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Emma K Sizemore Date

Zimbabwe's Maturing HIV Epidemic: A Triangulation Analysis of Prevalence, Behavioral, and Programmatic Data from 2000-2013

By

Emma K Sizemore
MPH

Hubert Department of Global Health

_____ [Chair's signature]
Roger Rochat, MD
Committee Chair

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By

Emma K Sizemore

Bachelor of Science in Biomedical Engineering
Georgia Institute of Technology
2010

Thesis Committee Chair: Roger Rochat, MD

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A thesis submitted to the Faculty of the
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Abstract

Zimbabwe's Maturing HIV Epidemic: A Triangulation Analysis of Prevalence, Behavioral, and Programmatic Data from 2000-2013

By Emma K Sizemore

Objective:
To assess Zimbabwe's HIV prevalence trends from 2000-2013 in light of recent behavioral and programmatic data, a data triangulation exercise including a systematic review of the available data on the HIV/AIDS epidemic and national response in Zimbabwe was conducted.

Materials and Methods:
HIV prevalence estimations from Zimbabwe's antenatal clinic sentinel surveillance were compared alongside data from the 2005/06 and 2010/11 DHS surveys and estimations generated using the USAID Spectrum software. Behavioral indicator data among men and women from the two DHS surveys were analyzed, and governmental programmatic data were assessed.

Results:
Zimbabwe's HIV prevalence among pregnant women declined from 32.1% to 15.5% from 2000 to 2012, with declines also seen in the two DHS surveys. Comprehensive knowledge of HIV/AIDS increased (from 46.5% to 53.0% among men, $p<0.001$, and from 43.4% to 55.9% among women, $p<0.001$) and self-reported condom use during most recent sex increased (from 16.2% to 18.1% among men and from 5.5% to 9.8% among women, $p<0.01$), while the mean number of lifetime partners increased among women (from 1.6 to 2.2, $p<0.001$) and the proportion of men reporting two or more partners in the last year rose (from 9.0% to 10.5%, $p<0.01$). Testing rates increased from 45.6 to 141.7 per 1,000 men and 56.1 to 162.8 per 1,000 women from 2008 to 2013 ($p<0.001$). Condom distribution rates increased by nearly 350% from 2008 to 2013 and rates of male circumcision grew tenfold from 2010 to 2013. ART coverage fluctuated from 2009 to 2013 while AIDS-related mortality declined.

Conclusions:
Zimbabwe's well-documented behavior change in the early 2000s in the setting of high exposure to AIDS-mortality may not be sustained as rates of some risky behaviors are on the rise. Policy-makers must now address geographic disparities in HIV prevalence and work to reverse the growing epidemic in these areas.

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Chapter 1 – Literature Review

As Zimbabwe's HIV epidemic approaches its thirtieth year, the reasons behind its great decline in HIV prevalence from 26.5% in 1997 down to 15.0% in 2013 are not understood clearly. Numerous studies have been done to assess how behavior change programs, testing and anti-retroviral therapy accessibility, male circumcision adoption, and condom distribution have contributed to this decline, yet data across these platforms has not yet been combined to provide a full scope of Zimbabwe's response to its HIV epidemic. To assess the currently available literature, the following review was performed, including a brief introduction to the setting of Zimbabwe, the history of its epidemic and governmental response, and pertinent studies aiming to determine the source of Zimbabwe's success against HIV.

Introduction to Zimbabwe

Zimbabwe is a landlocked country in Sub-Saharan Africa bordered by South Africa, Botswana, Zambia, and Mozambique and home to nearly 13 million people [1]. With sixteen different official languages [2], the nation contains many ethnic groups, the largest of which are the Shona who reside in the eastern Mashonaland provinces and the Ndebele in the western Matebeleland provinces [1, 3]. Exporting primarily agricultural goods and minerals, the country has an annual GDP of $12.8 billion USD and boasts a literacy rate of 96% [4].

Formerly known as the British colony, Rhodesia, Zimbabwe gained its independence in 1980, electing Robert Mugabe as the leader of the nation in a landslide victory. Although years of economic growth, improvements in healthcare, and strides in education followed, the nation's recent history is marred by great food insecurity in the former "breadbasket of Africa," political unrest following the controversial elections in 2008, and hyperinflation with the collapse of the Zimbabwean Dollar in 2009 [3].

HIV/AIDS in Zimbabwe

Additionally, over the last thirty years, Zimbabwe has dealt with one of the worst HIV epidemics in the world. In 1985, the first case of HIV/AIDS in Zimbabwe was identified. With primarily heterosexual transmission, the disease spread across all socioeconomic levels throughout Zimbabwe, affecting those residing in all ten provinces nearly equally [5]. In response, the Zimbabwean government began screening all blood products for HIV prior to transfusions that same year. In 1987, the National AIDS Coordination Program and Emergency Short Term Plan were established, promoting HIV and AIDS awareness and training health workers to identify and treat patients with this new infection [5]. Initially using fear-based messaging to provoke behavior change, Zimbabwe changed course and adopted the ABC campaign (Abstinence, Be faithful, and use Condoms), emphasizing the message through radio and television programs [6]. By 1993, over 10% of Zimbabweans were infected with HIV, and the government launched two Mid Term Plans to expand behavior change interventions and provide counseling to infected individuals [7]. At the turn of the century, the HIV prevalence at antenatal care (ANC) clinics peaked at 32.1% [8].

Having one of the highest HIV prevalences in the world, Zimbabwe turned a corner with the adoption of its National Policy on HIV and AIDS and the creation of its National AIDS Council (NAC) through an act of Parliament in late 1999. The NAC implemented a National HIV and AIDS Strategic Framework and introduced the AIDS Levy, a 3% payee and corporate tax, to help fund the country's HIV response [7]. In 2002, the life expectancy in Zimbabwe bottomed out at 38 years and HIV was declared a Zimbabwean National Health Emergency [5, 7].

With the arrival of additional funding primarily from the United States President's Emergency Plan for AIDS Relief (PEPFAR) and the Global Fund to Fight AIDS, Tuberculosis, and Malaria in the early 2000s, national programs were implemented to prevent new HIV infections through targeting behavior change, voluntary counseling and testing (VCT), and condom distribution, increasing awareness surrounding HIV/AIDS [3]. In 2004, an ART plan was established, bringing much-needed medication to those infected with HIV and soon thereafter the NAC established programs providing voluntary medical male circumcision (VMMC) and ART for the prevention of maternal to child transmission (PMTCT) [7]. Since, the Government of Zimbabwe has adopted multiple policies and strategies to address the protection of vulnerable populations, condom usage, and gender equality, as well as economic policies to improve healthcare funding within the country [7].

As Zimbabwe's HIV prevalence has dropped significantly over the last fifteen years, numerous studies have focused on the cause of its success. A review of the literature regarding the effects of behavior change, condom distribution, VCT, ART, and VMMC on Zimbabwe's HIV prevalence and incidence follows.

Behavior Change

The current hypothesis for Zimbabwe's successful drop in HIV prevalence is that the nation witnessed great reductions in risky behaviors over the late 1990s and early 2000s. In one of the first studies on this hypothesis, Gregson et al. conducted a prospective cohort survey of 9454 men aged 17-54 years and women aged 15-49 years from twelve communities across Zimbabwe's Manicaland province between July 1998 and February 2000 and again three years later (frequently referred to as the Manicaland cohort) to assess changes in sexual behavior

through this period [8]. Researchers tested participants for HIV and overall, HIV prevalence declined from 23.0% in the first round of surveys to 20.5% at the three-year follow-up in the open cohort ($p<0.05$) [8]. Men aged 17 to 29 years (from 10.6% to 8.1%, $p<0.01$) and women aged 15 to 24 years (from 15.9% to 8.0%, $p<0.001$) experienced the greatest declines in HIV prevalence [8]. Additionally, the authors note delays in sexual debut among teenagers, from 45% of 17-19 year-old men and 21% of 15-17 year-old women reporting having had sex in the initial survey to 27% of men aged 17-19 years and 9% of women aged 15-17 years reporting it three years later ($p<0.05$).[8] Furthermore, the percentage of men reporting having had a "recent casual partner" dropped from 25.9% to 13.2% ($p<0.001$), consistent condom use rose among women (from 26.2% to 36.5%, $p<0.003$), and reductions in the number of new sexual partners in the last year were seen among both men and women ($p<0.05$) [8]. Gregson et al. suggest that the drop in HIV prevalence corresponded with the reduction in risky sexual behaviors, recognizing the possible effects of social desirability bias, migration of HIV-positive individuals for treatment, and AIDS-related mortality on the observed decline in Manicaland.

Building upon the work of Gregson et al., in 2009, Hallett et al. developed a dynamic simulation model of HIV transmission in Zimbabwe incorporating ANC surveillance prevalence estimates and behavioral indicator data from DHS surveys and the Manicaland cohort [9]. Using these parameters as well as estimations for the rate of sexual partner change, mixing of high-risk groups, survival time from infection to death, and corrections for ART scale-up, the authors created HIV prevalence curves for urban and rural populations in simulations with and without the effects of behavior change. These curves were compared using the Bayesian Melding procedure. The authors concluded that behavior change – including increased condom usage and a reduction in sexual partners – very likely altered the natural course of Zimbabwe's HIV

epidemic over the last twenty years in both urban and rural settings ($p<0.01$) as the models with behavior change best mirrored ANC trends [9]. Furthermore, the authors inferred that the behavior change likely peaked between 1999 and 2004, coinciding with the establishment of Zimbabwe's NAC and the AIDS Levy to support prevention and testing programs. However, this model is a bit dated. As Zimbabwe scaled up its ART and VMMC programs after the time of this study's analysis, the course of the epidemic has likely been altered [9].

Shortly thereafter, Gregson et al. performed a thorough triangulation analysis of secondary epidemiological and behavioral data sources between 2004 and 2008, primarily using data from Zimbabwe's ANC surveillance program, the 1999 and 2005/06 DHS surveys, and knowledge, attitude, and practice surveys conducted by Population Services International (PSI), [10]. To determine the effects of migration on HIV prevalence, the authors examined the HIV prevalence among Zimbabwean migrants in the United Kingdom over the period of interest. Additionally, the authors obtained secondary VCT data, PMTCT data, and records from routine testing of blood products for transfusion, yet excluded this data due to bias from the introduction and scale-up of these programs during the study period. Prevalence estimates were calculated using 95% exact binomial confidence limits, and behavioral indicators were presented as proportions compared by chi-square tests with alpha=0.05 [10].

As in other studies, HIV prevalence fell across all data sources from 1999 to 2006. The median age at first sex fluctuated across most datasets throughout the 1990s and early 2000s, yet significant declines were observed among men 15-19 years old from 33% in 1994 to 27% in 2005 ($p<0.01$) and in the Manicaland cohort, previously described [10]. DHS data suggest a 10% decline in the proportion of men reporting non-regular partners from 57% in 1999 to 47% in the 2005/06 DHS surveys ($p<0.05$), while PSI surveys performed from 2001 to 2007 showed a

drop in the proportion of men from 32% in 2001 to 21% in 2003, with the proportion leveling near 20% in the following years [10]. Women report lower proportions, hovering near 15% in both DHS surveys and declining from 17% in 2001 to around 6% in 2007 in the PSI surveys ($p<0.05$).[10]. The authors ascribe the lower values seen in PSI data when compared to DHS data to differences in the wording of the surveys. Data sources regarding condom use at last sex across nine different surveys fail to show a trend, with levels among men ranging between 60-80% [10]. Authors concluded that the migration of HIV-positive individuals did not likely contribute significantly to Zimbabwe's drop in HIV prevalence, as the prevalence among women who immigrated to the UK remained lower than Zimbabwe's national average. This study is unique as it synthesizes many data sources to examine trends, lacking only programmatic and qualitative data in its analysis.

To provide a context for the quantitative data available regarding Zimbabwe's HIV epidemic, from September to November 2007, Muchini et al. held sixteen focus group discussions involving 90 men and 110 women [6]. Twelve of these focus groups were held in predominantly Shona regions in Zimbabwe's northern and eastern provinces, and the remaining four among Zimbabwe's Ndebele in the southern and western provinces. Participants were between the ages of 32 and 55 years old, as the study was designed to target those who could compare sexual behavior norms from the 1990s to the present. The mean age of participants was 42 years, with 54% residing in rural areas [6]. In addition to the focus group discussions, from 2006 to 2009, two-dozen key informant interviews were conducted and an extensive review was done to historically map HIV/AIDS programs across Zimbabwe from 1999-2004.

Focus groups described a reduction in the acceptance of multiple partnerships from the early nineties to the present as AIDS became more visible within communities. Furthermore,

respondents said that with Zimbabwe's economic crisis, men could no longer afford to go out to bars, pay for sex, or maintain concurrent relationships. Respondents also recalled an increase in prevention programs with the establishment of the NAC in 1999, as well as multiple media campaigns that increased awareness. Particularly, respondents emphasized messaging delivered on the community-level, especially the "be faithful" to your partner message enforced in churches [6]. However, as recollections of VCT and PMTCT programs varied across respondents, and these programs were not scaled up until after 2002, the authors concluded that these prevention programs likely did not contribute significantly to Zimbabwe's decline in HIV prevalence. Overall, Muchini et al. concluded that the reduction in the number of partnerships and risky sexual behaviors primarily resulted from increased exposure to AIDS-related mortality [6].

Using the model created by Hallett et al., Halperin et al. synthesized ANC surveillance data, 1999 and 2005/06 DHS data, the triangulation analysis done by Gregson et al., and the qualitative study by Muchini et al. to determine the sources that influenced the well-documented behavior change seen in the early twenty-first century in Zimbabwe [11]. Additionally, behavioral indicators from DHS surveys were compared across seven southern African countries to identify changes that set Zimbabwe's epidemic on a different course from those of its neighboring countries. The authors presented prevalence trends, behavioral data, and the context provided by Muchini et al.'s qualitative study at a stakeholders' meeting in 2008, where participants concluded that the reduction in concurrent sexual partnerships in the setting of high AIDS mortality was the greatest factor contributing to Zimbabwe's rapid decline in HIV prevalence [11].

Through comparing behavioral indicators across southern Africa, the authors noted that Zimbabwe stood out among its neighbors for its relatively high levels of secondary education and marriage, improving comprehensive knowledge regarding HIV/AIDS and providing a social structure in which the population could more easily follow the "be faithful" to one's partner messaging [11]. Furthermore, Zimbabwe's quick adoption of home-based care for those with AIDS likely increased personal exposure to AIDS-mortality, leading to the rapid behavior change seen at the turn of the century [11]. Overall, this incredibly thorough study establishes a detailed context of Zimbabwe's HIV epidemic in the early twenty-first century, yet, with Zimbabwe's 2008 economic crisis and political turmoil, the setting has changed. More recent data are available that could better inform decisions made about Zimbabwe's current epidemic and its future direction.

Although the aforementioned studies indicate Zimbabwe's decline in HIV prevalence can be primarily attributed to behavior change, the effects of programs like condom distribution, VCT, ART, and VMMC cannot be ignored.

Condom Distribution

Male condom distribution programs for HIV prevention have been around since the virus was identified as an STI in 1983 [3]. A meta-analysis done by Weller et al in 2007 assessing fourteen studies measuring HIV incidence among sexually active serodiscordant couples showed an 80% reduction in incidence among those couples that used a male condom consistently [12]. As an effective and inexpensive means to prevent HIV transmission, condom distribution has been a focus in Zimbabwe since the beginning of its epidemic, and numbers of condoms distributed for free and purchased have increased greatly since the early 1990s [3]. Although

reported condom use has risen in Zimbabwe [8], data is inconsistent [10]. Furthermore, these studies could be marred by social desirability bias, poor recall, or poorly worded questionnaires and surveys [13].

To determine the validity of self-reported condom use among women in Zimbabwe, Minnis et al. measured vaginal PSA levels among 910 women randomized to face-to-face interviewing or computer-assisted self-interviewing regarding recent sexual intercourse and condom use to measure recent semen exposure [13]. Researchers recruited participants from December 2006 to June 2007 from a cohort of women who participated in the Methods for Improving Reproductive Health in Africa (MIRA) trial examining the effects of diaphragms and lubricant gel in HIV transmission. Women were then interviewed face-to-face or through computer-assisted self-interviewing regarding their sexual activity in the previous seven days and asked to provide a vaginal fluid sample through a self-collected swab. Vaginal fluid specimens were tested for PSA, a protein found in semen that remains detectable for up to forty-eight hours after vaginal intercourse. Authors used a one-sided Fisher's exact test to compare rates of discrepancies of women reporting no recent sex or condom usage yet testing positive for PSA between the two methods of interviewing [13].

Of the 910 participants, 96.6% were married with a median number of 1.3 lifetime partners [13]. Among women who had detectable levels of PSA, 12% reported no recent vaginal sex and 36% reported consistently using a condom during sex over the last two days [13]. These discrepancies did not vary across interview techniques, and likely underrepresent rates of unprotected vaginal sex as PSA is only detectable in 29% of women twenty-four hours after unprotected intercourse [13]. Study findings of discrepancy between self-reported sexual behaviors echo those seen in Kenya [14], Madagascar [15], and the United States [16].

Examining national STI incidence trends could corroborate condom use on a population level, yet recent literature is lacking on this topic. As owning condoms does not guarantee their consistent use, the benefit of increased accessibility to condoms in Zimbabwe over the last twenty years cannot be clearly delineated.

Voluntary Counseling and Testing

HIV testing has been available in Zimbabwe since 1985, with great improvements in accessibility over the last decade. Voluntary counseling and tested (VCT) is defined as voluntary pre- and post-test counseling, voluntary HIV testing, and obtaining the results of the test [17]. Counseling incorporates education regarding HIV, assesses the client's risk, provides risk reduction strategies, and links those who test positive into care. Counseling may reduce risky behaviors, but data has not shown great reductions across all individuals who undergo VCT. As shown in numerous studies and meta-analyses across Africa, VCT appears to have the greatest impact on the reduction of risky sexual behaviors among those who test positive and in serodiscordant couples [18-21], but limited studies have been done in Zimbabwe to support this hypothesis.

In one pertinent study, Sherr et al. analyzed VCT uptake and influence on sexual behavior through examining testing and behavioral trends in the same Manicaland cohort previously described [22], Along with the interview-led questionnaire administered between 1998-2000 and again three years later in the province, free mobile VCT clinics were available at the twelve study sites while surveys were being conducted. Participants were given anonymous blood spot dipstick tests as part of the surveys to determine HIV prevalence, and were also offered VCT at the mobile clinics where they could follow-up on their results. Sexual behaviors

were compared for those who underwent VCT before and after testing by fitting ordinal logistic regression models stratified by test results, with the threshold for statistical significance set at alpha=0.05 [22].

In the follow-up survey, 19% reported having had an HIV test in the past (up from 6.6% at baseline), with higher testing rates seen among men (26% of men versus 14% of women, $p<0.001$) [22]. However, only 12% of men and 10% of women in the cohort had ever obtained their HIV test result [22]. Those who tested positive and obtained post-test counseling reported fewer partners ($p<0.01$) and, among women, higher rates of consistent condom use with their regular partners ($p<0.01$) [22]. Individuals who tested negative and underwent post-test counseling were more likely to report concurrent partnerships within the last year ($p<0.05$) in the follow-up survey, suggesting that risky behaviors increase after testing negative [22]. Despite this possible correlation between testing negative and engaging in risky sexual behaviors thereafter, the HIV incidence of those who underwent VCT did not differ from that observed in the larger cohort.

To determine if intensive VCT programs affected HIV incidence, Corbett et al. performed a retrospective secondary data analysis assessing HIV incidence among employees in businesses recruited across Zimbabwe's capitol city of Harare for the implementation of VCT programs [23]. Of the twenty-two businesses recruited, twelve were randomly assigned to intensive VCT programs with pre- and post-test counseling, risk assessment, HIV testing, result delivery, and risk reduction planning available on-site while the remaining twelve followed standard VCT protocols in which employees underwent pre-test counseling, risk assessment, and were given vouchers for testing at outside facilities. HIV incidence was calculated from the number of seroconversions in the two-year follow-up period ending in July 2004, and

multivariate regression analyses were utilized to control for potential confounders. Overall, HIV incidence did not vary significantly between the two study arms, echoing the results of the well-known meta-analysis by Weinhardt et al. done in United States [23, 24]. A study of the effects of VCT on HIV incidence among serodiscordant couples in Zimbabwe could provide further insights whether the reduction in risky behaviors seen among individuals who test positive will ultimately influence incidence. Despite causing no obvious reduction in HIV incidence, one clear benefit of VCT lies in the post-test counseling of those who test HIV positive that aims to link them into care.

Antiretroviral Therapy

Theoretically, the treatment of persons living with HIV (PLHIV) with antiretroviral therapy (ART) should raise the HIV prevalence as it increases the survival of those already infected; however, effective counseling and viral load suppression can negate this effect through reducing the risk of HIV transmission to non-infected partners [25]. Numerous studies have shown that viral load is the primary factor determining heterosexual transmission of HIV [26-29], and that viral load suppression achieved with ART can effectively reduce HIV transmission through heterosexual intercourse [29-31]. However, as ART access continues to be an issue in Zimbabwe, the full effects of ART on the nation's HIV incidence and prevalence are unknown.

ART was introduced in Zimbabwe in 2004 with the creation of the National Opportunistic Infections/ Antiretroviral Therapy Program, and decentralized to local health facilities in 2008 [32]. Despite a rapid increase in the number of sites providing ART since the early 2000s, the nation continues to face drug shortages in the setting of a broken healthcare system, preventing many from obtaining the life-saving treatment [33]. Although studies in the

developing world have shown that HIV-infected individuals have the same or better adherence rates than those in developed countries, there are higher rates of loss to follow-up when nations with weak health infrastructure expand ART programs [34, 35].

To determine the rates of retention in care and clinical outcomes of those enrolled in Zimbabwe's National ART Program, Mutasa-Apollo et al. performed a retrospective cohort study between October and December 2010 examining data from the medical records of those initiated on ART within the study period of 2007 to 2009 [32]. At this time, eligibility for ART extended to adults with a diagnosis of WHO clinical stage IV, stage III with a CD4+ count below 350 cells/µl, or stage I or II with a CD4+ count below 200 cells/µl. Furthermore, eligible patients must have completed counseling sessions and adhered to prophylactic treatment with co-trimoxazole for three months to be initiated on ART. Subjects received routine blood tests and periodic CD4+ counts, and their weight was measured regularly. Retention was defined as those alive and remaining on ART at the facility where they initiated treatment [32]. The median CD4+ counts and proportion of those retained in treatment at 6, 12, 24, and 36 months were calculated and presented with 95% confidence intervals.

Of the 3919 HIV-positive patients initiated on ART in the study period, retention on ART was 90.7%, 78.1%, 68.8%, and 64.4% at 6, 12, 24, and 36 months following initiation of treatment, respectively [32]. As expected, CD4+ counts rose among those retained in treatment, with the median increase from baseline of 265 cells/µl in women and 179 cells/µl in men 24 months from initiation of treatment [32]. Retention rates mirror those in other sub-Saharan African countries [36], as do the gains seen in CD4+ counts [37-39]. As higher CD4+ counts reduce risks of acquiring opportunistic infections, improved retention in care in Zimbabwe has

the potential to improve the length and quality of life of the millions of individuals living with HIV in the nation.

Male Circumcision

As male circumcision significantly reduces the risk of female-to-male HIV transmission by nearly 60% [40-43], efforts to increase its uptake have been a focus of HIV prevention programs worldwide. Although a minority of ethnic groups in Zimbabwe traditionally practices male circumcision [44], great strides have been made in improving access to and acceptability of voluntary medical male circumcision (VMMC) since 2009. Under the recommendations of the World Health Organization and UNAIDS and with the support of PEPFAR, the World Bank, and the Bill & Melinda Gates Foundation [45], Zimbabwe continues to scale-up its VMMC program, utilizing PrePex, a single-use device designed for non-surgical adult male circumcision, to improve accessibility of VMMC in rural areas.

Using an established model for HIV transmission through heterosexual intercourse, Hallett et al. modeled the potential effects of VMMC scale-up on HIV transmission in Zimbabwe [46]. This model incorporated partner switching parameters from the Manicaland cohort previously described [8, 47], assuming that the risk of female-to-male transmission is reduced by 60%, ART coverage increases to 90% by 2020, and the rate at which men are circumcised plateaus within five years of the VMMC program starting. Simulations show that as male circumcision rates increase, the first to benefit are those men undergoing circumcision. As HIV incidence drops in this population, their female partners are at a lower risk of being infected from them, so HIV incidence also drops among women. Finally, HIV incidence would decline in all men, as fewer women are infected. Ultimately, the authors believe that the benefit of male

circumcision is greater than the documented 60% risk reduction as overall incidence will decline over time, but the beneficial effects of VMMC will take years to have an impact on HIV prevalence. Furthermore, coverage rates must be high for these population-level benefits to be seen at all [46].

Studies regarding the benefit of male circumcision on reduced male-to-female HIV transmission are conflicting. A meta-analysis of the observational studies by Baeton et al. across Africa and Gray et al. in Uganda done by Hallett et al. showed a 46% reduction in male-to-female HIV transmission two years after the male partner undergoes circumcision (hazard rate 0.54, 95% CI 0.31-0.96, p=0.04) [48-50]. On the other hand, a randomized trial of HIV-positive men and their HIV-negative partners in Uganda by Wawer et al. showed an increased risk among female partners in those men who were randomized to immediate circumcision (adjusted hazard ratio of 1.49, 95% CI 0.62-3.57, p=0.368) at 24 months following circumcision when compared to the partners of men who were not circumcised, yet this study was underpowered [51]. Ultimately, the effects of VMMC on Zimbabwe's HIV prevalence have likely been minimal over the last decade, as VMMC was only promoted after 2009, and the effects of male circumcision on both female-to-male and male-to-female transmission on HIV prevalence would not yet have potentially measurable effects.

Summary

Overall, Zimbabwe's HIV prevalence has declined by more than 50% over the early twenty-first century, with reductions in risky sex behaviors in the setting of high AIDS-mortality observed in the late 1990s and early 2000s. Although behavior change appears to have played the greatest role in this reduction, one cannot overlook the effects of condom distribution, VCT, ART, and VMMC on the epidemic. The literature available pertaining to Zimbabwe's particular

epidemic thoroughly details the behavior changes that occurred at the turn of the century, consisting of quantitative, qualitative, and triangulation analyses. The evidence that the rates of risky sexual behaviors were reduced in Zimbabwe during the early twenty-first century is very strong, supported across multiple data sources and studies. As demonstrated in Muchini et al.'s qualitative study, this reduction in risky behaviors most likely stemmed from increased exposure to AIDS-related mortality secondary to Zimbabwe's system of home-based care, the dramatic devaluation of the Zimbabwean dollar beginning at the turn of the century, and the increase in HIV prevention and treatment programs seen in 1999 [6]. Although at risk of social desirability bias, as shown in Minnis et al.'s study of the discrepancy between reported and consistent condom use, the consistency of the data presented on behavioral indicator trends in Zimbabwe point toward a true reduction in risky behaviors [13].

Muchini et al.'s qualitative study enhances the understanding of the data, providing a context for the change in risky behaviors through focus group discussions, in-depth interviews, and a historical mapping of Zimbabwe's governmental and programmatic response to the epidemic [6]. This study stands out as the only qualitative study to examine why Zimbabwe's HIV prevalence declined so drastically, yet it cannot explain the continued drop in HIV prevalence since 2008. The social and economic context of the nation has changed with hyperinflation peaking in 2008 and political unrest following recent elections, raising unemployment rates and likely forcing many to travel across national borders for work. Additionally, Zimbabwe's governmental response to the epidemic has changed, as ART was scaled up in 2008, VMMC programs were introduced in 2009, and school-based educational programs have been increased.

Although most data used in the literature is more than a decade old, mathematical models have stepped in to supplement the available data without the expense or time required for prospective studies. Additionally, they can be utilized to predict HIV trends, as done in Hallett et al.'s model of the potential benefits of VMMC in Zimbabwe, guiding policy-makers [48]. These simulations are incredibly thorough, incorporating sexual mixing patterns from the Manicaland cohort and ART scale-up to generate HIV prevalence curves, and they can serve as a backbone for future models for Zimbabwe and other nations.

Despite the detail and diversity found in the literature on Zimbabwe's HIV epidemic, the data are limited. Few studies use data collected after 2005, and even fewer used data collected after 2008 [32]. Although there are particular limitations associated with using programmatic data reported by the NAC or MOHCW (it is dependent on the fluctuations of scale-up and scale-down year-to-year and province-to-province), it can supplement studies through demonstrating peaks and troughs in accessibility to condoms, testing, ART, or VMMC. Furthermore, if the goal of these studies are to inform policy-makers, combining data distributed by those stakeholders with data from other sources can help identify knowledge gaps or strengths and weaknesses of current programs.

Through this particular review, many data gaps were discovered. As discussed, recent data is lacking. Additionally, data is scarce regarding men who have sex with men and sex workers in Zimbabwe, largely because prostitution and homosexuality are illegal. There are few studies using data from the last decade regarding STI incidence in Zimbabwe [52-54], and evidence of declining STI incidence would support the increase seen in self-reported condom use. Furthermore, some of the data presented may not be representative of the entire country, as most of the discussed studies were done in Zimbabwe's eastern provinces [6, 8, 13, 22, 23],

which have a very different ethnic and cultural makeup than the nation's western provinces. Last, there is a need for more data on VMMC uptake and effectiveness specific to Zimbabwe as the program was only rolled out in 2009.

To build upon the strengths and address some of the limitations of the literature, the proposed HIV data triangulation exercise will combine prevalence, behavioral, and programmatic data across Zimbabwe, incorporating more recent data sources. It aims to engage stakeholders through workshops held before and after data analysis, bringing policy-makers from multiple organizations to the same table to discuss past trends, the current status, and the future direction of Zimbabwe's HIV epidemic, and will serve as an update to the literature regarding HIV in Zimbabwe. As nearly one in seven are infected with HIV in Zimbabwe, there remain great strides to be made in Zimbabwe's battle against HIV. This proposed analysis is intended to better inform future decisions made regarding HIV programs in Zimbabwe to ultimately reduce the burden of this disease.

Works Cited

1. Zimbabwe Population Census 2012 Harare, Zimbabwe: Zimbabwe National Statistics Agency; 2012 [cited 2014 8 Sep]. Available from: http://www.zimstat.co.zw/dmdocuments/Census/CensusResults2012/National_Report.pdf.

2. Constitution of Zimbabwe Harare, Zimbabwe2013 [cited 2015 March 30]. Available from: http://archive.kubatana.net/docs/legisl/constitution_zim_draft_copac_130125.pdf.

3. Kerina D, Babill S-P, F M. HIV/AIDS: The Zimbabwean Situation and Trends. American Journal of Clinical Medicine Research. 2013;1(1):15-22.

4. World Databank: World Bank; 2012 [cited 2014 8 Sep]. Available from: http://databank.worldbank.org/data/views/reports/chart.aspx.

5. Fraser N, James V, Milanzi A, Colvin M, Ibbetson H, Mpofu N, et al. Zimbabwe Analysis of HIV Epidemic, Response and Modes of Transmission Harare, Zimbabwe: National AIDS Council; 2011 [cited 2014 8 Sep]. Available from: http://ms-hiv-gdc.org/wp-content/uploads/group-documents/1/1314808832-Zimbabwesynthesisreport.pdf.

6. Muchini B, Benedikt C, Gregson S, Gomo E, Mate R, Mugurungi O, et al. Local perceptions of the forms, timing and causes of behavior change in response to the AIDS epidemic in Zimbabwe. AIDS and Behavior. 2011;15(2):487-98.

7. Global AIDS Response Progress Report 2012 Harare, Zimbabwe: National AIDS Council; 2012 [cited 2014 9 Sep]. Available from: http://www.unaids.org/en/dataanalysis/knowyourresponse/countryprogressreports/2012countries/ce_ZW_Narrative_Report.pdf.

8. Gregson S, Garnett GP, Nyamukapa CA, Hallett TB, Lewis JJC, Mason PR, et al. HIV decline associated with behavior change in eastern Zimbabwe. Science. 2006;311(5761):664-6.

9. Hallett TB, Gregson S, Mugurungi O, Gonese E, Garnett GP. Assessing evidence for behaviour change affecting the course of HIV epidemics: A new mathematical modelling approach and application to data from Zimbabwe. Epidemics. 2009;1(2):108-17.

10. Gregson S, Gonese E, Hallett TB, Taruberekera N, Hargrove JW, Lopman B, et al. HIV decline in Zimbabwe due to reductions in risky sex? Evidence from a comprehensive epidemiological review. International Journal of Epidemiology. 2010;39(5):1311-23.

11. Halperin DT, Mugurungi O, Hallett TB, Muchini B, Campbell B, Magure T, et al. A surprising prevention success: why did the HIV epidemic decline in Zimbabwe? PLoS medicine. 2011;8(2):e1000414.

12. Weller SC, Davis-Beaty K. Condom effectiveness in reducing heterosexual HIV transmission (Review). The Cochrane Library. 2007;4:1-24.

13. Minnis AM, Steiner MJ, Gallo MF, Warner L, Hobbs MM, Van der Straten A, et al. Biomarker validation of reports of recent sexual activity: results of a randomized controlled study in Zimbabwe. American Journal of Epidemiology. 2009;170(7):918-24.

14. Gallo MF, Behets FM, Steiner MJ, Thomsen SC, Ombidi W, Luchters S, et al. Validity of self-reported'safe sex'among female sex workers in Mombasa, Kenya—PSA analysis. International journal of STD & AIDS. 2007;18(1):33-8.

15. Gallo MF, Behets FM, Steiner MJ, Hobbs MM, Hoke TH, Van Damme K, et al. Prostate-specific antigen to ascertain reliability of self-reported coital exposure to semen. Sexually transmitted diseases. 2006;33(8):476-9.

16. Rose E, DiClemente RJ, Wingood GM, Sales JM, Latham TP, Crosby RA, et al. The validity of teens' and young adults' self-reported condom use. Archives of pediatrics & adolescent medicine. 2009;163(1):61-4.

17. Denison JA, O'Reilly KR, Schmid GP, Kennedy CE, Sweat MD. HIV voluntary counseling and testing and behavioral risk reduction in developing countries: a meta-analysis, 1990–2005. AIDS and Behavior. 2008;12(3):363-73.

18. Group CaTES. Efficacy of voluntary HIV-1 counselling and testing in individuals and couples in Kenya, Tanzania, and Trinidad: a randomised trial. The Lancet. 2000;356(9224):103-12.

19. Painter TM. Voluntary counseling and testing for couples: a high-leverage intervention for HIV/AIDS prevention in sub-Saharan Africa. Social Science & Medicine. 2001;53(11):1397-411.

20. Allen S, Serufilira A, Bogaerts J, Van de Perre P, Nsengumuremyi F, Lindan C, et al. Confidential HIV testing and condom promotion in Africa: Impact on HIV and gonorrhea rates. Jama. 1992;268(23):3338-43.

21. Allen S, Tice J, Van de Perre P, Serufilira A, Hudes E, Nsengumuremyi F, et al. Effect of serotesting with counselling on condom use and seroconversion among HIV discordant couples in Africa. Bmj. 1992;304(6842):1605-9.

22. Sherr L, Lopman B, Kakowa M, Dube S, Chawira G, Nyamukapa C, et al. Voluntary counselling and testing: uptake, impact on sexual behaviour, and HIV incidence in a rural Zimbabwean cohort. Aids. 2007;21(7):851-60.

23. Corbett EL, Makamure B, Cheung YB, Dauya E, Matambo R, Bandason T, et al. HIV incidence during a cluster-randomized trial of two strategies providing voluntary counselling and testing at the workplace, Zimbabwe. Aids. 2007;21(4):483-9.

24. Weinhardt LS, Carey MP, Johnson BT, Bickham NL. Effects of HIV counseling and testing on sexual risk behavior: a meta-analytic review of published research, 1985-1997. American journal of public health. 1999;89(9):1397-405.

25. Baggaley RF, Garnett GP, Ferguson NM. Modelling the impact of antiretroviral use in resource-poor settings. PLoS medicine. 2006;3(4):e124.

26. Quinn TC, Wawer MJ, Sewankambo N, Serwadda D, Li C, Wabwire-Mangen F, et al. Viral load and heterosexual transmission of human immunodeficiency virus type 1. New England journal of medicine. 2000;342(13):921-9.

27. Tovanabutra S, Robison V, Wongtrakul J, Sennum S, Suriyanon V, Kingkeow D, et al. Male viral load and heterosexual transmission of HIV-1 subtype E in northern Thailand. Journal of acquired immune deficiency syndromes (1999). 2002;29(3):275-83.

28. Gray RH, Wawer MJ, Brookmeyer R, Sewankambo NK, Serwadda D, Wabwire-Mangen F, et al. Probability of HIV-1 transmission per coital act in monogamous, heterosexual, HIV-1-discordant couples in Rakai, Uganda. The Lancet. 2001;357(9263):1149-53.

29. Attia S, Egger M, Müller M, Zwahlen M, Low N. Sexual transmission of HIV according to viral load and antiretroviral therapy: systematic review and meta-analysis. Aids. 2009;23(11):1397-404.

30. Castilla J, Del Romero J, Hernando V, Marincovich B, García S, Rodríguez C. Effectiveness of highly active antiretroviral therapy in reducing heterosexual transmission of HIV. JAIDS Journal of Acquired Immune Deficiency Syndromes. 2005;40(1):96-101.

31. Cohen MS, Chen YQ, McCauley M, Gamble T, Hosseinipour MC, Kumarasamy N, et al. Prevention of HIV-1 Infection with Early Antiretroviral Therapy. New England Journal of Medicine. 2011;365(6):493-505.

32. Mutasa-Apollo T, Shiraishi RW, Takarinda KC, Dzangare J, Mugurungi O, Murungu J, et al. Patient retention, clinical outcomes and attrition-associated factors of HIV-infected patients enrolled in Zimbabwe's National Antiretroviral Therapy Programme, 2007–2010. PloS one. 2014;9(1):e86305.

33. Todd C, Ray S, Madzimbamuto F, Sanders D. What is the way forward for health in Zimbabwe? The Lancet.375(9714):606-9.

34. Nachega JB, Mills EJ, Schechter M. Antiretroviral therapy adherence and retention in care in middle-income and low-income countries: current status of knowledge and research priorities. Current Opinion in HIV and AIDS. 2010;5(1):70-7.

35. Mills EJ, Nachega JB, Buchan I, Orbinski J, Attaran A, Singh S, et al. Adherence to antiretroviral therapy in sub-Saharan Africa and North America: a meta-analysis. Jama. 2006;296(6):679-90.

36. Fox MP, Rosen S. Patient retention in antiretroviral therapy programs up to three years on treatment in sub- Saharan Africa, 2007–2009: systematic review. Tropical Medicine & International Health. 2010;15(s1):1-15.

37. Lowrance DW, Ndamage F, Kayirangwa E, Ndagije F, Lo W, Hoover DR, et al. Adult clinical and immunologic outcomes of the national antiretroviral treatment program in Rwanda during 2004-2005. JAIDS Journal of Acquired Immune Deficiency Syndromes. 2009;52(1):49-55.

38. Auld AF, Mbofana F, Shiraishi RW, Sanchez M, Alfredo C, Nelson LJ, et al. Four-year treatment outcomes of adult patients enrolled in Mozambique's rapidly expanding antiretroviral therapy program. PLoS One. 2011;6(4):e18453.

39. Toure S, Kouadio B, Seyler C, Traore M, Dakoury-Dogbo N, Duvignac J, et al. Rapid scaling-up of antiretroviral therapy in 10,000 adults in Cote d'Ivoire: two-year outcomes and determinants. AIDS (London, England). 2008;22(7):873.

40. Auvert B, Taljaard D, Lagarde E, Sobngwi-Tambekou J, Sitta R, Puren A. Randomized, controlled intervention trial of male circumcision for reduction of HIV infection risk: the ANRS 1265 Trial. PLoS medicine. 2005;2(11):e298.

41. Gray RH, Kigozi G, Serwadda D, Makumbi F, Watya S, Nalugoda F, et al. Male circumcision for HIV prevention in men in Rakai, Uganda: a randomised trial. The Lancet. 2007;369(9562):657-66.

42. Weiss HA, Quigley MA, Hayes RJ. Male circumcision and risk of HIV infection in sub-Saharan Africa: a systematic review and meta-analysis. Aids. 2000;14(15):2361-70.

43. Weiss HA, Dickson KE, Agot K, Hankins CA. Male circumcision for HIV prevention: current research and programmatic issues. AIDS (London, England). 2010;24(0 4):S61.

44. Ashengo TA, Hatzold K, Mahler H, Rock A, Kanagat N, Magalona S, et al. Voluntary Medical Male Circumcision (VMMC) in Tanzania and Zimbabwe: Service Delivery Intensity and Modality and Their Influence on the Age of Clients. PLoS ONE. 2014;9(5):e83642.

45. UNAIDS. Joint Strategic Action Framework to Accelerate the Scale-Up of Voluntary Medical Male Circumcision for HIV Prevention in Eastern and Southern Africa. Geneva, Switzerland: UNAIDS, 2011.

46. Hallett TB, Singh K, Smith JA, White RG, Abu-Raddad LJ, Garnett GP. Understanding the impact of male circumcision interventions on the spread of HIV in southern Africa. PLoS One. 2008;3(5):e2212.

47. Gregson S, Nyamukapa CA, Garnett GP, Mason PR, Zhuwau T, Caraël M, et al. Sexual mixing patterns and sex-differentials in teenage exposure to HIV infection in rural Zimbabwe. The Lancet. 2002;359(9321):1896-903.

48. Hallett TB, Alsallaq RA, Baeten JM, Weiss H, Celum C, Gray R, et al. Will circumcision provide even more protection from HIV to women and men? New estimates of the population impact of circumcision interventions. Sexually transmitted infections. 2010:sti. 2010.043372.

49. Baeten JM, Donnell D, Kapiga SH, Ronald A, John-Stewart G, Inambao M, et al. Male circumcision and risk of male-to-female HIV-1 transmission: a multinational prospective study in African HIV-1 serodiscordant couples. AIDS (London, England). 2010;24(5):737.

50. Gray RH, Kiwanuka N, Quinn TC, Sewankambo NK, Serwadda D, Mangen FW, et al. Male circumcision and HIV acquisition and transmission: cohort studies in Rakai, Uganda. Aids. 2000;14(15):2371-81.

51. Wawer MJ, Makumbi F, Kigozi G, Serwadda D, Watya S, Nalugoda F, et al. Randomized trial of male circumcision in HIV-infected men: effects on HIV transmission to female partners, Rakai, Uganda. Lancet. 2009;374(9685):229.

52. Munjoma MW, Mapingure MP, Stray-Pedersen B. Risk factors for herpes simplex virus type 2 and its association with HIV among pregnant teenagers in Zimbabwe. Sexual health. 2010;7(1):87-9.

53. Van de Wijgert J, Mason PR, Gwanzura L, Mbizvo MT, Chirenje ZM, Iliff V, et al. Intravaginal practices, vaginal flora disturbances, and acquisition of sexually transmitted diseases in Zimbabwean women. Journal of Infectious Diseases. 2000;181(2):587-94.

54. Napierala Mavedzenge S, Muller EE, Lewis DA, Chipato T, Morrison CS, Weiss HA. Mycoplasma genitalium Is Associated With Increased Genital HIV Type 1 RNA in Zimbabwean Women. The Journal of infectious diseases. 2015;211(9):1388-98.

Chapter 2 – Manuscript

Zimbabwe's Maturing HIV Epidemic: A Triangulation Analysis of Prevalence, Behavioral, and Programmatic Data from 2000-2013

Emma K Sizemore[1], Abu S Abdul-Quadar[2], Amy Herman-Roloff[3], Peter Kilmarx[3], Vasco Chikwasha[4]

[1] Emory University Rollins School of Public Health and Emory University School of Medicine, Atlanta, Georgia, United States.

[2] U.S. Centers for Disease Control and Prevention Division of Global HIV/AIDS, Atlanta, Georgia, United States

[3] U.S. Centers for Disease Control and Prevention – Zimbabwe, Harare, Zimbabwe

[4] University of Zimbabwe, Harare, Zimbabwe

Contribution of Student

I, Emma Sizemore, was responsible for secondary data synthesis, analysis, and interpretation; figure and table development; planning and running the October 2014 stakeholders' meeting; and drafting this manuscript. Co-authors assisted in the acquisition of the secondary data and in editing this manuscript. No primary data was collected. This manuscript is intended for publication with PLOS One.

Abstract

Objective:
To assess Zimbabwe's HIV prevalence trends from 2000-2013 in light of recent behavioral and programmatic data, a data triangulation exercise including a systematic review of the available data on the HIV/AIDS epidemic and national response in Zimbabwe was conducted.

Materials and Methods:
HIV prevalence estimations from Zimbabwe's antenatal clinic sentinel surveillance were compared alongside data from the 2005/06 and 2010/11 DHS surveys and estimations generated using the USAID Spectrum software. Behavioral indicator data among men and women from the two DHS surveys were analyzed, and governmental programmatic data were assessed.

Results:
Zimbabwe's HIV prevalence among pregnant women declined from 32.1% to 15.5% from 2000 to 2012, with declines also seen in the two DHS surveys. Comprehensive knowledge of HIV/AIDS increased (from 46.5% to 53.0% among men, $p<0.001$, and from 43.4% to 55.9% among women, $p<0.001$) and self-reported condom use during most recent sex increased (from 16.2% to 18.1% among men and from 5.5% to 9.8% among women, $p<0.01$), while the mean number of lifetime partners increased among women (from 1.6 to 2.2, $p<0.001$) and the proportion of men reporting two or more partners in the last year rose (from 9.0% to 10.5%, $p<0.01$). Testing rates increased from 45.6 to 141.7 per 1,000 men and 56.1 to 162.8 per 1,000 women from 2008 to 2013 ($p<0.001$). Condom distribution rates increased by nearly 350% from 2008 to 2013 and rates of male circumcision grew tenfold from 2010 to 2013. ART coverage fluctuated from 2009 to 2013 while AIDS-related mortality declined.

Conclusions:
Zimbabwe's well-documented behavior change in the early 2000s in the setting of high exposure to AIDS-mortality may not be sustained as rates of some risky behaviors are on the rise. Policy-makers must now address geographic disparities in HIV prevalence and work to reverse the growing epidemic in these areas.

Introduction

Over the last thirty years, Zimbabwe has faced one of the worst HIV crises in the world. From its first diagnosed case of HIV/AIDS in 1985, Zimbabwe's HIV prevalence climbed through the 1990s, peaking at 32.1% in 2000, the highest prevalence in the world at the turn of the century [1, 2]. With primarily heterosexual transmission, the disease spanned all socioeconomic levels across Zimbabwe, affecting those in residing in all ten provinces nearly equally [1]. In response to the country's expanding epidemic, Zimbabwe turned a corner with the adoption of its National Policy on HIV and AIDS to guide HIV programs and the creation of the National AIDS Council (NAC) through an act of Parliament in late 1999. The NAC established a National HIV and AIDS Strategic Framework and implemented the AIDS Levy in 2000, a 3% individual and corporate tax, to help fund the country's HIV response [2].

With the arrival of additional funding primarily from the United States President's Emergency Plan for AIDS Relief and the Global Fund to Fight AIDS, Tuberculosis, and Malaria in the early 2000s, national programs were implemented to prevent new HIV infections through targeting behavior change, voluntary counseling and testing (VCT), and condom distribution, increasing awareness surrounding HIV/AIDS [3]. In 2004, an antiretroviral therapy (ART) plan was established, bringing much-needed medication to those infected with HIV [2]. In the following years, the NAC established programs providing voluntary medical male circumcision (VMMC) and ART for the prevention of maternal to child transmission (PMTCT), further working to reduce HIV transmission [2]. By 2013, Zimbabwe's HIV prevalence had dropped more than 50% from its peak in 2000, ending at 15%. (REF?)

As Zimbabwe's HIV epidemic approaches its thirtieth year, the nation continues to have one of the highest HIV prevalences in the world. Although the incidence has declined and

prevalence appears to be stabilizing as the epidemic has matured, many continue to become infected each year. It is crucial to have a better understanding the epidemic pattern so that prevention and treatment efforts can be redirected, if needed, and improved. In the timeline of the maturing epidemic, there are points where assessment of national policy, program implementation, surveillance, and research must be conducted to continue effective response to the epidemic. These may be points of policy changes, funding, prevalence or behavior changes, scale-up of prevention activities, or a combination of all these factors. Second generation HIV surveillance, designed in 2000 to continually tailor behavioral and prevalence data collection to the unique epidemic of a country or region [4], recommends that such an assessment, or exercise, take place for a continual informed response to the epidemic. In view of this, a data triangulation exercise including a systematic review of the available data on the HIV/AIDS epidemic and national response in Zimbabwe was conducted to better direct the nation's response to its evolving epidemic.

Materials and Methods

Data Triangulation

Triangulation is an approach to synthesizing data from multiple sources to strengthen understanding of complex health issues and make evidence-based public health decisions. The process involves stakeholder input on the pertinent public health questions, identification and gathering of the relevant existing data, iterative examination and assessment of the data, generation of hypotheses that explain and reconcile the diverse data, and stakeholder input on the final interpretations and recommendations. In August 2013, the Centers for Disease Control and Prevention (CDC) Zimbabwe and national Ministry of Health and Child Welfare (MOHCW) hosted an initial stakeholders' meeting in Harare, Zimbabwe, with the goals of identifying key

questions to be answered through the triangulation exercise as well as data sources that could help answer those questions. Participants were split into four groups with each focusing on one aspect of the HIV epidemic in Zimbabwe: epidemiology, HIV care and treatment, prevention, and persons living with HIV (PLHIV). For each group, questions requiring further investigation were proposed, scored on the availability of data to answer the question, importance, actionability, appropriateness for triangulation, and feasibility, and ranked. The top question from each group was selected and are as follows:

- **Epidemiology:** What are the determinants of the patterns and distribution of the epidemic? What are the key drivers and where are the hot spots of the epidemic by region? And what may be the future direction of the epidemic?
- **Prevention:** Are the current prevention services contributing to the decline in HIV infection in the country? i.e., what are the current coverage, intensity, impact, and 'quality' of the prevention services?
- **HIV Care and Treatment:** What are the factors affecting adults' and children's access to, retention in, and adherence to HIV care and treatment services in Zimbabwe?
- **PLHIV:** Are the sustainable livelihoods programs in Zimbabwe improving the quality of life of PLHIV?

Participants then brainstormed existing data sources that could answer each question, and, ultimately, the group elected to prioritize the first two questions regarding the epidemiology and prevention services for the data triangulation analysis.

Data Sources

To answer the selected questions, a secondary data analysis was performed using data from Zimbabwe's antenatal clinic (ANC) sentinel surveillance program, the 2005/06 and 2010/11 Demographic and Health Surveys (DHS), NAC prevalence estimations from the Epidemic Projection Package and Spectrum software, MOHCW programmatic data regarding condom distribution, STI incidence, VMMC, PMTCT, VCT, and ART, and the 2012 Zimbabwe National Census published by the Zimbabwe National Statistics Agency [5-7]. Summary data from these sources were acquired from the Zimbabwe Ministry of Health and Child Welfare and DHS for use in the analysis. No primary data was collected. Per capita values were calculated using the 2012 census.

ANC Sentinel Surveillance Data

Zimbabwe's ANC sentinel surveillance program was established in 1990 to track HIV prevalence through unlinked anonymous testing of blood samples taken from pregnant women for routine syphilis testing. In 2000, the surveillance methods were standardized and cross-sectional testing was done at fourteen ANC across Zimbabwe's ten provinces [8]. In 2001, 2002, 2004, 2006, and 2009 nineteen sites were utilized, and the program was expanded to 53 clinics for 2012.

2005/06 and 2010/11 DHS Data

The Demographic and Health Surveys of 2005/06 and 2011/11 are questionnaires and biomarker tests conducted by ZIMSTAT with the assistance of the MOHCW and Zimbabwe National Family Planning Council with funding assistance from many organizations designed to

provide demographic and health indicator data across Zimbabwe. Using the 2002 national census, the country was divided into enumeration areas (EAs) for sampling, and all households within EAs were identified. Women aged 15-49 years and men aged 15-54 years residing in households, including those who had spent the night prior, were eligible for the survey and dried blood spot HIV testing [7]. The following self-reported HIV-related behavioral indicators among those aged 15-49 years were included in the triangulation analysis: among men and women, comprehensive knowledge regarding HIV/AIDS[1], condom use during most recent sex, and total number of sexual partners in the last year; among those who have ever had sex, self-reported genital discharge, ulcer, sore, or diagnosed STI in the year prior and total number of lifetime partners; and among men, rates of paying for sex in the year prior and circumcision rates.

Spectrum Estimations

Annual HIV prevalence was estimated through first inputting ANC surveillance and DHS prevalence data into the Joint UNAIDS Programme on HIV and AIDS Epidemic Projection Package (EPP). Next, EPP's output prevalence curve was combined with demographic and epidemiologic data from the United Nations Population Division and ZIMSTAT and utilized by Spectrum software to project HIV incidence, prevalence, ART coverage, PMTCT demand, and the number of AIDS-related deaths and PLHIV.

[1] Comprehensive knowledge about HIV was defined as correctly identifying that the risk of transmitting HIV can be reduced by using condoms every time one has sex and by only having sex with one uninfected faithful partner, that HIV cannot be transmitted through mosquito bites or sharing food with someone who is HIV-positive (rejecting two local misconceptions), and that a healthy-looking individual can have HIV, as defined by UNAIDS [9].

Programmatic Data

Condom distribution, STI incidence, PMTCT, ART, and VCT summary data from 2008-2013 compiled by Zimbabwe's NAC and MOHCW were utilized to assess the national response to its HIV epidemic. VMMC data was only available for 2010-2013. Condom distribution rates are recorded by NAC and presented as condoms distributed per man or woman using 2012 census data [5]. STI incidence is reported as the rate of men or women presenting for the first time with genital discharge or ulceration per 1000 (using census data). Like STI data, PMTCT, VMMC, ART, and VCT data are required to be recorded by clinics and reported to the NAC quarterly, and VMMC and VCT data are presented as rates using 2012 census data.

Statistical Analyses

Original DHS data was analyzed using SAS software, weighting values per DHS protocol to determine HIV prevalence and behavioral data by age. The Mantel-Haenszel chi-square test of proportions with alpha=0.05 was utilized to compare prevalence, behavioral indicator, and programmatic data presented as proportions from one year to the next, and statistically significance differences were defined where $p<0.05$. Mean values calculated from DHS data were compared from the 2005/06 to the 2010/11 surveys using two-sample independent t-tests and an alpha=0.05.

Ethical Considerations

As this analysis used only anonymous secondary data, it was not considered human subject research and Emory IRB approval was not required.

Results

HIV Prevalence

Overall, HIV prevalence has declined among women at ANCs from 32.1% in 2000 to 15.5% in 2012 (Figure 1). DHS surveys show a similar decline, and the MOHCW's Spectrum Software prevalence estimation integrating DHS and ANC data dropped from its peak at 28.9% in 1997 to 15.0% in 2013. Although earlier ANC data suggests a higher prevalence among women at rural ANC sites than at urban sites, DHS data shows a higher prevalence among women living in urban areas (19.6% among urban women versus 16.8% among rural women in the 2010/11 DHS, relative risk of 1.166, 95% CI 1.052-1.293, p<0.01).

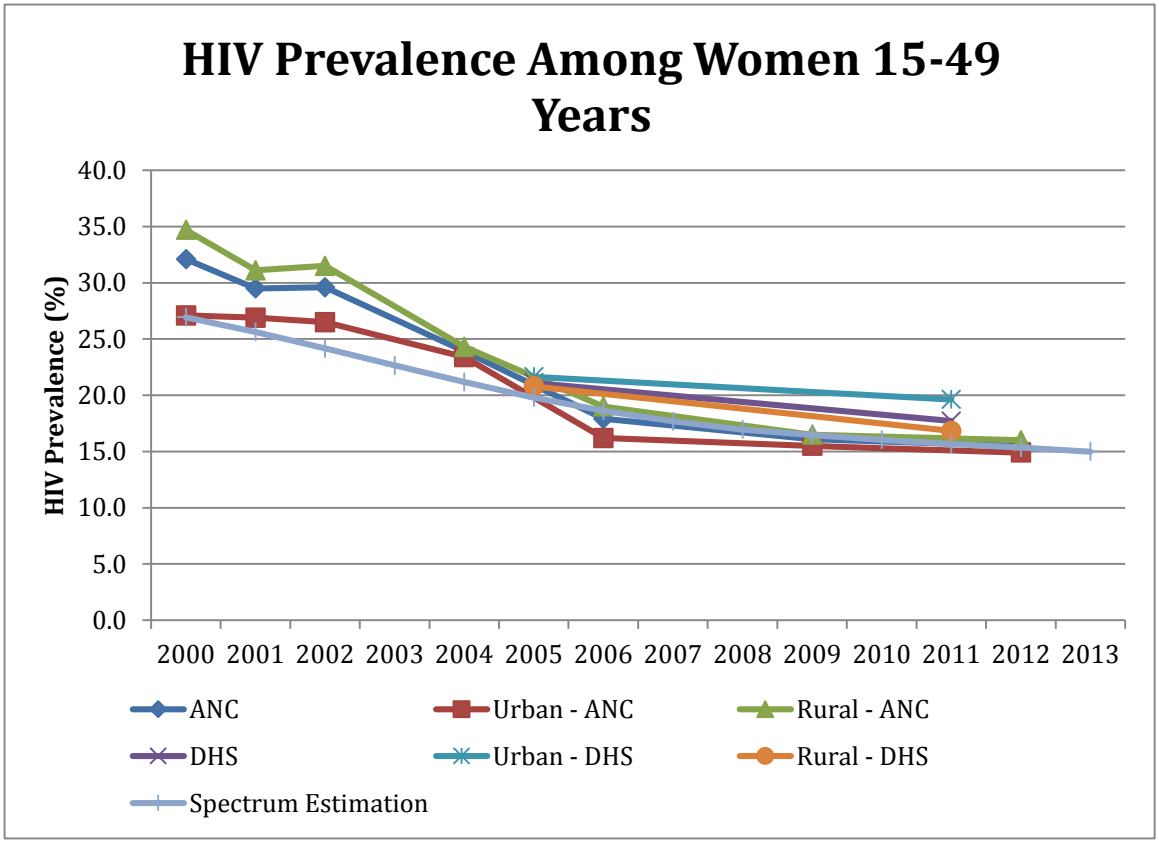
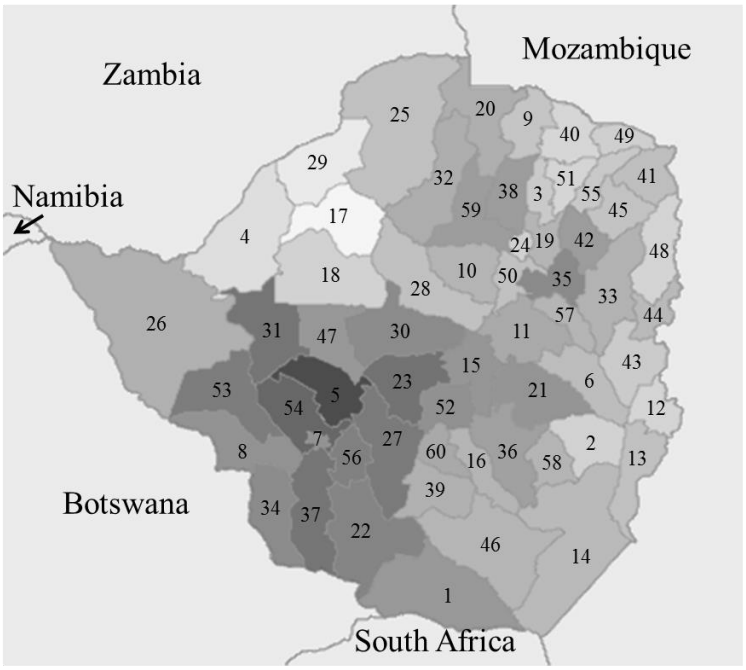


Figure 1. HIV Prevalence among Women 15-49 Years (ANC Surveillance, DHS, and Spectrum Estimations)

Although ANC data suggests that the urban-rural gap is closing, HIV prevalence varies geographically, with higher HIV prevalences among Zimbabwe's southwestern districts (Figure 2). The highest district-level prevalences are in Bubi (27.0%), Umguza (24.2%), and Gweru (23.8%), while the lowest are in Zimbabwe's northwestern districts of Gokwe North (6.5%), Kariba (8.3%), and Binga (10.1%). On the provincial level, Matebeleland South has the highest HIV prevalence at 23.5% in 2012 while Harare has the lowest prevalence at 9.3% that year. Zimbabwe's western provinces, Matebeleland North, Matebeleland South, and Bulawayo, experienced increasing prevalences from 2009 to 2012 while all other provinces saw further decline.



Legend

1. Beitbridge – 18.7%
2. Bikita – 11.8%
3. Bindura – 12.8%
4. Binga – 10.1%
5. Bubi – 27.0%
6. Buhera – 14.3%
7. Bulawayo – 19.4%
8. Bulilima – 19.4%
9. Centenary – 13.3%
10. Chegutu – 15.2%
11. Chikomba – 16.5%
12. Chimanimani – 11.5%
13. Chipinge – 13.8%
14. Chiredzi – 14.7%
15. Chirumhanzu – 19.0%
16. Chivi – 15.2%
17. Gokwe North – 6.5%
18. Gokwe South – 11.8%
19. Goromonzi – 15.2%
20. Guruve – 16.0%
21. Gutu – 19.2%
22. Gwanda – 21.2%
23. Gweru – 23.1%
24. Harare – 11.9%
25. Hurungwe – 13.8%
26. Hwange – 15.7%
27. Insiza – 22.3%
28. Kadoma – 13.9%
29. Kariba – 8.3%
30. Kwekwe – 20.3%
31. Lupane – 22.8%
32. Makonde – 16.1%
33. Makoni – 15.5%
34. Mangwe – 20.3%
35. Marondera – 20.4%
36. Masvingo – 17.7%
37. Matobo – 22.8%
38. Mazowe – 18.2%
39. Mberengwa – 15.7%
40. Mount Darwin – 11.3%
41. Mudzi – 14.1%
42. Murehwa – 18.2%
43. Mutare – 12.7%
44. Mutasa – 14.7%
45. Mutoko – 13.6%
46. Mwenezi – 15.1%
47. Nkayi – 18.8%
48. Nyanga – 11.6%
49. Rushinga – 12.2%
50. Seke – 13.9%
51. Shamva – 11.5%
52. Shurugwi – 19.7%
53. Thsolothso – 22.0%
54. Umguza – 24.2%
55. UMP – 12.9%
56. Umzingwane – 21.6%
57. Wedza – 15.2%
58. Zaka – 16.0%
59. Zvimba – 18.1%
60. Zvishavane – 16.7%

Figure 2. HIV Prevalence by District in 2013 (ANC Surveillance)

Data from ANCs (Figure 3) show that HIV prevalence is declining mostly among women under 30 years old. This trend may suggest a decline in incidence among younger women. Among women aged 40-49 years, however, HIV prevalence increased 18.4% in 2006 to 22.7% in 2012 at ANC sites, with a corresponding increase seen in DHS data among women aged 45-49 years. Bulawayo stands out for a relatively high prevalence among women aged 15-19 years at 8.2% in 2012 versus the national average of 5.4%.

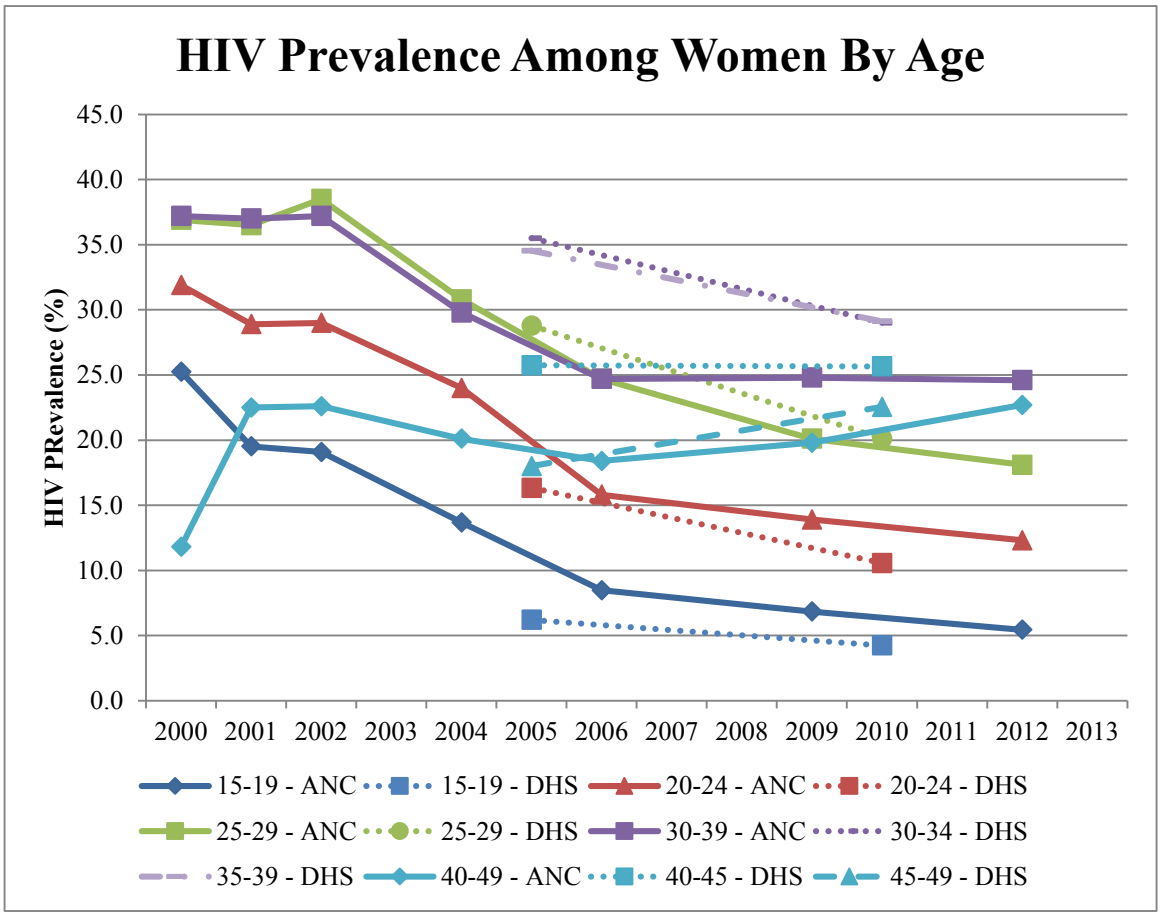


Figure 3. HIV Prevalence among Women by Age (ANC Surveillance and DHS)

When grouping women by birth year to create synthetic age cohorts, the prevalence declines as well (Figure 4). Women born between 1981 and 1985 saw a great drop in prevalence from 25.3% in 2000 (when they were aged 15-19 years) to 16.3% in 2005 (when they were aged

20-24 years); however, HIV prevalence then increases for that cohort, ending at 20.1% in 2010 (when they were aged 25-29 years), $p<0.01$. The second synthetic cohort, those born between 1976 and 1980, had a drop in prevalence from 31.9% in 2000 to 28.8% in 2005, then a very small increase to 29.0% in 2010. The final group, women born between 1971 and 1975, saw a decline in prevalence from 36.9% in 2000 to 35.5% in 2005, ending at 29.1% in 2010. Overall, although not all differences were statistically significant, according to DHS data, the prevalence increased within the younger cohort of women born between 1981 and 1985 from 2005/06 to 2010/11, and decreased within the older cohort of women born between 1971 and 1975 in this time.

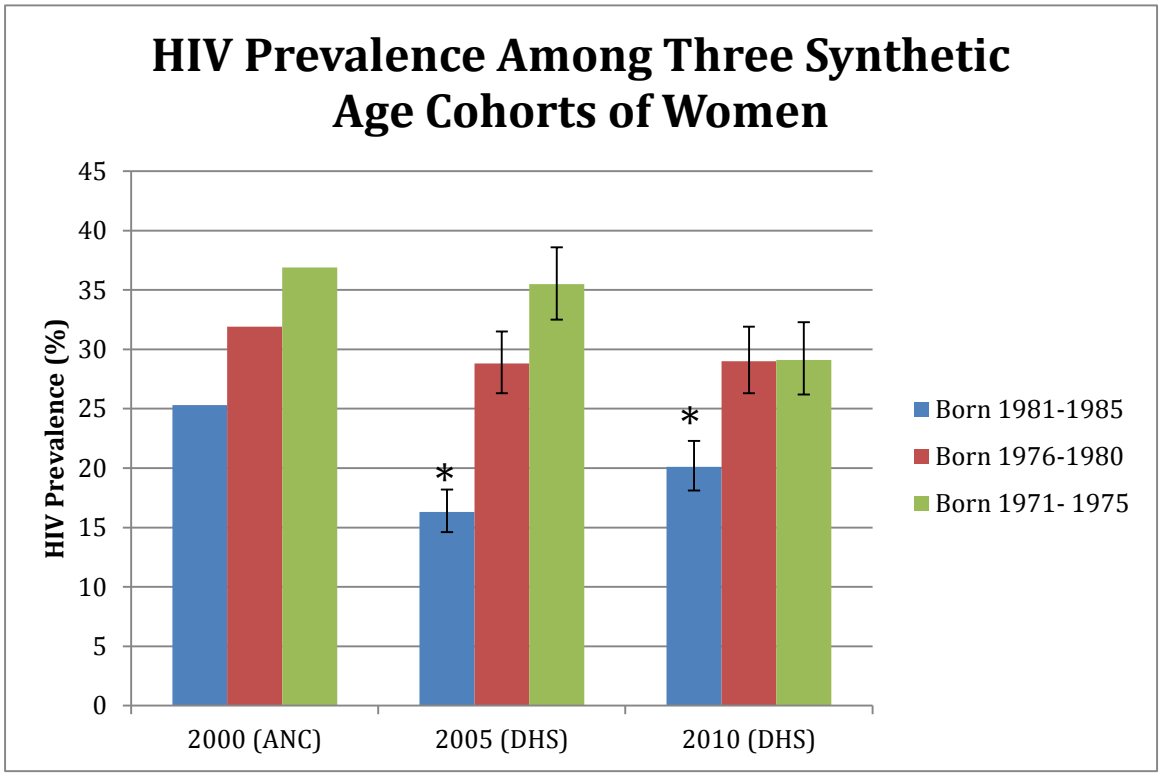


Figure 4. HIV Prevalence among Three Synthetic Age Cohorts of Women (ANC Surveillance and DHS)[2]

[2] In this graph, Group 1 contains women who were aged 15-19 years in 2000, 20-24 years in 2005, and 25-29 years in 2010. Group 2 includes women who were aged 20-24 years in 2000, 25-29 years in 2005, and 30-34 years in 2010. Group 3 consists of women aged 24-29 years in

Behavioral Indicators

National behavioral indicators from the 2005/06 and 2010/11 DHS surveys are shown in Table 1, and provincial level data can be found in Appendices 1 and 2. Nationally, comprehensive knowledge about HIV/AIDS has increased among both men and women from the 2005/06 to 2010/11 DHS ($p<0.001$), ending with 53.0% of men and 55.9% of women able to answer questions correctly regarding HIV prevention, treatment, and perception. On the provincial level, Matebeleland North, Matebeleland South, and Mashonaland East saw declines of comprehensive knowledge among men ($p<0.01$), with Matebeleland North having the lowest percentage of men with comprehensive knowledge at 24.1%. The highest levels of comprehensive knowledge among men are in Bulawayo and Mashonaland West at greater than 60%. Among women, only Matebeleland North had a drop in comprehensive knowledge levels from 41.1% to 36.7% ($p<0.01$), the lowest proportions in Zimbabwe.

Additionally, there was a significant increase in the proportion of men and women reporting using a condom during their last sexual encounter ($p<0.01$), with the highest levels of reported condom use seen in Matabeleland South and Bulawayo, ending at 26.4% and 27.3% among men and 14.5% and 20.5% among women, respectively. National self-reported STI rates among those who have ever had sex did not change significantly between the two surveys, from 7.5% in 2005/06 to 6.9% in 2010/11 among men ($p=0.23$) and from 10.0% to 10.6% among women ($p=0.23$). On the provincial level, STI rates increased significantly in men in Midlands and Matebeleland North, from 6.3% to 11.2% in Midlands and 3.7% to 15.5% in Matebeleland

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2000, 30-24 years in 2005, and 35-39 years in 2010. * indicates the statistically significant increase among women aged 20-24 years in 2005/06 (16.3%, 95% CI 14.6-18.2%) when compared to those aged 25-29 years in 2010/11 (20.1%, 95% CI 18.1-22.3%), $p<0.01$.

North ($p<0.01$), and among women in Matebeleland South and Mashonaland West, from 7.2% to 15.5% in Matebeleland South and 10.1% to 14.8% in Mashonaland West ($p<0.01$).

The proportion of men having two or more partners in the last year increased from 9.0% to 10.5% from 2005/06 to 2010/11 ($p<0.05$). The greatest jumps were seen among men in Matebeleland South from 1.3% to 10.2% and in Mashonaland East from 2.5% to 9.0% ($p<0.001$) Matebeleland South also has the highest proportion of women with two or more partners at 3.0%, nearly double the rate of the next highest province. The percentage of individuals ever tested for HIV more than doubled across the two surveys ($p<001$), increasing in all provinces and ending at 38.3% of men and 59.7% of women. Nationally, the proportion of men paying for sex in the last year did not change significantly from 2.6% in 2005/06 to 3.1% in 2010/10 ($p=0.09$), with the highest proportions in Harare (5.0%) and Manicaland (3.8%). With no clear geographic disparity, the proportion of surveyed men who reported being circumcised dropped from 10.3% to 9.1% ($p<0.05$). The mean number of lifetime partners among women who have had sex increased from 1.6 to 2.2 ($p<0.001$), with the highest means among women in Mashonaland West (3.8) and Matebeleland South (3.2). There was no significant change in the number of lifetime partners among men nationally, with only a significant increase seen in Midlands (from 4.8 to 6.2, $p<0.01$).

	Men			Women		
	2005/06	**2010/11**	**p-value**	**2005/06**	**2010/11**	**p-value**
Comprehensive Knowledge of HIV/AIDS	46.5%	53.0%	<0.001	43.4%	55.9%	<0.001
Used Condom During Most Recent Sex	16.2%	18.1%	0.002	5.5%	9.8%	<0.001
Had Genital Discharge, Ulcer, Sore, or STI in Last Year	7.5%	6.9%	0.23	10.6%	10.0%	0.23
Had Two or More Partners in Last Year	9.0%	10.5%	0.003	0.9%	1.1%	0.13
Ever Tested for HIV	18.6%	38.3%	<0.001	25.8%	59.7%	<0.001
Paid for Sex in Last Year	2.6%	3.1%	0.09	-	-	-
Circumcised	10.3%	9.1%	0.01	-	-	-
Mean Number of Lifetime Partners	5.5	5.8	0.12	1.6	2.2	<0.001

Table 1. Behavioral Indicators from the 2005/06 and 2010/11 DHS Surveys (DHS)

Voluntary Testing and Counseling

Nationally, 162.8 per 1,000 women and 141.7 per 1,000 men were tested for HIV in 2013, compared to 56.1 per 1,000 women and 45.6 per 1,000 men in 2008, statistically significant increases among both populations ($p<0.001$) (Figures 5 and 6). The increase can be seen in nearly all age groups except for a decline seen from 2012 to 2013 among men and women less than 15 years of age where rates dropped from 31.4 to 12.1 males per 1000 ($p<0.05$) and from 35.1 to 9.2 females per 1000 ($p<0.001$). Adults aged 25-29 years had the highest national testing rate at 222.3 per 1,000 men and women. No significant difference in testing rates was found between men and women in 2013. Testing rates are the lowest in Midlands (ending at 46.4 per 1,000 men and 97.9 per 1,000 women 15 years and older in 2013) and the highest in Bulawayo (at 186.8 per 1,000 men and 192.4 per 1,000 women in 2013).

As part of the PMTCT program, the number of pregnant women tested for HIV increased from 140,428 in 2007 to 381,859 in 2013 and the number of male partners also tested rose nearly tenfold from 7,831 in 2007 to 70,961 in 2013.

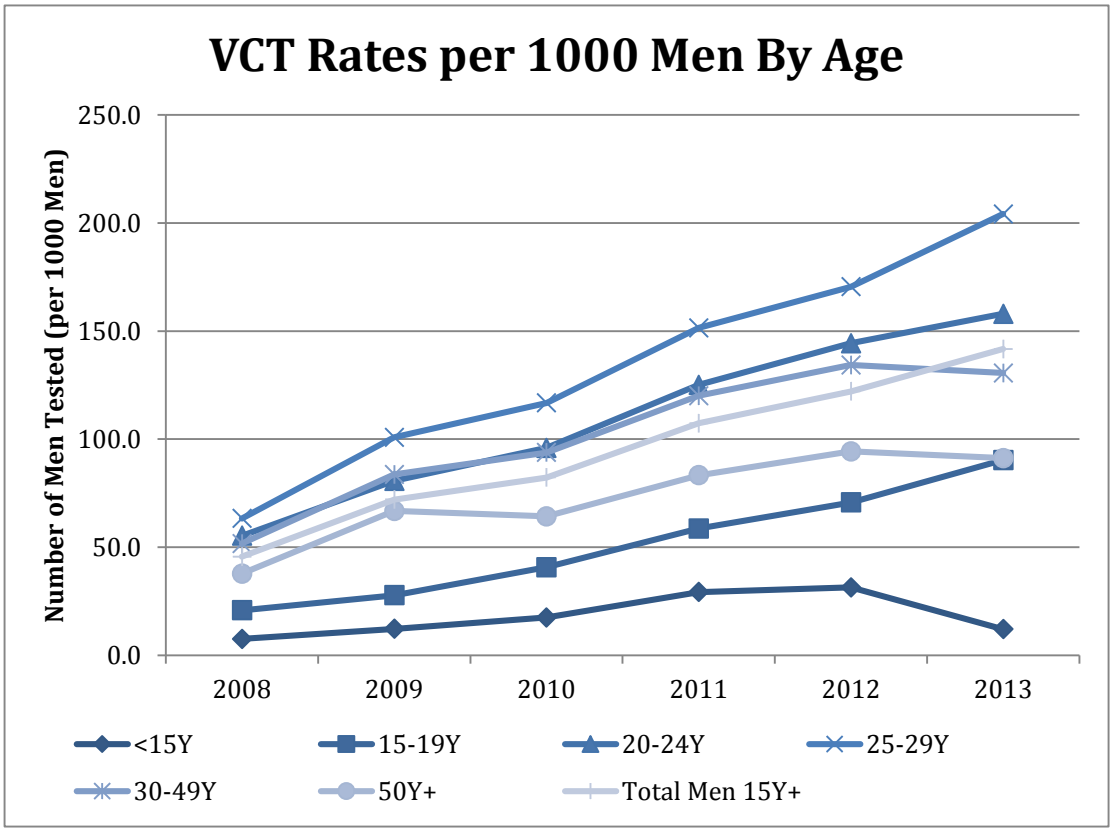


Figure 5. Voluntary Counseling and Testing Rates per 1000 Men by Age (NAC Data)

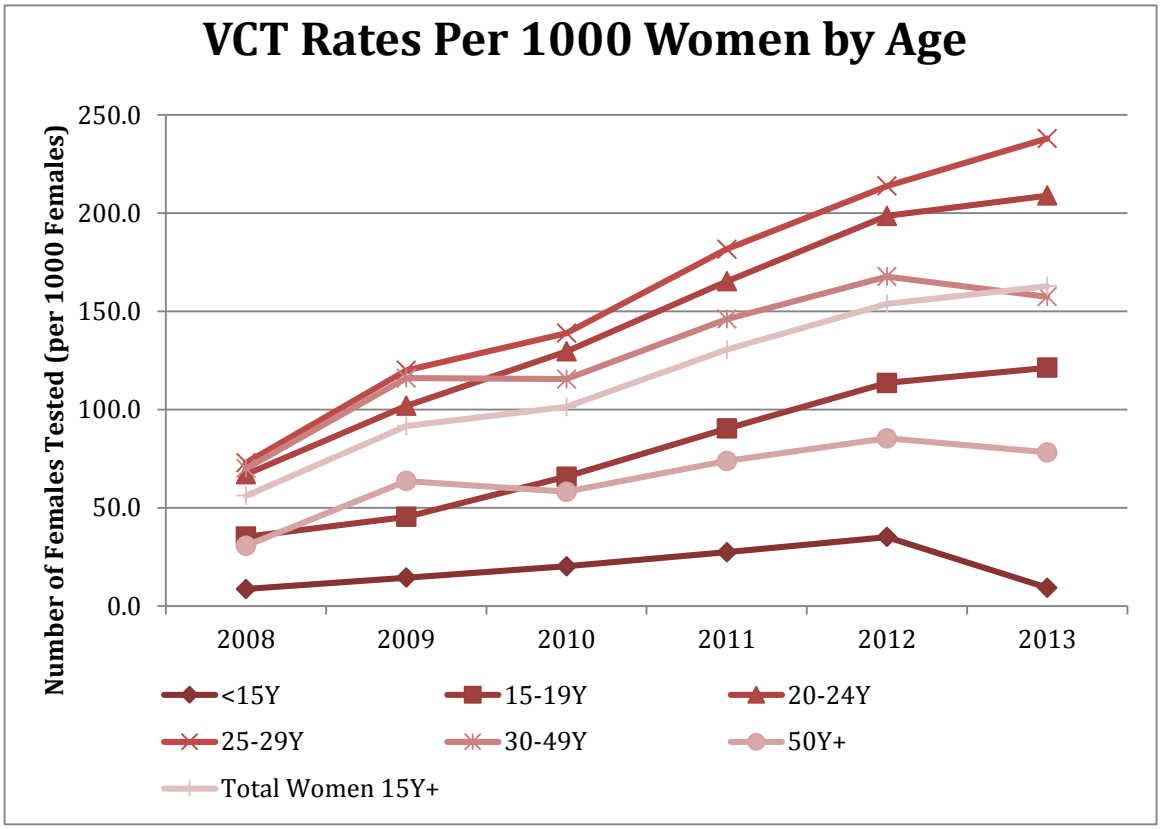


Figure 6. Voluntary Counseling and Testing Rates per 1000 Women (NAC Data)

Condom Distribution and STI Rates

There has been a very big (350%) increase in the number of condoms distributed per man per year, from 4.3 to 14.9 nationally from 2008 to 2013 (Figure 7). The number of female condoms distributed per woman per year, however, remains much lower, only increasing from 0.4 condoms per woman in 2008 to 1.0 in 2013. Male condom distribution rates are highest in Mashonaland Central, with 26.4 male condoms distributed per man in 2013, and lowest in Harare, with just 5.7 male condoms distributed per man in 2013.

Overall, the number of new STIs among men reported to the NAC per year has increased very little from 30.0 per 1,000 men in 2008 to 36.0 per 1,000 men in 2013, with slight fluctuation over the years (Figure 7). Among women, reported STI rates increased from 43.6 to 51.9 per

1000 women from 2008 to 2013. Both increases are statistically significant with p<0.001. Matebeleland South and Masvingo have the highest STI incidence at over 50 new STIs diagnosed per 1,000 men and greater than 60 per 1000 women in 2013.

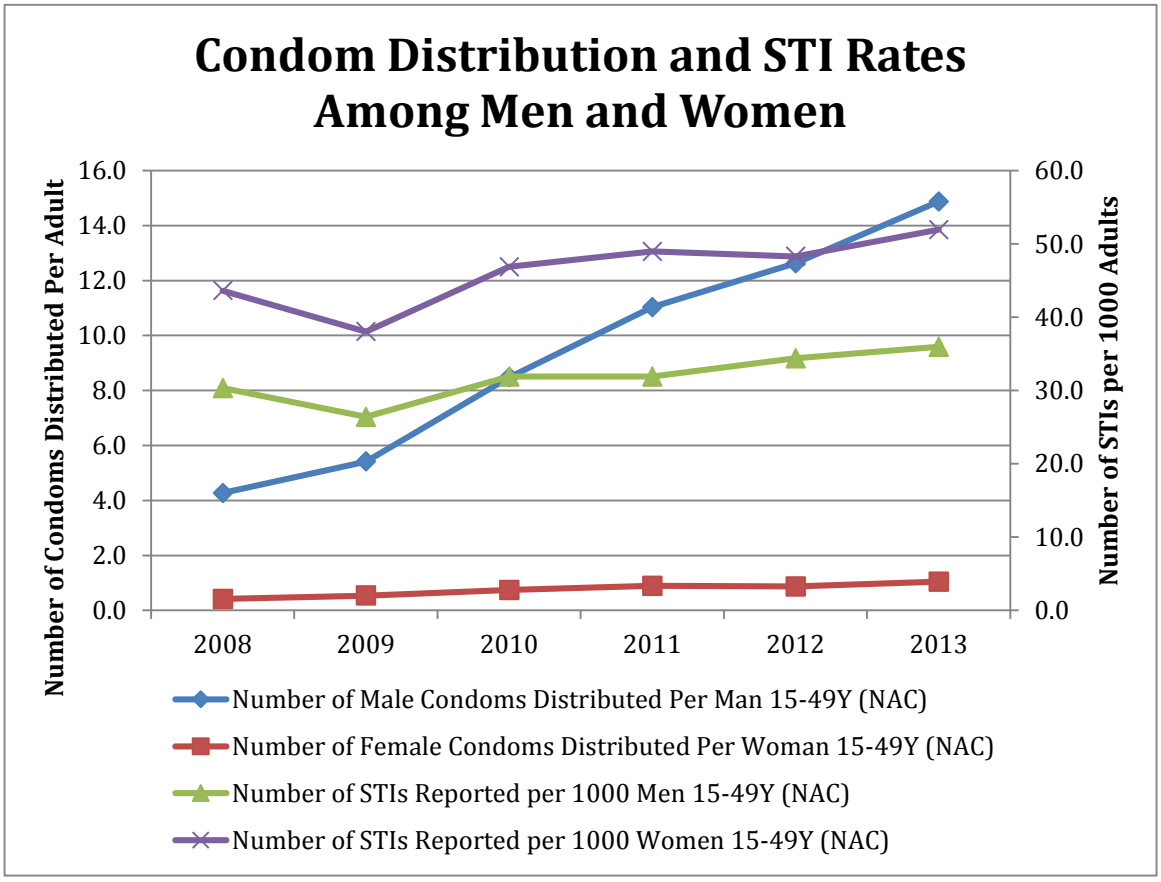


Figure 7. Condom Distribution and STI Rates among Men and Women (NAC Data)

Voluntary Medical Male Circumcision

VMMC rates have increased greatly since 2010, with higher rates in Zimbabwe's western provinces (Figure 8). Nationally, the number of men aged 15-49 years who were clinically circumcised each year increased more than tenfold, from 1.4 per 1000 men in 2010 to 19.2 per 1000 men in 2013 (p<0.05). Rates are highest among men 15-24 years old and lowest among

those over the age of 50. Bulawayo, Mashonaland West, Matebeleland North, and Matebeleland South had circumcision rates greater than 30.0 per 1,000 men in 2013, with Bulawayo maintaining the highest rates of clinical male circumcision each year (ending at 41.5 per 1,000 men). Lower rates of VMMC are seen in the eastern provinces, where fewer than 15.0 per 1,000 men underwent clinical circumcision in 2013.

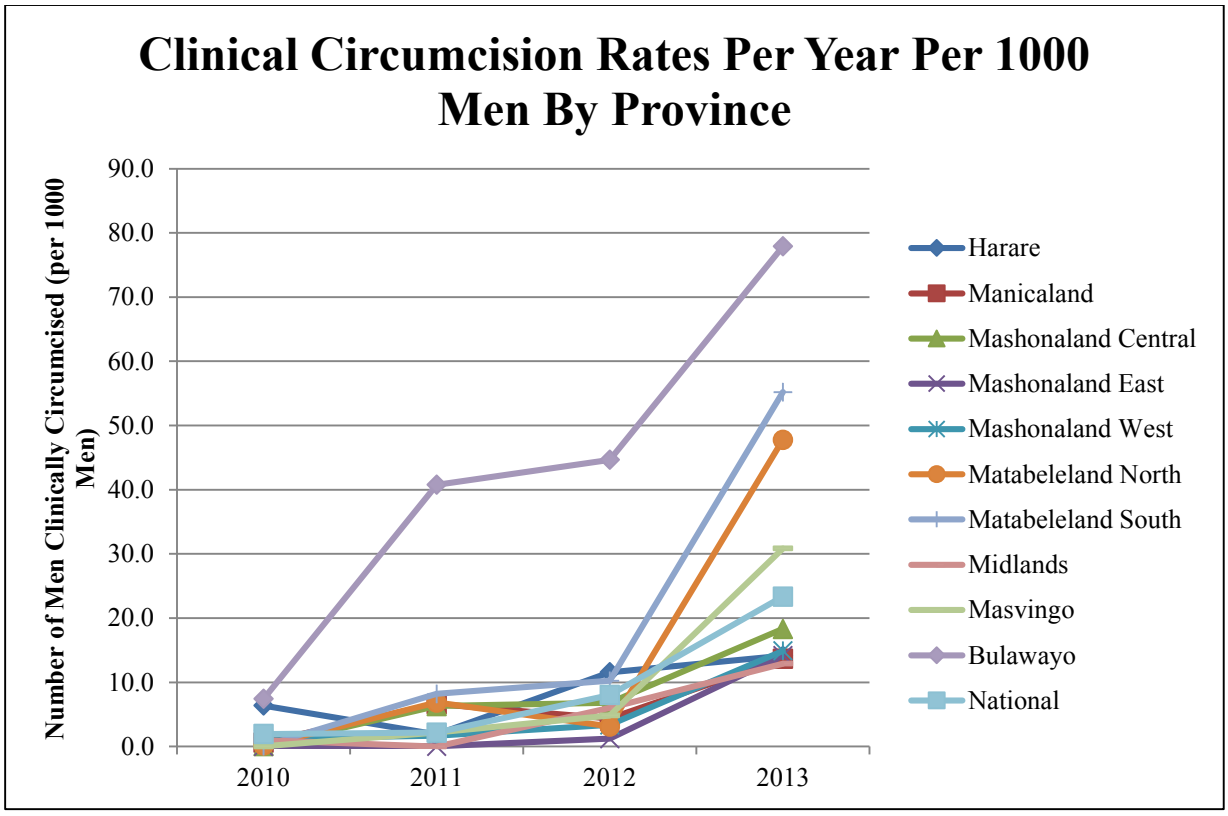


Figure 8. Clinical Circumcision Rates per Year per 1000 Men by Province (MOHCW)

ART and PMTCT

Using estimations of the number of persons in need of ART and data regarding the number of individuals and pregnant women on ART, ART coverage was estimated. Data from Zimbabwe's 2014 Global AIDS Response Country Progress Report were utilized for comparison as well (labeled "NAC 2014" in Figure 9 below) [10]. As Zimbabwe adopted the WHO's new

recommendations for ART initiation at the end of 2013 (expanding coverage to treat all HIV positive individuals with a CD4+ count of less than 500 where previous guidelines only initiated treatment at CD4+ counts below 350), the number of individuals requiring ART increased, affecting the calculation of ART coverage. Therefore, the trend in ART coverage over the last few years cannot be taken with too much weight. Among pregnant women and children living with HIV/AIDS in 2013, ART coverage is even lower, ending at 51.5% and 46.1%, respectively.

The number of HIV-exposed infants dispensed with ART increased greatly from 18,354 in 2007 to 54,469 in 2013, with a reduction in HIV prevalence among these infants from 14.1% in 2011 to 9.4% in 2013. Masvingo has the highest HIV prevalence among exposed infants at 12.0% in 2013.

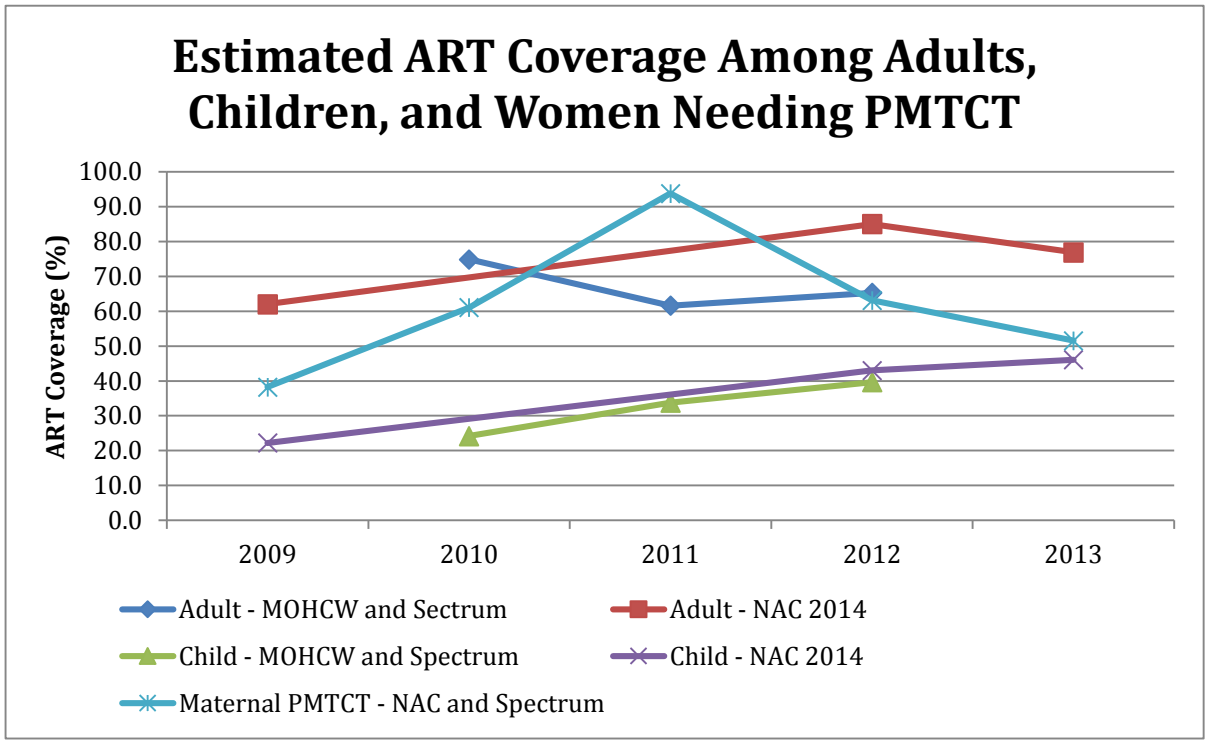


Figure 9. Estimated ART Coverage among Adults, Children, and Women Needing PMTCT (MOHCW, NAC, and Spectrum)

AIDS-Related Mortality

With the addition of ART, estimated AIDS-related mortality has declined over the last few years (Figure 10). Spectrum estimations showed a drop by twenty percent in four years from just over 80,000 in 2009 to nearly 64,000 in 2013, while the decline was more dramatic in Zimbabwe's NAC 2014 Global AIDS Response Progress Report, dropping 47% in two years from near 115,000 in 2010 to roughly 61,000 in 2012 [10].

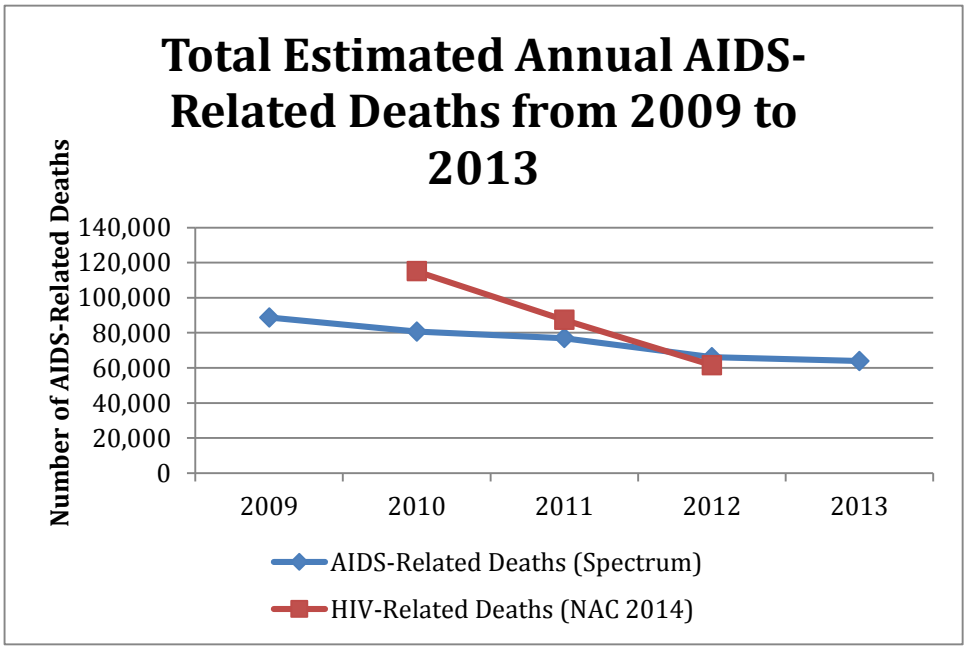


Figure 10. Total Estimated Annual AIDS-Related Deaths from 2009 to 2013 (Spectrum and NAC 2014)

Discussion

Although there are still geographic pockets of higher HIV prevalences, as shown across ANC sentinel surveillance and DHS population-based screening, Zimbabwe's HIV prevalence is declining. Given Zimbabwe's primarily heterosexually-transmitted epidemic [1], the great drop in prevalence seen among women 15-19 years old from 25.3% in 2000 to 5.4% in 2012 seen in

ANC surveillance data and corroborated by DHS data can serve as a proxy for a declining incidence, as this subpopulation most likely represents recent transmissions [11-15]. Numerous studies have attributed Zimbabwe's success against HIV to behavior change, yet, this study fails to demonstrate that the well-documented overall decline in risky behaviors seen from 1999 to 2005 continued from 2005 to 2011 [11, 16-18].

Of note, when examining the trends in the synthetic cohorts as in Figure 4, although not all differences were statistically significant, according to DHS data, the prevalence increased within the younger cohort of women born between 1981 and 1985 from 2005/06 to 2010/11, and decreased within the older cohort of women born between 1971 and 1975 in this time. The increase in prevalence seen in the younger cohort may pertain to increased sexual activity as this cohort ages while the decline in prevalence in the older cohort could be due to excess mortality in this group as the risk of AIDS-related mortality increases the longer one is infected with HIV. This analysis highlights the need for additional cohort studies in Zimbabwe examining HIV incidence to identify the ages at which seroconversion risks are greatest, allowing policy-makers to target specific age groups in prevention and diagnosis campaigns.

Regarding behavioral indicators, nationally, from the 2005/06 to 2010/11 DHS, comprehensive knowledge among both men and women has increased, although not throughout the country. Zimbabwe's western Matebeleland provinces and northeastern Mashonaland East province saw drops in comprehensive knowledge among men, with the level in Matebeleland North half that of the national average. On the other hand, self-reported condom usage during most recent sex increased among both men and women with the highest levels seen in Zimbabwe's western provinces and fewer men report paying for sex in the last year. However, the mean number of lifetime partners increased among women and the number of men reporting

two or more partners in the last year increased, particularly in the central and western provinces where HIV prevalence is highest. The number of partnerships may be on the rise, contradicting findings from the early 2000s and putting the nation's HIV epidemic on edge.

Although HIV prevalence is expected to decline as the infection spreads to populations with lower risk and the death toll creeps up due to the natural course of HIV epidemics, multiple models and reviews suggest that, historically, the decline in Zimbabwe's epidemic has been greatly influenced by these reductions in risky behaviors [11, 16-18]. When compared to other nations across southern Africa, Halperin et al. noted that Zimbabwe stands out among its neighbors for its relatively high levels of secondary education and marriage, improving comprehensive knowledge regarding HIV/AIDS and providing a social structure in which the population could more easily follow the "be faithful" to one's partner messaging prevalent in national campaigns [18]. Furthermore, Zimbabwe's quick adoption of home-based care for those with AIDS likely increased personal exposure to AIDS-mortality, contributing to the rapid behavior change seen at the turn of the century [18]. Muchini et al. found this theme of risky behavior reduction following close exposure to AIDS in their qualitative study consistent of focus group discussions and key informant interviews repeatedly, crediting it as the primary force behind Zimbabwe's success [19]. Additionally, many participants of these focus groups also cited poverty due to the recent economic crisis as a contributing factor to the reduction of partners, as well as the increase in accessible prevention programs [19]. As the economy recovers and AIDS-related mortality declines, perhaps the effect of the early 2000s context of high exposure to AIDS in the setting of an economy collapse has lessened, particularly in Zimbabwe's western provinces.

Aside from the mixed changes in risky behaviors observed in this study, programmatic interventions likely contributed to the decline in Zimbabwe's HIV incidence, as risks of transmission were reduced. For example, VCT can affect incidence through reducing risky behaviors among those who test positive, or, inversely, increasing them among those who test negative [20]. Some hypothesize that counseling will reduce risky behaviors [21], but data has shown minimal reductions of HIV or STD incidence among individuals who undergo VCT [21-23]. As shown in numerous studies and meta-analyses across Africa, VCT appears to have the biggest impact on the reduction of risky sexual behaviors among those who test positive and in discordant couples [20, 24-27], yet VCT does open the gate for those who test positive to be started on ART, reducing transmission rates as viral loads decline. Overall, VCT increased greatly in Zimbabwe from 2008 to 2013 per MOHCW data, and DHS self-reported testing rates corroborate this trend.

Although VCT rates among men and women do not differ significantly, at ANC's, nearly 3.4 women were tested per every male partner tested in 2013, leaving much room for improvement. As women are offered testing at these sites as part of their antenatal care, many of their male partners would need to join their partner on a visit or voluntarily go at another point, adding an extra obstacle to testing. Furthermore, if a pregnant woman tests negative, her male partner might be less inclined to get tested. An analysis of the 2005/06 DHS showed that among men and women who have ever been tested for HIV, the main means by which women were tested was to accept testing when offered (like at a healthcare facility) while men more commonly underwent voluntary testing [28]. As the 2010/11 DHS did not ask this same question, further research would need to be done to determine if the same holds true now.

Regarding the drop in testing rates among those under the age of fifteen from 2012 to 2013, there is no clear explanation. Zimbabwe requires parental consent for children to undergo HIV testing, and legislation on this topic did not change between 2012 and 2013. Likely, VCT programs targeting this population were scaled-back to focus on adult populations who can consent to testing on their own. Within clinics, parental consent to testing for minors continues to be a barrier, as a study by Kranzer et al. observed that the most common reason children and adolescents were not offered testing at a clinic were the healthcare worker's belief that the accompanying guardian was not appropriate to provide consent (for example a grandmother rather than a mother) [29]. Likely, in response to the parental consent issue, VCT programs targeting this population were scaled-back to focus on adult populations who can consent to testing on their own in this time frame.

VMMC reduces the risk of female-to-male HIV transmission by nearly 60% [30-33], and as it becomes more commonly practiced in Zimbabwe, we expect to see further declines in HIV prevalence. Simulations of the potential benefits of VMMC on Zimbabwe's epidemic done by Hallett et al. show that as male circumcision rates increase, the first to benefit are those men undergoing circumcision. As incidence drops in this population, their female partners are at a lower risk of being infected from them, so HIV incidence drops among women. Finally, HIV incidence would decline in all men, as fewer women are infected. Ultimately, the authors believe that the benefit of male circumcision is greater than the documented 60% risk reduction as overall incidence will decline over time, but the beneficial effects of VMMC will take years to have an impact on HIV prevalence [34]. Additionally, male-to-female transmission risks may be reduced by VMMC, as a meta-analysis of the observational studies by Baeton et al. across Africa and Gray et al. in Uganda done by Hallett et al. showed a 46% reduction in male-to-female HIV

transmission two years after the male partner undergoes circumcision (hazard rate 0.54, 95% CI 0.31-0.96, p=0.04) [35-37]. Although a minority of ethnic groups in Zimbabwe traditionally practices male circumcision [38], great strides have been made in improving access to and acceptability of VMMC since 2009, with increased uptake within the nation's western provinces; however, the effects of VMMC on Zimbabwe's HIV prevalence have likely been minimal over the last decade, as VMMC was only promoted recently and the effects of male circumcision on both female-to-male and male-to-female transmission on HIV prevalence would not yet be clear.

Theoretically, the treatment of PLHIV with ART should increase HIV prevalence as it increases survival of those already infected, yet effective counseling and viral load suppression can negate this effect through reducing the risk of HIV transmission to non-infected partner [39]. Numerous studies have shown that viral load is the primary factor determining heterosexual transmission of HIV [40-43], and that viral load suppression achieved with ART can effectively reduce HIV transmission through heterosexual intercourse [43-45]. However, as ART access continues to be an issue in Zimbabwe, the full effects of ART on the nation's HIV incidence and prevalence are unknown. Although ART coverage has increased since 2009, retention in care continues to be an issue. In a recent study done by Mutasa-Apollo et al. following adults initiated on ART between 2007 and 2009, only 66.9% of women and 59.7% of men initiated on ART remain on it at the same site three years later [46], aligning with other estimates across sub-Saharan Africa [47]. In this study, nearly a quarter of those not retained on therapy at 36 months had died; most within the first six months of beginning treatment. The authors suggested three primary factors associated with increased attrition: male sex, initiated on ART at a high-level facility (such as a hospital), low body weight, and WHO stage IV at initiation [46].

Last, although DHS data indicates that condom usage has increased, the national rate of self-reported STIs remains unchanged while STIs reported by clinics have increased. Only in Matebeleland South are high STI incidence rates seen across both datasets; therefore we cannot draw conclusions relating the increase in condom distribution rates to the reduction in HIV transmission.

Examining the data presented, it appears that Zimbabwe's western provinces are at risk of an HIV resurgence. With higher prevalences already, the increase in the number of partners, higher STI incidences, and decreased levels of comprehensive knowledge set the stage for increased HIV transmission. Although condom distribution, self-reported condom use, and VMMC rates are higher in these provinces, without an understanding of the means of HIV transmission, the epidemic could further take hold in this region. As these provinces are primarily comprised of the Ndebele population whereas Zimbabwe is a majority Shona, social and cultural differences may be at play. Historically, the Ndebele and the Shona have been in conflict, and tensions between the groups culminated in the Matebeleland Massacres in the mid-1980s following political unrest within the western provinces after the election of Robert Mugabe, a Shona. Furthermore, when reviewing DHS data, Matebeleland North stands out for its low literacy rates (83.5% and 87.9% among men and women, respectively, compared to the national averages of 95.9% and 93.8%) and having the highest rates of unemployment (with only 42.6% of men having employment in the last year versus 68.9% nationally), polygyny (with 6.8% of men having two or more wives versus the national average of 4.5%), and teen pregnancy (as 31.1% of women aged 15-19 years have begun childbearing) [7]. Given the precipice the western provinces may be approaching in their war with HIV, national policy and programs need to address the social and health disparities here to prevent a tragic increase in HIV in this region.

Several limitations might affect this study. ANC surveillance data was used as the primary prevalence data, which is not generalizable to the entire population. As 90% of pregnant women in Zimbabwe went to ANC's during their most recent pregnancy and 59% of women who were pregnant in the last two years received counseling, testing, and test results during an ANC visit, ANC surveillance data is fairly representative of the HIV prevalence among pregnant women [7]. However, it is less representative of HIV positive women, as they may have reduced fertility, women using contraception, and those residing in rural areas, and even less generalizable to men [48]. Thus, ANC data likely underestimate Zimbabwe's HIV prevalence in the general population. On the other hand, DHS data are subject to non-response bias, as those who know their status are more likely to refuse testing in population-based surveys [49]. For the 2005/06 and 2010/11 DHS, 15% and 12% of individuals selected for testing refused, respectively. However, Mapeta et al. showed that the exclusion of those who refused testing and who were not home for testing had negligible effects on the 2005/06 survey's prevalence values [50]. Additionally, behavioral indicator data are at risk for social desirability bias. In a study by Minnis et al. on discrepancies between self-reported abstinence and condom-use and the presence of semen biomarkers in vaginal fluids among women in Zimbabwe, the authors found that among women who had detectable levels of semen biomarkers, 12% reported no recent vaginal sex and 36% reported using a consistently using a condom during sex over the last two days [51]. Studies across Kenya [52], Madagascar [53], and the United States [54] have shown similar discrepancies, putting into question the reliability of self-reported behavioral indicators. Furthermore, existing data gaps limit this study, such as the lack of data on certain vulnerable populations (men who have sex with men, sex workers, and intravenous drug-users), trends in

STI prevalence, and HIV prevalence data at hot spots (mines, border crossings, commercial farms, etc.).

Overall, Zimbabwe has made incredible progress in its fight against HIV. Through its scale up of prevention efforts, testing, and treatment, the nation has seen a reduction in risky sexual behaviors and increased comprehensive knowledge regarding HIV/AIDS, VMMC rates, condom distribution, testing rates, and ART coverage over the early twenty-first century. With a prevalence of 15.0% and an increase in some risky behaviors concentrated in Zimbabwe's western provinces, however, there is still much room for improvement. Through this data triangulation exercise, the full scope of Zimbabwe's maturing epidemic can be better understood, setting the scene for the nation's future successes against this disease.

Works Cited

1. Fraser N, James V, Milanzi A, Colvin M, Ibbetson H, Mpofu N, et al. Zimbabwe Analysis of HIV Epidemic, Response and Modes of Transmission Harare, Zimbabwe: National AIDS Council; 2011 [cited 2014 8 Sep]. Available from: http://ms-hiv-gdc.org/wp-content/uploads/group-documents/1/1314808832-Zimbabwesynthesisreport.pdf.

2. Global AIDS Response Progress Report 2012 Harare, Zimbabwe: National AIDS Council; 2012 [cited 2014 9 Sep]. Available from: http://www.unaids.org/en/dataanalysis/knowyourresponse/countryprogressreports/2012countries/ce_ZW_Narrative_Report.pdf.

3. Kerina D, Babill S-P, F M. HIV/AIDS: The Zimbabwean Situation and Trends. American Journal of Clinical Medicine Research. 2013;1(1):15-22.

4. Organization WH. Guidelines for second generation HIV surveillance: an update: Know your epidemic. Geneva, Switzerland: World Health Organization, 2013.

5. Zimbabwe Population Census 2012 Harare, Zimbabwe: Zimbabwe National Statistics Agency; 2012 [cited 2014 8 Sep]. Available from: http://www.zimstat.co.zw/dmdocuments/Census/CensusResults2012/National_Report.pdf.

6. Zimbabwe Demographic and Health Survey 2005-06. Harare, Zimbabwe: Central Statistical Office, 2007 Contract No.: 10 Sep.

7. Zimbabwe Demographic and Health Survey 2010-11. Harare, Zimbabwe: Zimbabwe National Statistics Agency (ZIMSTAT), 2012 Contract No.: 8 Sep.

8. Gonese E, Dzangare J, Gregson S, Jonga N, Mugurungi O, Mishra V. Comparison of HIV Prevalence Estimates for Zimbabwe from Antenatal Clinic Surveillance (2006) and the 2005–06 Zimbabwe Demographic and Health Survey. PLoS ONE. 2010;5(11):e13819.

9. Joint United Nations Programme on HA, World Health O. Monitoring the Declaration of Commitment on HIV/AIDS: guidelines on construction of core indicators: 2010 reporting. Geneva: UNAIDS 2009. 2010.

10. Global AIDS Response Country Progress Report Harare, Zimbabwe: National AIDS Council; 2014 [cited 2014 8 Sep]. Available from: http://www.nac.org.zw/sites/default/files/Zimbabwe%20Country%20report2014_0.pdf.

11. Gregson S, Gonese E, Hallett TB, Taruberekera N, Hargrove JW, Lopman B, et al. HIV decline in Zimbabwe due to reductions in risky sex? Evidence from a comprehensive epidemiological review. International Journal of Epidemiology. 2010;39(5):1311-23.

12. Ghys PD, Kufa E, George MV. Measuring trends in prevalence and incidence of HIV infection in countries with generalised epidemics. Sexually Transmitted Infections. 2006;82(suppl 1):i52-i6.

13. Kilian AHD, Gregson S, Ndyanabangi B, Walusaga K, Kipp W, Sahlmüller G, et al. Reductions in risk behaviour provide the most consistent explanation for declining HIV-1 prevalence in Uganda. Aids. 1999;13(3):391-8.

14. Strickler H, Hoover DR, Dersimonian R. Problems in interpreting HIV sentinel seroprevalence studies. Annals of epidemiology. 1995;5(6):447-54.

15. Mertens T, Caraël M, Sato P, Cleland J, Ward H, Smith GD. Prevention indicators for evaluating the progress of national AIDS programmes. Aids. 1994;8(10):1359-70.

16. Gregson S, Garnett GP, Nyamukapa CA, Hallett TB, Lewis JJC, Mason PR, et al. HIV decline associated with behavior change in eastern Zimbabwe. Science. 2006;311(5761):664-6.

17. Hallett TB, Gregson S, Mugurungi O, Gonese E, Garnett GP. Assessing evidence for behaviour change affecting the course of HIV epidemics: A new mathematical modelling approach and application to data from Zimbabwe. Epidemics. 2009;1(2):108-17.

18. Halperin DT, Mugurungi O, Hallett TB, Muchini B, Campbell B, Magure T, et al. A surprising prevention success: why did the HIV epidemic decline in Zimbabwe? PLoS medicine. 2011;8(2):e1000414.

19. Muchini B, Benedikt C, Gregson S, Gomo E, Mate R, Mugurungi O, et al. Local perceptions of the forms, timing and causes of behavior change in response to the AIDS epidemic in Zimbabwe. AIDS and Behavior. 2011;15(2):487-98.

20. Sherr L, Lopman B, Kakowa M, Dube S, Chawira G, Nyamukapa C, et al. Voluntary counselling and testing: uptake, impact on sexual behaviour, and HIV incidence in a rural Zimbabwean cohort. Aids. 2007;21(7):851-60.

21. Kamb ML, Fishbein M, Douglas, Jr JM, et al. Efficacy of risk-reduction counseling to prevent human immunodeficiency virus and sexually transmitted diseases: A randomized controlled trial. JAMA. 1998;280(13):1161-7.

22. Weinhardt LS, Carey MP, Johnson BT, Bickham NL. Effects of HIV counseling and testing on sexual risk behavior: a meta-analytic review of published research, 1985-1997. American journal of public health. 1999;89(9):1397-405.

23. Higgins DL, Galavotti C, O'Reilly KR, Schnell DJ, Moore M, Rugg DL, et al. Evidence for the effects of HIV antibody counseling and testing on risk behaviors. Jama. 1991;266(17):2419-29.

24. Group CaTES. Efficacy of voluntary HIV-1 counselling and testing in individuals and couples in Kenya, Tanzania, and Trinidad: a randomised trial. The Lancet. 2000;356(9224):103-12.

25. Painter TM. Voluntary counseling and testing for couples: a high-leverage intervention for HIV/AIDS prevention in sub-Saharan Africa. Social Science & Medicine. 2001;53(11):1397-411.

26. Allen S, Serufilira A, Bogaerts J, Van de Perre P, Nsengumuremyi F, Lindan C, et al. Confidential HIV testing and condom promotion in Africa: Impact on HIV and gonorrhea rates. Jama. 1992;268(23):3338-43.

27. Allen S, Tice J, Van de Perre P, Serufilira A, Hudes E, Nsengumuremyi F, et al. Effect of serotesting with counselling on condom use and seroconversion among HIV discordant couples in Africa. Bmj. 1992;304(6842):1605-9.

28. Sambisa W, Curtis S, Mishra V. AIDS stigma as an obstacle to uptake of HIV testing: evidence from a Zimbabwean national population-based survey. AIDS care. 2010;22(2):170-86.

29. Kranzer K, Meghji J, Bandason T, Dauya E, Mungofa S, Busza J, et al. Barriers to provider-initiated testing and counselling for children in a high HIV prevalence setting: a mixed methods study. PLoS medicine. 2014;11(5):e1001649.

30. Auvert B, Taljaard D, Lagarde E, Sobngwi-Tambekou J, Sitta R, Puren A. Randomized, controlled intervention trial of male circumcision for reduction of HIV infection risk: the ANRS 1265 Trial. PLoS medicine. 2005;2(11):e298.

31. Gray RH, Kigozi G, Serwadda D, Makumbi F, Watya S, Nalugoda F, et al. Male circumcision for HIV prevention in men in Rakai, Uganda: a randomised trial. The Lancet. 2007;369(9562):657-66.

32. Weiss HA, Quigley MA, Hayes RJ. Male circumcision and risk of HIV infection in sub-Saharan Africa: a systematic review and meta-analysis. Aids. 2000;14(15):2361-70.

33. Weiss HA, Dickson KE, Agot K, Hankins CA. Male circumcision for HIV prevention: current research and programmatic issues. AIDS (London, England). 2010;24(0 4):S61.

34. Hallett TB, Singh K, Smith JA, White RG, Abu-Raddad LJ, Garnett GP. Understanding the impact of male circumcision interventions on the spread of HIV in southern Africa. PLoS One. 2008;3(5):e2212.

35. Hallett TB, Alsallaq RA, Baeten JM, Weiss H, Celum C, Gray R, et al. Will circumcision provide even more protection from HIV to women and men? New estimates of the population impact of circumcision interventions. Sexually transmitted infections. 2010:sti. 2010.043372.

36. Baeten JM, Donnell D, Kapiga SH, Ronald A, John-Stewart G, Inambao M, et al. Male circumcision and risk of male-to-female HIV-1 transmission: a multinational prospective study in African HIV-1 serodiscordant couples. AIDS (London, England). 2010;24(5):737.

37. Gray RH, Kiwanuka N, Quinn TC, Sewankambo NK, Serwadda D, Mangen FW, et al. Male circumcision and HIV acquisition and transmission: cohort studies in Rakai, Uganda. Aids. 2000;14(15):2371-81.

38. Ashengo TA, Hatzold K, Mahler H, Rock A, Kanagat N, Magalona S, et al. Voluntary Medical Male Circumcision (VMMC) in Tanzania and Zimbabwe: Service Delivery Intensity and Modality and Their Influence on the Age of Clients. PLoS ONE. 2014;9(5):e83642.

39. Baggaley RF, Garnett GP, Ferguson NM. Modelling the impact of antiretroviral use in resource-poor settings. PLoS medicine. 2006;3(4):e124.

40. Quinn TC, Wawer MJ, Sewankambo N, Serwadda D, Li C, Wabwire-Mangen F, et al. Viral load and heterosexual transmission of human immunodeficiency virus type 1. New England journal of medicine. 2000;342(13):921-9.

41. Tovanabutra S, Robison V, Wongtrakul J, Sennum S, Suriyanon V, Kingkeow D, et al. Male viral load and heterosexual transmission of HIV-1 subtype E in northern Thailand. Journal of acquired immune deficiency syndromes (1999). 2002;29(3):275-83.

42. Gray RH, Wawer MJ, Brookmeyer R, Sewankambo NK, Serwadda D, Wabwire-Mangen F, et al. Probability of HIV-1 transmission per coital act in monogamous, heterosexual, HIV-1-discordant couples in Rakai, Uganda. The Lancet. 2001;357(9263):1149-53.

43. Attia S, Egger M, Müller M, Zwahlen M, Low N. Sexual transmission of HIV according to viral load and antiretroviral therapy: systematic review and meta-analysis. Aids. 2009;23(11):1397-404.

44. Castilla J, Del Romero J, Hernando V, Marincovich B, García S, Rodríguez C. Effectiveness of highly active antiretroviral therapy in reducing heterosexual transmission of HIV. JAIDS Journal of Acquired Immune Deficiency Syndromes. 2005;40(1):96-101.

45. Cohen MS, Chen YQ, McCauley M, Gamble T, Hosseinipour MC, Kumarasamy N, et al. Prevention of HIV-1 Infection with Early Antiretroviral Therapy. New England Journal of Medicine. 2011;365(6):493-505.

46. Mutasa-Apollo T, Shiraishi RW, Takarinda KC, Dzangare J, Mugurungi O, Murungu J, et al. Patient retention, clinical outcomes and attrition-associated factors of HIV-infected patients enrolled in Zimbabwe's National Antiretroviral Therapy Programme, 2007–2010. PloS one. 2014;9(1):e86305.

47. Fox MP, Rosen S. Patient retention in antiretroviral therapy programs up to three years on treatment in sub- Saharan Africa, 2007–2009: systematic review. Tropical Medicine & International Health. 2010;15(s1):1-15.

48. Montana LS, Mishra V, Hong R. Comparison of HIV prevalence estimates from antenatal care surveillance and population-based surveys in sub-Saharan Africa. Sex Transm Infect. 2008;84 Suppl 1:i78-i84.

49. Reniers G, Eaton J. Refusal bias in HIV prevalence estimates from nationally representative seroprevalence surveys. AIDS (London, England). 2009;23(5):621.

50. Mapeta WT, Macro ICF. An Evaluation of the 2005-06 Zimbabwe Demographic and Health Survey HIV Prevalence Estimates for Potential Bias Due to Non-Response and Exclusion of Non-Household Population: ICF Macro; 2010.

51. Minnis AM, Steiner MJ, Gallo MF, Warner L, Hobbs MM, Van der Straten A, et al. Biomarker validation of reports of recent sexual activity: results of a randomized controlled study in Zimbabwe. American Journal of Epidemiology. 2009;170(7):918-24.

52. Gallo MF, Behets FM, Steiner MJ, Thomsen SC, Ombidi W, Luchters S, et al. Validity of self-reported'safe sex'among female sex workers in Mombasa, Kenya—PSA analysis. International journal of STD & AIDS. 2007;18(1):33-8.

53. Gallo MF, Behets FM, Steiner MJ, Hobbs MM, Hoke TH, Van Damme K, et al. Prostate-specific antigen to ascertain reliability of self-reported coital exposure to semen. Sexually transmitted diseases. 2006;33(8):476-9.

54. Rose E, DiClemente RJ, Wingood GM, Sales JM, Latham TP, Crosby RA, et al. The validity of teens' and young adults' self-reported condom use. Archives of pediatrics & adolescent medicine. 2009;163(1):61-4.

Chapter 3 – Implications and Recommendations

Despite seeing a great reduction in HIV prevalence, Zimbabwe continues to face one of the worst HIV epidemics in the world. This analysis could not fully support the hypothesis that behavior change contributed greatly to the decline in HIV incidence seen in Zimbabwe; although it demonstrated increased condom usage, recent data may indicate an increase in the number of sexual partnerships as well. Incorporating ANC surveillance data through 2013, 2005/06 and 2010/11 DHS data, and programmatic data from Zimbabwe's NAC and MOHCW, this study not only presents new data to the field, but also strengthened collaboration efforts between the CDC, MOHCW, University of Zimbabwe medical school, and USAID stakeholders. As the purpose of this study is to inform policy-makers in their quest to prevent HIV transmission and improve the quality of life of persons living with HIV, recommendations regarding areas where policy reform and further research are needed follow.

Given the economic crisis and mass exodus of healthcare providers in Zimbabwe over the last decade, the nation's healthcare system infrastructure leaves much to be desired. With limited providers and shortages of ART, patients initiated on ART struggle to remain in care, yielding worse clinical outcomes and increased transmission of HIV. To improve access to ART, additional mid-level providers should be trained and emigrated providers should be encouraged to return to Zimbabwe to practice without penalty. Funding earmarked to strengthen the healthcare system should be utilized to minimize user fees for patients to see healthcare providers, as these fees likely reduce access to care for those who need it most. Furthermore, funding should be managed on the district level with national and donor oversight to cater prevention and treatment efforts to the specific issues within districts. ART supply and distribution needs to be monitored more closely to anticipate medication shortages and ensure that those residing in rural areas have consistent access to treatment. Additionally, the

government must improve transparency concerning the distribution of funds received from donor organizations to encourage increases in overall health funding that can be used to tackle Zimbabwe's continuing HIV epidemic.

Regarding adolescents and young adults, school and community-based HIV education should incorporate comprehensive sex education and offer HIV testing on site to students and their families. Currently, minors in Zimbabwe require parental consent for HIV testing, delaying diagnosis and initiation on ART. This law harms HIV-positive minors and should be revoked. Discussions between minors and their guardians regarding testing should be facilitated and testing fairs for students, their families, and their communities should be encouraged. Additionally, there are likely families with children who may have been infected as infants but were never tested, and messaging campaigns to encourage and normalize testing in this special population should be promoted. Furthermore, early testing of children before age five should become the standard to prevent families from facing late diagnoses among children and to link those who test positive into care.

Although the HIV prevalence is lower among Zimbabwe's men than among its women, rates of VCT and comprehensive knowledge are also lower. As men tend to access healthcare less often than women, clinics may not be the most effective site for testing and educating men regarding HIV. Workplace VCT programs could lessen this gender disparity, providing testing, education, and promoting VMMC as an effective means to reduce HIV transmission risks. Regarding VMMC, programs need to focus efforts to increase male circumcision rates in Zimbabwe's eastern provinces where rates are much lower than the national average.

As data was also analyzed on the provincial level, some specific recommendations for provinces follow. As HIV prevalence increased among pregnant women in Mashonaland East

from 2009 to 2012, prevention efforts need to be prioritized in this province. In Mashonaland West, the mean number of lifetime partners increased among women while comprehensive knowledge and testing rates among women remain relatively low. Here, resources should be targeted to increase VCT and educational programs specific to women. Given the relatively low literacy rates and declining comprehensive knowledge in Matebeleland North, educational programs on HIV designed for illiterate individuals should be utilized. In Matebeleland South where the number of men reporting two or more partners in the last year increased greatly, the number of women reporting two or more partners is the highest within the country, and HIV prevalence is relatively high, programs focusing on risk reduction strategies should be increased. Midlands has the lowest VCT rates in Zimbabwe, so VCT accessibility should be assessed and improved. In Bulawayo, where HIV prevalence among women 15-19 years is the highest in the nation, school-based educational and testing programs targeting adolescents and teens could be of benefit. Harare has one of the highest rates of men paying for sex, prevention campaigns should be targeted toward sex workers. Furthermore, with male condom distribution rates nearly a third of the national rate, condom distribution should be increased in this province.

Through performing this analysis, multiple data gaps were recognized. First, hot spots of higher HIV prevalence need to be identified and studied. The quality of some district-level ANC data is poor (see Appendix 3), and prevalence data specific to those living on or near commercial farms, mines, and border crossings could demonstrate a need for focused interventions at these locations. In addition to identifying geographic hot spots, little data exists regarding populations at particularly high risk of acquiring HIV, such as men who have sex with men, sex workers, and intravenous drug users. As previously discussed, Zimbabwe's sociopolitical landscape is not conducive to interventions geared toward these populations as the behaviors that put them at

higher risk of HIV transmission also place them at risk for jail time. Similar to these vulnerable populations, recent available data underrepresent adolescents and both quantitative and qualitative studies examining HIV/AIDS-related behaviors and beliefs in this group could inform projections for the epidemic. Regarding the low ART coverage among children, barrier analyses could assist in retaining HIV-positive children in care, improving outcomes in this vulnerable group.

Concerning behavior change, additional studies of STI incidence could be utilized to assess the effects of social desirability bias further, either corroborating the increased incidence found in the NAC clinic-reporting data or supporting the increase in self-reported condom use seen in the DHS datasets. Additional STI trends have the potential to strengthen or weaken Zimbabwe's behavior change hypothesis, thus STI's should be studied further in the general population, in geographic "hot spots" for HIV transmission, and among special populations. Furthermore, studies utilizing computer-assisted interview or random response survey techniques could be utilized to reduce risks of social desirability bias.

To improve the understanding of behavioral surveys, additional qualitative studies should be performed. Qualitative research provides a context for quantitative data, and as Zimbabwe has faced hyperinflation and political instability since Muchini et al. conducted their study, more recent qualitative data could enhance the interpretation of behavioral data over the last few years.

Ultimately, Zimbabwe will see continued success in battling HIV as the understanding of its unique epidemic is enhanced through additional research and policy and programs adapt to these new findings. Knowledge translation will be of great importance as findings are published, and stakeholders must act to synthesize and apply new ideas to this maturing epidemic to see the greatest reduction in HIV incidence and improvements in quality of life for persons living with

HIV. Despite facing an economic crisis like no other and continued political turmoil, Zimbabwe has proven resilient. No other nation has seen a decline in HIV prevalence like Zimbabwe, and this small African country has the potential to be a model for HIV prevention and treatment in the developing world, if the current trajectory for prevalence continues. As tens of thousands of people continue to die of AIDS in Zimbabwe, the nation's battle against HIV is not yet a victory.

Appendices

Appendix 1. 2005/06 and 2010/11 DHS Behavioral Indicator Data by Province for Men Aged 15-49 Years

Province		Manicaland	Mashonaland Central	Mashonaland East	Mashonaland West	Matebeleland North	Matebeleland South	Midlands	Masvingo	Harare	Bulawayo
Comprehensive Knowledge Regarding HIV/AIDS	2005/06	43.8	46.8	50.5	48.6	39.5	58.5	47.8	43.2	39.5	62.9
	2010/11	58.9	54.4	41.8	63.7	24.1	40.1	50.3	50.4	58.3	61.4
	p-value	<0.001	0.0039	0.0021	<0.001	<0.001	<0.001	0.28	0.0087	<0.001	0.65
Used Condom During Last Sex	2005/06	15.2	17.4	12.2	16.4	15.3	19.5	11.4	14.7	17.4	28.7
	2010/11	17.3	15.6	17.4	16	18.4	26.4	18.1	12.1	19.8	27.3
	p-value	0.23	0.37	0.011	0.80	0.24	0.038	<0.001	0.16	0.11	0.65
Genital Discharge, Ulcer or Sore, or STI in Last Year	2005/06	14.8	8.9	5.3	9.2	3.7	4.4	6.3	8.0	7.1	3.7
	2010/11	8.0	6.5	7.4	1.2	15.5	7.6	11.3	6.9	6.1	4.5
	p-value	<0.001	0.13	0.21	<0.001	<0.001	0.17	0.0026	0.51	0.34	0.63
Two or More Partners in Last Year	2005/06	9.7	11.4	2.5	10.7	9.6	1.3	8.4	12.2	9.8	8.0
	2010/11	12.1	11.5	9.0	8.4	9.4	10.2	10.7	9.7	11.9	9.0
	p-value	0.12	0.93	<0.001	0.12	0.90	<0.001	0.085	0.16	0.086	0.62
Ever Tested for HIV	2005/06	20.5	14.9	17.7	17.0	12.6	9.0	12.2	18.7	26.8	27.6
	2010/11	42.4	38.9	35.7	40.3	40.3	27.4	30.7	34.5	42.4	44.0
	p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mean Number of Lifetime Partners	2005/06	4.5	5.0	5.9	6.7	5.0	5.7	4.8	4.5	6.4	6.4
	2010/11	4.7	5.0	6.3	6.3	6.2	5.9	6.2	4.7	6.5	5.0
	p-value	0.62	0.95	0.56	0.62	0.096	0.89	0.0092	0.79	0.93	0.056
Ever Paid for Sex	2005/06	3.0	3.2	2.4	2.4	3.5	1.7	1.8	3.1	2.9	1.6
	2010/11	3.8	2.6	2.9	2.2	1.6	2.4	3.2	1.9	5.0	1.2
	p-value	0.33	0.46	0.60	0.83	0.10	0.49	0.054	0.18	0.0056	0.58
Circumcised	2005/06	10.5	5.3	13.1	11.2	18.8	11.4	10.6	9.4	7.0	13.3
	2010/11	13.5	5.9	5.4	7.4	13.8	9.6	9.4	8.0	8.5	12.1
	p-value	0.051	0.66	<0.001	<0.001	0.061	0.45	0.40	0.39	0.14	0.60

Appendix 2. 2005/06 and 2010/11 DHS Behavioral Indicator Data by Province for Women Aged 15-49 Years

Province		Manicaland	Mashonaland Central	Mashonaland East	Mashonaland West	Matebeleland North	Matebeleland South	Midlands	Masvingo	Harare	Bulawayo
Comprehensive Knowledge Regarding HIV/AIDS	2005/06	41.4	44.5	40.0	32.9	41.1	33.3	53.3	33.3	43.5	67.9
	2010/11	51.8	54.0	61.5	52.1	36.7	50.7	62.7	50.7	60.6	66.3
	p-value	<0.001	<0.001	<0.001	<0.001	0.0068	<0.001	<0.001	<0.001	<0.001	0.53
Used Condom During Last Sex	2005/06	4.9	4.8	4.2	6.8	5.3	7.7	3.7	3.0	6.4	10.4
	2010/11	10.4	10.0	7.9	8.4	9.7	14.5	6.5	4.9	11.2	20.6
	p-value	<0.001	<0.001	0.0026	0.20	0.0079	0.0011	0.0026	0.028	<0.001	<0.001
Genital Discharge, Ulcer or Sore, or STI in Last Year	2005/06	11.2	12.2	12.9	10.1	6.2	7.2	10.8	14	10.5	4.8
	2010/11	13.4	10.5	7.1	14.8	3.8	15.5	4.9	14.5	8.2	4.6
	p-value	0.17	0.31	0.00043	0.0062	0.12	<0.001	<0.001	0.78	0.058	0.88
Two or More Partners in Last Year	2005/06	0.5	1.3	0.5	1.0	0.2	2.1	0.6	0.6	1.3	0.7
	2010/11	0.8	0.5	0.9	1.4	0.2	3.0	1.0	0.1	1.7	1.4
	p-value	0.36	0.076	0.32	0.41	0.87	0.41	0.25	0.059	0.41	0.21
Ever Tested for HIV	2005/06	31.9	23.1	23.9	27.9	22.9	21.4	18.2	22.8	33.0	27.2
	2010/11	60	61.3	58.9	61.0	61.8	63.4	52.6	57.7	62.2	62.3
	p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mean Number of Lifetime Partners	2005/06	1.4	1.7	1.7	1.8	2.0	2.2	1.6	1.3	1.5	2.0
	2010/11	1.5	1.7	1.7	3.8	2.1	3.2	1.6	1.3	3.1	2.2
	p-value	0.021	1.0	0.98	<0.001	0.71	0.023	0.90	0.23	<0.001	0.18

Appendix 3. NAC Spectrum Software District Prevalence Estimations and Reported Quality of Estimations, 2013[3]

District	Estimated HIV Prevalence Among Women Aged 15-49 Years	Quality of Estimations
Beitbridge	18.7%	Good
Bikita	11.8%	Uncertain
Bindura	12.8%	Good
Binga	10.1%	Moderately good
Bubi	27.0%	Uncertain
Buhera	14.3%	Moderately good
Bulawayo	19.4%	Good
Bulilima (North)	19.4%	Uncertain
Centenary	13.3%	Moderately good
Chegutu	15.2%	Moderately good
Chikomba	16.5%	Moderately good
Chimanimani	11.5%	Uncertain
Chipinge	13.8%	Good
Chiredzi	14.7%	Moderately good
Chirumhanzu	19.0%	Uncertain
Chivi	15.2%	Moderately good
Gokwe North	6.5%	Moderately good
Gokwe South	11.8%	Good
Goromonzi	15.2%	Good
Guruve	16.0%	Moderately good
Gutu	19.2%	Moderately good
Gwanda	21.2%	Good
Gweru	23.1%	Moderately good
Harare	11.9%	Good
Hurungwe	13.8%	Good
Hwange	15.7%	Moderately good
Insiza	22.3%	Moderately good
Kadoma	13.9%	Moderately good
Kariba	8.3%	Uncertain
Kwekwe	20.3%	Good
Lupane	22.8%	Moderately good
Makonde	16.1%	Moderately good
Makoni	15.5%	Moderately good
Mangwe (South)	20.3%	Moderately good
Marondera	20.4%	Moderately good
Masvingo	17.7%	Moderately good

[3] Unpublished data obtained from NAC 2014 HIV estimations project per Vasco Chikwasha. Determination of data quality unknown.

Matobo	22.8%	Moderately good
Mazowe	18.2%	Good
Mberengwa	15.7%	Moderately good
Mount Darwin	11.3%	Moderately good
Mudzi	14.1%	Uncertain
Murehwa	18.2%	Moderately good
Mutare	12.7%	Good
Mutasa	14.7%	Uncertain
Mutoko	13.6%	Uncertain
Mwenezi	15.1%	Moderately good
Nkayi	18.8%	Moderately good
Nyanga	11.6%	Moderately good
Rushinga	12.2%	Moderately good
Seke	13.9%	Uncertain
Shamva	11.5%	Moderately good
Shurugwi	19.7%	Uncertain
Thsolothso	22.0%	Moderately good
Umguza	24.2%	Moderately good
UMP	12.9%	Moderately good
Umzingwane	21.6%	Uncertain
Wedza	15.2%	Uncertain
Zaka	16.0%	Moderately good
Zvimba	18.1%	Good
Zvishavane	16.7%	Moderately good

Appendix 4. Scientific Poster

Zimbabwe's Maturing HIV Epidemic: A Data Triangulation Analysis of Prevalence, Behavioral, and Programmatic Data

Emma K Sizemore[1], Abu S Abdul-Quadar[2], Amy Herman-Roloff[3], Peter Kilmarx[3], Vasco Chikwasha[4]

[1] Emory University Rollins School of Public Health and Emory University School of Medicine, Atlanta, Georgia, United States. [2] U.S. Centers for Disease Control and Prevention Division of Global HIV/AIDS, Atlanta, Georgia, United States. [3] U.S. Centers for Disease Control and Prevention – Zimbabwe, Harare, Zimbabwe. [4] University of Zimbabwe, Harare, Zimbabwe

Introduction

Over the last thirty years, Zimbabwe has faced one of the worst HIV crises in the world. From its first diagnosed case of HIV/AIDS in 1985, Zimbabwe's HIV prevalence climbed through the 1990s, peaking at 32.1% in 2000, the highest prevalence in the world at the turn of the century, and dropping to 15.0% in 2013 [1, 2].

In the timeline of the maturing epidemic, there are points where assessment of national policy, program implementation, surveillance, and research must be conducted to continue effective response to the epidemic. These may be points of policy changes, funding, prevalence or behavior changes, scale-up of prevention activities, or a combination of all these factors. Second generation HIV surveillance, designed in 2000 to continually tailor behavioral and prevalence data collection to the unique epidemic of a country or region [3], recommends that such an assessment, or exercise, take place for a continual informed response to the epidemic. In view of this, a data triangulation exercise including a systematic review of the available data on the HIV/AIDS epidemic and national response in Zimbabwe was conducted to better direct the nation's response to its evolving epidemic.

Materials and Methods

Data Triangulation

In August 2013, the Centers for Disease Control and Prevention (CDC) Zimbabwe and national Ministry of Health and Child Welfare (MOHCW) hosted an initial stakeholders' meeting in Harare, Zimbabwe, where the following questions were proposed for analysis:

Epidemiology: What are the determinants of the patterns and distribution of the epidemic? What are the key drivers and where are the hot spots of the epidemic by region? And what may be the future direction of the epidemic?

Prevention: Are the current prevention services contributing to the decline in HIV infection in the country? i.e., what are the current coverage, intensity, impact, and 'quality' of the prevention services?

To answer the above questions, over the following year, a secondary data analysis was performed using the following data sources:

- Antenatal Clinic Surveillance (ANC) Prevalence – 2000-2012
- NAC Spectrum Prevalence Estimations – 2000-2013
- Demographic Health Surveys (DHS) - 2005/06 & 2010/11
- NAC & MOHCW Programmatic Data – 2008-2013

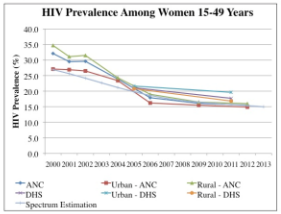
Data Analysis

Original DHS data was analyzed using SAS software, weighting values per DHS protocol to determine HIV prevalence and behavioral data by age. The Mantel-Haenszel chi-square test of proportions with alpha=0.05 was utilized to compare prevalence, behavioral indicator, and programmatic data presented as proportions from one year to the next, and statistically significance differences were defined where p<0.05. Mean values calculated from DHS data were compared from the 2005/06 to the 2010/11 surveys using two-sample independent t-tests and an alpha=0.05.

Results

HIV Prevalence

- HIV prevalence declined among women at ANCs from 32.1% in 2000 to 15.5% in 2012
- DHS data indicates a decline from 21.1% in 2005/06 to 17.7% in 2010/11
- MOHCW's Spectrum prevalence dropped from its peak at 28.9% in 1997 to 15.0% in 2013



Geographic Desparity

Although the urban-rural gap is closing, there remains a geographic disparity in prevalence.

Highest in Southwest
- Bubi – 27.0%
- Umguza – 24.2%
- Gweru – 23.8%

Lowest in Northwest
- Gokwe North – 6.5%
- Kariba 8.3%
- Binga 10.1%

Age Disparity

- HIV prevalence declining mostly among younger women, ending at 9.6% in 2012 among those aged 15-24 years
  - May suggest an overall decline in incidence
- Among women 40-49 years, HIV prevalence increased from 18.4% in 2006 to 22.7% in 2012

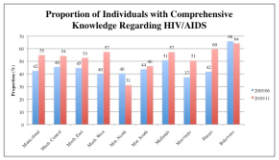
HIV Prevalence Among Men

Lower than in women with a decline from 14.5% in 2005/06 to 12.3% in 2010/11 (p<0.01)

Behavioral Indicators

Comprehensive Knowledge

- Increased among both men and women from the 2005/06 to 2010/11 DHS (p<0.001)
- Declines among men in: Matebeleland North, Matebeleland South, Bulawayo, and Mashonaland East
- Declines among women in: Matebeleland North and Bulawayo saw declines among women.



Other Indicators

- Proportion reporting using a condom during their last sex increased nationally (p<0.01)
  - Highest levels in Matabeleland South and Bulawayo (14.5% and 20.5% among women and 26.4% and 27.3% among men)
- Proportion of men having two or more partners in the last year increased (p<0.05)
  - Greatest jumps seen in Matebelaland South from 1.3% to 10.2% and in Mashonaland East from 2.5% to 9.0% (p<0.001)
  - Matebeleland South has highest proportion of women with 2+ partners at 3.0%, nearly double the rate of the next highest province

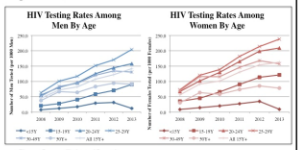
	Men			Women		
	2005/2006	2010/2011	P-value	2005/2006	2010/2011	P-value
Comprehensive Knowledge of HIV	46.5%	53.0%	<0.001	43.4%	55.9%	<0.001
Used Condom at Last Sex	16.2%	18.1%	0.002	5.5%	9.8%	<0.001
Had 2+ Partners in Last Year	9.0%	10.5%	0.003	0.9%	1.1%	0.13
Ever Tested for HIV	18.6%	38.3%	<0.001	25.8%	59.7%	<0.001
Paid for Sex in Last Year	2.6%	3.1%	0.09	-	-	-
Mean Number of Lifetime Partners	5.5	5.8	0.12	1.6	2.2	<0.001

- Proportion of men paying for sex in the last year did not change significantly,
  - Highest proportions in Harare (5.0%) and Manicaland (3.8%)
- Mean number of lifetime partners among women increased (p<0.001)
  - Highest means among women in Mashonaland West (3.8) and Matebelaland South (3.2)

Programmatic Data

Voluntary Counseling and Testing (VCT)

- Among men, increased from 45.6 to 141.7 tested per 1000 men from 2008 to 2013 (p<0.001)
- Among women, increased from 56.1 to 162.8 tested per 1,000 women from 2008 to 2013 (p<0.001)



Condom Distribution

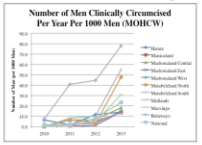
- 350% increase in the number of male condoms distributed per man per year, from 4.3 to 14.9 nationally from 2008 to 2013
- Number of female condoms distributed per woman per year increased from 0.4 condoms per woman in 2008 to 1.0 in 2013

STI Incidence

- Number of new STIs among men reported to the NAC per year has increased from 30.0 to 36.0 per 1000 men from 2008 to 2013, with slight fluctuation over the years (p<0.001)
- Among women, increased from 43.6 to 51.9 per 1000 women from 2008 to 2013 (p<0.001)

Voluntary Medical Male Circumcision

- Nationally, the number of men aged 15-49 years who were clinically circumcised each year increased more than tenfold (p<0.05)
- Geographic disparity with western provinces have circumcision rates greater than 30.0 per 1000 men in 2013, twice the rate of eastern provinces



ART Coverage

- Fluctuated from 2008 to 2013 among adults, ending at 76.9%
- Among pregnant women and children, ART coverage is even lower, ending at 51.5% and 46.1%, respectively in 2013

Conclusions

Overall, Zimbabwe's HIV prevalence has dropped by more than 50% from 2000 to 2013. Tthe great drop in prevalence seen among women 15-19 years old from 25.3% in 2000 to 5.4% in 2012 can serve as a proxy for a declining incidence, as this subpopulation most likely represents recent transmissions [4,5]. Additionally, as shown in multiple studies, a reduction of risky behaviors in the setting of close exposure to AIDS-mortality in the late 1990s and early 2000s likely played the greatest role in the drop in prevalence [5-10]. However, this analysis reveals that some risky behaviors are on the rise. Although self-reported condom usage has increased and the proportion of men paying for sex in the last year has not changed significantly, the mean number of lifetime partners among women and the proportion of men reporting two or more partners in the last year have risen. Zimbabwe's Western provinces appear to be struggling the most, with higher HIV prevalence, lower proportions of comprehensive knowledge of HIV, and rising rates of risky behaviors.

Zimbabwe's programmatic response to its epidemic on the whole has been quite successful, as condom distribution, testing, and male circumcision have increased over the last decade. With more than one in seven infected with HIV, however, there is still much room for improvement. Through this data triangulation exercise, the full scope of Zimbabwe's maturing epidemic can be better understood, setting the scene for the nation's future successes against this disease.

Works Cited

1. Fraser N, James V, Milanzi A, Colvin M, Ibbetson H, Mpofu N, et al. Zimbabwe Analysis of HIV Epidemic, Response and Modes of Transmission Harare, Zimbabwe: National AIDS Council; 2011 [cited 2014 8 Sep].
2. Global AIDS Response Progress Report 2012 Harare, Zimbabwe: National AIDS Council; 2012 [cited 2014 9 Sep].
3. World Health Organization. Guidelines for second generation HIV surveillance: an update: Know your epidemic. Geneva, Switzerland: World Health Organization, 2013.
4. Ghys PD, Kufa E, George MV. Measuring trends in prevalence and incidence of HIV infection in countries with generalised epidemics.
5. Gregson S, Gonese E, Hallett TB, Taruberekera N, Hargrove JW, Lopman B, et al. HIV decline in Zimbabwe due to reductions in risky sex? Evidence from a comprehensive epidemiological review. International Journal of Epidemiology. 2010;39(5):1311-23.
6. Hallett TB, Gregson S, Mugurungi O, Gonese E, Garnett GP. Assessing evidence for behaviour change affecting the course of HIV epidemics: A new mathematical modelling approach and application to data from Zimbabwe. Epidemics. 2009;1(2):108-17.
7. Halperin DT, Mugurungi O, Hallett TB, Muchini B, Campbell B, Magure T, et al. A surprising prevention success: why did the HIV epidemic decline in Zimbabwe? PLoS medicine. 2011;8(2):e1000414.
8. Gregson S, Garnett GP, Nyamukapa CA, Hallett TB, Lewis JJC, Mason PR, et al. HIV decline associated with behavior change in eastern Zimbabwe. Science. 2006;311(5761):664-6.
9. Muchini B, Benedikt C, Gregson S, Gonese E, Mate R, Mugurungi O, et al. Local perceptions of the forms, timing and causes of behavior change in response to the AIDS epidemic in Zimbabwe. AIDS and Behavior. 2011;15(2):487-98.
10. Sexually Transmitted Infections. 2006;82(suppl 1):i52-i6.

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