and non-conflict areas. Findings from this aim provided guidance on the appropriate modeling techniques to utilize for subsequent aims.

1.1.2 Aim 2

Specific Aim 2: Elucidated the associations between conflicts, HIV testing, and HIV prevalence using generalized linear mixed models with spatial random effects. The outcome was defined as the number of individuals within each administrative region that reported previously having tested for HIV and receiving the results from the most recent test and HIV prevalence. In these models, we adjusted for demographics such as religion, sex, age, socioeconomic status (SES), and marital status.

1.1.3 Aim 3

Specific Aim 3: Evaluated the associations between armed conflicts and high-risk sexual behaviors using generalized linear mixed models with spatial random effects. High-risk sexual behavior was defined as the number of individuals within each administrative region that reported:

1) having two or more sexual partners in the past 12 months,

2) having a sexual partner in the past 12 months who was neither a spouse nor a cohabitant and using a condom at last sexual intercourse with such a partner.

In these models, we also adjusted for common confounders such as religion, sex, age, SES, and marital status.

2.0 Background

2.1 Introduction

The Human Immuno-Virus (HIV) is a necessary agent in the development of Acquired Immuno-Deficiency Syndrome (AIDS). Since HIV's discovery and first recorded outbreak in the 1970s [15], the World Health Organization (WHO) estimates that HIV and AIDS have claimed more than 35 million lives [16]. Spread via contaminated bodily fluids, the virus works by attacking and compromising the host's immune system, specifically affecting CD4+ T cells [16]. CD4+ T cells are biomarkers of clinical disease in people living with HIV as they are used for staging and treatment purposes.

2.2 Etiology of HIV

It is believed that HIV originated from the Simian version of the virus known as SIV around 1920 in Kinshasa, Congo when the virus transferred from Chimpanzees to humans [15]. However, the current epidemic of HIV is believed to have started around the mid-1970s to late 1970s [15]. By the early 1970s, the virus is believed to have spread to all five continents and is assumed to have affected between 100,000 to 300,000 people [15]. HIV first came to the attention of public health authorities around 1981 when cases of a rare form of Pneumonia known as *Pneumocystis carinii pneumonia* was being recorded in young, previously healthy gay men in Los Angeles and about four cases were recorded in IV drug users [15]. At the same time, a rare form of cancer known as Kaposi 's sarcoma was being diagnosed in previously healthy gay men in New York and California [15]. By the end of the year, 270 gay men were diagnosed with an immuno-deficiency disorder and about 121 of them died [15]. Soon after, the disease was detected in hemophiliacs, heterosexual women, and children [15]. It wasn't until May of 1983 when the virus responsible for the immune deficiency diseases was finally isolated at the Pasteur Institute in France and was determined to be a retrovirus [15].

Since then, much has become known about HIV, its modes of transmission, and its mechanism. To begin, HIV is a lentivirus that belongs to the Retroviridae family [17]. Shaped in the form of a capsule, with a 120 nm diameter, it has a single stranded RNA that uses reverse transcriptase to change from RNA to DNA and integrates into the host's genome [17]. The virus can spread via blood, semen, vaginal fluid, rectal fluid, and breast milk [18].Once it enters the body, the virus uses CD4 receptors as a primary binding site, causing conformational changes that allow it to fuse with the host cells and insert its RNA into them [17]. Using reverse transcriptase, the viral RNA is changed into viral DNA and makes its way to the nucleus of the cell where it can now integrate with the host's DNA and create a provirus [17]. The virus is now able to make many copies of its self and these copies exit the host cell through a process known as budding in which it obtains host membrane proteins and lipid bilayer [17]. The infected CD4 cells eventually die as a result of being infected, often times via self-destruction [17].

2.2.1 Role of CD4+ T Cells

CD4+ T cells, commonly referred to as helper T cells, play an important role in the immune system. Belonging to the group of thymus-derived lymphocytes (T lymphocytes), CD4's main role is to recruit other immune cells, such as killer T cells (CD8) to sites of infection [19]. They also play the important role of suppressing the immune response once an infection has been cleared [19]. The HIV virus impairs the immune response mainly by killing off CD4 cells [17]. As the viral load increases, the number of CD4 cells decreases [17]. It is important to note that about 90-95% of the CD4 cells that die when the body becomes infected with HIV are not infected with the virus [19]. A CD4 cell is considered to be infected with HIV when it has viral DNA. The virus only infects about 5% of CD4 cells and uses them for replication [19]. Those usually die via self-destruction [19]. The remaining CD4 cells die as a result of the following process: once the infected CD4 cells (i.e. those used for viral replication) start to express viral protein on their surfaces, the body sends in additional CD4 cells to the site of infection, as a natural defense mechanism [19]. Once these naïve CD4 cells become exposed to HIV, although they are not being used for viral replication, they also begin to express viral proteins on their surfaces [19]. The body now responds by stimulating the creation of interleukin 1 beta, an inflammatory cytokine, within these exposed but not infected cells [19]. The high amount of inflammation within these cells causes apoptosis [19]. Once apoptosis occurs, similar to a big explosion, the pro-inflammatory cytokines are released from the destroyed cells and come into contact with other naïve CD4 cells [19]. Through a chain reaction, those CD4 cells also go through inflammation and apoptosis and as a result, release more cytokines [19]. This causes a constant state of inflammation within the body, which eventually leads to weakening and death of many more CD4 cells, and thus the weakening of the immune system [19]. For this reason, CD4 counts have become useful biomarkers in HIV.

In the early phases of an HIV infection, CD4 counts fall rather rapidly as viral replication reaches its peak. This is known as the acute stage [15]. The infected person usually experiences flu like symptoms [15]. About 4-6 months after infection, there is a steady state of viral replication, known as the clinical latency stage [15]. Although in this stage viral replication has slowed down, CD4 cells are still being used for replication and as the body tries to stabilize its CD4 counts by creating new ones, it simply cannot keep up with the constant loss of CD4 cells [17]. In this stage there are no symptoms, but CD4 cell counts are lower at this stage than they were pre-infection [15](1). Once CD4 counts reach 200 cells/mm^3 of blood, then the person is considered to have AIDS [15]. This can occur years after infection. When an infection progresses to AIDS depends on many factors such as health status prior to infection, how much of the virus the individual was exposed to, when they started ART (i.e. at what CD4 count) and how well they follow their ART regimen, amongst many other factors [15].

2.3 HIV in Sub-Saharan Africa

In 2014, the Joint United Nations Programme on HIV/AIDS (UNAIDS) launched the 90-90-90 targets with the goals of diagnosing 90% of all those with HIV, providing treatment to 90% of those diagnosed, and achieving viral suppression for 90% of those on treatment (i.e. 73% of people with HIV) by 2020 [20]. As of 2016, a systematic analysis of HIV treatment cascades from 69 countries found that the rates of diagnosis ranged from 87% (the Netherlands) to 11% (Yemen), treatment rates ranged from 71% (Switzerland) to 3% (Afghanistan), and viral suppression rates ranged from 68% (Switzerland) to 7% (China) [20, 21]. The lowest achievement rates were in low and middle-income countries [20, 21].

West and Central Africa lag behind in terms of access to treatment [11]. Some of the challenges to achieving these goals have mainly dealt with gaps in HIV diagnosis and thus provision of treatment [20]. Incidence rates have also not declined as quickly expected but are actually rising in around 50 countries around the world [11]. Other barriers such as lack of trained counselors, HIV-associated stigma, lack of good quality data, non-uniformity in data collection, unacceptably high rates of pediatric HIV cases that are not on treatment, and the lack of a continuous supply of ART currently serve as major impediments to reaching the 90-90-90 goals [20].

The bulk of people with HIV live in low- and middle-income countries of Africa, with Sub-Saharan Africa disproportionately affected, having the highest rates of HIV in the world [22]. In 2020, there were 37.6 million people in the world with HIV [23] . More than half of those (20.7 million, 54%) resided in eastern and southern Africa [23] proving that geography needs to be taken into account when evaluating HIV prevalence [10]. The afore-mentioned challenges are an impediment to reaching the UN's 90-90-90 goals and should be addressed to ensure that the target is reached in a timely manner.

2.4 Armed Conflicts

It has been reported that about 191 million deaths that occurred in the 20th century as a result of armed conflicts [24]. There have also been reported many effects of conflict on public health as they tend to lead to the destruction of health infrastructures and demolition of health care facilities [24]. Health sectors become undersupplied, life expectancy becomes poorer, and there is an increase in migration which often translates to an increase in professional migration [24]. Increases in infectious diseases, extreme poverty, food insecurity, instability and insecurity are often too common in these settings [24].

2.5 Armed Conflicts in Sub-Saharan Africa

SSA is the region with the highest number of armed conflicts [25], refugees and internally displaced people in the world [6]. Armed conflicts, for the most part, have also been concentrated in certain pockets of SSA with more recent conflict having occurred in the Horn and West Africa [26].

2.6 Armed Conflicts and HIV

With research having shown that armed conflicts can play a propagative or protective role in HIV prevalence, it is paramount to understand the effect that they possibly have on HIV testing and high-risk sexual behaviors as these play an important role in the spread of HIV [27,28]. A prime example of the effects of armed conflict on HIV prevalence would be war torn Sierra Leone where the HIV prevalence rate peaked to 14.9% during the civil war of 1991-2002 and decreased to 0.9 after the war [29]. Post war, testing remained low with rates less than 30% and ART uptake at 29% [29].

2.7 Gap in the Literature

Previous studies that sought to evaluate the possible relationship between armed conflicts and HIV were qualitative in nature, focused on one country or one group of individuals, and often did not include any spatial components. This was the first project of its kind to not only evaluate a quantitative relationship between the two, but to do so using a large diverse group of individuals in SSA while accounting for geospatial influences.

3.0 Significance and Innovation

This study was highly innovative as it was the first study of its kind to quantitatively assess the associations between armed conflicts, HIV testing, HIV prevalence, and high-risk sexual behaviors while accounting for spatial autocorrelation. It is a novel approach to a question that has not been quantitatively and fully evaluated. The DHS and ACLED datasets were the ideal datasets to use to answer this question as the DHS offers detailed geographic information and individual/administrative region level characteristics and the ACLED provides conflict data. Both datasets were collected over a long span of time and once combined provided information on a diverse population.

3.1 Clinical and Public Health Significance

3.1.1 HIV/AIDS Is Still of Major Public Health Concern

HIV/AIDS has been of major concern to public health officials since the pandemic's debut in the early 1980s. In 2018, there were 37.9 million people living with HIV/AIDS, with about 1.7 million newly infected cases [10]. In this same year, about 770,000 people died of AIDS related illnesses [10]. In an effort to slow the spread of HIV and end the pandemic by 2030 UNAIDS developed the 90-90-90 goals [10]. However, despite the progress that has been made towards these goals, there are still countries in SSA that lag behind and have yet to reach the first goal of 90% of PLWH knowing their status. There may be multiple explanations for these existing disparities, but one major characteristic that is often overlooked is the possible role that armed conflicts may play. The presence of armed conflict in a community or country can have a meaningful impact on the health and behaviors of the inhabitants living in the affected areas. Previous studies have found that factors such as sexual violence, the extensive movements of refugees and internally displaced people, a higher prevalence of HIV/AIDS amongst soldiers, and limited access to health care services can intensify HIV transmission in places affected by armed conflict [1].

Armed conflict can also serve as a protective factor for HIV. Other studies having found a decrease in HIV infection rates attributed to community isolation via the destruction of transportation systems, a disruption of sexual activities (i.e. having multiple sexual partners or hiring sexual workers) and an inflow of humanitarian aid. However, our understanding of HIV testing and high-risk sexual behaviors such as multiple partners, and lack of or inconsistent condom use, in the context of armed conflict, is limited. Because previous research has not quantitatively evaluated these relationships, it is difficult to ascertain the full impact of armed conflicts on HIV transmission.

3.1.2 Importance of Accounting for Armed Conflicts When Evaluating HIV/AIDS Transmission in Sub-Saharan Africa

Often entangled in armed conflict, SSA is the region with the highest number of armed conflicts [25], refugees, and internally displaced people in the world [6]. This high prevalence of armed conflicts coupled with the fact that armed conflicts have negative impacts on health systems and population health [30] makes it crucial to understand the effect of armed conflicts on HIV transmission. With research having shown that armed conflicts can play a propagative or protective role in HIV prevalence, it is paramount to understand the effect that they possibly have on HIV testing and high-risk sexual behaviors as these play an important role in the spread of HIV [27,28]. Geographical location within SSA is another aspect that needs to be taken into account as disparities in HIV rates exist in SSA with higher rates often reported in the East and South of the continent [10]. Armed conflicts, for the most part, have also been concentrated in certain pockets of SSA with more recent conflict having occurred in the Horn and West Africa [26]. With these existing disparities, it is necessary to evaluate the effect of armed conflicts on HIV testing, prevalence, and high-risk sexual behaviors using a large representative group of participants from diverse areas of SSA.

3.1.3 Gaining Better Understanding of Patterns of HIV Testing to Effectively Assess HIV Prevalence

Research shows that a crucial aspect of slowing HIV transmission is via HIV testing [27] and curbing high-risk sexual behaviors [28]. HIV testing is necessary in delineating who is in need of treatment and is the first step to making sure that those in need of treatment receive it [31],[32]. Most new HIV infections occur as a result of infected people being unaware of their status and not being linked to care [33]. Unfortunately, in areas of armed conflicts, access to HIV treatment and prevention services is jeopardized once access to healthcare settings becomes limited or destroyed [34] and countries begin to experience a decrease in health staff and utilization of health services [25,35]. Armed conflicts can also result in a shortage in testing kits and preventative items such as condoms [34]. However, one study by Betsi et al. that sought to evaluate the effects of the armed conflict in Ivory Coast on HIV found that while one area of the country experienced a decrease in condom sales, another saw a rise in sales [35].

High-risk sexual behaviors such as multiple partners and inconsistent condom use is another area to consider when evaluating the role of armed conflicts on HIV transmission. Armed conflicts may play a role on increased high-risk sexual behaviors as breakdowns in social structures can lead to risky behavior (i.e. substance abuse) [36], [37] and gender-based violence, and increased poverty can lead to transactional sex [2], [25], [36], [38]. Research has shown that victims of gender-based violence are at increased risk of HIV infection as the perpetrators of such violence are more likely to have HIV, impose risky sexual behaviors on their victims and more likely to have multiple partners [39]. Factors such as an increase in rape, gender-based violence [39], and transactional sex [40] can be even more concerning especially as limited access to condoms might lead to rampant unprotected sex in these instances [40]. Lastly, armed conflicts can also increase partner exchange with shorter term relationships occurring more frequently [25], [36].

3.1.4 The role of armed conflicts on HIV testing and high-risk sexual behaviors

The propagative role of high-risk sexual behaviors such as multiple partners [41],[42] and inconsistent condom use [42],[43] on HIV transmission have been well delineated and a qualitative study by Muhwezi et al. found a high propensity to high-risk sexual behaviors such as multiple partners and transactional sex in members of a post-conflict community in Uganda [44]. Nevertheless, there is a paucity in the literature about the quantitative association between armed conflicts, HIV testing, HIV prevalence, and high-risk sexual behaviors. Many of the previous studies were either qualitative, used country -level data while focusing on one group of individuals i.e. refugees, and or focused on HIV incidence or prevalence rates. This study made use of administrative region level data to determine the associations between conflicts and HIV testing, HIV prevalence, and high-risk sexual behaviors while adjusting for common confounders. Due to the limited assessment of the possible relationship between armed conflicts and HIV that using data from a specific country or one group of individuals provides, we used a large and diverse group of participants.

3.1.5 Summary

The purpose of this study was to quantitatively assess the association between armed conflicts, HIV testing, HIV prevalence, and high-risk sexual behaviors in SSA. In Aim 1, we found that HIV prevalence and stigma were significantly lower in conflict areas. We also found that previous HIV testing and HIV knowledge were also significantly lower in conflict areas

In Aim 2, we found that conflicts with a duration less than a year and with less than 1000 fatalities were associated with reduced rates of HIV prevalence. In addition, conflicts that lasted more than a year or that had more than 1000 fatalities were not significantly associated with previous HIV testing or HIV prevalence. Furthermore, we found that close proximity to conflict was associated with reduced rates of HIV prevalence and that there were higher prevalence rates in areas further away from conflict. In Aim 3, we found that compared to experiencing 0 days in conflict, experiencing 1-30 days in conflict was significantly associated with higher rates of multiple partnerships and inconsistent condom use with risky partners. Spending 6+ months to 1 year in conflict was significantly associated with a reduced rate of inconsistent condom use with risky partners but was not associated with multiple partnerships. We found that the number of conflict fatalities was significantly associated with higher rates of inconsistent condom use with risky sexual partners. Compared to experiencing 0 fatalities, experiencing 70-1000 fatalities quadrupled the rate of inconsistent condom use with risky partners and almost doubled the rate of multiple partnerships whereas experiencing more than 1000 fatalities was significantly associated with 11 times the rate of inconsistent condom use with risky partners. Our results also indicate that close proximity to an area of conflict is associated with lower rates of high-risk sexual behaviors

This study was the first to statistical modeling techniques to evaluate these associations using administrative region-level DHS data and a large group of participants in SSA. It is vital to understand this relationship as it can help guide future HIV interventions for individuals who have experienced or are experiencing armed conflicts. With the DHS and ACLED datasets being the ideal datasets to study this relationship, findings from this study can have a long lasting impact on HIV intervention guidelines. Because SSA has the highest rates of HIV and an alarming rate of armed conflicts, a significant association between armed conflicts and HIV testing or high-risk sexual behaviors can lead to more effective interventions that target those involved in armed conflicts. These interventions can improve testing rates and decrease high-risk sexual behaviors in this population via various means such as education and an increased availability of testing kits and condoms.

3.1.6 Impact

The HIV pandemic is still a major public health concern. With the UN's goal of ending the HIV pandemic by 2030, effective and strategic interventions are necessary. Because refugees and internally displaced people face barriers to HIV treatment due to exclusionary health policies [45], and they are often not included in national HIV strategic plans [46] interventions are much needed. Findings from this study can offer guidance for designing strategic HIV interventions for this group of people and others living in areas of armed conflicts. As many of the studies that evaluated the effects of armed conflicts on HIV incidence or prevalence were from the early 2000s, this study will provide new and updated assessment of these associations.

3.1.7 Conceptual Map

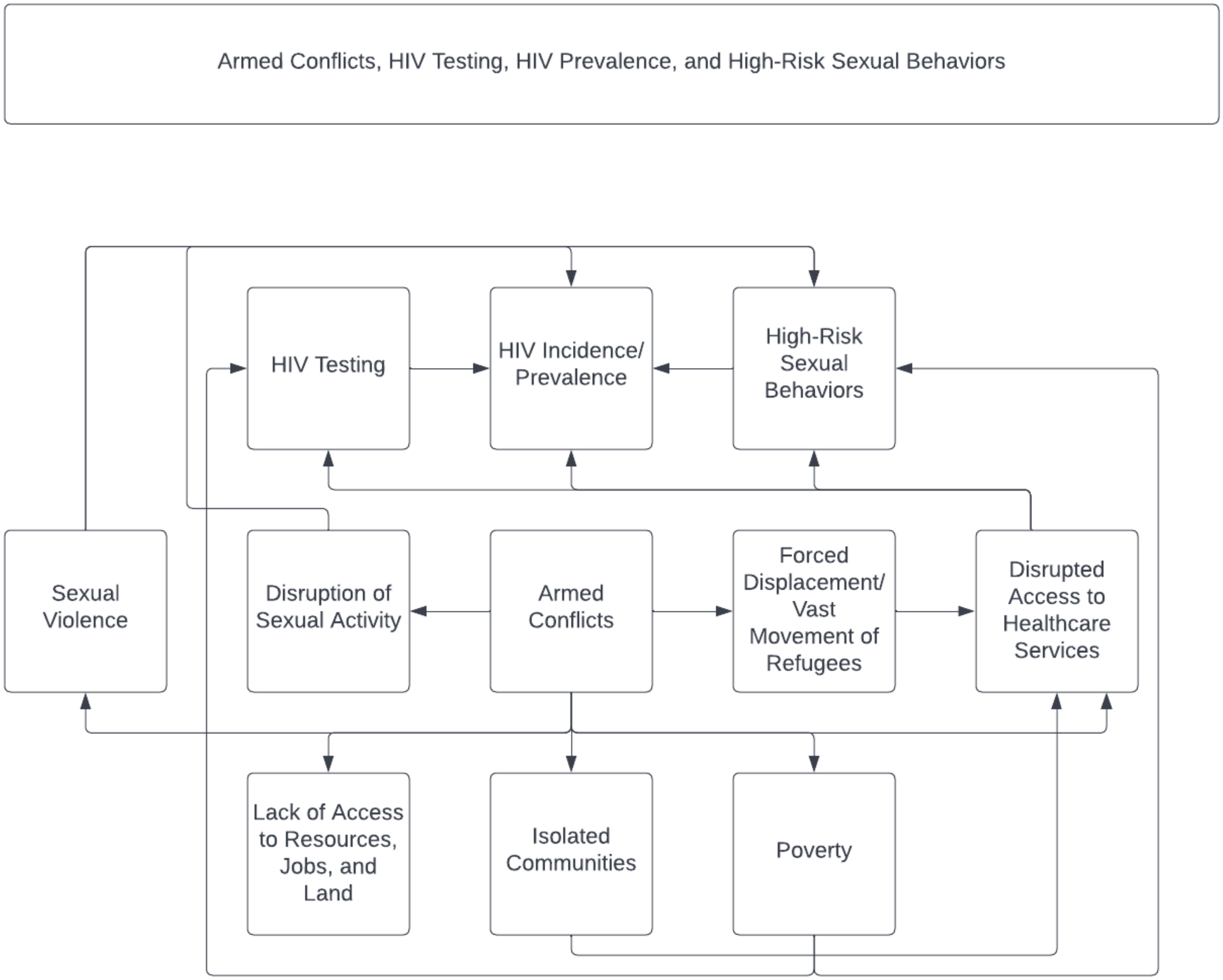

Figure 3-1 Armed Conflicts, HIV Testing, HIV Prevalence, and High-Risk Sexual Behaviors Conceptual Map

[1] The literature shows that armed conflicts cause forced displacement/vast movement of refugees, disrupted access to healthcare services, a disruption in sexual activity, sexual violence, isolated communities, lack of access to resources, jobs, and land and poverty. Forced displacement of refugees can lead to disrupted access to healthcare services. Disrupted access to healthcare services can lead to reduced HIV testing, treatment, and

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reduced access to condoms which can have an effect on high-risk sexual behaviors and HIV prevalence. A disruption in sexual activity, and sexual violence can both have an effect on HIV prevalence, and high-risk sexual behaviors (i.e. higher number of sexual partners). Lack of access to resources and poverty can lower HIV testing, and have an effect on HIV prevalence and high-risk sexual behaviors (i.e. increase in multiple partnerships as a result of poverty).

4.0 References

1. Bennett BW, Marshall BD, Gjelsvik A, McGarvey ST, Lurie MN. HIV Incidence Prior to, during, and after Violent Conflict in 36 Sub-Saharan African Nations, 1990-2012: An Ecological Study. *PLoS One*. 2015;10(11):e0142343. doi:10.1371/journal.pone.0142343
2. Spiegel PB. HIV/AIDS among conflict-affected and displaced populations: dispelling myths and taking action. 2004;(0361-3666 (Print))
3. Spiegel PB, Bennedsen AR, Claass J, et al. Prevalence of HIV infection in conflict-affected and displaced people in seven sub-Saharan African countries: a systematic review. *The Lancet*. 2007/06/30/ 2007;369(9580):2187-2195. doi:https://doi.org/10.1016/S0140-6736(07)61015-0
4. Supervie V, Halima Y, Blower S. Assessing the impact of mass rape on the incidence of HIV in conflict-affected countries. *AIDS*. 2010;24(18)
5. Amowitz LL, Reis C Fau - Lyons KH, Lyons Kh Fau - Vann B, et al. Prevalence of war-related sexual violence and other human rights abuses among internally displaced persons in Sierra Leone. (0098-7484 (Print))
6. *The Armed Conflict Survey 2019*. IISS; 2019:270-356. Accessed June 2020. https://www.iiss.org/publications/armed-conflict-survey/2019/armed-conflict-survey-2019/subsaharan-africa
7. Kim AA, Malele F Fau - Kaiser R, Kaiser R Fau - Mama N, et al. HIV infection among internally displaced women and women residing in river populations along the Congo River, Democratic Republic of Congo. (1573-3254 (Electronic))
8. Mulanga C Fau - Bazepeo SE, Bazepeo Se Fau - Mwamba JK, Mwamba Jk Fau -

Butel C, et al. Political and socioeconomic instability: how does it affect HIV? A case study in the Democratic Republic of Congo. (0269-9370 (Print))

9. Flechner D. A human rights approach to protecting people living with HIV/AIDS in Angola. *International Social Science Journal*. 2005/12/01 2005;57(186):627-637. doi:10.1111/j.1468-2451.2005.00580.x

10. AIDSinfo. Accessed June 5, 2020. http://aidsinfo.unaids.org/

11. UNAIDS. 90-90-90 An ambitious treatment target to help end the AIDS epidemic. https://files.unaids.org/en/media/unaids/contentassets/documents/unaidspublication/2014/90-90-90_en.pdf

12. Shukla M, Agarwal M, Singh JV, Tripathi AK, Srivastava AK, Singh VK. High-risk sexual behavior among people living with HIV/AIDS attending tertiary care hospitals in district of Northern India. *Indian J Sex Transm Dis AIDS*. Jan-Jun 2016;37(1):46-51. doi:10.4103/0253-7184.176212

13. Rosenberg NE, Pettifor AE, Myers L, et al. Comparing four service delivery models for adolescent girls and young women through the 'Girl Power' study: protocol for a multisite quasi-experimental cohort study. *BMJ Open*. 12/14 07/11/received 11/06/revised 11/08/accepted 2017;7(12):e018480. doi:10.1136/bmjopen-2017-018480

14. Chen L, Jha P, Stirling B, et al. Sexual risk factors for HIV infection in early and advanced HIV epidemics in sub-Saharan Africa: systematic overview of 68 epidemiological studies. *PLoS One*. 2007;2(10):e1001-e1001. doi:10.1371/journal.pone.0001001

15. Services USDoHH. What Are HIV and AIDS? HIV.gov. Accessed 09/14, 2021. https://www.hiv.gov/hiv-basics/overview/about-hiv-and-aids/what-are-hiv-and-aids

16. Wu G, Zaman MH. Low-cost tools for diagnosing and monitoring HIV infection in low-resource settings. *Bulletin of the World Health Organization*. 2012;90:914-920.

17. Organization WH. Guidelines for HIV diagnosis and monitoring of antiretroviral therapy, Rev. 2. 2009.

18. Info H. The Basics of HIV Prevention. NIH. Updated 05/01/2020. Accessed 09/15, 2021. https://hivinfo.nih.gov/understanding-hiv/fact-sheets/basics-hiv-prevention

19. Luckheeram RV, Zhou R, Verma AD, Xia B. CD4+ T cells: differentiation and functions. *Clinical and developmental immunology*. 2012;2012

20. Bain LE, Nkoke C, Noubiap JJN. UNAIDS 90–90–90 targets to end the AIDS epidemic by 2020 are not realistic: comment on “Can the UNAIDS 90–90–90 target be achieved? A systematic analysis of national HIV treatment cascades”. *BMJ Global Health*. 2017;2(2):e000227.

21. Levi J, Raymond A, Pozniak A, Vernazza P, Kohler P, Hill A. Can the UNAIDS 90-90-90 target be achieved? A systematic analysis of national HIV treatment cascades. *BMJ global health*. 2016;1(2):e000010.

22. Cuadros DF, Awad SF, Abu-Raddad LJ. Mapping HIV clustering: a strategy for identifying populations at high risk of HIV infection in sub-Saharan Africa. *Int J Health Geogr*. 2013;12:28-28. doi:10.1186/1476-072X-12-28

23. UNAIDS. *UNAIDS 2022 Epidemiological Estimates*. 2022. https://www.unaids.org/sites/default/files/media_asset/UNAIDS_FactSheet_en.pdf

24. Garry S, Checchi F. Armed conflict and public health: into the 21st century. *Journal of Public Health*. 2019;42(3):e287-e298. doi:10.1093/pubmed/fdz095

25. Mock NB, Duale S Fau - Brown LF, Brown Lf Fau - Mathys E, et al. Conflict and HIV: A framework for risk assessment to prevent HIV in conflict-affected settings in Africa. (1742-7622 (Print))

26. Aucoin C. Less armed conflict but more political violence in Africa. Accessed 2020, June. issafrica.org/iss-today/less-armed-conflict-but-more-political-violence-in-africa

27. Bakari JP, McKenna S Fau - Myrick A, Myrick A Fau - Mwinga K, Mwinga K Fau - Bhat GJ, Bhat Gj Fau - Allen S, Allen S. Rapid voluntary testing and counseling for HIV. Acceptability and feasibility in Zambian antenatal care clinics. (0077-8923 (Print))

28. Rosenberg MS, Gómez-Olivé FX, Rohr JK, et al. Sexual Behaviors and HIV Status: A Population-Based Study Among Older Adults in Rural South Africa. *Journal of acquired immune deficiency syndromes (1999)*. 2017;74(1):e9-e17. doi:10.1097/QAI.0000000000001173

29. Yendewa GA, Poveda E, Yendewa SA, Sahr F, Quiñones-Mateu ME, Salata RA. HIV/AIDS in Sierra Leone: Characterizing the Hidden Epidemic. *AIDS Rev*. Apr-Jun 2018;20(2):104-113. doi:10.24875/AIDSRev.M18000022

30. Murray CJL, King G, Lopez AD, Tomijima N, Krug EG. Armed conflict as a public health problem. *BMJ (Clinical research ed)*. 2002;324(7333):346-349. doi:10.1136/bmj.324.7333.346

31. Kay ES, Batey DS, Mugavero MJ. The HIV treatment cascade and care continuum: updates, goals, and recommendations for the future. *AIDS research and therapy*. 2016;13:35-35. doi:10.1186/s12981-016-0120-0

32. Qiao S, Zhang Y, Li X, Menon JA. Facilitators and barriers for HIV-testing in Zambia: A systematic review of multi-level factors. *PLoS One*. 2018;13(2):e0192327-e0192327. doi:10.1371/journal.pone.0192327

33. García-Deltoro M. Rapid Initiation of Antiretroviral Therapy after HIV Diagnosis. (1698-6997 (Electronic))

34. Oser R, Bisola Ojikutu; Willis Odek, Munirat Ogunlayi, and Jo Bakualufu Ntumba. HIV Treatment in Complex Emergencies. USAID's AIDS Support and Technical Assistance Resources, AIDSTAR-One, Task Order 1. https://publications.jsi.com/JSIInternet/Inc/Common/_download_pub.cfm?id=13042&lid=3

35. Betsi NA, Koudou BG, Cissé G, et al. Effect of an armed conflict on human resources and health systems in Côte d'Ivoire: Prevention of and care for people with HIV/AIDS. *AIDS Care*. 2006/05/01 2006;18(4):356-365. doi:10.1080/09540120500200856

36. Hankins CA, Friedman SR, Zafar T, Strathdee SA. Transmission and prevention of HIV and sexually transmitted infections in war settings: implications for current and future armed conflicts. *AIDS*. 2002;16(17)

37. Becker JU, Theodosis C Fau - Kulkarni R, Kulkarni R. HIV/AIDS, conflict and security in Africa: rethinking relationships. (1758-2652 (Electronic))

38. Burton A, Jennifer Butler, Priya Marwah, Cecile Mazzacurati, Marian Schilperoord and Richard Steen. Addressing HIV and sex work. https://www.fmreview.org/sites/fmr/files/FMRdownloads/en/AIDS/25-27.pdf

39. UK P. Factsheet HIV and failing states. STOPAIDS. Accessed June, 2020. https://stopaids.org.uk/wp/wp-content/uploads/2017/06/Factsheet-failing-states.pdf

40. Humanitarian Emergencies, Armed Conflict and the HIV Response. Avert. Accessed June 2020, https://www.avert.org/professionals/hiv-programming/emergencies-conflicts-and-hiv-response

41. Kalichman SC, Ntseane D, Nthomang K, Segwabe M, Phorano O, Simbayi LC. Recent multiple sexual partners and HIV transmission risks among people living with HIV/AIDS in Botswana. *Sexually Transmitted Infections*. 2007;83(5):371. doi:10.1136/sti.2006.023630

42. Katamba A, Ogwang MD, Zamar DS, et al. Cango Lyec (Healing the Elephant): HIV incidence in post-conflict Northern Uganda. *EClinicalMedicine*. Jun 2020;23:100408. doi:10.1016/j.eclinm.2020.100408

43. Du P, Crook T, Whitener C, Albright P, Greenawalt D, Zurlo J. HIV transmission risk behaviors among people living with HIV/AIDS: The need to integrate HIV prevention interventions and public health strategies into HIV care. Article. *J Public Health Manage Pract*. 2015;21(2):E1-E10. doi:10.1097/PHH.0000000000000038

44. Muhwezi W, Kinyanda E, Mungherera M, et al. Vulnerability to high risk sexual behaviour (HRSB) following exposure to war trauma as seen in post-conflict communities in eastern uganda: A qualitative study. Article. *Confl Health*. 2011;5(1)22. doi:10.1186/1752-1505-5-22

45. Guidelines for the Delivery of Antiretroviral Therapy to Migrants and Crisis-Affected Persons in Sub-Saharan Africa. UNHCR. Accessed June, 2020. https://www.unhcr.org/en-us/541fe8a19.pdf

46. Spiegel PB. HIV in emergencies – much achieved, much to do.

5.0 Original Manuscript 1: HIV Testing, HIV Knowledge and Attitudes, HIV Prevalence, and High-Risk Sexual Behaviors in Context of Armed Conflicts in Sub Saharan Africa

5.1 Introduction

By the end of 2018, approximately 26 million people with HIV were living in Sub-Saharan Africa (SSA); in fact, that area has the majority (68%) of the world's HIV cases [1,2]. In addition to having the highest HIV rates, SSA serves as the region with the highest number of armed conflicts [3], refugees, and internally-displaced people in the world [4]. Many countries in SSA have been affected by armed conflict, and approximately 1.1 million conflict-related deaths were recorded in this region between 1989 and 2016 [5]. Previous research has outlined that armed conflicts can have detrimental health impacts on civilians directly or indirectly [6]. Armed conflict areas were found to have high rates of trauma-attributable mortality, an increased infectious disease burden such as increased risks of diarrheal illnesses, respiratory infections, measles, and tuberculosis, and increased rates of sexually transmitted infections via changes in sexual behavior changes and disruption in sexual health services when compared to non-conflict areas [7]. However, in areas of SSA where HIV is prevalent, the association between HIV and armed conflict is unclear.

Previous research findings evaluating the relationship between HIV and armed conflicts have been mixed due to numerous factors such as differences in study populations, study modalities, and or confounding factors [8-13]. Some studies have found low HIV prevalence rates in countries with years of armed conflicts such as Sierra Leone, South Sudan, and Angola when compared to surrounding countries not involved in conflict, suggesting a protective relationship between HIV and prolonged conflicts [11,12]. On the contrary, other studies have found a propagative relationship suggesting that armed conflicts are associated with an increase in HIV prevalence via a decrease in preventive resources such as HIV education and condoms and reduced access to health services [5,14], specifically, HIV-related health care [7,14,15].

Furthermore, the decreased access to HIV-related services may possibly associate with decreased HIV testing rates [16]. HIV testing remains the most important factor in measuring HIV prevalence [16] and is the first step in preventing HIV transmission [17]. Yet, despite this fact, testing rates are not optimal in the majority of countries in SSA [2]. Testing rates and treatment are especially low (<29% and <30%, respectively) in war-torn areas [18].

In addition to lack of HIV testing, the propagative role of high-risk sexual behaviors such as multiple partners [19,20] and inconsistent condom use [20,21] on HIV transmission have also been well documented. Multiple sexual partnerships are common among people living with HIV (PLWH) [22] and positively associated with HIV status [23,24]. In addition, studies have found that the types of sexual partners (i.e. spouse, co-habitant, non-primary) and condom usage can serve as significant determinants of HIV in SSA [25], as condom usage provides a protective effect against HIV transmission [22].

In the context of armed conflicts and high-risk sexual behaviors, a qualitative study by Muhwezi et al. found a high propensity for behaviors such as multiple partners and transactional sex in members of a post-conflict community in Uganda [26]. Another study by Malamba et al. also found that in conflict-affected populations, 12 or more war related traumatic events were associated with an increased risk of HIV infection (HR 2.9, 95% confidence interval 1.28-6.6) [27]. Although SSA is a region with a high prevalence of HIV and armed conflicts, there exists substantial heterogeneity in both of these factors. HIV prevalence ranges from less than 1% in Senegal (West Africa) to as high as 25% in Lesotho (South Africa) [2,28], and higher rates of armed conflicts are concentrated in the Horn (i.e. Ethiopia) and West Africa [29]. Furthermore, there is a paucity in the literature on the association between armed conflicts and HIV indicators because previous research on HIV in armed conflict settings often focused on one specific country or population [8,30,31]. Thus, the purpose of this study was to address the gaps in the literature by using descriptive statistics to evaluate differences in different indicators of HIV between conflict and non-conflict areas, using Demographic and Health Surveys (DHS) in combination with Armed Conflict Location and Event Data (ACLED) from 11 different countries in SSA. We expected that HIV knowledge and testing would be lower in conflict areas and that HIV prevalence and high-risk sexual behaviors would be higher. Findings from this study will add to the literature by helping elucidate the relationship between armed conflicts and HIV.

5.2 Methods

5.2.1 Demographic and Health Surveys and Armed Conflict Data

The DHS program collects nationally- and regionally-representative data on socio-demographics, reproduction and fertility, HIV/AIDS, and other factors in low- and middle-income countries every 5 years. The DHS surveys also capture geographic details of each administrative region (level 1) which is the equivalent of a state or a province and corrects for differences in response rates by applying DHS-provided weights to the dataset. Further descriptions of the DHS surveys, procedures, and variables can be found on the DHS website [32].

The study population consists of individuals between the ages of 15 and 49 years residing in 11 countries in SSA. We used data from countries in SSA that had at least one round of DHS data that included the HIV/AIDS questionnaire, demographic and geographic data. The countries selected by region were, West Africa: Guinea and Senegal; Central Africa: Cameroon; East Africa: Burundi, Ethiopia, Malawi, Rwanda, Tanzania, Zambia and Zimbabwe; South Africa: Lesotho. The years of data ranged from 2010 to 2018, and with the exception of Senegal and Guinea, all of the selected countries were considered as high HIV burden countries based on the number of people living with HIV, new HIV infections, and HIV-related deaths [33].

In addition to the DHS, we used data from the ACLED project, which collects, analyzes, and maps crises around the world. Its dataset provides geographical location such as latitude and longitude of all reported armed conflicts, political violence, and protests, in addition to noting the perpetrators, dates, and types and numbers of fatalities.

For this investigation, we merged the DHS and ACLED datasets and used them to generate weighted administrative region level 1 variables. We used the administrative region level 1 as the unit of analysis and conducted all analyses using SAS 9.4 [34]. In addition, we used QGIS [35] for maps, Tableau [36] for graphs, and RStudio [37] for tabulations.

5.2.2 Definitions of Variables

Outcomes: The outcomes were the proportions in each administrative region 1 with HIV knowledge and attitude, HIV testing, HIV prevalence, and high-risk sexual behaviors. **HIV knowledge and attitude** was defined as comprehensive knowledge and stigma.

Comprehensive HIV knowledge was determined by correct responses to two survey items: knowledge that a healthy-looking person can have HIV and rejection of the two most common local misconceptions about HIV/AIDS transmission or prevention. Stigma was defined as an unwillingness to buy fresh vegetables from a shopkeeper or vendor with a known HIV infection [38]. **Previous HIV testing** was defined as having tested for HIV and received results of most recent test. **HIV prevalence** was calculated using the results of the DHS-administered HIV test which is determined using Dried Blood Spots (DBS) collected at the time of the surveys. **High-risk sexual behavior** was defined as lack of condom use in the previous 12 months with a high-risk sexual partner (i.e. not a spouse or co-habitant).

Risk Factor: Conflict was the only risk factor and was dichotomized with regions classified as conflict or non-conflict areas from 2005 to 2018. According to ACLED a conflict could consist of a battle, violence against civilians, explosion/remote violence, riot, protest, and/or strategic development such as looting or property disruption [39]. Therefore, we designated an administrative region as a conflict area if there were any of the previously mentioned events. In addition, we calculated the total number of conflict events, fatalities, and distance to nearest conflict. We calculated distance to nearest conflict using the Haversine formula and the latitudes and longitudes of the conflict areas and DHS survey census enumeration areas. For conflict, we used the location of the first reported conflict within an administrative region. For the DHS surveys, we used the location of the center of the first census enumeration area within an administrative region. It is important to note that in order to maintain confidentiality, DHS randomly displaces the latitude and longitude positions of all surveys by 2-10 Km based on rurality and restricts such displacement to administrative region boundary lines [40].

5.2.3 Mapping and Graphing

With administrative region as the unit of analysis, we constructed maps and bar charts using mean percentages of all the outcomes to illustrate the geographic distribution of HIV in the context of armed conflict across the countries in SSA. For the maps, in addition to the dataset with the outcomes at the administrative region level, we also utilized subnational region boundary map files from the DHS spatial data repository. Furthermore, we utilized the default projection in QGIS, which is the WGS84 Geographic Coordinate System,

To assess the differences in the means of the outcome variables between conflict and non-conflict areas we utilized two-sample T-tests and pairwise comparisons. We assumed unequal variances and accounted for country in the pairwise comparisons. $P<0.05$ was considered statistically significant.

5.3 Results

We included 168 administrative regions in the analyses (Table 1). The mean age across countries in SSA was 28 years and we found significant differences in remaining socio-demographics between conflict and non-conflict areas (Table 2). In conflict areas, there were higher percentages of males (33 vs. 29%, P <.001), urban areas (36 vs. 21%, P <.001), married individuals (52 vs. 47%, P 0.01), and Muslims (35 vs. 13%, P <.001). We also found lower rates of education (lack of education 30 vs. 17%, P <.001, primary education 32 vs. 59%, P <.001) and employment (63 vs. 69%, P 0.003) in conflict areas.

Overall, conflict areas had significantly lower: comprehensive HIV knowledge, stigma, previous HIV testing (49 vs. 64%, P <.001), and prevalence (5 vs. 7%, P 0.02). However, there was an insignificant difference in high-risk sexual behaviors (53 vs 51%, P 0.4) between conflict and non-conflict areas.

A depiction of previous HIV testing rates by country in Figure 1C shows testing was lowest in Guinea regardless of conflict status. Zambia had the highest previous testing rate among countries in conflict areas while Rwanda and Lesotho had the highest rates among non-conflict areas (Figures 2C, 2D). Figure 1B shows HIV prevalence by country. Senegal had the lowest rates of HIV prevalence regardless of conflict status. Zimbabwe had the highest prevalence among conflict areas (Figure 2A), while Lesotho had the highest prevalence among non-conflict areas (Figure 2B). There was also a trend toward increased high-risk sexual behavior in conflict areas but this did not reach statistical significance (Table 2). In conflict areas, Zimbabwe and Burundi had the lowest and highest rates of high-risk sexual behavior, respectively (Figure 2E). In non-conflict areas, Lesotho had the lowest rate of high-risk sexual behavior, while Guinea had the highest rates (Figure 2F).

Pairwise comparisons revealed that HIV knowledge (Least Square (LS) means 30 vs.42) and stigma (LS means 67 vs.83) were lower in conflict vs. non-conflict areas (both $P<0.0001$). In addition, significant differences were observed in previous HIV testing between conflict (LS means 52) and non-conflict (LS means 70) areas (both $P<0.0001$). Differences in HIV prevalence and high-risk sexual behavior were not significant ($P=0.12$ and 0.07, respectively).

5.4 Discussion

The goal of this study was to investigate the relationship between HIV knowledge and attitudes, HIV testing, HIV prevalence, and high-risk sexual behaviors with armed conflicts in SSA. The relationship between HIV and armed conflicts is complex, and previous studies evaluating this relationship show conflicting findings [8-13]. Aspects of armed conflicts such as immobility/isolation can serve as protective factors [11]; however, breakdowns in societal norms in combination with a lack of supplies [5,14] may possibly associate with a reduction in HIV testing, a promotion of high-risk sexual behaviors, and lower HIV knowledge rates—all accelerating HIV transmission [41]. Based on these factors, we theorized that HIV knowledge and testing would be lower in conflict areas and that HIV prevalence and high-risk sexual behaviors would be higher. However, our findings for HIV prevalence were opposite of what we theorized as we found that HIV prevalence was lower in armed conflict areas.

Our findings, when compared to those of previous studies [15,42,43], indicate a need to consider how HIV prevalence varies across areas of conflict in SSA. A recently published study found that in conflict zones in Nigeria, HIV prevalence was significantly greater with individuals almost 3 times as likely to test positive for HIV, compared to those in non-conflict zones [42]. Similarly, a study by Kim found that civil conflict was significantly associated with 8% higher HIV rates and rates continued to increase as conflict intensified [15]. In contrast to these studies, Kerridge et al. found no significant relationship between armed conflicts and HIV, as measured using disability-adjusted life years (DALY), and found that the relationship between the two factors is mediated and moderated by factors such as ethnic/religious heterogeneity, baseline HIV prevalence, substance use, and number of refugees [43].

In our study, we found significantly lower rates of HIV prevalence in areas of armed conflict. One of the reasons for the difference in findings between this study and other studies could be the countries selected for this study. Previous studies evaluating the relationship between armed conflicts and HIV have often focused on individual countries. Furthermore, HIV prevalence in SSA is highly heterogeneous with 54% of cases residing in East and South Africa, and 13% residing in West and Central Africa [16,44]. Yet all of the countries that did not experience conflict in this study were found in East and South Africa. Our findings might have been different if more countries with conflict in East (i.e. Eritrea, Sudan) and South Africa were included in this study. Unfortunately, DHS does not have HIV prevalence data on these countries and we could not include them in this study.

Furthermore, the low HIV prevalence in conflict areas might have been explained by gender differences. We found a significantly, lower percentage of women in conflict areas. However, it is well known that women in SSA are disproportionately affected by HIV/AIDS, and in certain countries are four times more likely to have HIV, compared to their male counterparts [45].

In the context of risky sexual behaviors, armed conflicts are associated with an increase in sexual partners, especially among women, who may fall victim to rape and sexual violence [46,47], become involved in transactional sex, or forced into sexual slavery [47,48]. This increase in sexual partners [19,20], combined with an accompanying reduction in condom and healthcare accessibility often associated with armed conflict, create an environment that could fuel HIV transmission [5,14]. Upon exploring the relationship between conflicts and high-risk sexual behaviors, we did not have significant findings. However, we showed a significant association between armed conflicts and HIV knowledge and attitudes. Previous research has shown that HIV knowledge is lower in refugee camps [41]. Similarly, in this study, we found significantly lower comprehensive HIV knowledge in areas of conflict. It is well known that HIV knowledge is associated with education, with youths with a primary education almost twice as likely to have comprehensive HIV knowledge, compared to youths without education [49]. Women with some formal education have also been found to be 2.37 times more likely to have good knowledge of HIV transmission compared to those without any education [41]. In addition, it is well known that wars are destructive to education and impede educational attainment mainly via the destruction of the education infrastructure with conflict affected countries found to have lower rates of primary education [50]. In tandem with previous research, we found that areas of conflict had higher levels of no education, and lower levels of primary education. This is especially important given the relationship between education and HIV knowledge. These findings warrant a further investigation using a modeling approach to fully assess this relationship. Furthermore, the association between HIV knowledge and education, especially in areas of conflict warrants that measures should be taken to increase HIV knowledge in these areas.

The main limitation of this study was the potential of selection bias. Countries with more intense conflicts were not included in this study due to lack of data in these countries and this might have influenced our findings. Countries involved in more intense fighting often have limited high-quality data with the safety of data collectors usually a cause of concern [42]. In addition, there might have been data collection limitations within areas of conflict. Lastly, it is well known that men, especially young men, engage in riskier sexual activities [51], yet in our study we found more men in conflict areas and a mean age of 28 which might have explained the slightly higher occurrence of high-risk sexual behaviors in conflict areas.

Despite these limitations, the use of a large pooled dataset enabled the clear visualization of country-level differences for the outcomes of interest. An additional strength of the study was the ability to evaluate longer-term trends by using data collected from multiple DHS phases.

5.5 Conclusion

Overall, we found both positive and negative results. On a positive note, we found that HIV prevalence and stigma were significantly lower in conflict areas. Adversely however, we found that previous HIV testing and HIV knowledge were significantly lower in conflict areas. The co-existence of both positive and negative findings can be explained by the heterogeneity of the study population and the complexity of the relationship between conflicts and HIV measures. Because comprehensive HIV knowledge and HIV testing are both important factors in reducing HIV infections, the low prevalence, despite low HIV knowledge and low previous testing might be explained by other factors such as engagement in high-risk behaviors, number of sexual partners, and geographical location, to name a few. We found that some of the countries, despite having low prevalence countries located in the West of Africa such as Guinea and Senegal also had low HIV knowledge, stigma, and previous testing. Whereas countries located in the South Africa such as Lesotho had HIV knowledge rates less than 40%, but also had high prevalence, previous testing, and stigma. Geographically speaking, it is well known that West African countries often have lower prevalence rates than South African countries [2,28]. In addition to geography, our findings of both positive and negative outcomes can also be explained by societal factors such as poverty, education, sexual norms, and the availability of healthcare, which have been shown to be associated with HIV prevalence, testing, and or knowledge [5,7,14-16].

With the exception of HIV prevalence, findings from this study were in line with previous research. The lower HIV prevalence in areas of conflict that we found in this study opposes previous findings but is possibly explained by the complexity of the relationship between conflicts and HIV prevalence, the heterogeneity of the study population, and pre-conflict prevalence rates. It is possible that some of the conflict areas had relatively low HIV prevalence rates prior to the onset of conflict and therefore continued to have low rates during conflict even if prevalence rates during conflict were slightly elevated. The opposite might also hold with countries that had high prevalence. For example, Lesotho did not experience any conflicts yet was the country with the highest HIV prevalence and Senegal had administrative regions that experienced conflicts but overall had the lowest HIV prevalence. It is possible that factors not controlled for in this study are driving the low prevalence rates in conflict-areas. Nevertheless, our findings add knowledge to the field and suggest that there exists a relationship between conflicts and HIV indicators. Some possible pathways might be via a lack of HIV testing, a deficit in HIV knowledge and stigma, and an increase in high-risk sexual behaviors. Findings from this study also support the use of geospatial methods to analyze differences in HIV, in the context of armed conflict, among countries in SSA. Geospatial methods are capable of detecting differences within and across countries and should be employed when evaluating HIV and armed conflict trends. Future research evaluating the effect of armed conflicts on HIV transmission should account for these geospatial differences and possible confounders such as education and religion, which we also found to significantly differ between conflict and non-conflict areas. Lastly, public health interventions should focus on increasing HIV knowledge and testing in conflict-areas.

5.6 Tables

Table 5-1 DHS Sample Sizes for the 11 Countries in Sub-Saharan Africa

Country	Years of Survey	Number of Individuals	Number of Administrative Regions (Level 1)	Average Number of Individuals/Administrative Region (Level 1)	Conflict
Burundi	2010, 2016	37170	23	1616	Yes
Cameroon	2011, 2018	41468	12	3456	Yes
Ethiopia	2011, 2016	56644	11	5149	Yes
Guinea	2012, 2018	26914	12	2243	Yes
Lesotho	2014	9247	4	2312	No
Malawi	2010, 2015/16	61525	30	2051	No
Rwanda	2010, 2014	38448	30	1282	No
Senegal	2010/11, 2017	43200	15	2880	Yes
Tanzania	2012	19319	9	2147	No
Zambia	2013, 2018	54728	10	5473	Yes
Zimbabwe	2010/11, 2015	34248	12	2854	Yes
Total		422911	168	2517	

Table 5-2 Comparing Mean Proportions and Standard Deviations of Demographics and Outcomes between Conflict and Non-Conflict Areas in SSA

	Conflict Areas	Non-Conflict Areas	P-value
Number of Administrative Regions (Level 1)	79	89	
Age [a]	28.12 (0.53)	28.25 (0.60)	0.166
Female [a]	66.66 (8.91)	71.28 (6.65)	<0.001
Rural [a]	65.68 (20.22)	79.22 (23.10)	<0.001
Marital Status			
Married [a]	52.28 (12.47)	47.22 (12.58)	0.01
Divorced [a]	2.39 (1.81)	3.10 (1.89)	0.014
Never Married [a]	35.64 (7.76)	33.91 (8.96)	0.186
Wealth Status			
Poorer Wealth Quintile [a]	19.24 (7.44)	18.98 (6.80)	0.819
Poorest Wealth Quintile [a]	20.16 (14.45)	19.04 (9.75)	0.556
Middle Wealth Quintile [a]	19.75 (8.20)	19.55 (5.83)	0.857
Richer Wealth Quintile [a]	19.02 (8.06)	20.95 (6.72)	0.092
Richest Wealth Quintile [a]	23.09 (19.69)	21.90 (18.67)	0.69
Religion			

Muslim [a]	35.07 (41.96)	12.51 (24.94)	<0.001
Christian [a]			
Other [a]			
Education			
No Education [a]	30.00 (23.80)	16.70 (15.41)	<0.001
Primary Education [a]	31.77 (11.69)	58.54 (16.58)	<0.001
Secondary Education [a]	33.42 (19.06)	22.11 (12.14)	<0.001
Higher Education [a]	4.80 (4.83)	2.68 (3.63)	0.001
Employed [a]	62.69 (13.41)	69.46 (15.09)	0.003
Outcomes			
HIV Knowledge and Attitudes			
Basic HIV Knowledge [a]	45.79 (18.65)	59.50 (14.32)	<0.001
Comprehensive HIV Knowledge [a]	37.81 (16.93)	46.31 (13.98)	0.001
HIV Stigma [a]	60.64 (23.55)	78.00 (18.15)	<0.001
Ever Tested for HIV [a]	51.04 (19.70)	66.64 (18.83)	<0.001
Tested for HIV and Received Results [a]	49.07 (19.48)	64.32 (18.68)	<0.001
HIV Prevalence [a]	4.58 (5.52)	6.66 (6.17)	0.023

Non-Primary Sexual Partners [a]	12.57 (10.74)	12.06 (8.91)	0.736
Lack of Condom Use with Non-Primary Sexual Partners [a]	52.56 (14.63)	50.87 (12.53)	0.421
Exposure			
Conflict			
Number of Conflict Days (Mean (SD))	87.6 (130)	N/A	N/A
Number of Conflict Fatalities (Mean (SD))	200 (730)	N/A	N/A
Distance to Conflict in KM ((Mean (SD))	78.5 (104.5)	318.7. (270.3)	<0.001

[a] Mean Percentages and Standard Deviations with administrative region 1 as the unit of analysis

5.7 Figures

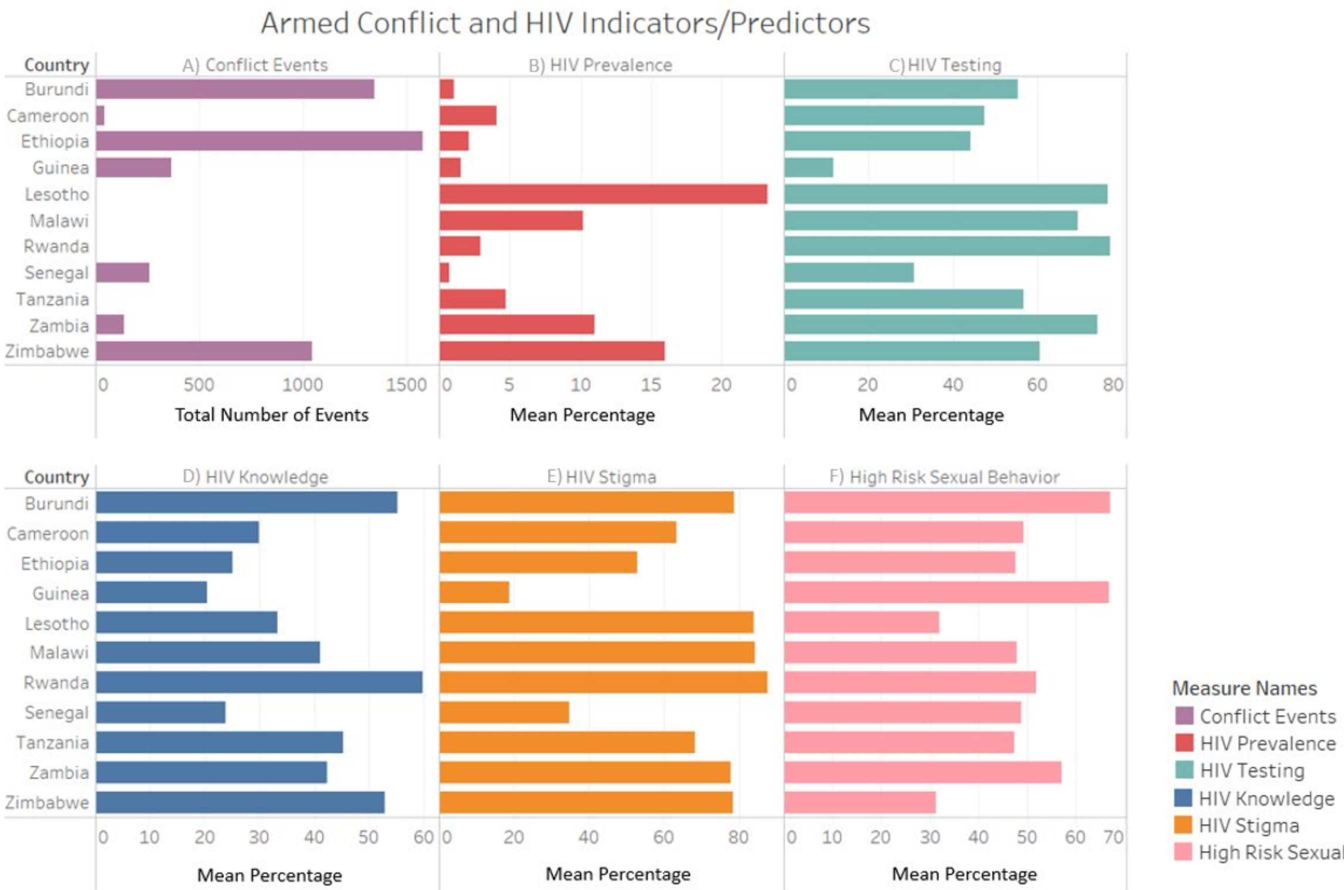

Figure 5-1 Bar Charts of Number of Conflict Events (Purple) and Mean Percentages of HIV Prevalence (Red), HIV Testing (Green), HIV Knowledge (Blue), HIV Stigma (Orange), and High-Risk Sexual Behavior (Pink), by Country

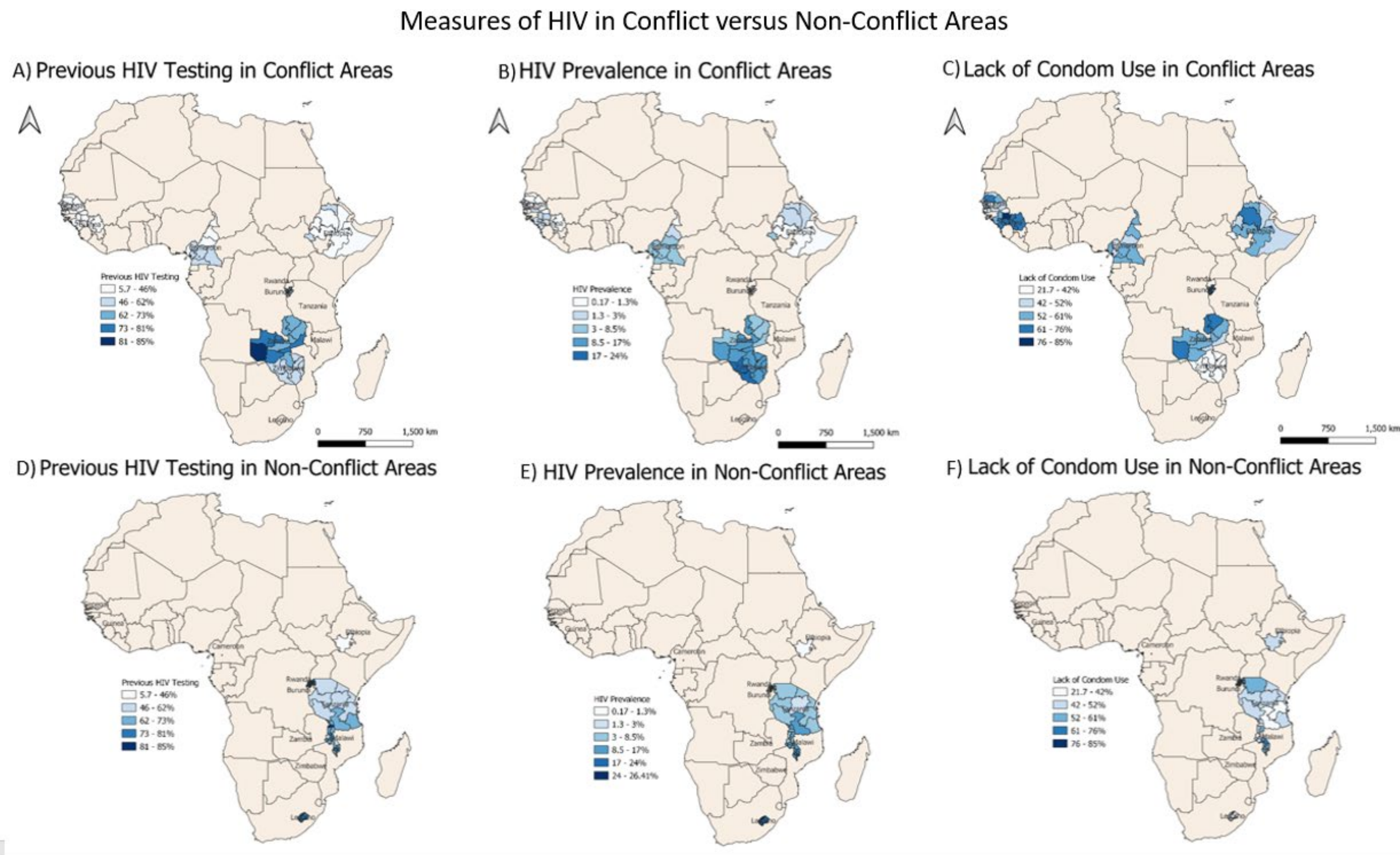

Figure 5-2 Maps of Measures of HIV in Conflict (top) and Non-Conflict (bottom) Areas

5.8 References

1. Organization WH. HIV/AIDS. https://www.afro.who.int/health-topics/hivaids. Accessed 09/15, 2021.

2. Baranczuk Z, Estill J, Blough S, et al. Socio-behavioural characteristics and HIV: findings from a graphical modelling analysis of 29 sub-Saharan African countries. *Journal of the International AIDS Society.* 2019;22(12):e25437-e25437.

3. Mock NB, Duale S Fau - Brown LF, Brown Lf Fau - Mathys E, et al. Conflict and HIV: A framework for risk assessment to prevent HIV in conflict-affected settings in Africa. (1742-7622 (Print)).

4. The Armed Conflict Survey 2019. In: Vol 2019. IISS; 2019: https://www.iiss.org/publications/armed-conflict-survey/2019/armed-conflict-survey-2019/subsaharan-africa. Accessed June 2020.

5. Boerma T, Tappis H, Saad-Haddad G, et al. Armed conflicts and national trends in reproductive, maternal, newborn and child health in sub-Saharan Africa: what can national health surveys tell us? *BMJ global health.* 2019;4(Suppl 4):e001300-e001300.

6. Garry S, Checchi F. Armed conflict and public health: into the 21st century. *J Public Health (Oxf).* 2020;42(3):e287-e298.

7. Murray CJL, King G, Lopez AD, Tomijima N, Krug EG. Armed conflict as a public health problem. *BMJ (Clinical research ed).* 2002;324(7333):346-349.

8. Supervie V, Halima Y, Blower S. Assessing the impact of mass rape on the incidence of HIV in conflict-affected countries. *AIDS.* 2010;24(18).

9. Kim AA, Malele F, Kaiser R, et al. HIV infection among internally displaced women and women residing in river populations along the Congo River, Democratic Republic of Congo. *AIDS Behav.* 2009;13(5):914-920.

10. Mulanga C Fau - Bazepeo SE, Bazepeo Se Fau - Mwamba JK, Mwamba Jk Fau - Butel C, et al. Political and socioeconomic instability: how does it affect HIV? A case study in the Democratic Republic of Congo. (0269-9370 (Print)).

11. Spiegel PB. HIV/AIDS among conflict-affected and displaced populations: dispelling myths and taking action. 2004(0361-3666 (Print)).

12. Spiegel PB, Bennedsen AR, Claass J, et al. Prevalence of HIV infection in conflict-affected and displaced people in seven sub-Saharan African countries: a systematic review. *The Lancet.* 2007;369(9580):2187-2195.

13. Flechner D. A human rights approach to protecting people living with HIV/AIDS in Angola. *International Social Science Journal.* 2005;57(186):627-637.

14. Singh NS, Ataullahjan A, Ndiaye K, et al. Delivering health interventions to women, children, and adolescents in conflict settings: what have we learned from ten country case studies? *The Lancet.* 2021;397(10273):533-542.

15. Kim Y. Armed conflict, health spending, and HIV. *The International Journal of Health Planning and Management.* 2018;33(3):581-595.

16. Worku MG, Tesema GA, Teshale AB. Prevalence and associated factors of HIV testing among reproductive-age women in eastern Africa: multilevel analysis of demographic and health surveys. *BMC Public Health.* 2021;21(1):1262-1262.

17. HIV Testing. https://www.cdc.gov/hiv/testing/index.html. Published 2020. Updated June 9. Accessed 03/17, 2022.

18. Yendewa GA, Poveda E, Yendewa SA, Sahr F, Quiñones-Mateu ME, Salata RA. HIV/AIDS in Sierra Leone: Characterizing the Hidden Epidemic. *AIDS Rev.* 2018;20(2):104-113.

19. Kalichman SC, Ntseane D, Nthomang K, Segwabe M, Phorano O, Simbayi LC. Recent multiple sexual partners and HIV transmission risks among people living with HIV/AIDS in Botswana. *Sexually Transmitted Infections.* 2007;83(5):371.

20. Katamba A, Ogwang MD, Zamar DS, et al. Cango Lyec (Healing the Elephant): HIV incidence in post-conflict Northern Uganda. *EClinicalMedicine.* 2020;23:100408.

21. Du P, Crook T, Whitener C, Albright P, Greenawalt D, Zurlo J. HIV transmission risk behaviors among people living with HIV/AIDS: The need to integrate HIV prevention interventions and public health strategies into HIV care. *J Public Health Manage Pract.* 2015;21(2):E1-E10.

22. Chimoyi LA, Musenge E. Spatial analysis of factors associated with HIV infection among young people in Uganda, 2011. *BMC Public Health.* 2014;14:555-555.

23. Babalola S. Factors associated with HIV infection among sexually experienced adolescents in Africa: a pooled data analysis. (1608-5906 (Print)).

24. Kembo J. Risk factors associated with HIV infection among young persons aged 15-24 years: evidence from an in-depth analysis of the 2005-06 Zimbabwe Demographic and Health Survey. *Sahara j.* 2012;9(2):54-63.

25. Magadi M, Desta M. A multilevel analysis of the determinants and cross-national variations of HIV seropositivity in sub-Saharan Africa: evidence from the DHS. *Health Place.* 2011;17(5):1067-1083.

26. Muhwezi W, Kinyanda E, Mungherera M, et al. Vulnerability to high risk sexual behaviour (HRSB) following exposure to war trauma as seen in post-conflict communities in eastern uganda: A qualitative study. *Confl Health.* 2011;5(1).

27. Malamba SS, Muyinda H, Spittal PM, et al. "The Cango Lyec Project - Healing the Elephant": HIV related vulnerabilities of post-conflict affected populations aged 13-49 years living in three Mid-Northern Uganda districts. *BMC Infect Dis.* 2016;16(1):690.

28. AIDSinfo. http://aidsinfo.unaids.org/. Published 2018. Accessed June 5, 2020.

29. Aucoin C. Less armed conflict but more political violence in Africa. issafrica.org/iss-today/less-armed-conflict-but-more-political-violence-in-africa. Published 2017. Accessed 2020, June.

30. Bennett BW, Marshall BD, Gjelsvik A, McGarvey ST, Lurie MN. HIV Incidence Prior to, during, and after Violent Conflict in 36 Sub-Saharan African Nations, 1990-2012: An Ecological Study. *PLoS One.* 2015;10(11):e0142343.

31. Amowitz LL, Reis C, Lyons KH, et al. Prevalence of war-related sexual violence and other human rights abuses among internally displaced persons in Sierra Leone. *Jama.* 2002;287(4):513-521.

32. The Demographic and Health Surveys Program. https://dhsprogram.com/. Accessed January, 2020.

33. Stover J, Brown T, Puckett R, Peerapatanapokin W. Updates to the Spectrum/Estimations and Projections Package model for estimating trends and current values for key HIV indicators. *AIDS.* 2017;31.

34. SAS 9.4. In. Cary, NC, USA: SAS Institute Inc.

35. Association Q. QGIS Geographic Information System. In. QGIS.org2022.

36. Tableau. Academic programs. In. Seattle: Tableau; 2020.

37. R Studio Team (2021). RStudio: Integrated Development Environment for R. http://www.rstudio.com/. Accessed.

38. Surveys DaH. AIS Individual Questionnaire DHS6. In:2011.

39. ACLED. Strategic Developments in the ACLED Dataset. https://acleddata.com/acleddatanew/wp-content/uploads/dlm_uploads/2019/04/ACLED-Strategic-Developments_FINAL.pdf. Accessed 09/15, 2021.

40. Program TD. GPS Data Collection. In.

41. Khan MN, Rahman MM, Rahman MM, Islam MM. HIV transmission knowledge among Rohingya refugee women in Bangladesh: a cross-sectional survey. *BMJ open.* 2021;11(10):e047516-e047516.

42. Aliyu GG, Aliyu SH, Ehoche A, et al. The Burden of HIV, Hepatitis B and Hepatitis C by Armed Conflict Setting: The Nigeria AIDS Indicator and Impact Survey, 2018. *Ann Glob Health.* 2021;87(1):53-53.

43. Kerridge BT, Saha TD, Hasin DS. Armed Conflict, Substance Use and HIV: A Global Analysis. *AIDS and behavior.* 2016;20(3):473-483.

44. Bakari JP, McKenna S Fau - Myrick A, Myrick A Fau - Mwinga K, Mwinga K Fau - Bhat GJ, Bhat Gj Fau - Allen S, Allen S. Rapid voluntary testing and counseling for HIV. Acceptability and feasibility in Zambian antenatal care clinics. (0077-8923 (Print)).

45. Woolf-King SE, Maisto SA. Alcohol Use and High-Risk Sexual Behavior in Sub-Saharan Africa: A Narrative Review. *Arch Sex Behav.* 2011;40(1):17-42.

46. Bendavid E, Boerma T, Akseer N, et al. The effects of armed conflict on the health of women and children. *Lancet (London, England).* 2021;397(10273):522-532.

47. Vu A, Adam A, Wirtz A, et al. The Prevalence of Sexual Violence among Female Refugees in Complex Humanitarian Emergencies: a Systematic Review and Meta-analysis. *PLoS Curr.* 2014;6:ecurrents.dis.835f10778fd10780ae10031aac10712d10773b10533ca10777.

48. Kadir A, Shenoda S, Goldhagen J. Effects of armed conflict on child health and development: A systematic review. *PLoS One.* 2019;14(1):e0210071-e0210071.

49. Dadi TK, Feyasa MB, Gebre MN. HIV knowledge and associated factors among young Ethiopians: application of multilevel order logistic regression using the 2016 EDHS. *BMC Infect Dis.* 2020;20(1):714.

50. O'Brien ML. Disruption and decline: the gendered consequences of civil war and political transition for education in Tajikistan. *Post Sov Aff.* 2020;36(4):323-345.

51. Fleming PJ, DiClemente RJ, Barrington C. Masculinity and HIV: Dimensions of Masculine Norms that Contribute to Men’s HIV-Related Sexual Behaviors. *AIDS and Behavior.* 2016;20(4):788-798.

6.0 Original Manuscript 2: Association Between HIV Testing, HIV Prevalence and Conflicts in Sub-Saharan Africa

6.1 Introduction

By the end of 2018, majority of the world's HIV cases, approximately 26 million, were living in Sub-Saharan Africa (SSA) [1,2]. In addition to having the highest HIV rates, SSA serves as the region with the highest number of armed conflicts [3], refugees, and internally displaced people in the world [4]. Many countries in SSA have been affected by armed conflict, and approximately 1.1 million conflict related deaths were recorded in this region between 1989 and 2016 [5]. Recent events such as the civil war in Tigray, Ethiopia , deadly clashes between ethnic groups such as the Oromos and Somalis in Ethiopia [6], and fatal clashes between civilians and police forces such as the violent crackdowns in Zimbabwe [7], and Cameroon [8] are examples of concerning conflicts in SSA. Events such as these not only claim countless innocent lives, but can also destabilize the public health structures via the destruction of healthcare systems [9], blockage of relief supplies and mass starvation [10], as is the case in Tigray, Ethiopia . Therefore, in areas of SSA where HIV is prevalent, armed conflicts can also have indirect detrimental health impacts on communities[11].

One of the ways in which conflicts can have detrimental health impacts on a community might be via HIV testing. HIV testing still remains the most important means of halting the HIV pandemic [12] as it identifies people at risk and can help ensure that those who are infected are linked to care [13]. A lack of or delayed testing not only impacts HIV transmission but also impacts clinical outcomes as early, sustained antiretroviral treatment improves clinical outcomes. Late diagnosis of HIV can add to the pandemic and result in large scale problems [14] such as an increase in disease burden for the patients and the public health system [15].

Furthermore, HIV testing remains the most important factor in measuring HIV prevalence [16]. In a cross-sectional study evaluating 16 Sub-Saharan African countries, testing for HIV and obtaining the results was found as a prerequisite to determining one's HIV status [17]. Yet, despite the importance of HIV testing on HIV transmission, testing rates are not optimal in the majority of countries in SSA [2], [17], [18] despite large-scale initiatives to increase testing uptake [19]. It has been reported that approximately 1.1 million people with HIV in eastern and southern Africa, and 1.3 million in western and central Africa are unaware of their status [19]. There is an especially low uptake of HIV testing amongst the poorest and least educated [19].

Testing rates in areas of conflict are also concerning as the breakdown of health systems, a common feature of armed conflicts, can serve as an impediment to HIV testing and prompt initiation of HIV treatment[20] by decreasing access to health services [21], [16]. Testing rates and treatment in war-torn areas have been found to be as low as less than 29 and 30%, respectively [22].

HIV testing is paramount in truly understanding HIV prevalence in a specific population. Previous research evaluating HIV testing uptake amongst adolescents in post-conflict areas in Uganda, found that HIV prevalence was high among non-testers [23] and was significantly associated with war related trauma [24].The association between HIV prevalence and areas of armed conflict is unclear and previous research findings have been mixed [25-30]. While some studies have found that countries that experienced years of conflict had lower HIV prevalence than neighboring countries without any conflict, suggesting a protective relationship between HIV and conflicts, other studies have found a propagative relationship suggesting that armed conflicts are associated with an increase in HIV prevalence via a decrease in preventative resources such as HIV education and reduced access to health services [5, 20, 21], specifically, HIV-related health care [11, 21, 31]. On this note, a recent study in Nigeria has found that HIV prevalence was significantly greater in conflict zones, compared to non-conflict zones [32].

Previous studies evaluating the association between conflicts and HIV prevalence have had conflicting findings and have shown that armed conflicts can either play a propagative or protective role in HIV prevalence [28], [29], [30]. In addition, previous studies have often focused on specific groups of individuals or countries [25], [33], [34] affected by armed conflict. As for HIV testing, there is still a paucity in the literature about HIV testing in areas that have been or are currently being affected by armed conflict. This study is the first to assess the effect of armed conflicts on HIV testing and prevalence in Sub-Saharan Africa (SSA), using a large diverse group of participants and statistical modelling techniques.

6.2 Methods

In this study, we utilized DHS and ACLED data to evaluate the association between previous HIV testing, HIV prevalence, and conflicts in SSA, using a cross-sectional ecologic study design. We used generalized linear mixed models with spatial random effects to control for spatial autocorrelation with previous HIV testing or HIV prevalence as the outcomes, and conflict duration, conflict fatalities, and or distance to the nearest conflict as the main risk factors. In the adjusted models, we controlled for common confounders such as age, sex, religion, marital status, wealth, education, employment, in addition to spatial autocorrelation. In the conflict fatalities models, we also adjusted for conflict duration. Using this approach, we generated rate ratios to elucidate the effect of conflict on previous HIV testing and HIV prevalence.

6.2.1 Population and Datasets

The study population consisted of individuals between the ages of 15 and 49 years old, residing in 11 countries in SSA. The countries designated by region were as follows: West Africa: Guinea and Senegal; Central Africa: Cameroon; East Africa: Burundi, Ethiopia, Rwanda, Tanzania; South Africa: Malawi, Zambia, Zimbabwe, and Lesotho. Countries with multiple phases of cross-sectional DHS data were chosen, and all of the countries, with the exception of Lesotho and Tanzania, had two rounds of DHS data available on the outcomes of interest. Administrative region level 1 (i.e. state/province) variables were constructed by aggregating the individual level variables to obtain weighted proportions and counts per region.

The Armed Conflict Location and Event Dataset (ACLED) is a project concerned with the collection, analysis, and mapping of crises around the world. Its dataset provides geographical location such as latitude and longitude of all reported armed conflicts, political violence, and protests in addition to noting the perpetrators, dates, types and number of fatalities.

6.2.2 Definition of Variables

Exposures: The main risk factor of interest for this study was conflict. Here we defined it as any battle, violence against civilians, explosion/remote violence, riot, protest, and/or strategic development (i.e. looting or property disruption) and we sought to quantify conflict intensity. To achieve this, we developed three different measures of conflict, including the number of days spent in conflict, the number of conflict fatalities, and the distance to the nearest area of conflict. Number of days spent in conflict was categorized, based on quintiles, into five groups: 0 days, 1 to 30 days, 30+ days to 6 months, 6+ months to 1 year, and greater than 1 year. Conflict fatalities was also categorized by quintiles into five groups: 0, 1-4, 5-17, 18 to 69, 70 to 1000 and 1000+ fatalities. Distance was calculated as the minimum distance (in Kilometers) from the centroid of the first Census Enumeration Area within an administrative region 1 to an area of conflict using the Haversine formula as coordinate data included latitudes and longitudes in decimal degrees. Resulting distances were then categorized as: <35 KM, 35-120 KM, 121-330 KM and 330+ KM. We accounted for lagged effects of conflict by using conflict data up to 5 years prior to the administration of the first DHS survey (i.e. battles that occurred between 2005-2010 for DHS survey 2010).

Outcomes: The outcomes of interest were previous HIV testing and HIV prevalence. Previous HIV testing was defined as the number of individuals within each administrative region who reported ever testing for HIV and receiving the results of the most recent test. HIV prevalence was defined as the number of positive test results from the DHS-administered HIV tests. The measures of previous HIV testing and HIV prevalence were separate and independent of each other.

Covariates: The covariates included in the analyses were age, sex, education, wealth index, marital status, religion, and urban/rural residence. The religions were limited to Christianity and Islam, and marital status was defined as married or divorced. For wealth, we accounted for the poorest and richest wealth quintiles and for education, we accounted for lack of an education and primary education.

6.2.3 Statistical Analyses

We ran generalized linear mixed models with spatial random effects using SAS 9.4. This approach provides a general overview of the association between armed conflicts and the outcomes after controlling for geographic variability using random effects. As the histograms of the outcomes were skewed and indicative of a Poisson or Negative Binomial distribution, the model was based on a negative binomial distribution. A negative binomial distribution accounts for overdispersion (i.e. greater variability than expected) as it is a more relaxed approach and does not make the same assumptions of equal mean and variance as a Poisson model. The models included a log link and an offset that was created using the log of the sample sizes of the respective outcomes. For previous HIV testing, we used the log of the total number of individuals as the offset, and for HIV prevalence we used the log of the total number of individuals who took the DHS administered HIV test as the offset. In addition to the models, we used ANOVA to compare group means and Fisher's exact test to compare the categorical variables, by country.

In addition, we used weights that were aggregated and scaled at the administrative region level (i.e. state/province) to make the results nationally representative. Previous research has shown that results from a weighted analysis are more reliable if the weights are scaled [36]. Therefore, we used a validated weighting scale that divides the cluster size by the sum of the weights [36].

To create the models, an exponential spatial covariance structure that accounted for regional spatial effects was used where region was defined based on contiguity as follows: West: Senegal, Guinea, Central: Cameroon; East: Tanzania, Burundi, Rwanda;

South: Zambia, Zimbabwe, Lesotho, Malawi, and North/East: Ethiopia. With the exponential spatial covariance approach, the covariance between two observations relied on a distance metric [37]. Prior to modelling, variograms of the outcomes and predictors were also constructed, using Moran's I and Geary's C coefficients, to detect spatial autocorrelation within the outcome values.

Associations are reported as rate ratios with fixed time and can be interpreted as the rate of previous HIV testing or rate of HIV prevalence. Let y_{ij} denote the number of individuals who have previously tested for HIV or who are HIV positive per administrative region *i* (*i*=1, …, n_i) and region *j* (*j*=1, …, m) that has a sample size N_{ij}, a generalized linear mixed model with random effects and offset is represented as follows:

$$g\left(E(y_{ij}|X_{ij})\right) = \beta_0 + \beta X_{ij} + v_{ij} + b_j + e \qquad (6.1)$$

Where g is a log link function that allows for the interpretation of the fixed effects regression coefficients, βs as log rate ratio, X_{ij} is a vector of covariates, v_{ij} are administrative region specific random effects for the within region variability, b_j are the random effects for the between region variability, e accounts for the offset $(1/N_{ij})$. Here, the coefficient vector includes conflict, age, sex, religion, wealth, education, employment, and urbanity. That is, β is a column vector ($\beta_{conflict}$, β_{age}, β_{sex}, $\beta_{religion}$, $\beta_{marital}$, β_{wealth}, $\beta_{education}$, $\beta_{employment}$, β_{urban}).

6.3 Results

We used data from 11 countries, 168 administrative regions (i.e. state/province) and 422,911 individuals (Table 1). When evaluating differences in sociodemographic by country, we found that the mean age throughout the countries was 28 and that there were a majority of female survey respondents in all of the countries (Table 2). Malawi had the lowest mean percentage of urban areas (13%), and marriage rates ranged from 35% in Rwanda to 67% in Guinea. Ethiopia had both the highest mean percentages of the poorest wealth quintile (25%) and the richest wealth quintile (36%). Senegal had the highest percentage of Muslims (96%); Zambia had the highest percentage of Christians (99%). In terms of education, low education was most pronounced in Guinea (65% for no education and 14% for primary education).

HIV testing and prevalence differed by country. . Out of all the countries, Rwanda had the highest rates of previous HIV testing and receiving the results (77%); Guinea had the lowest (12%). HIV prevalence was lowest in Senegal (0.7%) and highest in Lesotho (23%).

Conflict indicators also differed by country. Lesotho, Malawi, Rwanda, and Tanzania did not experience any conflict and had the highest distances to an area of conflict. Burundi had the highest percentage of nearby conflicts with 83% of its conflicts occurring less than 35 KM away. Out of the countries with conflict, Burundi, Ethiopia, and Zimbabwe were the only countries with 1+ year spent in conflict. Ethiopia also had the highest number of fatalities with 36% of conflicts experiencing 70-1000 fatalities and 27% experiencing over 1000 fatalities. Guinea had the lowest number of fatalities with 42% of conflicts experiencing 0 fatalities.

Prior to modelling, we used variograms to determine the existence of spatial autocorrelation. For both previous HIV testing and HIV prevalence, the results of the variograms were suggestive of significant spatial autocorrelation. Previous HIV testing and receiving the results of the most recent test had a Moran's I Z value of 9.7, p-value <.0001 and a Geary's C Z value of -0.81, p-value 0.42. For HIV prevalence, the values were 22.8 p-value <.0001, for Moran's I and -3.5 p-value 0.0004 for Geary's C. The existence of spatial autocorrelation indicates that closer administrative regions were more likely to have similar values. We accounted for this spatial autocorrelation in the models by including spatial random effects.

6.3.1 Results for the Association Between Previous HIV Testing and Conflict

Most of our findings when evaluating the association between previous HIV testing and conflict were not significant. When evaluating the association between previous HIV testing and number of days spent in conflict, those that experienced 1-30 days of conflict had an insignificant 22% reduced likelihood of previous HIV testing in the unadjusted model (RR 0.78, 95% CI 0.24, 2.52) compared to administrative regions without any conflict. This decreased to a 5% reduced likelihood in the adjusted model (RR 0.95, 95% CI 0.87, 1.04) where we adjusted for age, sex, religion, marital status, wealth, education, employment, and spatial autocorrelation using spatial random effects. In administrative regions with over a year of conflict, previously testing for HIV and receiving the results was more likely (RR 1.11, 95% CI 0.96, 1.29), but this was also not significant.

For conflict fatalities, we adjusted for conflict duration and found that compared to areas with 0 fatalities, those in areas that experienced conflict fatalities were less likely to have previously tested for HIV and receive the results. Administrative regions that experienced 1-4 fatalities had a 6% reduced likelihood (RR 0.94, 95% CI 0.88, 0.99) of previous HIV testing. Experiencing 5-17 deaths or 70-1000 deaths were also indicative of a decrease in previous testing, but not significantly (RR 0.97 95% CI 0.87, 1.05, and RR

0.93 95% CI 0.9, 1, respectively). Experiencing 1000+ deaths was also not significantly associated with having previously tested for HIV and receiving the results (RR 1.45, 95% CI 0.98, 2.15).

These trends indicate that with the exception of administrative regions that experienced 1-4 fatalities, there is no significant association between previous HIV testing and conflicts. We noticed that when conflict has a low intensity (i.e. low number of days, low fatalities) then there is a lower likelihood of previous HIV testing. However, conflicts that last over a year or that have over 1000 fatalities have an increased likelihood of previous testing, although none of these findings were significant.

Furthermore, being closer to an area of conflict was also not significantly associated with previous HIV testing. There was a 3%, insignificant, decrease in previous HIV testing and receiving the results among regions with conflicts <35 or 35-120 KM away compared to regions with conflicts >330 KM away (RR 0.97, 95% CI 0.85, 1.10). Conflicts that were 121-330 KM away were also not statistically associated with HIV testing likelihood (RR 0.99, 95% CI 0.91, 1.09).

6.3.2 Results for the Association between HIV Prevalence and Conflict

When evaluating the association between number of days spent in conflict and HIV prevalence, we found in the adjusted model that spending 30+ days-6 months in conflict was significantly associated with a 48% decrease in HIV prevalence, when compared to those with 0 days in conflict (RR 0.52, 95% CI 0.33, 0.98).

Upon evaluating the association between conflict fatalities and HIV prevalence, 70-1000 fatalities was associated with a 36% reduction in HIV prevalence compared to not having any fatalities (RR 0.64, 95% CI 0.45, 0.9).

Upon evaluating the association between distance and HIV prevalence, we found that when compared to conflicts that were over 330 KM away, conflicts that were close by were significantly associated with a lower rate of HIV prevalence. We found that conflicts that were less than 35 KM away had an 82% lower rate of HIV prevalence (RR 0.18, 95% CI 0.12, 0.26). As distance from an area of conflict increased, there was a 70% decrease in HIV prevalence rate for conflicts 35-120 KM away (RR 0.3 95% CI 0.21, 0.42) and a 63% decrease in prevalence rate for conflicts 121-330 KM away (RR 0.37 95% CI 0.26, 0.51).

The rest of the findings in the models with HIV prevalence as the outcome were not statistically significant. Spending 6+ months-1 year in an area of conflict was insignificantly associated with a 39% decrease in HIV prevalence (RR 0.61, 95% CI 0.38, 1.08), and spending over a year in conflict was associated with a 37% increase in HIV prevalence, but not significantly (RR 1.37, 95% CI 0.3, 6.3).
Upon evaluating the association between conflict fatalities and HIV prevalence, having 5-17 or 18-69 fatalities was also associated with a decreased likelihood of HIV prevalence but not significantly (RR 0.89 95% CI 0.6, 1.3, and RR 0.73 95% CI 0.5, 1.14, respectively). Experiencing more than 1000 fatalities was associated with a 47% increased likelihood of HIV prevalence also not significantly (RR 1.47, 95% CI 0.6, 3.4).

6.4 Discussion

The overarching goal of this manuscript was to determine the association between HIV testing, HIV prevalence and conflicts. We hypothesized that exposure to conflict would lead to lower HIV testing rates and higher HIV prevalence; however, findings from this study indicate that the associations vary based on conflict intensity and proximity. The key findings were that spending 30+ days-6 months in conflict was significantly associated with a 48% decrease in HIV prevalence, when compared to those with 0 days in conflict, experiencing 70-1000 fatalities was associated with a 36% reduction in HIV prevalence compared to not having any fatalities (RR 0.64, 95% CI 0.45, 0.9), and administrative regions (i.e. state/province) closest to areas of conflict had lower rates of HIV prevalence compared to administrative regions that were further away from conflict areas.

The relationship between HIV prevalence and armed conflicts can be quite complex. Conflicts can possibly decrease the risk of acquiring HIV via the reduction of mobility and an increase in social services in refugee camp settings [3], [38], [28] or it can increase the risk via increased sexual violence, disrupted health infrastructures and social service breakdowns [28]. Previous research have found that in post-conflict areas, HIV prevalence was significantly associated with war trauma experiences [24], [39], with those who experienced war trauma being 2.5 times as likely to have HIV [24]. Another study found that individuals who experienced abduction in times of conflict were over three times more likely to become infected with HIV [39]. The most-conflict affected areas were also found to have higher HIV prevalence, compared to areas that were less affected [24]. Similarly in our study, we found that spending over a year in conflict or experiencing 1000+ fatalities was associated with a higher likelihood of HIV prevalence. In areas with less than a year of conflict and less than 1000 fatalities, we found a decreased likelihood of HIV prevalence. We also found that living closer to an area of conflict was associated with a decreased likelihood of HIV prevalence. HIV prevalence rates increased as distance from conflict increased. Because DHS HIV test uptake was high on average and did not differ between conflict and non-conflict areas, these findings may indicate that close proximity to conflict has a protective association with HIV prevalence.

For previous HIV testing, contrary to our hypothesis, we did not find any significant associations between previous HIV testing and conflicts. One possible explanation for these findings might be interventions in conflict settings. There has been increased international focus on producing guidelines for the administration of infectious disease services in areas of conflict [20]. A systematic review of interventions in armed conflict settings showed that majority of armed conflict interventions in SSA occur in South Sudan, Sudan, Tanzania and Ethiopia [20]. Meteke et al. also found that antenatal sexually transmitted infection (STI) risk screening with associated educational interventions was the third most reported conflict intervention [20]. In our study, Ethiopia was one of the countries with the most intense conflicts with a greater number of days spent in conflict and a higher number of fatalities. Such interventions might explain our findings if STI risk screening resulted in increased HIV testing. This would especially be the case if interventions ensure that HIV testing in conflict areas is comparable to testing in non-conflict areas. .

In addition, the question used for these analyses only measures previous testing but does not account for the time when the test was taken. As a result, all those who report previous testing, whether 10 years or 1 month prior to the survey are grouped together. This makes it impossible to know whether the test was taken during or prior to the armed conflict.

One of the limitations of this study was that we could not account for war-related trauma, rape, and other war-related factors that could possibly play a role in the relationship between armed conflict and HIV testing and HIV prevalence. Secondly, HIV incidence might have been a stronger indicator of HIV trends; however, this data was not available in the DHS dataset. Lastly, countries that were involved in conflicts that were more violent were not included in the analyses due to poor or lack of DHS data, possibly limiting our ability to accurately evaluate this association.

One of the major strengths of this project was its novel approach that incorporated spatial mixed effects in a model aimed to outline the association between conflicts and HIV testing and prevalence. Another benefit of the study was that we used different measures of conflict and conflict data up to 5 years prior to the DHS survey which allowed us to account for lagged effects.

6.5 Conclusion

Overall, we found that conflicts with a duration less than a year and with less than 1000 fatalities were associated with reduced rates of HIV prevalence. However, conflicts that lasted more than a year or that had more than 1000 fatalities were not significantly associated with previous HIV testing or HIV prevalence. We also found that close proximity to conflict was associated with reduced rates of HIV prevalence. There were higher prevalence rates in areas further away from conflict. Future studies should consider conducting this study using a different study population to determine if findings remain consistent. It would be especially informative to use data from countries with more intense conflicts.

6.6 Tables

Table 6-1 Countries and Years of DHS Data Selected

Country	Years of Survey	Number of Individuals	Number of Administrative Regions (Level 1)	Average Number of Individuals/Administrative Region (Level 1)	Conflict
Burundi	2010, 2016	37170	23	1616	Yes
Cameroon	2011, 2018	41468	12	3456	Yes
Ethiopia	2011, 2016	56644	11	5149	Yes
Guinea	2012, 2018	26914	12	2243	Yes
Lesotho	2014	9247	4	2312	No
Malawi	2010, 2015/16	61525	30	2051	No
Rwanda	2010, 2014	38448	30	1282	No
Senegal	2010/11, 2017	43200	15	2880	Yes
Tanzania	2012	19319	9	2147	No
Zambia	2013, 2018	54728	10	5473	Yes
Zimbabwe	2010/11, 2015	34248	12	2854	Yes
Total		422911	168	2517	

Table 6-2 Sociodemographic, Outcomes, and Risk Factors by Country

	Burundi	Cameroon	Ethiopia	Guinea	Lesotho	Malawi	Rwanda	Senegal	Tanzania	Zambia	Zimbabwe	P-value
Number of Administrative Regions (Level 1)	23	12	11	12	4	30	30	15	9	10	12	
Age [a]	28.05 (0.49)	27.97 (0.41)	28.08 (0.21)	28.76 (0.98)	28.03 (0.24)	28.08 (0.33)	28.33 (0.57)	27.80 (0.43)	28.80 (0.80)	28.35 (0.21)	28.06 (0.45)	<0.001
Female [a]	71.74 (2.76)	69.82 (2.07)	57.13 (2.40)	75.04 (4.29)	72.00 (0.77)	77.24 (1.60)	70.77 (1.73)	75.18 (2.86)	56.99 (1.79)	55.19 (1.71)	56.04 (2.15)	<0.001
Rural [a]	77.46 (24.68)	47.11 (24.41)	72.54 (19.58)	66.25 (22.30)	77.96 (20.28)	86.86 (14.14)	81.25 (22.58)	57.63 (17.75)	76.08 (15.08)	57.28 (13.62)	69.43 (19.53)	<0.001
Marital Status												
Married [a]	41.03 (6.59)	39.45 (15.57)	56.06 (9.62)	67.36 (9.00)	50.73 (4.77)	56.69 (5.82)	34.62 (6.04)	60.94 (8.46)	51.84 (4.37)	54.04 (5.02)	52.24 (6.85)	<0.001

Divorced [a]	0.44 (0.36)	1.13 (0.97)	4.03 (1.85)	1.18 (0.57)	1.12 (0.52)	4.34 (1.72)	2.83 (1.16)	2.51 (0.78)	4.52 (1.80)	4.89 (0.97)	2.84 (0.87)	<0.001
Never Married [a]	39.17 (7.79)	38.22 (7.52)	33.69 (8.29)	28.18 (7.86)	38.01 (3.95)	24.28 (2.74)	41.75 (4.20)	35.07 (8.05)	33.65 (5.23)	36.77 (3.92)	36.30 (6.83)	<0.001
Wealth Index												
Poorest Wealth Quintile [a]	16.49 (9.55)	14.85 (18.50)	24.65 (20.37)	22.41 (9.73)	22.93 (14.10)	18.85 (8.28)	18.34 (9.00)	23.98 (16.58)	16.89 (9.79)	19.22 (11.47)	23.19 (13.18)	0.488
Poorer Wealth Quintile [a]	17.73 (7.01)	19.28 (10.85)	12.91 (7.58)	21.76 (4.46)	22.04 (8.20)	19.75 (5.14)	19.14 (6.58)	22.45 (7.78)	17.77 (7.16)	19.78 (7.14)	18.27 (6.39)	0.103
Middle Wealth Quintile [a]	18.22 (5.99)	22.80 (9.90)	12.41 (7.95)	19.66 (7.67)	20.47 (3.63)	20.50 (3.91)	19.62 (6.20)	24.01 (8.48)	19.07 (5.86)	20.97 (4.91)	17.38 (8.86)	0.008

Richer Wealth Quintile [a]	18.85 (8.38)	22.54 (7.73)	13.88 (8.59)	22.73 (5.92)	18.34 (7.69)	20.77 (5.56)	20.18 (6.85)	17.58 (9.16)	22.78 (6.67)	19.52 (6.98)	22.63 (7.35)	0.094
Richest Wealth Quintile [a]	28.71 (21.65)	23.01 (19.88)	36.15 (28.59)	17.13 (22.15)	16.21 (13.23)	20.13 (11.59)	22.72 (21.16)	11.97 (14.09)	23.50 (17.18)	20.52 (12.57)	23.92 (17.66)	0.14
Muslim [a]	4.08 (4.15)	13.21 (9.58)	43.31 (33.48)	88.46 (20.21)	0.26 (0.21)	11.04 (17.81)	2.00 (2.09)	95.90 (4.99)	NaN (NA)	0.46 (0.59)	0.58 (0.36)	<0.001
Christian [a]	93.92 (4.77)	72.52 (20.16)	55.39 (32.82)	9.99 (17.00)	95.73 (0.98)	87.58 (17.61)	96.84 (2.39)	3.80 (4.67)	NaN (NA)	98.68 (0.92)	83.46 (5.44)	<0.001
Education												
No Education	31.86 (9.75)	13.58 (18.16)	39.01 (17.40)	64.85 (12.48)	3.96 (2.31)	12.53 (7.39)	12.67 (4.39)	51.97 (15.06)	13.54 (4.53)	6.37 (2.93)	1.40 (1.20)	<0.001
Primary Education [a]	40.70 (5.19)	31.57 (9.05)	38.57 (8.89)	13.55 (3.53)	47.26 (10.85)	65.72 (5.90)	66.39 (6.35)	21.95 (4.65)	63.72 (12.94)	43.67 (8.02)	27.21 (11.02)	<0.001

Secondary Education [a]	25.37 (10.18)	47.83 (17.41)	13.21 (7.57)	17.94 (6.91)	43.02 (8.43)	20.00 (6.94)	18.38 (5.91)	23.80 (9.84)	22.20 (14.30)	43.71 (7.34)	64.42 (8.83)	<0.001
Higher Education [a]	2.08 (3.94)	7.03 (6.23)	9.22 (7.12)	3.66 (4.46)	5.75 (4.27)	1.76 (1.72)	2.55 (2.81)	2.27 (2.34)	0.60 (0.60)	6.26 (2.80)	6.97 (3.60)	<0.001
Employed [a]	79.20 (8.41)	66.69 (6.67)	54.02 (9.15)	70.73 (8.51)	36.29 (8.00)	62.68 (8.92)	79.26 (8.93)	51.75 (5.96)	81.34 (8.62)	60.27 (5.47)	46.27 (9.50)	<0.001
Tested for HIV and Received Results [a]	55.16 (11.91)	47.32 (11.50)	44.21 (15.10)	11.80 (5.46)	76.54 (2.68)	69.43 (7.00)	77.02 (3.69)	30.71 (6.91)	56.51 (5.79)	74.17 (4.58)	60.52 (8.13)	<0.001
HIV Prevalence [a]	1.05 (0.85)	4.05 (1.64)	2.15 (1.69)	1.51 (0.43)	23.20 (2.56)	10.19 (4.48)	2.90 (1.57)	0.72 (0.46)	4.75 (2.62)	10.97 (3.79)	15.96 (3.12)	<0.001
Conflict Days												<0.001
0 Days	5 (21.7)	2 (16.7)	1 (9.1)	5 (41.7)	4 (100.0)	30 (100.0)	30 (100.0)	1 (6.7)	9 (100.0)	0 (0.0)	2 (16.7)	
1-30 Days	2 (8.7)	9 (75.0)	4 (36.4)	4 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	11 (73.3)	0 (0.0)	8 (80.0)	0 (0.0)	

1+Month -6 Months	12 (52.2)	1 (8.3)	4 (36.4)	2 (16.7)	0 (0.0)	0 (0.0)	0 (0.0)	2 (13.3)	0 (0.0)	2 (20.0)	6 (50.0)	
6+ Months-1 Year	3 (13.0)	0 (0.0)	1 (9.1)	1 (8.3)	0 (0.0)	0 (0.0)	0 (0.0)	1 (6.7)	0 (0.0)	0 (0.0)	3 (25.0)	
1+ Year	1 (4.3)	0 (0.0)	1 (9.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (8.3)	
Conflict Fatalities												<0.001
0 Deaths	5 (21.7)	2 (16.7)	1 (9.1)	5 (41.7)	4 (100.0)	30 (100.0)	30 (100.0)	6 (40.0)	9 (100.0)	4 (40.0)	2 (16.7)	
1-4 Deaths	0 (0.0)	3 (25.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (20.0)	0 (0.0)	3 (30.0)	1 (8.3)	
5-17 Deaths	3 (13.0)	3 (25.0)	1 (9.1)	5 (41.7)	0 (0.0)	0 (0.0)	0 (0.0)	4 (26.7)	0 (0.0)	1 (10.0)	5 (41.7)	
18-69 Deaths	8 (34.8)	2 (16.7)	2 (18.2)	1 (8.3)	0 (0.0)	0 (0.0)	0 (0.0)	1 (6.7)	0 (0.0)	2 (20.0)	3 (25.0)	
70-1000 Deaths	6 (26.1)	2 (16.7)	4 (36.4)	1 (8.3)	0 (0.0)	0 (0.0)	0 (0.0)	1 (6.7)	0 (0.0)	0 (0.0)	1 (8.3)	
1000+ Deaths	1 (4.3)	0 (0.0)	3 (27.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	

Distance to Conflict												<0.001
<35 KM	19 (82.6)	4 (33.3)	3 (27.3)	2 (16.7)	0 (0.0)	0 (0.0)	0 (0.0)	8 (53.3)	0 (0.0)	4 (40.0)	3 (25.0)	
35-120 KM	4 (17.4)	3 (25.0)	2 (18.2)	5 (41.7)	0 (0.0)	0 (0.0)	17 (56.7)	7 (46.7)	0 (0.0)	2 (20.0)	3 (25.0)	
121-330 KM	0 (0.0)	5 (41.7)	2 (18.2)	4 (33.3)	0 (0.0)	7 (23.3)	13 (43.3)	0 (0.0)	1 (11.1)	4 (40.0)	5 (41.7)	
>330 KM	0 (0.0)	0 (0.0)	4 (36.4)	1 (8.3)	4 (100.0)	23 (76.7)	0 (0.0)	0 (0.0)	8 (88.9)	0 (0.0)	1 (8.3)	

[a] Mean Proportions and Standard Deviations with administrative region 1 as the unit of analysis

Table 6-3 Negative Binomial Regression Estimates of Rate Ratio and 95% CI for the Association Between Ever Tested for HIV and Received Results from Most Recent Test and Armed Conflict Indicators

HIV Tested and Received Results											
Number of Days				Number of Fatalities				Distance			
	Rate Ratio	95% CI	P-value		Rate Ratio	95% CI	P-value		Rate Ratio	95% CI	P-value
Unadjusted				Unadjusted				Unadjusted			
0 Days	1	Reference		0 Deaths	1	Reference		>330 KM	1	Reference	
1-30 Days	0.78	0.24, 2.52	0.23	<5 Deaths	0.87	.	.	<35 KM	0.90	0.25, 3.21	0.49
30+ Days-6 Months	0.91	0.35, 2.4	0.44	5-17 Deaths	0.80	.	.	35-120 KM	0.82	0.19, 3.46	0.32
6+ Months-1 Year	0.71	0.1, 5.2	0.28	18-69 Deaths	0.88	.	.	121-330 KM	1.01	0.26, 3.97	0.93
1+ Year	0.73	0.04, 13.3	0.41	70-1000 Deaths	0.83	.	.				

				>1000 Deaths	0.56	.	.				
Adjusted				**Adjusted**				**Adjusted**			
0 Days	1	Reference		0 Deaths	1	Reference		>330 KM	1	Reference	
1-30 Days	0.95	0.87, 1.04	0.31	1-4 Deaths	0.94	0.88, 0.99	0.04	<35 KM	0.97	0.85, 1.10	0.59
30+ Days-6 Months	0.91	0.8, 1.03	0.14	5-17 Deaths	0.96	0.88, 1.06	0.42	35-120 KM-	0.97	0.86, 1.10	0.67
6+ Months-1 Year	0.91	0.79, 1.04	0.16	18-69 Deaths	0.92	0.83, 1.03	0.15	121-330 KM	0.99	0.91, 1.09	0.98
1+ Year	1.11	0.96, 1.29	0.15	70-1000 Deaths	0.93	0.81, 1.07	0.32				
				1000+ Deaths	1.45	0.98, 2.15	0.06				
Mean Age	1.04	0.77, 1.4	0.81		0.99	0.94, 1.05	0.85		1.01	0974, 1.07	0.87
Female	0.99	0.99, 1	0.12		0.99	0.99, 1	0.14		0.99	0.99, 1	0.07
Muslim	0.99	0.99, 1	0.08		0.99	0.99, 1	0.08		0.99	0.99, 1	0.11

Married	0.99	0.99, 1	0.11		1	0.99, 1	0.016		0.99	0.99, 0.99	0.0006
Divorced	1.01	1, 1	<.0001		1	1, 1	<.0001		1.00	1, 1	<.0001
Poorest Wealth Quintile	0.99	0.99, 0.99	<.0001		1	1, 1	.05		10.99	0.991	0.41
Richest Wealth Quintile	1.00	1, 1	0.01		1.00	1, 1	0.0003		1.00	1, 1	0.002
No Education	1.00	1, 1	0.29		0.99	0.99, 0.99	<.0001		0.99	0.99, 0.99	<.0001
Primary Education	1.00	1, 1	0.001		10.99	1, 1	0.006		1.00	1, 1	<.0001
Employment	0.99	0.99, 1	0.06		0.99	0.99, 1	0.1		0.99	0.99, 0.99	0.008
Urban	0.98	0.97, 1	0.25		0.99	0.99, 1	0.05		0.99	0.99, 1	0.5
Conflict Duration					0.99	0.99, 1	0.18				

Table 6-4 Negative Binomial Regression Estimates of Rate Ratio and 95% CI for the Association Between HIV Prevalence and Armed Conflict Indicators

HIV Prevalence											
Number of Days				**Number of Fatalities**				**Distance**			
	Rate Ratio	95% CI	P-value		Rate Ratio	95% CI	P-value		Rate Ratio	95% CI	P-value
Unadjusted											
0 Days	1	Reference		0 Deaths	1	Reference		>330 KM	1	Reference	
1-30 Days	0.96	0.028, 32.2	0.90	<5 Deaths	1.08	.	.	<35 KM	0.97	0.01 , 101	0.95
30+ Days-6 Months	1.15	0.01, 96.9	0.76	5-17 Deaths	1.11	.	.	35-120 KM	0.90	0.004, 188	0.84
6+ Months-1 Year	1.04	0.005, 223.6	0.94	18-69 Deaths	1.35	.	.	121-330 KM	1.03	0.01, 104	0.94
1+ Year	0.54	9.6E-06, 29735.6	0.60	70-1000 Deaths	0.53	.	.				

				1000+ Deaths	0.13	.	.				
Adjusted											
0 Days	1	Reference		0 Deaths	1	Reference		>330 KM	1	Reference	
1-30 Days	0.78	0.56, 0.82	0.13	<5 Deaths	1.00	0.8, 1.3	0.97	<35 KM	0.18	0.12, 0.26	<.0001
30+ Days-6 Months	0.52	0.33, 0.81	0.005	5-17 Deaths	0.91	0.6, 1.3	0.61	35-120 KM	0.30	0.21, 0.42	<.0001
6+ Months-1 Year	0.61	0.38, 0.98	0.04	18-69 Deaths	0.77	0.5, 1.14	0.19	121-330 KM	0.37	0.26, 0.51	<.0001
1+ Year	1.37	0.3, 6.3	0.69	70-1000 Deaths	0.68	0.47, 0.98	0.04				
				1000+ Deaths	1.93	0.7, 5.6	0.22				
Mean Age	1.06	0.86, 1.3	0.57		1.05	0.85, 1.3	0.63		1.09	0.93, 1.28	0.29
Female	1.00	1, 1	0.01		1.00	0.99, 1	0.05		0.99	0.99, 1	0.81

Muslim	0.99	0.99, 0.99	0.005		0.99	0.99, 0.99	0.01		0.99	0.99, 0.99	0.005
Married	1.00	1, 1	0.0003		1.00	1, 1	0.004		1.00	1, 1	0.057
Divorced	1.00	1.03, 1.05	<.0001		1.00	1, 1	0.0003		1.00	0.99, 1	0.15
Poorest Wealth Quintile	1.00	1, 1	0.005		1	1,1	.02		1	1, 1	0.003
Richest Wealth Quintile	1.00	0.99, 1	0.95		1	0.99, 1	0.49		1	0.99, 1	0.93.
No Education	0.99	0.99, 0.99	<.0001		0.99	0.99, 0.99	<.0001		0.99	0.99, 0.99	<.0001
Primary Education	0.99	0.99, 0.99	<.0001		0.99	0.99, 0.99	0.003		0.99	0.99, 0.99	0.002
Employment	0.99	0.99, 1	0.05		0.99	0.99, 1	0.12		1	1, 1	0.02

Urban	1.00	0.99, 1	0.89		1.00	0.99, 1.01	0.75		1.01	1, 1.02	<.0001
Conflict Duration					0.99	0.99, 1	0.6				

6.7 Figures

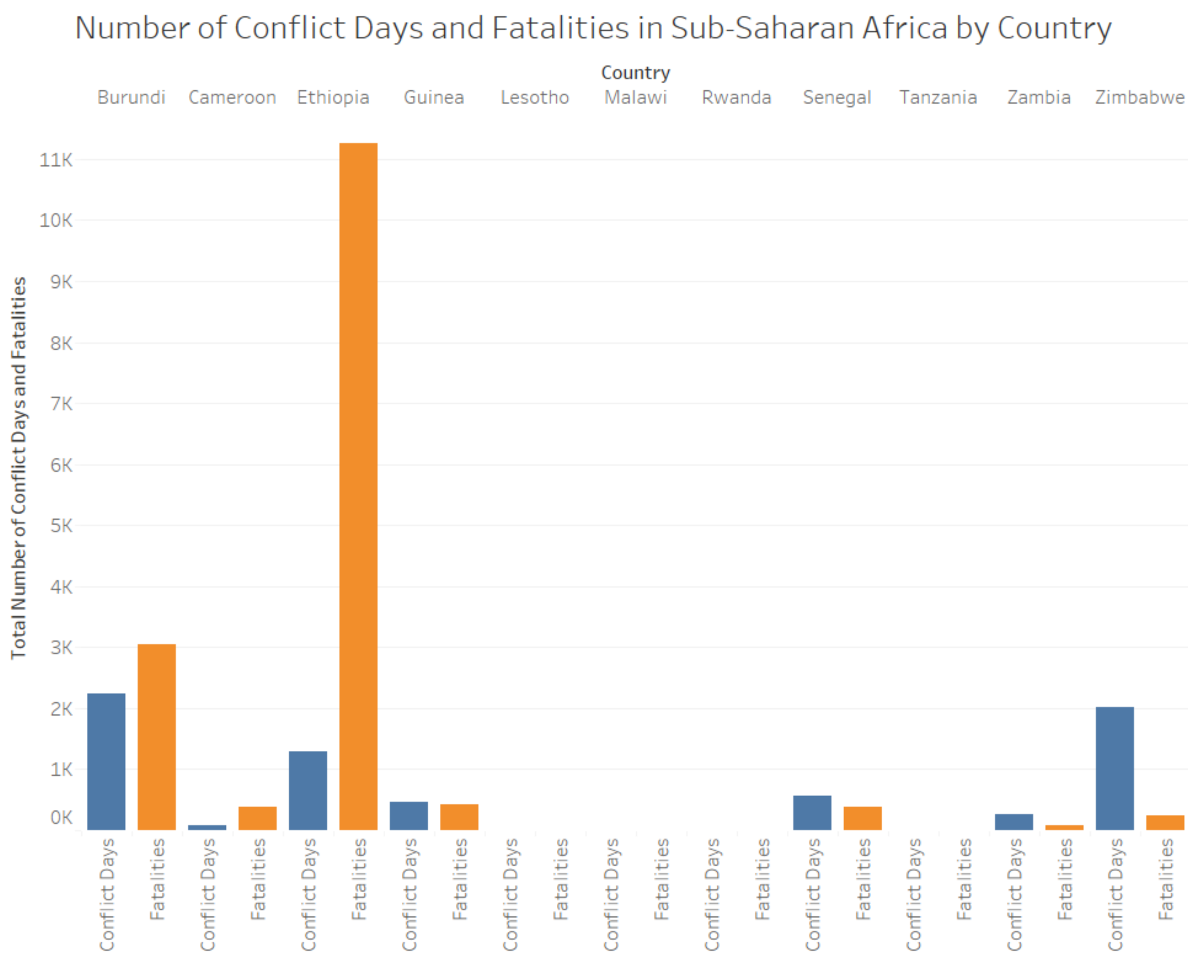

Figure 6-1 Total Number of Conflict Days and Fatalities in SSA by Country

6.8 References

1. Organization WH. HIV/AIDS. https://www.afro.who.int/health-topics/hivaids. Accessed 09/15, 2021.

2. Baranczuk Z, Estill J, Blough S, et al. Socio-behavioural characteristics and HIV: findings from a graphical modelling analysis of 29 sub-Saharan African countries. *Journal of the International AIDS Society.* 2019;22(12):e25437-e25437.

3. Mock NB, Duale S Fau - Brown LF, Brown Lf Fau - Mathys E, et al. Conflict and HIV: A framework for risk assessment to prevent HIV in conflict-affected settings in Africa. (1742-7622 (Print)).

4. The Armed Conflict Survey 2019. In: Vol 2019. IISS; 2019: https://www.iiss.org/publications/armed-conflict-survey/2019/armed-conflict-survey-2019/subsaharan-africa. Accessed June 2020.

5. Boerma T, Tappis H, Saad-Haddad G, et al. Armed conflicts and national trends in reproductive, maternal, newborn and child health in sub-Saharan Africa: what can national health surveys tell us? *BMJ global health.* 2019;4(Suppl 4):e001300-e001300.

6. Hagmann T, Abdi MM. ‘Inter-ethnic violence in Ethiopia’s Somali Regional State, 2017-2018. Conflict Research Programme. https://www.lse.ac.uk/ideas/Assets/Documents/Conflict-Research-Programme/crp-memos/Inter-ethnic-conflicts-SRS-Final-April-2020.pdf. Published 2020. Accessed 03/03, 2022.

7. Lange K. The Current Conflict Situation in Zimbabwe. IFAIR. https://ifair.eu/2019/08/12/the-current-conflict-situation-in-zimbabwe/. Published 2019. Updated 08/12/2019. Accessed 03/03, 2022.

8. Lange K. The Current Conflict Situation in Cameroon. IFAIR. https://ifair.eu/2019/07/25/the-current-conflict-situation-in-cameroon/. Published 2019. Updated 07/25/2019. Accessed 03/03, 2022.

9. Gesesew H, Berhane K, Siraj ES, et al. The impact of war on the health system of the Tigray region in Ethiopia: an assessment. *BMJ Global Health.* 2021;6(11):e007328.

10. Dyer O. Tigray's hospitals lack necessities as relief supplies are blocked, say doctors. *Bmj.* 2022;376:o34.

11. Murray CJL, King G, Lopez AD, Tomijima N, Krug EG. Armed conflict as a public health problem. *BMJ (Clinical research ed).* 2002;324(7333):346-349.

12. Mishra V, Vaessen M, Boerma JT, et al. HIV testing in national population-based surveys: experience from the Demographic and Health Surveys. *Bull World Health Organ.* 2006;84(7):537-545.

13. Adebayo OW, Salerno JP. Facilitators, Barriers, and Outcomes of Self-Initiated HIV Testing: An Integrative Literature Review. *Res Theory Nurs Pract.* 2019;33(3):275-291.

14. Araya AX, Bravo P, Carrasco P, et al. [Facilitators and barriers to HIV testing: a literature review]. *Rev Chilena Infectol.* 2013;30(6):638-643.

15. Gullón A, Verdejo J, de Miguel R, Gómez A, Sanz J. Factors associated with late diagnosis of HIV infection and missed opportunities for earlier testing. *AIDS Care.* 2016;28(10):1296-1300.

16. Worku MG, Tesema GA, Teshale AB. Prevalence and associated factors of HIV testing among reproductive-age women in eastern Africa: multilevel analysis of demographic and health surveys. *BMC Public Health.* 2021;21(1):1262-1262.

17. Staveteig S, Croft TN, Kampa KT, Head SK. Reaching the 'first 90': Gaps in coverage of HIV testing among people living with HIV in 16 African countries. *PLoS One.* 2017;12(10):e0186316-e0186316.

18. Asaolu IO, Gunn JK, Center KE, Koss MP, Iwelunmor JI, Ehiri JE. Predictors of HIV Testing among Youth in Sub-Saharan Africa: A Cross-Sectional Study. *PLoS One.* 2016;11(10):e0164052-e0164052.

19. Ante-Testard PA, Benmarhnia T, Bekelynck A, et al. Temporal trends in socioeconomic inequalities in HIV testing: an analysis of cross-sectional surveys from 16 sub-Saharan African countries. *Lancet Glob Health.* 2020;8(6):e808-e818.

20. Meteke S, Stefopulos M, Als D, et al. Delivering infectious disease interventions to women and children in conflict settings: a systematic reviefw. *BMJ Glob Health.* 2020;5(Suppl 1).

21. Singh NS, Ataullahjan A, Ndiaye K, et al. Delivering health interventions to women, children, and adolescents in conflict settings: what have we learned from ten country case studies? *The Lancet.* 2021;397(10273):533-542.

22. Yendewa GA, Poveda E, Yendewa SA, Sahr F, Quiñones-Mateu ME, Salata RA. HIV/AIDS in Sierra Leone: Characterizing the Hidden Epidemic. *AIDS Rev.* 2018;20(2):104-113.
23. Ssebunya RN, Wanyenze RK, Namale L, et al. Prevalence and correlates of HIV testing among adolescents 10-19 years in a post-conflict pastoralist community of Karamoja region, Uganda. *BMC Public Health.* 2018;18(1):612.
24. Malamba SS, Muyinda H, Spittal PM, et al. "The Cango Lyec Project - Healing the Elephant": HIV related vulnerabilities of post-conflict affected populations aged 13-49 years living in three Mid-Northern Uganda districts. *BMC Infect Dis.* 2016;16(1):690.
25. Supervie V, Halima Y, Blower S. Assessing the impact of mass rape on the incidence of HIV in conflict-affected countries. *AIDS.* 2010;24(18).
26. Kim AA, Malele F, Kaiser R, et al. HIV infection among internally displaced women and women residing in river populations along the Congo River, Democratic Republic of Congo. *AIDS Behav.* 2009;13(5):914-920.
27. Mulanga C Fau - Bazepeo SE, Bazepeo Se Fau - Mwamba JK, Mwamba Jk Fau - Butel C, et al. Political and socioeconomic instability: how does it affect HIV? A case study in the Democratic Republic of Congo. (0269-9370 (Print)).
28. Spiegel PB. HIV/AIDS among conflict-affected and displaced populations: dispelling myths and taking action. 2004(0361-3666 (Print)).
29. Spiegel PB, Bennedsen AR, Claass J, et al. Prevalence of HIV infection in conflict-affected and displaced people in seven sub-Saharan African countries: a systematic review. *The Lancet.* 2007;369(9580):2187-2195.

30. Flechner D. A human rights approach to protecting people living with HIV/AIDS in Angola. *International Social Science Journal.* 2005;57(186):627-637.

31. Kim Y. Armed conflict, health spending, and HIV. *The International Journal of Health Planning and Management.* 2018;33(3):581-595.

32. Aliyu GG, Aliyu SH, Ehoche A, et al. The Burden of HIV, Hepatitis B and Hepatitis C by Armed Conflict Setting: The Nigeria AIDS Indicator and Impact Survey, 2018. *Ann Glob Health.* 2021;87(1):53-53.

33. Bennett BW, Marshall BD, Gjelsvik A, McGarvey ST, Lurie MN. HIV Incidence Prior to, during, and after Violent Conflict in 36 Sub-Saharan African Nations, 1990-2012: An Ecological Study. *PLoS One.* 2015;10(11):e0142343.

34. Amowitz LL, Reis C, Lyons KH, et al. Prevalence of war-related sexual violence and other human rights abuses among internally displaced persons in Sierra Leone. *Jama.* 2002;287(4):513-521.

35. Ivis F. Calculating Geographic Distance: Concepts and Methods. In. Toronto, Ontario, Canada: Canadian Institute for Health Information; 2006.

36. Dai L, Sweat MD, Gebregziabher M. Modeling excess zeros and heterogeneity in count data from a complex survey design with application to the demographic health survey in sub-Saharan Africa. *Statistical Methods in Medical Research.* 2016;27(1):208-220.

37. SAS Enterprise Guide 8.2: User's Guide. SAS Institue Inc. Published 2019. Accessed.

38. Hankins CA, Friedman SR, Zafar T, Strathdee SA. Transmission and prevention of HIV and sexually transmitted infections in war settings: implications for current and future armed conflicts. *AIDS.* 2002;16(17).

39. Katamba A, Ogwang MD, Zamar DS, et al. Cango Lyec (Healing the Elephant): HIV incidence in post-conflict Northern Uganda. *EClinicalMedicine.* 2020;23:100408.

7.0 Original Manuscript: Association Between High-risk Sexual Behaviors and Armed Conflict in Sub-Saharan Africa

7.1 Introduction

At the end of 2018, 26 million of the world's HIV cases were living in Sub-Saharan Africa (SSA) [1,2] making SSA the region with the highest rates of HIV prevalence. In addition to high HIV rates, SSA has the highest number of armed conflicts [3], refugees, and internally displaced people in the world [4]. Many countries in SSA have been affected by armed conflict with such conflicts responsible for approximately 1.1 million deaths between 1989 and 2016 [5]. Armed conflicts in this region remain a cause for grave concern and recent conflicts include the civil war in Tigray, Ethiopia, where rape is used as a weapon of war [6]; deadly clashes between ethnic groups in South Ethiopia [7]; and fatal clashes between civilians and police forces in Zimbabwe [8] and Cameroon [9]. Events such as these can be detrimental to public health [6] as armed conflicts can have damaging health impacts on civilians directly and indirectly[10]. This is specially concerning in areas with high HIV prevalence rates.

The association between HIV risk and armed conflicts is unclear. Findings from previous studies have been contradictory due to numerous factors [11-16]. Some studies have found that in areas of armed conflicts factors such as social isolation and decreased mobility can be protective against HIV. On the contrary, other studies found that armed conflicts are associated with a decrease in HIV preventative resources such as condoms [5,17] and higher occurrences of rape and sexual and gender-based violence, which are often weaponized [18]. In addition, previous research has found that during war, poverty and breakdowns in social structures can lead to high-risk sexual behaviors such as multiple partners [19], [3], [20] and reduced condom usage as access to condoms becomes limited in armed conflict settings [21]. In a qualitative study, Muhwezi et al. found a high propensity to high-risk sexual behaviors such as multiple partners and transactional sex in members of a post-conflict community in Uganda [22]. In another study evaluating HIV related vulnerabilities in post conflict societies in Uganda, Malamba et al. found that only about 11% had consistently used a condom with their last three sexual partners in the previous 12 months [23].

High-risk sexual behaviors are concerning in the context of HIV because unprotected sexual contact remains a pivotal means of transmitting the virus. Previous studies have reported that high-risk sexual behaviors such as multiple partners and inconsistent condom use can have a propagative role on HIV transmission [24], [14], [15], that multiple sexual partnerships are extremely common amongst HIV positive individuals [25] and are strongly positively associated with HIV status [26]. It is well documented that those who report having multiple sex partners in the 12 months before the Demographic and Health Survey (DHS) have a significantly elevated risk of HIV (OR 1.568, p-value 0.023) when compared to those who have no sex partners in that same time frame [27]. Lakew et al found that individuals with multiple partners had significantly higher odds of being HIV infected when compared to individuals who only had one partner [28].

In addition to multiple partners, condom usage is also a significant determinant of HIV in Sub-Saharan Africa (SSA) [29] and provides a protective effect against HIV [25]. Condom usage is extremely important in limiting HIV transmission and is a very effective prevention strategy [30] as the risk of sexually acquiring HIV can be attenuated via the use of condoms [31]. In the context of armed conflicts, it is known that organizations that provide assistance in areas of conflict might distribute condoms to refugees and people affected by the conflict [32], however little is known about whether or not condoms are used in these settings.

The gaps in research that exist create an opportunity to further our understanding of the associations between HIV risk and areas of armed conflict in SSA. There is a paucity in the literature about the quantitative relationship between armed conflicts and high-risk sexual behaviors in areas of conflict. In addition, many of the previous studies were either qualitative and or used country level data while focusing on one group of individuals. The purpose of this study was to address these gaps in the literature. We hypothesized that conflicts are associated with an increase in high-risk sexual behaviors and used Demographic and Health Surveys (DHS) and Armed Conflict Location and Event Data (ACLED) data from 11 countries in SSA to evaluate the effect of conflicts on high-risk sexual behaviors in SSA.

7.2 Methods

In this study, we utilized DHS and ACLED data to evaluate the association between previous HIV testing, HIV prevalence, and conflicts in SSA, using a cross-sectional ecologic study design. We used generalized linear mixed models with spatial random effects to control for spatial autocorrelation with multiple sexual partners and inconsistent condom use with risky partners as the outcomes, and conflict duration, conflict fatalities, and or distance to the nearest conflict as the main risk factors. In the adjusted models, we controlled for common confounders such as age, sex, religion, marital status, wealth, education, employment, in addition to spatial autocorrelation. In the conflict fatalities models, we also adjusted for conflict duration. Using this approach, we generated rate ratios to elucidate the effect of conflict on multiple sexual partnerships and inconsistent condom use with risky partners.

7.2.1 DHS and Armed Conflict Datasets

The study population consisted of individuals 15 to 49 years old, residing in 11 countries in SSA. The countries designated by region were as follows: West Africa: Guinea and Senegal; Central Africa: Cameroon; East Africa: Burundi, Ethiopia, Rwanda, Tanzania; South Africa: Malawi, Zambia, Zimbabwe, and Lesotho. We chose countries with multiple phases of cross-sectional DHS data, and all of the countries, with the exception of Lesotho and Tanzania, had two rounds of DHS data available on the outcomes of interest. Administrative region level 1 (i.e. state/province) variables were constructed by aggregating the individual level variables to obtain weighted proportions and counts per region.

The Armed Conflict Location and Event Dataset (ACLED) is a project concerned with the collection, analysis, and mapping of crises around the world. Its dataset provides geographical location such as latitude and longitude of all reported armed conflicts, political violence, and protests in addition to noting the perpetrators, dates, types and number of fatalities.

7.2.2 Definition of Variables

Exposures: The main risk factor of interest for this study was conflict. Here we defined it as any battle, violence against civilians, explosion/remote violence, riot, protest, and/or strategic development (i.e. looting or property disruption) and we sought to quantify conflict intensity. To achieve this, we developed three different measures of conflict, including the number of days spent in conflict, the number of conflict fatalities, and the distance to the nearest area of conflict. Number of days spent in conflict was categorized, based on quintiles, into five groups: 0 days, 1 to 30 days, 30+ days to 6 months, 6+ months to 1 year, and greater than 1 year. Conflict fatalities was also categorized by quintiles into five groups: 0, 1-4, 5-17, 18 to 69, 70 to1000 and 1000+. Distance was calculated as the minimum distance (in Kilometers) from the centroid of the first census enumeration area within an administrative region 1 to an area of conflict using the Haversine formula as coordinate data included latitudes and longitudes in decimal degrees. Resulting distances were then categorized as: <35 KM, 35-120 KM, 121-330 KM and 330+ KM. We accounted for lagged effects of conflict by using conflict data up to 5 years prior to the administration of the first DHS survey (i.e. battles that occurred between 2005-2010 for DHS survey 2010).

Outcomes: The outcome of interest was high-risk sexual behavior and was defined using administrative region level counts of two measures. The first measure accounted for multiple sexual partnerships, and the second measure was defined as the number of individuals who did not use a condom at last sexual intercourse with a risky partner (a sexual partner who is neither a spouse nor a cohabitant).

Covariates: The covariates included in the analyses were age, sex, education, wealth index, marital status, religion, and urban/rural residence. We defined religion as Christian or Muslim; marital status as married, divorced; wealth index as poorest, richest; and education as no and primary education. In the conflict fatalities models, we also accounted for conflict duration.

7.2.3 Statistical Analyses

To elucidate the effect of armed conflicts on high-risk sexual behaviors, we ran generalized linear mixed models with spatial random effects using SAS 9.4. This approach provides a general overview of the association between conflicts and the outcomes after controlling for geographic variability using spatial random effects. As the histograms of the outcomes were skewed and indicative of a Poisson or Negative Binomial distribution, we based our models on a negative binomial distribution. A negative binomial distribution accounts for overdispersion (i.e. greater variability than expected) as it is a more relaxed approach and does not make the same assumptions of equal mean and variance as a Poisson model. The models included a log link and an offset that we created using the log of the total number of individuals. In addition to the models, we used ANOVA to compare group means and Fisher's exact test to compare the categorical variables, by country.

In addition, we used weights that were aggregated and scaled at the administrative region level to make the results nationally representative. Previous research has shown that results from a weighted analysis are more reliable if the weights are scaled [34]; therefore, we used a validated weighting scale that divides the cluster size by the sum of the weights [34].

To create the models, an exponential spatial covariance structure that accounted for regional spatial effects was used where region was defined based on contiguity as follows: West: Senegal, Guinea, Central: Cameroon; East: Tanzania, Burundi, Rwanda; South: Zambia, Zimbabwe, Lesotho, Malawi, and North/East: Ethiopia. With the exponential spatial covariance approach, the covariance between two observations relied on a distance metric [35]. Prior to modelling, variograms of the outcomes and predictors were also constructed, using Moran's I and Geary's C coefficients, to detect spatial autocorrelation between the outcome values.

Associations are reported as rate ratios with fixed time and can be interpreted as the rate of multiple sexual partnerships or rate of inconsistent condom use with risky sexual partners. Let y_{ij} denote the number of individuals who have multiple partners or who do not use condoms with high-risk sexual partners per administrative region *i* (*i*=1, …, n_i) and region *j* (*j*=1, …, m) that has a sample size N_{ij}, a generalized linear mixed model with random effects and offset is represented as follows:

$$g\big(E(y_{ij}|X_{ij})\big) = \beta_0 + \beta X_{ij} + v_{ij} + b_j + e \qquad (7.1)$$

Where g is a log link function that allows for the interpretation of the fixed effects regression coefficients, βs as log rate ratio, X_{ij} is a vector of covariates, v_{ij} are administrative region specific random effects for the within region variability, b_j are the random effects for the between region variability, e accounts for the offset $(1/N_{ij})$. Here, the coefficient vector includes conflict, age, sex, religion, wealth, education, employment, and urbanity. That is, β is a column vector ($\beta_{conflict}$, β_{age}, β_{sex}, $\beta_{religion}$, $\beta_{marital}$, β_{wealth}, $\beta_{education}$, $\beta_{employment}$, β_{urban}).

7.3 Results

7.3.1 Results from the Sociodemographic Comparisons by Country

We used data from 11 countries, 168 administrative regions (i.e. state/province) and 422,911 individuals (Table 1). When evaluating differences in sociodemographic by country we found that the mean age throughout the countries was 28 and that there were a majority of females in all of the countries (Table 2). Malawi had the lowest mean percentage of urban areas (13 %) and marriage rates ranged from 35% in Rwanda to 67%

in Guinea. Ethiopia had both the highest mean percentages of the poorest wealth quintile (25%) and the richest wealth quintile (36%). As for religion, Senegal had the highest percentage of Muslims (96%) and Zambia had the highest percentage of Christians (99%). In terms of education, low education was most pronounced in Guinea (65% for no education and 14% for primary education).

We also noticed country differences in multiple partners and lack of condom use with high-risk sexual partners and country differences in conflict indicators. Lesotho, Malawi, Rwanda, and Tanzania did not experience any conflict and had the highest distances to an area of conflict. Out of the countries with conflict, Burundi, Ethiopia, and Zimbabwe were the only countries with 1+ year spent in conflict. Ethiopia also had the highest fatalities with 36% of conflicts experiencing 70-1000 fatalities and 27% experiencing over 1000 fatalities whereas Guinea had the lowest number of fatalities (42% with 0 fatalities). Burundi had the highest percentage of nearby conflicts with 83% of its conflicts occurring less than 35 KM away.

The results of the variograms were suggestive of significant spatial autocorrelations in both measures of high-risk sexual behaviors indicating that closer regions were more likely to have similar values. The variable for multiple partnerships had a Moran's I Z value of 15.88, p-value <.0001 and a Geary's C Z value of -4.14, p-value <.0001. For the lack of condom use with a risky partner variable, the values were 14.57 p-value <.0001, and -4.17 p-value <0.0001, respectively.

7.3.2 Results for the Association Between Multiple Sexual Partners and Armed Conflict

When evaluating the association between multiple sexual partners and number of days spent in conflict, we found that compared to regions without any conflict, those that experienced 1-30 days of conflict had a 34% increased likelihood of having multiple partners in the unadjusted model (RR 1.34, 95% CI 0.13, 14), and a 72% increased likelihood in the adjusted model (RR 1.72, 95% CI 1.11, 2.65). Experiencing 30+ Days - 6 months (RR 1.03 95% CI 0.64, 1.65), 6 months-1 year (RR 0.9, 95% CI 0.55, 1.49), or more than 1 year of conflict (RR 2.12, 95% CI 0.84, 5.38) were not significantly associated with having multiple partners.

For conflict fatalities, we found that compared to areas with 0 fatalities, areas with 70-1000 fatalities were significantly associated with higher rates of multiple partners (RR 1.97, 95% CI 1.3, 3). The rest of the fatalities quintiles were not significantly associated with multiple sexual partnerships.

For distance to conflict, we found that being closer to an area of conflict was significantly associated with decreased rates of having multiple sexual partners. We found that when compared to regions with conflicts that were greater than 330 KM away, regions with conflicts less than 35 KM away were significantly associated with a 73% reduced rate of multiple partners (RR 0.27, 95% CI 0.17, 0.42). Regions 35-120 KM away were associated with a 57% reduced rate (RR 0.43, 95% CI 0.25, 0.76) and those 121-330 KM away were associated with a 38% reduced rate (RR 0.62, 95% CI 0.39, 0.98).

7.3.3 Results for the Association Between Lack of Condom Use and Armed Conflict

When evaluating the association between number of days spent in conflict and lack of condom use with risky sexual partners, we found in the adjusted model that spending 1-30 days in conflict was significantly associated with a 64% increase in inconsistent condom use with risky partners, when compared to those with 0 days in conflict (RR 1.64, 95% CI 1.12, 2.39). Spending 6+ months-1 year in conflict was significantly associated with a 50% decreased rate of inconsistent condom use with a risky partner (RR 0.5, 95% CI 0.35, 0.7). Spending over a year in an area of conflict was not significantly associated with this high-risk behavior (RR 1.55, 95% CI 0.57, 4.3).

All of the associations between conflict fatalities and inconsistent condom use with risky sexual partners were significant. We found that, compared to not having any fatalities, experiencing 1-4 fatalities was significantly associated with almost 3 times the rate of inconsistent condom use with a risky partner (RR 2.65 95% CI 2.04, 3.43). Having 5-17 fatalities was associated with a 70% higher rate (RR 1.7 95% CI 1.3, 2.2) and 18-69 fatalities was associated with double the rate of inconsistent condom use with risky sexual partners (RR 2.3 95% CI 1.7, 3). Experiencing 70-1000 fatalities was associated with 4 times the likelihood of inconsistent condom use with risky partners (RR 3.99, 95% CI 2.9, 5.6), while experiencing more than 1000 fatalities was associated with 11 times the rate of lack of condom use with risky sexual partners (RR 11, 95% CI 4.4, 28).

The results from the association between distance to an armed conflict and lack of condom use with risky partners show that when compared to conflicts that are over 330 KM away, conflicts that are close by are significantly associated with a decreased likelihood of the outcome, indicating that those who live closer to conflict areas are more likely to use condoms with risky sexual partners. We found that conflicts that were less than 35 KM away had a 71% reduced likelihood of the outcome (RR 0.29, 95% CI 0.16, 0.52). There was a 78% decrease in rate for conflicts 35-120 KM away (RR 0.22 95% CI

0.11, 0.43) and a 51% decrease in rate for conflicts 121-330 KM away (RR 0.49 95% CI 0.27, 0.89).

7.4 Discussion

The overarching goal of this manuscript was to determine the association between armed conflicts and HIV risk as indicated by high-risk sexual behaviors. We hypothesized that exposure to conflict would be associated with a higher occurrence of high-risk sexual behaviors but found that conflicts can be associated with a higher or lower occurrence of high-risk sexual behaviors depending on different factors.

Overall, we found that compared to experiencing 0 days in conflict, experiencing 1-30 days in conflict was significantly associated with higher rates of multiple partnerships and inconsistent condom use with risky partners. Spending 6+ months to 1 year in conflict was significantly associated with a reduced rate of inconsistent condom use with risky partners but was not associated with multiple partnerships. Lastly, spending over a year in conflict was not significantly associated with either measure of high-risk sexual behaviors.

In the fatalities models, we found that the number of conflict fatalities were significantly associated with higher rates of inconsistent condom use with risky sexual partners. Compared to experiencing 0 fatalities, experiencing 70-1000 fatalities quadrupled the rate of inconsistent condom use with risky partners and almost doubled the rate of multiple partnerships. Compared to experiencing 0 fatalities, experiencing more than 1000 fatalities was significantly associated with 11 times the rate of inconsistent condom use with risky partners.

The high likelihood of high-risk sexual behaviors in areas with a greater number of conflict fatalities (i.e. 70-1000 deaths) might be explained by social instability in these areas. Previous studies have found that in areas of armed conflict, there is an increase in poverty, powerlessness, and social instability [20] with armed conflicts often leading to the destruction of health infrastructures and a scarcity of resources [20]. Previous research has shown that poverty is an important indicator of condom usage with low household wealth and low income associated with lack of condom use. The literature also shows that poverty in armed conflict areas increases as the duration of the conflict increases [36]. In addition to poverty, previous studies have also found an increase in transactional sex for survival and an increase in sexual partner change rates in areas of emergencies [20]. The above-mentioned factors are likely explanations for the higher likelihood of high-risk sexual behaviors in areas of conflict, especially those with a high number of fatalities, and indicate that interventions are needed to increase education on high-risk sexual behaviors and condom usage in areas of armed conflict.

In the distance to a conflict area analyses, we found that as distance from an area of conflict increased, so did the likelihood of high-risk sexual behaviors. Overall, our results indicate that close proximity to an area of conflict is associated with lower rates of high-risk sexual behaviors. These findings differ from what we initially hypothesized and differ from the findings with conflict duration and conflict fatalities. In those models, both measures of conflict were associated with increased rates of high-risk sexual behaviors. However, in the distance models, close proximity to an area of conflict was associated with reduced rates of high-risk sexual behaviors. A possible explanation for this finding might be the countries selected for these analyses. For example, we found that Burundi did not experience many fatalities, yet 83% of its regions were located less than 35 KM away from an area of conflict. Similarly, Ethiopia had the highest number of fatalities and the highest number of days spent in conflict, yet 36% of the administrative regions in this country were more than 330 KM away from conflict. These findings point to the complexity of the relationship between conflicts and high-risk sexual behaviors further demonstrating that this association is multi-faceted and varies depending on the measure of conflict used.

There were some limitations with this study. To begin, with cross sectional data it is difficult to determine temporality. Therefore we could not compare the prevalence of high-risk sexual behaviors prior to and post the onset of conflict. We were able to determine the existence of an association between armed conflicts and high-risk sexual behaviors, but we could not account for any pre-conflict behaviors. Another limitation is that areas affected by more intense armed conflicts might be less likely to have good quality data. Excluding these areas from the analyses also slightly impeded our ability to assess the relationship between armed conflicts and high-risk sexual behaviors. However, the structure of the dataset used for these analyses was adequate in providing a more comprehensive analysis of the association between high-risk sexual behaviors and armed conflicts than have been provided by previous studies. In addition, this project was novel and made use of data from multiple and diverse countries in SSA to try to assess the relationship between high-risk sexual behaviors and conflicts while accounting for spatial autocorrelation.

7.5 Conclusion

Overall, we found that the association between high-risk sexual behaviors and armed conflicts vary based on the measure of armed conflict used and conflict intensity. For number of days spent in conflict and number of fatalities, the rates of high-risk sexual behaviors are highest for conflicts with a few number of days or high number of fatalities. When utilizing distance to an area of conflict as the measure of conflict, we noticed that as distance from an area of conflict increased, so did the rate of high-risk sexual behaviors. Further research should be conducted to delineate if findings from this project are consistent in areas that are more negatively impacted by armed conflicts. Future studies should also account for pre-armed conflict conditions to evaluate whether high-risk sexual behaviors increase with the onset of conflict.

7.6 Tables

Table 7-1 Countries and Years of DHS Data Selected

Country	Years of Survey	Number of Individuals	Number of Administrative Regions (Level 1)	Average Number of Individuals/Administrative Region (Level 1)	Conflict
Burundi	2010, 2016	37170	23	1616	Yes
Cameroon	2011, 2018	41468	12	3456	Yes
Ethiopia	2011, 2016	56644	11	5149	Yes
Guinea	2012, 2018	26914	12	2243	Yes
Lesotho	2014	9247	4	2312	No
Malawi	2010, 2015/16	61525	30	2051	No
Rwanda	2010, 2014	38448	30	1282	No
Senegal	2010/11, 2017	43200	15	2880	Yes
Tanzania	2012	19319	9	2147	No
Zambia	2013, 2018	54728	10	5473	Yes
Zimbabwe	2010/11, 2015	34248	12	2854	Yes
Total		422911	168	2517	

Table 7-2 Sociodemographic, Outcomes, and Risk Factors by Country

	Burundi	Cameroon	Ethiopia	Guinea	Lesotho	Malawi	Rwanda	Senegal	Tanzania	Zambia	Zimbabwe	P-value
Number of Administrative Regions (Level 1)	23	12	11	12	4	30	30	15	9	10	12	
Age [a]	28.05 (0.49)	27.97 (0.41)	28.08 (0.21)	28.76 (0.98)	28.03 (0.24)	28.08 (0.33)	28.33 (0.57)	27.80 (0.43)	28.80 (0.80)	28.35 (0.21)	28.06 (0.45)	<0.001
Female [a]	71.74 (2.76)	69.82 (2.07)	57.13 (2.40)	75.04 (4.29)	72.00 (0.77)	77.24 (1.60)	70.77 (1.73)	75.18 (2.86)	56.99 (1.79)	55.19 (1.71)	56.04 (2.15)	<0.001
Rural [a]	77.46 (24.68)	47.11 (24.41)	72.54 (19.58)	66.25 (22.30)	77.96 (20.28)	86.86 (14.14)	81.25 (22.58)	57.63 (17.75)	76.08 (15.08)	57.28 (13.62)	69.43 (19.53)	<0.001
Marital Status												
Married [a]	41.03 (6.59)	39.45 (15.57)	56.06 (9.62)	67.36 (9.00)	50.73 (4.77)	56.69 (5.82)	34.62 (6.04)	60.94 (8.46)	51.84 (4.37)	54.04 (5.02)	52.24 (6.85)	<0.001
Divorced [a]	0.44 (0.36)	1.13 (0.97)	4.03 (1.85)	1.18 (0.57)	1.12 (0.52)	4.34 (1.72)	2.83 (1.16)	2.51 (0.78)	4.52 (1.80)	4.89 (0.97)	2.84 (0.87)	<0.001
Never Married [a]	39.17 (7.79)	38.22 (7.52)	33.69 (8.29)	28.18 (7.86)	38.01 (3.95)	24.28 (2.74)	41.75 (4.20)	35.07 (8.05)	33.65 (5.23)	36.77 (3.92)	36.30 (6.83)	<0.001
Wealth Index												
Poorest Wealth Quintile [a]	16.49 (9.55)	14.85 (18.50)	24.65 (20.37)	22.41 (9.73)	22.93 (14.10)	18.85 (8.28)	18.34 (9.00)	23.98 (16.58)	16.89 (9.79)	19.22 (11.47)	23.19 (13.18)	0.488
Poorer Wealth Quintile [a]	17.73 (7.01)	19.28 (10.85)	12.91 (7.58)	21.76 (4.46)	22.04 (8.20)	19.75 (5.14)	19.14 (6.58)	22.45 (7.78)	17.77 (7.16)	19.78 (7.14)	18.27 (6.39)	0.103
Middle Wealth Quintile [a]	18.22 (5.99)	22.80 (9.90)	12.41 (7.95)	19.66 (7.67)	20.47 (3.63)	20.50 (3.91)	19.62 (6.20)	24.01 (8.48)	19.07 (5.86)	20.97 (4.91)	17.38 (8.86)	0.008
Richer Wealth Quintile [a]	18.85 (8.38)	22.54 (7.73)	13.88 (8.59)	22.73 (5.92)	18.34 (7.69)	20.77 (5.56)	20.18 (6.85)	17.58 (9.16)	22.78 (6.67)	19.52 (6.98)	22.63 (7.35)	0.094
Richest Wealth Quintile [a]	28.71 (21.65)	23.01 (19.88)	36.15 (28.59)	17.13 (22.15)	16.21 (13.23)	20.13 (11.59)	22.72 (21.16)	11.97 (14.09)	23.50 (17.18)	20.52 (12.57)	23.92 (17.66)	0.14

Religion											
Muslim [a]	4.08 (4.15)	13.21 (9.58)	43.31 (33.48)	88.46 (20.21)	0.26 (0.21)	11.04 (17.81)	2.00 (2.09)	95.90 (4.99)	NaN (NA)	0.46 (0.59)	0.58 (0.36)	<0.001
Christian [a]	93.92 (4.77)	72.52 (20.16)	55.39 (32.82)	9.99 (17.00)	95.73 (0.98)	87.58 (17.61)	96.84 (2.39)	3.80 (4.67)	NaN (NA)	98.68 (0.92)	83.46 (5.44)	<0.001
Education												
No Education [a]	31.86 (9.75)	13.58 (18.16)	39.01 (17.40)	64.85 (12.48)	3.96 (2.31)	12.53 (7.39)	12.67 (4.39)	51.97 (15.06)	13.54 (4.53)	6.37 (2.93)	1.40 (1.20)	<0.001
Primary Education [a]	40.70 (5.19)	31.57 (9.05)	38.57 (8.89)	13.55 (3.53)	47.26 (10.85)	65.72 (5.90)	66.39 (6.35)	21.95 (4.65)	63.72 (12.94)	43.67 (8.02)	27.21 (11.02)	<0.001
Secondary Education [a]	25.37 (10.18)	47.83 (17.41)	13.21 (7.57)	17.94 (6.91)	43.02 (8.43)	20.00 (6.94)	18.38 (5.91)	23.80 (9.84)	22.20 (14.30)	43.71 (7.34)	64.42 (8.83)	<0.001
Higher Education [a]	2.08 (3.94)	7.03 (6.23)	9.22 (7.12)	3.66 (4.46)	5.75 (4.27)	1.76 (1.72)	2.55 (2.81)	2.27 (2.34)	0.60 (0.60)	6.26 (2.80)	6.97 (3.60)	<0.001
Employed [a]	79.20 (8.41)	66.69 (6.67)	54.02 (9.15)	70.73 (8.51)	36.29 (8.00)	62.68 (8.92)	79.26 (8.93)	51.75 (5.96)	81.34 (8.62)	60.27 (5.47)	46.27 (9.50)	<0.001
High-Risk Sexual Behaviors											
Multiple Partners	0.97 (0.68)	11.90 (5.40)	2.34 (1.79)	4.82 (1.95)	11.96 (1.09)	2.86 (0.95)	1.64 (0.73)	2.72 (1.28)	10.21 (3.87)	7.88 (2.74)	6.18 (1.19)	<0.001
Lack of Condom Use with Risky Partners	66.98 (11.56)	49.30 (8.05)	47.65 (9.57)	66.83 (10.95)	31.86 (7.15)	47.94 (11.19)	51.81 (8.93)	48.71 (7.96)	47.39 (8.98)	56.99 (5.76)	31.17 (8.60)	<0.001
Measures of Conflict											
Conflict Days												<0.001
0 Days	5 (21.7)	2 (16.7)	1 (9.1)	5 (41.7)	4 (100.0)	30 (100.0)	30 (100.0)	1 (6.7)	9 (100.0)	0 (0.0)	2 (16.7)	
1-30 Days	2 (8.7)	9 (75.0)	4 (36.4)	4 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	11 (73.3)	0 (0.0)	8 (80.0)	0 (0.0)	
30+ Days -6 Months	12 (52.2)	1 (8.3)	4 (36.4)	2 (16.7)	0 (0.0)	0 (0.0)	0 (0.0)	2 (13.3)	0 (0.0)	2 (20.0)	6 (50.0)	
6+ Months-1 Year	3 (13.0)	0 (0.0)	1 (9.1)	1 (8.3)	0 (0.0)	0 (0.0)	0 (0.0)	1 (6.7)	0 (0.0)	0 (0.0)	3 (25.0)	
1+ Year	1 (4.3)	0 (0.0)	1 (9.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (8.3)	

Conflict Fatalities												<0.001
0 Deaths	5 (21.7)	2 (16.7)	1 (9.1)	5 (41.7)	4 (100.0)	30 (100.0)	30 (100.0)	6 (40.0)	9 (100.0)	4 (40.0)	2 (16.7)	
1-4 Deaths	0 (0.0)	3 (25.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (20.0)	0 (0.0)	3 (30.0)	1 (8.3)	
5-17 Deaths	3 (13.0)	3 (25.0)	1 (9.1)	5 (41.7)	0 (0.0)	0 (0.0)	0 (0.0)	4 (26.7)	0 (0.0)	1 (10.0)	5 (41.7)	
18-69 Deaths	8 (34.8)	2 (16.7)	2 (18.2)	1 (8.3)	0 (0.0)	0 (0.0)	0 (0.0)	1 (6.7)	0 (0.0)	2 (20.0)	3 (25.0)	
70-1000 Deaths	6 (26.1)	2 (16.7)	4 (36.4)	1 (8.3)	0 (0.0)	0 (0.0)	0 (0.0)	1 (6.7)	0 (0.0)	0 (0.0)	1 (8.3)	
1000+ Deaths	1 (4.3)	0 (0.0)	3 (27.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Distance to Conflict												<0.001
<35 KM	19 (82.6)	4 (33.3)	3 (27.3)	2 (16.7)	0 (0.0)	0 (0.0)	0 (0.0)	8 (53.3)	0 (0.0)	4 (40.0)	3 (25.0)	
35-120 KM	4 (17.4)	3 (25.0)	2 (18.2)	5 (41.7)	0 (0.0)	0 (0.0)	17 (56.7)	6 (40.0)	0 (0.0)	2 (20.0)	3 (25.0)	
121-330 KM	0 (0.0)	4 (33.3)	2 (18.2)	4 (33.3)	0 (0.0)	6 (20.0)	13 (43.3)	1 (6.7)	1 (11.1)	4 (40.0)	5 (41.7)	
330+ KM	0 (0.0)	1 (8.3)	4 (36.4)	1 (8.3)	4 (100.0)	24 (80.0)	0 (0.0)	0 (0.0)	8 (88.9)	0 (0.0)	1 (8.3)	

[a] Mean Proportions and Standard Deviations with administrative region 1 as the unit of analysis

Table 7-3 Negative Binomial Regression Estimates of Rate Ratio and 95% CI for the Association Between Multiple Sexual Partnerships and Armed Conflict Indicators

Multiple Partners											
Number of Days				**Number of Fatalities**				**Distance**			
	Rate Ratio	95% CI	P-value		Rate Ratio	95% CI	P-value		Rate Ratio	95% CI	P-value
Unadjusted											
0 Days	1	Reference		0 Deaths	1	Reference		330+ KM	1	Reference	
1-30 Days	1.34	0.13, 13.97	0.36	<5 Deaths	1.35	.	.	<35 KM	1.2	0.06, 22	0.6
30+ Days-6 Months	0.75	0.04, 15.9	0.44	5-17 Deaths	1.31	.	.	35-120 KM	0.8	0.06, 11	0.51
6+ Months-1 Year	0.88	0.05, 15.77	0.67	18-69 Deaths	0.91	.	.	121-330 KM	1.19	0.06, 33	0.4
1+ Year	0.65	0.004, 111	0.48	70-1000 Deaths	0.75	.	.				

				1000+ Deaths	0.30	.	.				
Adjusted											
0 Days	1	Reference		0 Deaths	1	Reference		330+ KM	1	Reference	
1-30 Days	1.72	1.11, 2.65	0.01	<5 Deaths	1.35	0.94, 1.9	0.1	<35 KM	0.27	0.17, 0.42	<.0001
30+ Days -6 Months	1.03	0.64, 1.65	0.91	5-17 Deaths	0.8	0.57, 1.16	0.26	35-120 KM	0.43	0.25, 0.76	0.003
6+ Months-1 Year	0.91	0.55, 1.49	0.7	18-69 Deaths	0.68	0.46, 1	0.06	121-330 KM	0.62	0.39, 0.99	0.04
1+ Year	2.13	0.84, 5.38	0.11	70-1000 Deaths	1.98	1.3, 3	0.001				
				1000+ Deaths	1.3	0.4, 3.8	0.67				
Mean Age	2.93	0.83, 10.4	0.1		0.86	0.75, 0.97	0.02		0.98	0.9, 1.1	0.71

Female	1.00	1, 1.007	0.03		0.99	0.99, 0.99	0.0001		1	1, 1	<.0001
Muslim	0.999	0.99, 1	0.23		1	0.99, 1	0.08		0.99	0.99, 1	0.13
Married	1.00	0.99, 1.008	0.19		0.99	0.99, 1	0.05		0.99	0.99, 0.99	<.0001
Divorced	0.99	0.97, 1.01	0.35		1	0.99, 1	0.07		1	1, 1	0.02
Poorest Wealth Quintile	0.99	0.991, 0.996	<.0001		0.99	0.989, 1	0.7		1	1, 1	0.009
Richest Wealth Quintile	0.99	0.98, 0.99	0.004		0.99	0.99, 0.99	<.0001		0.99	0.99, 0.99	.0001
No Education	1.00	0.99, 1	0.63		0.99	0.99, 0.99	<.0001		0.99	0.99, 0.99	<.0001
Primary Education	0.997	0.99, 0.99	0.002		0.99	0.99, 0.99	<.0001		0.99	0.99, 0.997	<.0001
Employment	1.00	0.99, 1.01	0.30		1	1, 1	<.0001		1	1, 1	<.0001
Urban	1.07	0.98, 1.17	0.14		1	1, 1	0.001		1	0.99, 1	0.5
Conflict Duration					0.99	0.99, 1	0.6				

Table 7-4 Negative Binomial Regression Estimates of Rate Ratio and 95% CI for the Association Between Lack of Condom Use with Risky Sexual Partners and Armed Conflict Indicators

Lack of Condom Use with Risky Sexual Partners											
Number of Days				**Number of Fatalities**				**Distance**			
	Rate Ratio	95% CI	P-value		Rate Ratio	95% CI	P-value		Rate Ratio	95% CI	P-value
Unadjusted											
0 Days	1	Reference		0 Deaths	1	Reference		330+ KM	1	Reference	
1-30 Days	1.47	0.18, 12.13	0.26	<5 Deaths	0.96	.	.	<35 KM	1.4	0.09, 20	0.4
30+ Days-6 Months	0.97	0.06, 16.27	0.90	5-17 Deaths	1.08	.	.	35-120 KM	0.98	0.05, 20	0.9
6+ Months-1 Year	0.66	0.02, 65.96	0.45	18-69 Deaths	0.85	.	.	121-330 KM	1.4	0.06, 32	0.4
1+ Year	0.42	0.03, 6.02	0.15	70-1000 Deaths	1.35	.	.				

				1000+ Deaths	0.27	.	.				
Adjusted											
0 Days	1	Reference		0 Deaths	1	Reference		330+ KM	1	Reference	
1-30 Days	1.64	1.12, 2.40	0.01	<5 Deaths	2.6	2, 3	<.0001	<35 KM	0.29	0.16, 0.53	<.0001
30+ Days -6 Months	0.96	0.60, 1.51	0.85	5-17 Deaths	1.7	1.3, 2.2	0.0002	35-120 KM	0.21	0.11, 0.43	<.0001
6+ Months-1 Year	0.50	0.35, 0.71	0.0002	18-69 Deaths	2.3	1.7, 3	<.0001	121-330 KM	0.49	0.27, 0.89	0.02
1+ Year	1.55	0.57, 4.26	0.39	70-1000 Deaths	3.9	2.9, 5.6	<.0001				
				1000+ Deaths	11	4.4, 28	<.0001				
Mean Age	2.74	1.05, 7.16	0.04		1.12	0.94, 1.3	0.14		1.04	0.9, 1.2	0.6

Female	1.003	1, 1.005	0.03		0.99	0.99, 0.99	<.0001		1	1, 1	<.0001
Muslim	1.00	0.998, 1.001	0.69		1	1, 1	0.004		0.99	0.99, 0.99	<.0001
Married	0.997	0.994, 0.999	0.005		0.99	0.99, 0.99	<.0001		0.99	0.99, 0.99	<.0001
Divorced	1.03	1.02, 1.05	<.0001		1	0.99, 1	0.05		1	1, 1	<.0001
Poorest Wealth Quintile	0.995	0.993, 0.997	<.0001		1	1, 1	0.0005		1.0	1, 1	0.12
Richest Wealth Quintile	0.995	0.99, 1	0.03		1	0.99, 1	0.35		0.99	0.99, 0.99	<.0001
No Education	0.999	0.997, 1.002	0.55		0.99	0.99, 0.99	0.97		0.99	0.99, 1	<.0001
Primary Education	0.996	0.994, 0.998	0.001		0.99	0.99, 0.99	<.0001		0.99	0.99, 0.99	<.0001
Employment	1.005	1.001, 1.01	0.01		1	1, 1	<.0001		1	1, 1	<.0001

Urban	1.10	1.02, 1.18	0.02		0.99	0.98, 0.99	<.0001		1.02	1.02, 1.03	<.0001
Conflict Duration					0.99	0.99, 0.99	<.0001				

7.7 Figures

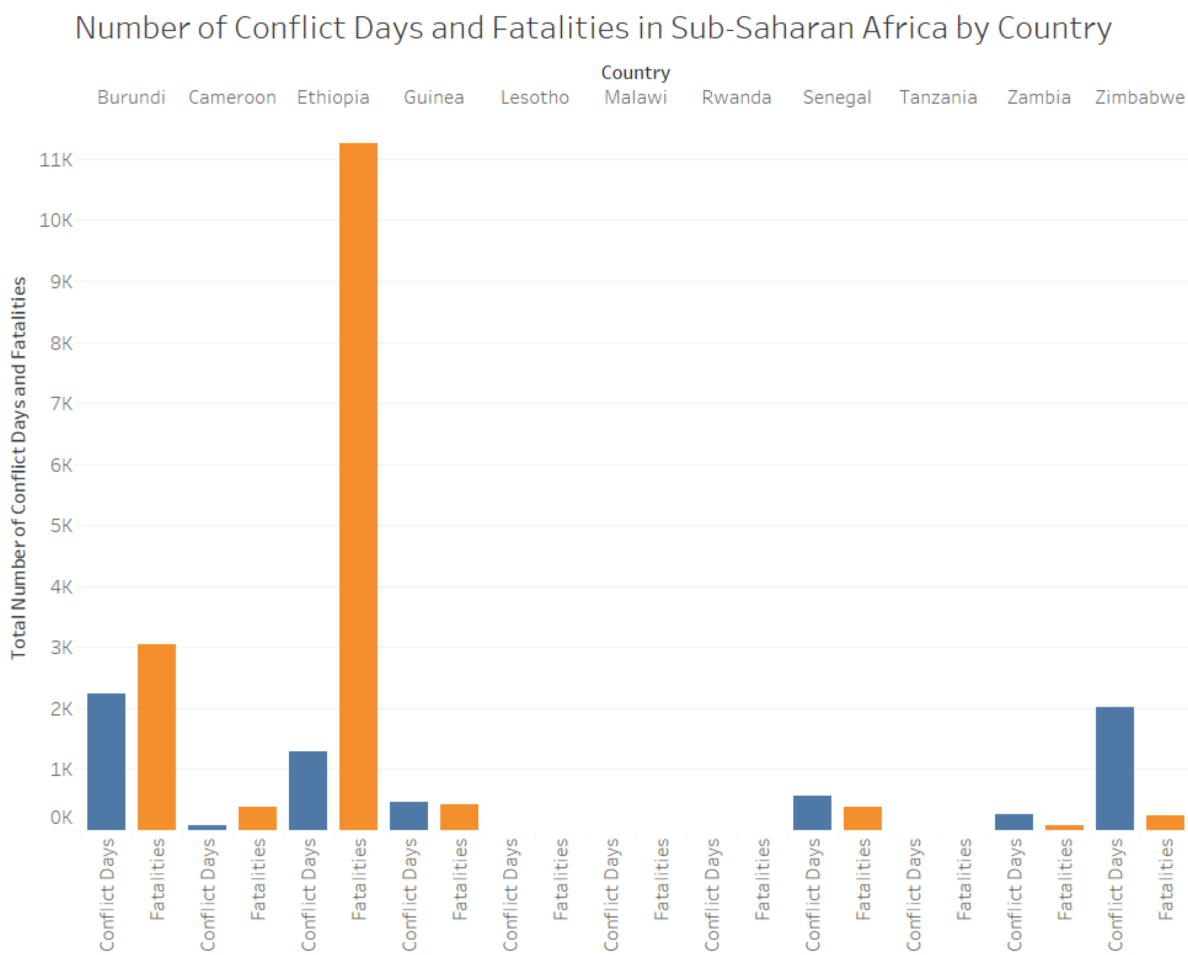

Figure 7-1 Total Number of Conflict Days and Fatalities in SSA by Country

7.8 References

1. Organization WH. HIV/AIDS. https://www.afro.who.int/health-topics/hivaids. Accessed 09/15, 2021.
2. Baranczuk Z, Estill J, Blough S, et al. Socio-behavioural characteristics and HIV: findings from a graphical modelling analysis of 29 sub-Saharan African countries. *Journal of the International AIDS Society.* 2019;22(12):e25437-e25437.
3. Mock NB, Duale S Fau - Brown LF, Brown Lf Fau - Mathys E, et al. Conflict and HIV: A framework for risk assessment to prevent HIV in conflict-affected settings in Africa. (1742-7622 (Print)).
4. The Armed Conflict Survey 2019. In: Vol 2019. IISS; 2019: https://www.iiss.org/publications/armed-conflict-survey/2019/armed-conflict-survey-2019/subsaharan-africa. Accessed June 2020.
5. Boerma T, Tappis H, Saad-Haddad G, et al. Armed conflicts and national trends in reproductive, maternal, newborn and child health in sub-Saharan Africa: what can national health surveys tell us? *BMJ global health.* 2019;4(Suppl 4):e001300-e001300.
6. Gesesew H, Berhane K, Siraj ES, et al. The impact of war on the health system of the Tigray region in Ethiopia: an assessment. *BMJ Global Health.* 2021;6(11):e007328.
7. Hagmann T, Abdi MM. 'Inter-ethnic violence in Ethiopia's Somali Regional State, 2017-2018. Conflict Research Programme. https://www.lse.ac.uk/ideas/Assets/Documents/Conflict-Research-

Programme/crp-memos/Inter-ethnic-conflicts-SRS-Final-April-2020.pdf. Published 2020. Accessed 03/03, 2022.

8. Lange K. The Current Conflict Situation in Zimbabwe. IFAIR. https://ifair.eu/2019/08/12/the-current-conflict-situation-in-zimbabwe/. Published 2019. Updated 08/12/2019. Accessed 03/03, 2022.

9. Lange K. The Current Conflict Situation in Cameroon. IFAIR. https://ifair.eu/2019/07/25/the-current-conflict-situation-in-cameroon/. Published 2019. Updated 07/25/2019. Accessed 03/03, 2022.

10. Murray CJL, King G, Lopez AD, Tomijima N, Krug EG. Armed conflict as a public health problem. *BMJ (Clinical research ed).* 2002;324(7333):346-349.

11. Supervie V, Halima Y, Blower S. Assessing the impact of mass rape on the incidence of HIV in conflict-affected countries. *AIDS.* 2010;24(18).

12. Kim AA, Malele F, Kaiser R, et al. HIV infection among internally displaced women and women residing in river populations along the Congo River, Democratic Republic of Congo. *AIDS Behav.* 2009;13(5):914-920.

13. Mulanga C Fau - Bazepeo SE, Bazepeo Se Fau - Mwamba JK, Mwamba Jk Fau - Butel C, et al. Political and socioeconomic instability: how does it affect HIV? A case study in the Democratic Republic of Congo. (0269-9370 (Print)).

14. Spiegel PB. HIV/AIDS among conflict-affected and displaced populations: dispelling myths and taking action. 2004(0361-3666 (Print)).

15. Spiegel PB, Bennedsen AR, Claass J, et al. Prevalence of HIV infection in conflict-affected and displaced people in seven sub-Saharan African countries: a systematic review. *The Lancet.* 2007;369(9580):2187-2195.

16. Flechner D. A human rights approach to protecting people living with HIV/AIDS in Angola. *International Social Science Journal.* 2005;57(186):627-637.

17. Singh NS, Ataullahjan A, Ndiaye K, et al. Delivering health interventions to women, children, and adolescents in conflict settings: what have we learned from ten country case studies? *The Lancet.* 2021;397(10273):533-542.

18. Bendavid E, Boerma T, Akseer N, et al. The effects of armed conflict on the health of women and children. *Lancet (London, England).* 2021;397(10273):522-532.

19. UK P. Factsheet HIV and failing states. STOPAIDS. https://stopaids.org.uk/wp/wp-content/uploads/2017/06/Factsheet-failing-states.pdf. Published 2014. Accessed June, 2020.

20. Hankins CA, Friedman SR, Zafar T, Strathdee SA. Transmission and prevention of HIV and sexually transmitted infections in war settings: implications for current and future armed conflicts. *AIDS.* 2002;16(17).

21. Humanitarian Emergencies, Armed Conflict and the HIV Response. Avert. https://www.avert.org/professionals/hiv-programming/emergencies-conflicts-and-hiv-response. Published 2019. Accessed June 2020.

22. Muhwezi W, Kinyanda E, Mungherera M, et al. Vulnerability to high risk sexual behaviour (HRSB) following exposure to war trauma as seen in post-conflict communities in eastern uganda: A qualitative study. *Confl Health.* 2011;5(1).

23. Malamba SS, Muyinda H, Spittal PM, et al. "The Cango Lyec Project - Healing the Elephant": HIV related vulnerabilities of post-conflict affected populations

aged 13-49 years living in three Mid-Northern Uganda districts. *BMC Infect Dis.* 2016;16(1):690.

24. Bennett BW, Marshall BD, Gjelsvik A, McGarvey ST, Lurie MN. HIV Incidence Prior to, during, and after Violent Conflict in 36 Sub-Saharan African Nations, 1990-2012: An Ecological Study. *PLoS One.* 2015;10(11):e0142343.

25. Chimoyi LA, Musenge E. Spatial analysis of factors associated with HIV infection among young people in Uganda, 2011. *BMC Public Health.* 2014;14:555-555.

26. Babalola S. Factors associated with HIV infection among sexually experienced adolescents in Africa: a pooled data analysis. (1608-5906 (Print)).

27. Kembo J. Risk factors associated with HIV infection among young persons aged 15-24 years: evidence from an in-depth analysis of the 2005-06 Zimbabwe Demographic and Health Survey. *Sahara j.* 2012;9(2):54-63.

28. Lakew Y, Benedict S, Haile D. Social determinants of HIV infection, hotspot areas and subpopulation groups in Ethiopia: evidence from the National Demographic and Health Survey in 2011. *BMJ open.* 2015;5(11):e008669-e008669.

29. Magadi M, Desta M. A multilevel analysis of the determinants and cross-national variations of HIV seropositivity in sub-Saharan Africa: evidence from the DHS. *Health Place.* 2011;17(5):1067-1083.

30. Analogbei T, Dear N, Reed D, et al. Predictors and Barriers to Condom Use in the African Cohort Study. *AIDS Patient Care STDS.* 2020;34(5):228-236.

31. Patel P, Borkowf CB, Brooks JT, Lasry A, Lansky A, Mermin J. Estimating per-act HIV transmission risk: a systematic review. *Aids.* 2014;28(10):1509-1519.

32. War, oppression, refugee camps fuel spread of HIV. Migration and HIV. *Bridg Wash D C.* 1998(5):4-5.

33. Ivis F. Calculating Geographic Distance: Concepts and Methods. In. Toronto, Ontario, Canada: Canadian Institute for Health Information; 2006.

34. Dai L, Sweat MD, Gebregziabher M. Modeling excess zeros and heterogeneity in count data from a complex survey design with application to the demographic health survey in sub-Saharan Africa. *Statistical Methods in Medical Research.* 2016;27(1):208-220.

35. SAS Enterprise Guide 8.2: User's Guide. SAS Institue Inc. Published 2019. Accessed.

36. Gareth E. Tackling Conflict, Fragility and Insecurity: Creating the Conditions for Effective Poverty Reduction. Paper presented at: DFID Conference on Future of International Development; March 10 2009, 2009; London.

8.0 Discussion

The overarching goal of this project was to assess the association between armed conflicts and HIV. We tested the hypotheses that armed conflicts are associated with lower HIV testing rates, higher HIV prevalence, and higher rates of high-risk sexual behaviors through three specific aims. For Aim 1: we evaluated HIV testing, HIV prevalence, HIV knowledge and attitudes, and high-risk sexual behaviors in the context of armed conflicts using descriptive statistics. For Aim 2 we evaluated the association between HIV testing, HIV prevalence, and armed conflicts using generalized linear mixed models with spatial random effects. Lastly, in Aim 3 we evaluated the association between high-risk sexual behaviors and armed conflicts, using the same approach as in Aim 2.

For the first aim, maps, tables, and pairwise comparisons were utilized to assess differences in HIV testing, HIV prevalence, HIV knowledge and attitudes, and high-risk sexual behaviors between conflict and non-conflict areas. We had both positive and negative findings. On a positive note, we found that HIV prevalence and stigma were significantly lower in conflict areas. Conversely however, we found that previous HIV testing and HIV knowledge were significantly lower in conflict areas. The co-existence of both positive and negative findings can be explained by the heterogeneity of the study population and the complexity of the relationship between conflicts and HIV measures. The low prevalence, despite low HIV knowledge and low previous testing might be explained by other factors such as engagement in high-risk behaviors, number of sexual partners, geographical location, societal factors such as poverty, education, sexual norms, and the availability of healthcare, which have been shown to be associated with HIV prevalence, testing, and or knowledge [1-5].

The primary goal of aim 2 was to evaluate the association between armed conflicts, previous HIV testing, and HIV prevalence. We hypothesized that exposure to conflict would be associated with lower HIV testing rates and higher HIV prevalence. The relationship between HIV prevalence and armed conflicts can be quite complex. Conflict can possibly decrease the risk of acquiring HIV via the reduction of mobility and an increase in social services in refugee camp settings [6], [7], [8] or it can increase the risk via increased sexual violence, disrupted health infrastructures and social service breakdowns [8]. Previous research have found that the most-conflict affected areas were also found to have higher HIV prevalence, compared to areas that were less affected [9]. In our study, we found that conflicts with a duration less than a year and with less than 1000 fatalities were associated with reduced rates of HIV prevalence. However, conflicts that lasted more than a year or that had more than 1000 fatalities were not significantly associated with previous HIV testing or HIV prevalence. We also found that close proximity to conflict was associated with reduced rates of HIV prevalence and that there were higher prevalence rates in areas further away from conflict. Because DHS HIV test uptake was high on average and did not differ between conflict and non-conflict areas, these findings may indicate that close proximity to conflict has a protective association with HIV prevalence.

The core goal of Aim 3 was to evaluate the association between conflicts and high-risk sexual behaviors. The impact of armed conflict on high-risk sexual behaviors in Sub-Saharan Africa is currently unknown. There is a paucity in the literature about the possible association between armed conflicts and these behaviors. We have addressed this problem by using generalized linear mixed effects models with a negative binomial regression and spatial random effects to assess this relationship.

Previous studies have found an increase in transactional sex for survival and an increase in sexual partner change rates in areas of emergencies [7] and so we hypothesized that exposure to conflict would be associated with a higher occurrence of high-risk sexual behaviors. However, we found that conflicts could be associated with a higher or lower occurrence of high-risk sexual behaviors depending on different factors. We found that compared to experiencing 0 days in conflict, experiencing 1-30 days in conflict was significantly associated with higher rates of multiple partnerships and inconsistent condom use with risky partners. Spending 6+ months to 1 year in conflict was significantly associated with a reduced rate of inconsistent condom use with risky partners but was not associated with multiple partnerships. We found that the number of conflict fatalities was significantly associated with higher rates of inconsistent condom use with risky sexual partners. Compared to experiencing 0 fatalities, experiencing 70-1000 fatalities quadrupled the rate of inconsistent condom use with risky partners and almost doubled the rate of multiple partnerships whereas experiencing more than 1000 fatalities was significantly associated with 11 times the rate of inconsistent condom use with risky partners. Our results also indicate that close proximity to an area of conflict is associated with lower rates of high-risk sexual behaviors. These findings point to the complexity of the relationship between conflicts and high-risk sexual behaviors further demonstrating that this association is multi-faceted and varies depending on the measure of conflict used. The high likelihood of high-risk sexual behaviors in areas with a greater number of conflict fatalities (i.e. 70-1000 deaths) might be explained by social instability in these areas. Previous studies have found that in areas of armed conflict, there is an increase in poverty, powerlessness, and social instability [7] with armed conflicts often leading to the destruction of health infrastructures and a scarcity of resources [7]. Previous research has shown that poverty is an important indicator of condom usage with low household wealth and low income associated with lack of condom use. The literature also shows that poverty in armed conflict areas increases as the duration of the conflict increases [10]. In addition to poverty, previous studies have also found an increase in transactional sex for survival and an increase in sexual partner change rates in areas of emergencies [7].

There were some limitations with this study. To begin, with cross sectional data we could not account for any pre-conflict behaviors and could not account for temporality by comparing pre-post conflict data. Additionally, areas affected by intense armed conflicts are less likely to have good quality data. Excluding these areas from the analyses might have slightly impeded our ability to assess the relationship between armed conflicts and high-risk sexual behaviors. Also, the use of self-reported data and factors such as social desirability and the fear of stigma might lead to participants exaggerating previous HIV testing, under reporting the number of multiple or risky partners and over reporting condom usage. Furthermore, we could not account for war related trauma, rape, and other war related factors that could possibly play a role in the relationship between armed conflicts, HIV testing, HIV prevalence, and high-risk sexual behaviors as they were not captured in the DHS and ACLED datasets. Additionally, it might have been more informative to use HIV incidence as opposed to HIV prevalence, however, HIV incidence data is not available in the DHS dataset. Lastly, given the study design, the ecologic fallacy, and the inability to determine causality were additional limitations.

Despite the limitations, to our knowledge, this was the first study to examine aggregated counts of HIV outcomes in relation to armed conflict areas and our findings provided a more thorough understanding of HIV and armed conflicts than provided by previous studies. Additionally, this project was novel and made use of a diverse group of participants to try to assess the relationship between HIV indicators, high-risk sexual behaviors and conflicts while accounting for spatial autocorrelation. By using a large pooled dataset, we were able to clearly visualize differences in the outcomes of interest between conflict and non-conflict areas. An added benefit of this study was that using conflict data up to 5 years prior to the DHS survey allowed us to account for lagged effects. Lastly, there was the novelty of using different categories of distance to an area of conflict, as opposed to using a buffer zone (i.e. conflicts that occur in a 50 km radius) which is a common practice in the scientific literature.

To conclude, our findings suggest that there exists a relationship between armed conflicts and HIV indicators. Some possible pathways might be via a deficit in HIV knowledge, an increase in HIV prevalence and high-risk sexual behaviors. The findings from this study could be especially useful in the development of interventions. I believe that for the following interventions to be effective they would have to be delivered using means that do not rely on health infrastructures and governments, but would have to be carried out by aid organizations such as UNAIDS, Red Cross Red Crescent, in conflict areas and refugee settings. Possible interventions include increasing HIV knowledge via pamphlet distribution, social media postings, mass messaging, or via loud speakers in refugee camps or during aid distribution. There are often public health interventions in conflict settings, these can be used to make condoms and HIV tests readily available in these settings. The use of HIV self-test kits might be an efficient and feasible way to facilitate HIV testing in these settings. Additionally, findings from this study are supportive of the addition of a conflict instrument to DHS surveys to facilitate the evaluation of the effect of armed conflicts on health outcomes at the individual level. Furthermore, the study methodology can be utilized to examine other diseases in areas of conflict such as tuberculosis, cholera, COVID-19 and other infectious diseases that might be prevalent in armed conflict areas.

Further research should be conducted to delineate if findings from this project are consistent in areas that are impacted by more intense armed conflicts. Future studies should also account for pre-armed conflict conditions to evaluate whether HIV prevalence and high-risk sexual behaviors increase with the onset of conflict. In addition, future studies can utilize different conflict datasets such as the Uppsala conflict dataset, which has a more stringent definition of conflict, with all conflicts requiring a minimum of one fatality prior to being recorded. Lastly, future studies should consider conducting this study using a different study population to determine if findings remain consistent. It would be specially interesting to evaluate changes in Ukraine’s HIV incidence/prevalence by the end of the war.

8.1 References

1. Boerma T, Tappis H, Saad-Haddad G, et al. Armed conflicts and national trends in reproductive, maternal, newborn and child health in sub-Saharan Africa: what can national health surveys tell us? *BMJ global health.* 2019;4(Suppl 4):e001300-e001300.
2. Singh NS, Ataullahjan A, Ndiaye K, et al. Delivering health interventions to women, children, and adolescents in conflict settings: what have we learned from ten country case studies? *The Lancet.* 2021;397(10273):533-542.
3. Murray CJL, King G, Lopez AD, Tomijima N, Krug EG. Armed conflict as a public health problem. *BMJ (Clinical research ed).* 2002;324(7333):346-349.
4. Kim Y. Armed conflict, health spending, and HIV. *The International Journal of Health Planning and Management.* 2018;33(3):581-595.
5. Worku MG, Tesema GA, Teshale AB. Prevalence and associated factors of HIV testing among reproductive-age women in eastern Africa: multilevel analysis of demographic and health surveys. *BMC Public Health.* 2021;21(1):1262-1262.
6. Mock NB, Duale S Fau - Brown LF, Brown Lf Fau - Mathys E, et al. Conflict and HIV: A framework for risk assessment to prevent HIV in conflict-affected settings in Africa. (1742-7622 (Print)).
7. Hankins CA, Friedman SR, Zafar T, Strathdee SA. Transmission and prevention of HIV and sexually transmitted infections in war settings: implications for current and future armed conflicts. *AIDS.* 2002;16(17).
8. Spiegel PB. HIV/AIDS among conflict-affected and displaced populations: dispelling myths and taking action. 2004(0361-3666 (Print)).

9. Malamba SS, Muyinda H, Spittal PM, et al. "The Cango Lyec Project - Healing the Elephant": HIV related vulnerabilities of post-conflict affected populations aged 13-49 years living in three Mid-Northern Uganda districts. *BMC Infect Dis.* 2016;16(1):690.

10. Gareth E. Tackling Conflict, Fragility and Insecurity: Creating the Conditions for Effective Poverty Reduction. Paper presented at: DFID Conference on Future of International Development; March 10 2009, 2009; London.