Using repeated home-based HIV testing services to reach and diagnose HIV infection among persons who have never tested for HIV, Chókwè Health Demographic Surveillance System, Chókwè District, Mozambique, 2014–2017

---Manuscript Draft---

**Manuscript Number:** PONE-D-20-18756

**Article Type:** Research Article

**Full Title:** Using repeated home-based HIV testing services to reach and diagnose HIV infection among persons who have never tested for HIV, Chókwè Health Demographic Surveillance System, Chókwè District, Mozambique, 2014–2017

**Short Title:** Using repeated home-based HIV testing services to reach persons who have never tested for HIV

**Corresponding Author:** Carol Lin
US Centers for Disease Control and Prevention
Atlanta, UNITED STATES

**Keywords:** HIV testing, Home-based HIV testing services, community testing, HTS, HTC, HIV testing coverage, HIV testing uptake, HIV testing modality, HIV testing evaluation

**Abstract:**

**Background :** HIV prevalence in Mozambique (12.6%) is one of the highest in the world, yet ~40% of people living with HIV (PLHIV) do not know their HIV status. Strategies to increase HIV testing uptake and diagnosis among PLHIV are urgently needed. Home-based HIV testing services (HBHTS) have been evaluated primarily as a 1-time campaign strategy. Little is known about the potential of repeating HBHTS to diagnose HIV infection among persons who have never been tested (NTs), nor about factors/reasons associated with never testing in a generalized epidemic setting.

**Methods :** During 2014–2017, counselors visited all households annually in the Chókwè Health and Demographic Surveillance System (CHDSS) and offered HBHTS. Cross-sectional surveys were administered to randomly selected 10% or 20% samples of CHDSS households with participants aged 15–59 years before HBHTS were conducted during the visit. Descriptive statistics and logistic regression were used to assess the proportion of NTs, factors/reasons associated with never having been tested, HBHTS acceptance, and HIV-positive diagnosis among NTs.

**Results :** The proportion of NTs decreased from 25% (95% confidence interval [CI]:23%–26%) during 2014 to 12% (95% CI:11%, 13%), 7% (95% CI:6%–8%), and 7% (95% CI:6%–8%) during 2015, 2016, and 2017, respectively. Adolescent boys and girls and adult men were more likely than adult women to be NTs. In each of the four years, the majority of NTs (87%–90%) accepted HBHTS. HIV-positive yield among NTs subsequently accepting HBHTS was highest (13%, 95% CI:10%–15%) during 2014 and gradually reduced to 11% (95% CI:8%–15%), 9% (95% CI:6%–12%), and 2% (95% CI:0%–4%) during 2015, 2016, and 2017, respectively.

**Conclusions :** The repeated HBHTS was helpful to increase HIV testing coverage and identify PLHIV in Chókwè. In high HIV-prevalence settings with low testing coverage, repeated HBHTS can be considered to increase HIV testing uptake and diagnosis among NTs.

**Order of Authors:**
Carol Lin
Isabelle Casavant
Alicia Jaramillo
Timothy Green

**Additional Information:**

**Question**

**Response**

**Financial Disclosure**

The funders had no role in study design, data collection and analysis, decision to
Enter a financial disclosure statement that describes the sources of funding for the work included in this submission. Review the submission guidelines for detailed requirements. View published research articles from PLOS ONE for specific examples.

This statement is required for submission and will appear in the published article if the submission is accepted. Please make sure it is accurate.

**Unfunded studies**
Enter: The author(s) received no specific funding for this work.

**Funded studies**
Enter a statement with the following details:
- Initials of the authors who received each award
- Grant numbers awarded to each author
- The full name of each funder
- URL of each funder website
- Did the sponsors or funders play any role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript?
  - NO - Include this sentence at the end of your statement: The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.
  - YES - Specify the role(s) played.

* typeset

**Competing Interests**

Use the instructions below to enter a competing interest statement for this submission. On behalf of all authors, disclose any competing interests that could be perceived to bias this work—acknowledging all financial support and any other relevant financial or non-financial competing interests.

This statement will appear in the published article if the submission is accepted. Please make sure it is accurate. View published research articles.
from *PLOS ONE* for specific examples.

**NO authors have competing interests**

Enter: *The authors have declared that no competing interests exist.*

**Authors with competing interests**

Enter competing interest details beginning with this statement:

*I have read the journal's policy and the authors of this manuscript have the following competing interests: [insert competing interests here]*

* typeset

| Ethics Statement |
|------------------|
| Enter an ethics statement for this submission. This statement is required if the study involved: |
| • Human participants |
| • Human specimens or tissue |
| • Vertebrate animals or cephalopods |
| • Vertebrate embryos or tissues |
| • Field research |
| Write "N/A" if the submission does not require an ethics statement. |
| General guidance is provided below. Consult the [submission guidelines for detailed instructions.](#) Make sure that all information entered here is included in the Methods section of the manuscript. |

The study was approved by the National Health Bioethics Committee of Mozambique and was reviewed and determined to be research with Centers for Disease Control and Prevention (CDC) non-engaged by the CDC Center for Global Health.
| Format for specific study types |
|---------------------------------|
| **Human Subject Research (involving human participants and/or tissue)** |
| • Give the name of the institutional review board or ethics committee that approved the study |
| • Include the approval number and/or a statement indicating approval of this research |
| • Indicate the form of consent obtained (written/oral) or the reason that consent was not obtained (e.g. the data were analyzed anonymously) |

| **Animal Research (involving vertebrate animals, embryos or tissues)** |
| • Provide the name of the Institutional Animal Care and Use Committee (IACUC) or other relevant ethics board that reviewed the study protocol, and indicate whether they approved this research or granted a formal waiver of ethical approval |
| • Include an approval number if one was obtained |
| • If the study involved non-human primates, add additional details about animal welfare and steps taken to ameliorate suffering |
| • If anesthesia, euthanasia, or any kind of animal sacrifice is part of the study, include briefly which substances and/or methods were applied |

| **Field Research** |
| Include the following details if this study involves the collection of plant, animal, or other materials from a natural setting: |
| • Field permit number |
| • Name of the institution or relevant body that granted permission |

| **Data Availability** |
| Authors are required to make all data underlying the findings described fully available, without restriction, and from the time of publication. PLOS allows rare exceptions to address legal and ethical concerns. See the PLOS Data Policy and FAQ for detailed information. |

Yes - all data are fully available without restriction
A Data Availability Statement describing where the data can be found is required at submission. Your answers to this question constitute the Data Availability Statement and will be published in the article, if accepted.

**Important:** Stating ‘data available on request from the author’ is not sufficient. If your data are only available upon request, select ‘No’ for the first question and explain your exceptional situation in the text box.

Do the authors confirm that all data underlying the findings described in their manuscript are fully available without restriction?

Describe where the data may be found in full sentences. If you are copying our sample text, replace any instances of XXX with the appropriate details.

- If the data are **held or will be held in a public repository**, include URLs, accession numbers or DOIs. If this information will only be available after acceptance, indicate this by ticking the box below. For example: *All XXX files are available from the XXX database (accession number(s) XXX, XXX).*
- If the data are all contained **within the manuscript and/or Supporting Information files**, enter the following: *All relevant data are within the manuscript and its Supporting Information files.*
- If neither of these applies but you are able to provide **details of access elsewhere**, with or without limitations, please do so. For example:

  *Data cannot be shared publicly because of [XXX]. Data are available from the XXX Institutional Data Access / Ethics Committee (contact via XXX) for researchers who meet the criteria for access to confidential data.*

  *The data underlying the results presented in the study are available from [include the name of the third party]*

All relevant data are within the paper and its Supporting Information files.
and contact information or URL).

- This text is appropriate if the data are owned by a third party and authors do not have permission to share the data.

Additional data availability information:
Using repeated home-based HIV testing services to reach and diagnose HIV infection among persons who have never tested for HIV, Chókwè Health Demographic Surveillance System, Chókwè District, Mozambique, 2014–2017

Carol Lin¹, Isabelle Casavant³, Alicia Jaramillo⁴, Timothy Green²

1. Division of Global HIV and TB, Center for Global Health, U.S. Centers for Disease Control and Prevention, 1600 Clifton Road, Atlanta, Georgia, United States of America
   clin@cdc.gov

2. Division of HIV/AIDS Prevention, National Center for HIV/AIDS, Viral Hepatitis, STD and TB Prevention, U.S. Centers for Disease Control and Prevention, Atlanta, Georgia, United States of America

3. U.S. Centers for Disease Control and Prevention, Maputo, Mozambique

4. Jhpiego Corporation, Maputo, Mozambique
Abstract

**Background:** HIV prevalence in Mozambique (12.6%) is one of the highest in the world, yet ~40% of People living with HIV (PLHIV) do not know their HIV status. Strategies to increase HIV testing uptake and diagnosis among PLHIV are urgently needed. Home-based HIV testing services (HBHTS) have been evaluated primarily as a 1-time campaign strategy. Little is known about the potential of repeating HBHTS to diagnose HIV infection among persons who have never been tested (NTs), nor about factors/reasons associated with never testing in a generalized epidemic setting.

**Methods:** During 2014–2017, counselors visited all households annually in the Chókwè Health and Demographic Surveillance System (CHDSS) and offered HBHTS. Cross-sectional surveys were administered to randomly selected 10% or 20% samples of CHDSS households with participants aged 15–59 years before HBHTS were conducted during the visit. Descriptive statistics and logistic regression were used to assess the proportion of NTs, factors/reasons associated with never having been tested, HBHTS acceptance, and HIV-positive diagnosis among NTs.

**Results:** The proportion of NTs decreased from 25% (95% confidence interval [CI]:23%–26%) during 2014 to 12% (95% CI:11%, 13%), 7% (95% CI:6%–8%), and 7% (95% CI:6%–8%) during 2015, 2016, and 2017, respectively. Adolescent boys and girls and adult men were more likely than adult women to be NTs. In each of the four years, the majority of NTs (87%–90%) accepted HBHTS. HIV-positive yield among NTs subsequently accepting HBHTS was highest (13%, 95% CI:10%–15%) during 2014 and gradually reduced to 11% (95% CI:8%–15%), 9% (95% CI:6%–12%), and 2% (95% CI:0%–4%) during 2015, 2016, and 2017, respectively.

**Conclusions:** The repeated HBHTS was helpful to increase HIV testing coverage and identify PLHIV in Chókwè. In high HIV-prevalence settings with low testing coverage, repeated HBHTS can be considered to increase HIV testing uptake and diagnosis among NTs.
Introduction

Mathematical models and observational studies conclude that HIV test-and-treat strategies hold great potential for reducing HIV transmission, morbidity, and mortality in generalized epidemic settings [1–4]. Recent evidence has also established that persons who take antiretroviral therapy (ART) daily as prescribed and achieve and maintain an undetectable viral load have effectively no risk for transmitting the virus to an HIV-negative sex partner [5, 6, 36]. The success of HIV test-and-treat strategies depends on HIV testing uptake, linkage to care, and adherence to ART among HIV-positive persons. However, HIV testing uptake remains low: a quarter of persons living with HIV (PLHIV) worldwide remain unaware of their infection status and present at clinics at a late disease stage [37]. Identifying effective HIV testing strategies to increase uptake, especially among those persons who have never been tested (NTs), and assessing factors and reasons associated with never testing remain crucial.

With an estimated 2,200,000 people living with HIV, adult (ages 15–49) HIV prevalence in Mozambique (12.6%) in 2018 was one of the highest in the world [7, 8]. In 2018, an estimated 150,000 new HIV infections were identified and 5,000 AIDS-related deaths occurred [8]. Implementing effective HIV testing and linkage to ART services are the key strategies employed by Mozambique’s government for preventing HIV transmission [38]. Although uptake of HIV testing has increased, the overall testing coverage in Mozambique remains low. Approximately 40% of PLHIV were never tested and do not know their HIV status [8]. Strategies for increasing HIV testing uptake, especially, among people who were never tested for HIV and diagnosis of HIV infection are urgently needed.

Facility-based HIV testing services (FBHTS), including voluntary, provider-initiated HIV testing services (HTS), have not been sufficient to meet the Joint United Nations Programme on HIV/AIDS (UNAIDS) 90-90-901 target and the associated goals for bringing the global HIV epidemic under control

1 By 2020, 90% of all people living with HIV will know their HIV status; 90% of all people with diagnosed HIV infection will receive sustained antiretroviral therapy; 90% of all people receiving antiretroviral therapy will have viral suppression.
by 2020 in sub-Saharan Africa [9, 10]. Community-based HTS, including home-based HTS (HBHTS), mobile-based HTS (MBHTS), and index testing are additional strategies to increase HIV testing uptake [11–16]. The HBHTS strategy consists of offering HIV testing and counseling to individuals encountered at their home, for all homes in a defined geographic area. HBHTS can overcome HIV-testing barriers, including lack of knowledge and distance to testing sites, long wait times, transportation costs, lost wages, costs associated with childcare, and concerns about confidentiality and stigma [13, 17, 18]. HBHTS also allows couples and families to be counseled together about HIV testing, HIV risk reduction, and ART [13]. A meta-analysis of 28 studies concluded that community testing achieves higher testing uptake and helps to identify HIV-positive persons at an earlier stage of their infection (i.e., at higher CD4+ counts) than FBHTS, but the proportion of new HIV-positive diagnoses (yield) by FBHTS is higher [13]. Similarly, a randomized controlled trial in Lesotho comparing HBHTS with MBHTS demonstrated that HBHTS can achieve higher testing uptake, but MBHTS detects a higher proportion of new HIV infections [19]. Recently, a study conducted in South Africa compared index testing to other community testing modalities (mobile, homebased or workplace) and concluded that index testing identified higher HIV positivity proportions than other modalities overall but the proportions of HIV uptake and positive diagnosis by index testing among persons aged 25-49 years were lower [36]. Another meta-analysis of 21 studies during 2002–2012 in 5 African countries concluded that HBHTS can substantially increase previously undiagnosed persons’ awareness of their HIV status [20]. These HBHTS evaluation studies have been focused on a one-time campaign approach (i.e., a single period during which HTS teams travel door-to-door and offer HTS).

Helleringer et al. (2013) [18] evaluated repeated HBHTS through 2 HBHTS campaigns in Likoma, Malawi, but the evaluation was limited to overall acceptance of HBHTS, HIV prevalence, and associated costs. Little is known about the potential of annually repeating HBHTS to reach and diagnose HIV infection among NTs, nor about factors and reasons associated with never testing. This information
is needed to assess the value of the HBHTS strategy in helping countries to achieve >90% awareness of status among HIV-infected persons. Without testing, undiagnosed HIV-seropositive individuals will not receive the treatment they need to slow disease progression and prevent transmission. Additionally, understanding the different factors or reasons associated with never testing may be helpful in developing and identifying strategies for increasing HIV testing uptake. For this paper, we used HIV prevention survey (HPS) and HBHTS data collected annually during 2014–2017 (4 different rounds) through the Chókwè Health Demographic Surveillance System (CHDSS) in Chókwè District, Mozambique, to assess (a) the proportion of NTs aged 15-59 before and after HBHTS were implemented, (b) factors or reasons associated with never testing, and (c) HBHTS acceptance and positive diagnosis results (yield) among NTs.

Methods

Setting and study design

Chókwè District is located in Gaza Province and has the highest adult (15-49 yrs old) HIV prevalence (25%) in Mozambique [7, 21]. A Health Demographic Surveillance System (HDSS) was first established by Chókwè Health Research and Training Center (CITSC) in 2010. CHDSS covers Chókwè city and several neighborhood villages which, together, include approximately 100,000 of the total Chókwè district population of 183,000, and approximately 58,000 residents aged 15-59 years. During 4 separate rounds between 2014–2017, HTS counselors visited all CDHSS households and offered HBHTS to household members who had not previously tested HIV-positive. Households with at least one eligible member who had not been offered HTS were revisited at least one more time. During these rounds, HPS was offered to household members aged 15-59 years in a randomly selected 10% (Rounds 1-2, 2014-2016) or 20% (Rounds 3-4, 2016-2017) sample of CHDSS households. For eligible participants who consented to both the HPS and HBHTS, a 20-30 minute HPS questionnaire was administered first by trained interviewers in Portuguese or Shangana before HBHTS was conducted. in
this study. The study was approved by the National Health Bioethics Committee of Mozambique and was reviewed and determined to be research with Centers for Disease Control and Prevention (CDC) non-engaged by the CDC Center for Global Health.

HIV testing and counseling

Rapid HIV testing and confidential pre- and post-test counseling were provided by trained counselors at CDHSS participants’ homes according to Mozambique’s national guidelines. HIV-positive participants were provided additional HIV counseling (e.g., referrals, linkages to care, information about the benefits of early treatment and adherence, disclosure, partner or family HIV testing, and condom use). Counselors conducted up to 5 follow-up home visits to encourage HIV-positive participants to enroll in and adhere to HIV care. HIV-negative and HIV-indeterminate participants were provided risk-reduction counseling, including recommendations for periodic HIV testing and behavioral prevention strategies/service; uncircumcised men were referred to voluntary medical male circumcision services. Pregnant women were referred for antenatal care when needed.

Outcomes and other HIV testing-related variables

The primary outcome variable was never having been tested for HIV. All persons surveyed were asked, “Have you ever been tested for HIV?” Additional outcome variables included acceptance of HBHTS among NTs, and HIV-positive yield among NTs who tested for HIV after their survey interview. For participants who responded “Yes” to ever testing for HIV, information about location of their most recent HIV test was collected. For participants who responded “No” to ever having been tested for HIV, the reasons for not being tested and intention to test for HIV during the next 12 months were assessed.

Demographic, behavioral, and psychological variables

The HPS questionnaire included standard measures on demographics (sex, age, and marital status), drug use (marijuana or other during the prior 3 months), experience of physical or sexual violence (during the
prior 12 months), and sexual history. Sexual history-related measures included number of sex partners during the prior 12 months, status of the most recent sexual partner (i.e., spouse, casual or exchange sex partner), if a condom was used during most recent sexual act, and if the participant asked about the sex partner’s HIV and sexually transmitted infection status. In addition, a series of questions related to comprehensive HIV knowledge, beliefs about ART, and HIV/AIDS stigma were also asked. Specific questions (multiple choice questions) or items included in these three composite measures are available in the Supporting information (S1).

**Statistical analysis**

The analysis was based on all HPS participants. The observed data were analyzed using SAS® (version 9.3, SAS Institute, Inc., Cary, North Carolina, USA) survey procedures that account for correlations among participants within a household following by a sensitivity analysis. Summary statistics of demographic and behavioral characteristics, knowledge about HIV, beliefs about ART, and stigma scores of all survey respondents and NTs were calculated. Additionally, the proportions of respondents tested for HIV by testing location, and whether or not HIV testing was discussed with partners, were calculated. Similarly, the proportions of NTs by reasons for never having been tested, intention to have an HIV test during the next 12 months, HBHTS acceptance, and HIV test results among NTs subsequently accepting HBHTS were calculated.

To assess the changes among NTs, the number and proportion, including 95% Wald confidence intervals (CIs), of NTs in each round were calculated. To identify the factors associated with never having been tested, bivariate and multivariable analyses were conducted for each survey round using the annual data. Logistic regression analyses were used to identify factors associated with never having been tested. A

---

2 Around 65%, 72%, 69% and 66% of the eligible participants were reached during the 4 survey rounds. Among those reached, the survey refusal rates were 15%, 15%, 15% and 21%.
backward-elimination procedure was used to select the final model. Two-way interaction terms between the factors were also evaluated.

To assess the magnitude of HBHTS acceptance among NTs and HIV-positive diagnoses among NTs accepting HBHTS, the proportions of NTs, including 95% Wald or Wilson CIs, accepting HBHTS and with HIV-positive test results were calculated for each round. To assess the relationship between acceptance of HBHTS among NTs and reasons for not testing, we combined the data over survey rounds (2014–2017). Proportions of NTs accepting HBHTS and diagnosed as HIV-positive by the statistically significant factors identified (i.e., sex and age) by logistic regression and by reported reasons for never having been tested were estimated.

To test the robustness of the observed findings, we conducted a sensitivity analysis. We re-analyzed the data using a weighted approach with a survey weight calculated by age, gender and region (urban or rural).

**Results**

Survey participants’ demographic, behavioral, and psychological characteristics were similar in all survey rounds (Table 1). The proportions of survey respondents who were female ranged from 63% to 73%; 58%–62% were aged ≥25 years; 49%–56% were married; and 85%–90% had ever had sex. The proportions of respondents with >1 sex partner, knowing persons who had died with AIDS, and engaging in sexual risk behaviors (i.e., having unprotected sex or never ask partners about HIV status) decreased over time. The median scores for HIV knowledge, beliefs about ART, and stigma were 7–8 (out of 9), 5 (out of 6), and 8-10 (out of 16), respectively.

**Proportion of NTs and HIV testing-associated characteristics**

The proportion of NTs decreased over time, from 25% (95% CI: 23%–26%) during 2014 to 12% (95% CI: 11%–13%), 7% (95% CI: 6%–8%), and 7% (95% CI: 6%–8%) during subsequent years. During the
first round before HBHTS was first implemented, the most frequently reported location for the most recent HIV test was hospitals in Chókwè (45%), followed by home in Chókwè (13%), other location in Chókwè (10%), and at work in Chókwè (2%). After HBHTS was implemented, home in Chókwè became the most frequently reported location for the most recent HIV test, increasing from 13% during 2014 to 50%, 50%, and 49% during the 2015-2017 rounds, respectively. Hospitals in Chókwè became the second most frequently reported location (41%–43%) during the 2nd to 4th rounds.

Factors and reasons associated with never having been tested

Factors associated with NT, after adjusting for all the other variables in the model, were similar for all 4 survey rounds (Table 2). During survey rounds 1-3, adolescent (ages 15–17 years) boys and girls and adult (ages ≥18) men were more likely than adult women to be NTs (P < .001). Adolescent girls had 4.91 (95% CI: 3.16–7.63), 6.23 (4.02–9.64), and 16.17 (6.86–38.16) times the adjusted odds of never having been tested, compared with adult women in 2014, 2015 and 2016, respectively. Adult men had 3.64 (95% CI: 2.88–4.61), 3.62 (2.52–5.20), and 3.29 (2.17–5.00) times the adjusted odds of never having been tested, compared with adult women in 2014, 2015, and 2016, respectively. Age (but not sex) remained a statistically significant factor in 2017, with adolescents having 9.50 (95% CI: 5.85–15.41) times the adjusted odds of never having been tested, compared with adults (ages≥25).

Participants who had ever had sex, who had higher HIV knowledge scores, or who had ever asked partners about HIV status were less likely to be NTs for each of the 4 years.

The most frequently reported reasons for never having been tested were similar across survey rounds (Table 3). The frequently reported reasons for never have been tested during 2014, 2015, 2016, and 2017, respectively, were limited access or time (26%, 35%, 25%, and 27%), indifference (19%, 21%, 20%, and 17%), low perceived risk for HIV infection (33%, 16%, 20%, and 21%), lack of being offered testing by healthcare provider (12%, 12%, 17% and 22%), and fear of needles, blood or testing-HIV positive (9%, 7%, 16%, and 12%).
HIV testing acceptance among NTs and HIV-positivity diagnosis among NTs accepting HBHTS

The acceptance rate of HBHTS among NTs was high throughout all 4 years (Table 4). After the survey was administered, 90% (95% CI: 87%–92%), 87% (95% CI: 83%–90%), 88% (95% CI: 83%–91%), and 88% (95% CI: 83%–91%) of NTs accepted HBHTS during 2014-2017. The yield of new HIV-positive diagnoses among NTs subsequently accepting HBHTS, was 13% (95% CI: 10%–15%) during 2014 and gradually reduced to 11% (95% CI: 8%–15%), 9% (95% CI: 6%–12%), and 2% (95% CI: 1%–4%) during 2015, 2016, and 2017. Among NTs aged ≥25 years (98% of whom had ever had sex) offered HBHTS, the proportion of HIV-positive diagnosis was ~20% during the first 3 years but decreased to 5% during 2017.

For all 4 survey rounds combined, >80% of NTs accepted HBHTS across all sex and age groups, and all reasons NTs reported for never testing previously, except for fear of needles or testing HIV-positive (Table 4). Of 498 NTs who reported limited access or time as reasons for never testing, 470 (94%) accepted HBHTS, of whom 11% tested HIV-positive. Of 437 and 340 NTs who reported low perceived risk or being indifferent as reasons for never testing previously, 389 (89%) and 291 (86%) accepted HBHTS, of whom 7% and 10% tested HIV-positive, respectively. Of 185 NTs who reported being afraid of needles or of testing HIV-positive as a reason for never previously testing, 131 (71%) accepted HBHTS, of whom, 9% tested HIV-positive.

The sensitivity analysis results using the weighted approach are given in Table 1 and Table S2-S4. The estimates using the weighted approach and the observed data were similar (i.e., the counts were slightly different; the proportions were very close; and significant factors identified were the same).

Discussion

During 2014–2017, we used 4 rounds of HPS and HBHTS data to investigate the potential of repeating HBHTS annually for reaching NTs, and to determine factors or reasons associated with never having
been tested previously, acceptance of HBHTS and yield of new HIV diagnosis among NTs who participated in these surveys. The results revealed that the proportion of participants who reported never having been tested previously for HIV decreased substantially after HBHTS was implemented, from 25% to 7% after 2 rounds of HBHTS. During these first two rounds, 87% to 90% of survey participants who had never tested previously for HIV subsequently accepted HBHTS, and the yield of new HIV diagnoses among those who accepted was high (11%-13%). Additionally, home rather than a hospital in Chókwè became the most frequently reported most recent HIV testing location. These results suggest that two rounds of HBHTS in high prevalence settings was helpful to substantially reduce the proportion of NTs while achieving a high yield of new HIV diagnoses among NTs tested.

Similar to the findings from a one-time HBHTS campaign [20], repeated HBHTS was well-received by different socio-demographic groups including those who reported various reasons for not having tested for HIV previously. During the four survey rounds, 87%-90% of NTs accepted HBHTS, including close to 90% of adolescents and young NTs (ages 15-24 years), male and female NTs, and NTs with limited access or time for testing, perceived low risk, and lack of support for testing. A majority (71%) of NTs who reported fear of learning they were HIV-positive or fear of blood, needles, or pain accepted HBHTS; among those, 9% were diagnosed as HIV-positive.

HIV-positive yield among NTs decreased from 13% during 2014 to 2% during 2017. The decrease in positive yield coincided with a decreasing proportion of NTs who had ever had sex (from 80% during 2014 to 65%, 57%, and 33% in subsequent years) and an increasing proportion of NTs who were aged <18 (from 30% during 2014 to 46%, 58%, and 80% in subsequent years). Among NTs aged ≥25 years (97% of whom had sex), the positive yield was ~20% during the first 3 years, decreasing to 6% during 2017. These findings suggest that when HBHTS is repeated, screening for sexual risk behavior should be considered to avoid unnecessary costs associated with testing persons who are pre-sexual debut and are likely not to have not been exposed to HIV.
Strategies for increasing HIV testing uptake among adolescents are important for HIV epidemic control because 14% of all new HIV infections occur during adolescence (ages 10–19 years) [22]. Additionally, during 2005–2012, HIV-related deaths among adolescents increased by 50%, whereas the total number of HIV-related deaths decreased by 30% globally [22]. After adjusting for sexual behaviors, adolescents aged 15–17 remained substantially more likely to have never tested during all 4 years of the CHDSS. Although the yield of new HIV diagnoses among these adolescents was low (1%) and many of them had never had sex (55%), increasing HIV testing uptake for sexually active adolescents can potentially increase early HIV diagnosis and use of ART and thus reduce HIV-related death. The majority of HIV-infected adolescents are unaware of their HIV status and thus haven’t initiated ART [22].

Previous findings also indicate that HIV testing might increase HIV knowledge and lead to reductions in sexual risk even when test results are negative [23]. Chókwè is in the province (Gaza) with the highest adult (ages 15–49 years) HIV infection rates in Mozambique [7, 21]; therefore, helping HIV-negative adolescents remain negative by connecting them to youth-friendly prevention services (e.g., family planning, HIV/sexually transmitted infection prevention, and preexposure prophylaxis) and by reinforcing prevention behaviors is particularly important. As part of HBHTS, counselors routinely provided risk reduction counseling, distributed condoms, and provided important information about family planning and treatment for sexually transmitted infections, and circumcision referral for adolescent males and adult men, as warranted.

Men were more likely to be NTs than women during all four survey rounds. This is concerning because 74% of Mozambican girls have their first sexual experience before age 18 and young Mozambican girls commonly have sex with older men, who are potentially at higher risk for HIV infection [24]. Men are also 2–3 times more likely to transmit HIV to women than women are to men [25], yet economic reasons contribute to men’s reluctance to access HTS. This might explain why HIV disproportionately affects adolescent girls; 75% of infected adolescents (ages 15–19) in Mozambique are female [24].
Although our results reveal that the HBHTS approach is well-accepted by adolescent NTs and adult male NTs, men have been less easily contactable at home [26, 27]. Additional strategies that specifically target girls and older men to reduce sexual risk and to reach and increase the uptake of HIV testing remain important for HIV epidemic control.

Increased comprehensive knowledge of HIV, including how HIV is transmitted, prevented, and treated, was determined to be negatively associated with NTs (ages 15–59) during all 4 years, after adjusting for sex, age, and sexual behaviors. In contrast, findings in Nigeria and Ghana indicated that HIV testing uptake is low among university students who generally had good knowledge about HIV/AIDS and knew where to get HIV testing [28, 29]. The unwillingness of students to take an HIV test might be attributed to fear, anxiety, and stigma or discrimination. Similarly, from our results, we determined that the fear factor was hardest to overcome; 71% of NTs reported fear as a reason for never having been tested accepted HBHTS. This demonstrates that knowing where to test for HIV might be insufficient.

Comprehensive knowledge about HIV/AIDS is also important for decreasing fear and stigma or discrimination against PLHIV [30, 31, 32] and increasing HIV testing uptake and linkage to care. Increased effort to expand awareness of HIV testing and knowledge is needed, particularly because of the high illiteracy rates in Mozambique (50% among Portuguese speakers and 94% among non-Portuguese speakers) [17].

For the sensitivity analysis, the estimates using the weighted approach and the observed data were very similar because of random sampling. This confirms the distributions of race, gender and region of the 10% or 20% random samples of CHDSS households with members aged 15–59 years were similar to the underlying population. When comparing the demographic distributions (e.g., age, gender) of the survey respondents to baseline census data, there were a slightly higher proportion (3–5 percentage points) of older persons (ages 45–59) and a lower proportion (1–10 percentage points) of males among survey respondents. This might be because men are more likely to be away from home during the day and older
persons are more likely to be at home. Although the weighted results were similar to the results using observed data, given that 40%-48% of eligible participants were not reached at home or refused to respond during the 4 survey rounds, and we do not know if these not-reached or refused-to-respond eligible participants can be represented by the HPS respondents, we do not generalize the weighted results to all CHDSS participants in the district.

There are several additional limitations of this study. Although HBHTS tested many residents in 2014-2017, including persons who had never tested previously for HIV, other HTS delivery strategies such as routine HIV testing at district health facilities, and school-based and outreach testing for youth and adults were also being implemented and likely contribute to the reduction of NTs. Additionally, data collected through HPS interviews are subject to recall or reporting bias, particularly for sensitive questions such as drug use and sexual behaviors. Furthermore, the generalizability of the findings might be limited to similar settings as the CHDSS and might not be generalizable to the entire population of Mozambique or Sub-Saharan Africa. However, our results remain informative because a strong similarity exists in the barriers and facilitators to HIV testing across Sub-Saharan Africa, despite the heterogeneity of that region [33].

Future studies are needed for linking those testing HIV-positive with treatment and investigating the need for additional interventions to reach NTs who cannot be reached by HBHTS even after multiple repetitions. Although HBHTS costs have been studied in Kenya and Uganda and HBHTS was reported to compare favorably with other HTS delivery strategies at the time [34,35], additional cost-effectiveness analyses that compare HBHTS with other delivery strategies (e.g., index testing) and that evaluate the efficiency of repeated HBHTS among populations with different magnitudes of underlying HIV prevalence will be helpful. Despite these limitations, to our knowledge, this is the first study to investigate repeated HBHTS in reaching, testing, and diagnosing HIV infection among NTs and fills a crucial gap in the literature.
Conclusions

The repeated HBHTS approach was helpful to increase HIV testing coverage and identifying PLHIV in Chókwè. HBHTS acceptance rates were high across all sex, gender and NTs with different barriers. HIV-positive yields among NTs who accepted HBHTS exceeded 10%. In high HIV-prevalence settings with low testing coverage, repeated HBHTS can be considered to increase testing uptake and HIV diagnosis among NTs.

Acknowledgments

The authors would like to thank Key Smith for her helpful editorial review to enhance the manuscript. The authors also would like to acknowledge Dr. Alfredo Vergara, Dawud Ujamaa and Judite Cardoso for their contribution in data collection. The project has been supported by the President’s Emergency Plan for AIDS Relief (PEPFAR) through the Centers for Disease Control and Prevention (CDC) under the terms of [CoAg#GH00080].

Author Contributions

Conceptualization: Carol Lin
Data collection: Isabelle Casavant, Alicia Jaramillo
Formal analysis: Carol Lin, Timothy Green
Writing- original draft: Carol Lin, Timothy Green
Writing- review & editing: Carol Lin, Timothy Green, Isabelle Casavant, Alicia Jaramillo

Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the funding agencies.

References
1. Granich RM, Gilks CF, Dye C, De Cock KM, Williams BG. Universal voluntary HIV testing with immediate antiretroviral therapy as a strategy for elimination of HIV transmission: a mathematical model. Lancet. 2009; 373(9657):48–57.

2. Tanser F, Bärnighausen T, Grapsa E, Zaidi J, Newell ML. High coverage of ART associated with decline in risk of HIV acquisition in rural KwaZulu-Natal, South Africa. Science. 2013; 339(6122):966–71.

3. Stover J, Hallett TB, Wu Z, Warren M, Gopalappa C, Pretorius C, et al; New Prevention Technology Study Group. How can we get close to zero? The potential contribution of biomedical prevention and the investment framework towards an effective response to HIV. PLoS One. 2014; 9(11):e111956.

4. Waletsky RP, Borre ED, Bekker LG, Resch SC, Hyle EP, Wood R, et al. The anticipated clinical and economic effects of 90-90-90 in South Africa. Ann Intern Med. 2016; 165(5):325–33.

5. The editors. U=U taking off in 2017 [Editorial]. The Lancet HIV. 2017; 4(11):e475.

6. Rodger A, Cambiano V, Bruun T, Vernazza P, Collins S, Corbelli GM, Degen O, et al. Risk of HIV transmission through condomless sex in gay couples with suppressive ART: the PARTNER2 study expanded results in gay men [Abstract WEAX0104LB]. Presented at the 22nd International AIDS Conference, July 23–27, 2018, Amsterdam, Netherlands. https://programme.aids2018.org/Abstract/Print/?abstractid=13470

7. Feldblum JP, Enosse S, Dubé K, Arnaldo P, Muluana C, Banze R, et al. HIV prevalence and incidence in a cohort of women at higher risk for HIV acquisition in Chókwè, Southern Mozambique. PLoS One. 2014; 9(5):e97547.

8. UNAIDS. UNAIDS data 2018: Mozambique [Internet]. https://www.unaids.org/en/regionscountries/countries/mozambique
9. Fylkesnes K, Sandoy IF, Jurgensen M, Chipimo PJ, Mwangala S, Michelo C. Strong effects of home-based voluntary HIV counselling and testing on acceptance and equity: a cluster randomized trial in Zambia. Soc Sci Med. 2013; 86:9–16.

10. Mohlabane N, Tutshana B, Peltzer K, Mwisongo Z. Barriers and facilitators associated with HIV testing uptake in South African health facilities offering HIV counselling and testing. Health SA Gesondheid. 2016; 21:86–95.

11. Sweat M, Morin S, Celentano D, Mulawa M, Singh B, Mbwambo J, et al. Community-based intervention to increase HIV testing and case detection in people aged 16-32 years in Tanzania, Zimbabwe, and Thailand (NIMH Project Accept, HPTN 043): a randomized study. Lancet Infect Dis. 2011; 11(7):525–32.

12. Maheswaran H, Thulare H, Stanistreet D, Tanser F, Newell ML. Starting a home and mobile HIV testing service in a rural area of South Africa. J Acquir Immune Defic Syndr. 2012; 59(3):e43–6.

13. Suthar AB, Ford N, Bachanas PJ, Wong VJ, Rajan JS, Saltzman AK, et al. Towards universal voluntary HIV testing and counselling: a systematic review and meta-analysis of community-based approaches. PLoS Med. 2013; 10:e1001496.

14. Ahmed S, Delaney K, Villalba-Diebold P, Aliyu G, Constantine N, Ememabelem M, et al. HIV counseling and testing and access-to-care needs of populations most-at-risk for HIV in Nigeria. AIDS Care. 2013; 25:85–94.

15. Sharma M, Ying R, Tarr G, Barnabas R. Systematic review and meta-analysis of community and facility-based HIV testing to address linkage to care gaps in Sub-Saharan Africa. Nature. 2015; 528(7580):S77–85. doi: 10.1038/nature16044.
16. Sharma M, Barnabas RV, Celum C. Community-based strategies to strengthen men’s engagement in the HIV care cascade in Sub-Saharan Africa. PLoS Med. 2016; 14(4):e1002262. doi:10.1371/journal.pmed.10022.

17. Paulin HN, Blevins M, Koethe JR, Hinton N, Vaz LM, Vergara AE, et al. HIV testing service awareness and service uptake among female heads of household in rural Mozambique: results from a province-wide survey. BMC Public Health. 2015; 15:1388.

18. Helleringer S, Mkandawire J, Reniers G, Kalilani-Phiri L, Kohler HP. Should home-based HIV testing and counseling services be offered periodically in programs of ARV treatment as prevention? A case study in Likoma (Malawi). AIDS Behav. 2013; 17(6):2100–8.

19. Labhardt ND, Motlomelo M, Cerutti B, Pfeiffer K, Kamele M, Hobbins MA, Ehmer J. Home-based versus mobile clinic HIV testing and counseling in rural Lesotho: a cluster-randomized trial. PLoS Med. 2014; 11(12):e1001768.

20. Sabapathy K, Van den Bergh R, Fidler S, Hayes R, Ford N. Uptake of home-based voluntary HIV testing in Sub-Saharan Africa: a systematic review and meta-analysis. PLoS Med. 2012; 9:e1001351.

21. Baltazar CS, Horth R, Ingwane C, Sathane I, César F, Ricardo H, et al. HIV prevalence and risk behaviors among Mozambicans working in South African mines. AIDS Behav. 2015;19(Suppl 1):S59–67.

22. World Health Organization. HIV and adolescents: guidance for HIV testing and counselling and care for adolescents living with HIV; recommendations for a public health approach and considerations for policy-makers and managers. 

http://apps.who.int/iris/bitstream/handle/10665/94334/9789241506168_eng.pdf;jsessionid=F6D5E5FF4798F25B314D718FDD6F2DCF?sequence=1
23. Scott-Sheldon LA, Carey MP, Carey KB, Cain D, Simbayi LC, Mehlomakhulu V, et al. HIV testing is associated with increased knowledge and reductions in sexual risk behaviours among men in Cape Town, South Africa. Afr J AIDS Res. 2013; 12(4):195–201.

24. Audet C, Burlison J, Moon T, Sidat M, Vergara A, Vermund S. Sociocultural and epidemiological aspects of HIV/AIDS in Mozambique. BMC Int Health Hum Rights. 2010; 10:15.

25. Mhlongo S, Dietrich J, Otwombe KN, Robertson G, Coates TJ, Gray G. Factors associated with not testing for HIV and consistent condom use among men in Soweto, South Africa. PLoS One. 2013; 8(5):e6263.

26. Novitsky V, Bussmann H, Okui L, Logan A, Moyo S, van Widenfelt E, et al. Estimated age and gender profile of individuals missed by a home-based HIV testing and counselling campaign in a Botswana community. J Int AIDS Soc. 2015; 18:19918. doi: 10.7448/IAS.18.1.19918.

27. Iwuji CC, Orne-Gliemann J, Larmarange J, Okesola N, Tanser F, Thiebaut R, et al.; ANRS 12249 TasP trial group. Uptake of home-based HIV testing, linkage to care, and community attitudes about ART in rural KwaZulu-Natal, South Africa: descriptive results from the first phase of the ANRS 12249 TasP Cluster-Randomised Trial. PLoS Med. 2016; 9;13(8):e1002107. doi: 10.1371/journal.pmed.1002107.

28. Abiodun O, Sotunsu J, Ani F and Jaiyesimi E. Knowledge of HIV/AIDS and predictors of uptake of HIV counseling and testing among undergraduate students of a privately owned university in Nigeria. BMC Res Notes. 2014; 7:639.

29. Asante. HIV/AIDS knowledge and uptake of HIV counselling and testing among undergraduate private university students in Acca, Ghana. Reproduct Health. 2013; 10:17.

30. Pickles D, King L, Belan I. Attitudes of nursing students towards caring for people living with HIV/AIDS: thematic literature review. J Adv Nurs. 2009; 65:2262–73.
31. Sengputa S, Banks B, Jonas D, Miles MS, Smith GC. HIV interventions to reduce HIV/AIDS stigma: a systematic review. AIDS Behav. 2011; 15:1075–87.

32. Feyissa TG, Abebe L, Girma E, Woldie M. Stigma and discrimination against people living with HIV by healthcare providers, Southwest Ethiopia. BMC Public Health. 2012; 12:522.

33. Musheke M, Ntalasha H, Gari S, McKenzie O, Bond V, Martin-Hilber A, et al. A systematic review of qualitative findings on factors enabling and deterring uptake of HIV testing in Sub-Saharan Africa. BMC Public Health. 2013; 13:220.

34. Negin J, Wariero J, Mutuo P, Jan S, Pronyk P. Feasibility, acceptability and cost of home-based HIV testing in rural Kenya. Trop Med Int Health. 2009; 8:849–55.

35. Menzies N, Abang B, Wanyenze R, Nuwaha F, Mugisha B, Coutinho A, et al. The costs and effectiveness of four HIV counseling and testing strategies in Uganda. AIDS. 2009; 23(3):395–401.

36. Shamu S, Farirai T, Kuwanda L, Slabbert J., Guloba G, Khupakonske S, et al. Comparison of community-based HIV counselling and testing (CBCT) through index client tracing and other modalities: Outcomes in 13 South African high HIV prevalence districts by gender and age. Plos one. 2019. Sep 6;14(9):e0221215.

37. Makhema J, Wirth KE, Pretorius Holme M, Gaolathe T, Mmalane M, Kadima E, et al. Universal testing, expanded treatment, and incidence of HIV infection in Botswana. New England Journal of Medicine. 2019; 381(3):230–42. https://doi.org/10.1056/NEJMoa1812281 PMID: 31314967

38. World Health Organization. https://www.unaids.org/en/resources/infographics/hiv-testing-what-you-need-to-know

39. Mozambique Country Operational Plan 2019 Strategic Direction Summary. https://www.state.gov/wp-content/uploads/2019/09/Mozambique_COP19-Strategic-Directional-Summary_public.pdf
### Table 1. Sample characteristics and proportions of participants never having been tested for HIV, by survey round (2014-2017)

|                  | Total No. | Never Tested Perc. | Total No. | Never Tested Perc. | Total No. | Never Tested Perc. | Total No. | Never Tested Perc. |
|------------------|-----------|--------------------|-----------|--------------------|-----------|--------------------|-----------|--------------------|
|                  | N         | %                  | N         | %                  | N         | %                  | N         | %                  |
|                  | 2014      | 2015               | 2016      | 2017               | 2014      | 2015               | 2016      | 2017               |
| UW/W             | 3024/3027 | UW/W               | 3151/3148 | UW/W               | 5061/5049 | UW/W               | 4415/4415 | UW/W               |
|                  | 25/24     | 12/12              | 7/8       | 7/7                | 25/26     | 5/5                | 4/2       | 2/2                |
| Sex              | 1115/1164 | 37/35              | 887/1211  | 18/17              | 1381/1932 | 12/13              | 1326/1695 | 10/9               |
| Female           | 1909/1863 | 18/17              | 2264/1937 | 9/9                | 3680/3117 | 6/6                | 3089/2720 | 6/6                |
| Age              | <18       | 434/431            | 49/48     | 508/543            | 33/30     | 848/905            | 25/26     | 816/772            | 30/29       |
|                  | 18-24     | 758/806            | 26/24     | 728/744            | 9/10      | 1090/1171          | 5/5       | 1021/1036          | 2/2         |
|                  | ≥25       | 1832/1790          | 18/18     | 1915/1860          | 7/8       | 3123/2973          | 3/4       | 2578/2607          | 2/2         |
| Relationship     | Married/Marital union | 1699/1690 | 18/18     | 1748/1668          | 7/7       | 2625/2506          | 4/5       | 2178/2145          | 13/12       |
|                  | Other     | 1324/1336          | 33/32     | 1402/1478          | 18/18     | 2429/2537          | 11/11     | 2236/2270          | 17/22       |
| Knowing people died with AIDS | No | 1728/1716 | 26/25 | 2167/2210 | 11/12 | 3422/3395 | 6/7 | 3052/3077 | 6/6 |
|                  | Yes       | 1035/1091          | 17/17     | 782/765            | 7/8       | 1099/1131          | 4/6       | 868/803            | 3/3         |
| Ever have sex    | No        | 302/293            | 50/50     | 368/395            | 36/34     | 615/662            | 26/25     | 679/672            | 31/28       |
|                  | Yes       | 2711/2721          | 22/21     | 2778/2747          | 8/9       | 4427/4372          | 5/6       | 3752/3740          | 3/2         |
| Number of sex partners in the past 12 months | ≤1 | 2211/2177 | 22/22 | 2660/2523 | 11/12 | 3969/3736 | 7/8 | 3811/3678 | 7/7 |
|                  | >2        | 794/828            | 31/29     | 449/574            | 15/14     | 766/993            | 8/9       | 352/440            | 8/7         |
| Having casual sex or exchange Partner | No | 2112/2103 | 22/22 | 2302/2287 | 11/12 | 3663/3689 | 8/9 | 3193/3208 | 8/8 |
|                  | Yes       | 736/752            | 30/29     | 582/649            | 15/15     | 972/1040           | 8/8       | 891/941            | 6/5         |
| Having unprotected sex (no condom) with last sex partner | No | 922/978 | 28/27 | 964/1078 | 19/18 | 1654/1853 | 13/13 | 1735/1855 | 14/12 |
|                  | Yes       | 1877/1825          | 23/22     | 1893/1835          | 9/9       | 2914/2815          | 5/6       | 2308/2255          | 25/30       |
| Never asked partner about HIV status when have sex | No | 1625/1672 | 19/18 | 1678/1752 | 11/12 | 2906/2977 | 8/8 | 2722/2748 | 9/8 |
|                  | Yes       | 1199/1160          | 32/32     | 1169/1149          | 13/14     | 1648/1678          | 8/10      | 1307/1353          | 6/6         |
| Drug use in the last 3 months | No | 2897/2889 | 24/23 | 3092/3064 | 11/12 | 4983/4952 | 7/8 | 4334/4308 | 7/7 |
|                  | Yes       | 127/138            | 39/36     | 59/84              | 20/20     | 78/97              | 18/16     | 81/108             | 6/10        |
| Having STI in the past 12 months | No | 2185/2174 | 27/27 | 2497/2523 | 13/13 | 4226/4261 | 8/9 | 3622/3811 | 8/8 |
|                  | Yes       | 839/853            | 17/16     | 654/625            | 6/7       | 835/787            | 4/6       | 593/605            | 1/1         |
| Partner violence in the past 12 months | No | 2683/2652 | 25/24 | 2948/2950 | 12/13 | 4777/4807 | 8/9 | 4190/4170 | 7/7 |
|                  | Yes       | 315/348            | 20/20     | 192/186            | 6/6       | 126/142            | 6/6       | 148/167            | 1/1         |
| Knowledge about HIV Score  (max: 9) | Yes | 7/6,8| 7/6,8 | 7/6,8| 6/4,8 | 6/4,8 | 8/6,9| 6/5,8 | 6/4,7 | 6/4,7 |
| Stigma Score (max: 16) | 1(8,10)/10(8,10) | 9(8,10) | 9(8,10) | 8(8,10)/8(8,10) | 8(8,10) | 8(8,10)/8(8,10) | 8(8,10) | 8(8,8)/8(8,8) | 8(8,8) | 8(8,8) |
|------------------------|------------------|---------|---------|-----------------|---------|-----------------|---------|----------------|---------|---------|
| Belief about ART Score (max: 6) | 5(3,5)/5(4,5) | 4(2,5) | 4(2,5) | 5(2,5) | 5(2,5) | 5(2,5) | 5(2,5) | 5(2,5) | 5(2,5) | 5(2,5) |

UW: unweighted, observed data

W: weighted
Table 2: Demographic and behavioral factors associated with never tested for HIV before

|                   | 2014                      | 2015                      | 2016                      | 2017                      |
|-------------------|---------------------------|---------------------------|---------------------------|---------------------------|
|                   | Crude OR (95% CI)         | Adjusted OR (95% CI)       | Crude OR (95% CI)         | Adjusted OR (95% CI)       |
| **Sex**           |                           |                           |                           |                           |
| Male              | 2.71 (2.27, 3.33)         | 2.35 (1.88, 3.00)         | 2.21 (1.78, 2.74)         | 1.81 (1.43, 2.28)         |
| Female            | 1                         | 1                         | 1                         | 1                         |
| **Age**           |                           |                           |                           |                           |
| <18               | 4.37 (3.45, 5.52)         | 6.80 (5.25, 8.82)         | 10.0 (7.80, 13.00)        | 27.71 (19.33, 39.73)      |
| ≥ 25              | 1.56 (1.27, 1.92)         | 1.33 (0.97, 1.84)         | 1.53 (1.09, 2.15)         | 1.59 (0.96, 2.65)         |
| **Relationship**  |                           |                           |                           |                           |
| Other             | 2.16 (1.81, 2.57)         | 2.98 (2.34, 3.78)         | 3.17 (2.49, 4.02)         | 8.62 (6.60, 12.39)        |
| **Married/marital union** | 1     | 1                         | 1                         | 1                         |
| **Knowing people died with AIDS** | No     | 1.60 (1.32, 1.95)         | 1.85 (1.32, 2.57)         | 1.54 (1.11, 2.15)         |
| Yes               |                           |                           |                           |                           |
| **Ever have sex** |                           |                           |                           |                           |
| No                | 3.59 (2.79, 4.64)         | 6.65 (4.10, 10.81)        | 6.12 (4.73, 7.91)         | 6.34 (4.02, 10.14)        |
| Yes               | 1.05 (0.99, 1.08)         | 0.84 (0.80, 0.89)         | 1.04 (0.97, 1.11)         | 1.05 (0.96, 1.13)         |
| **Having casual sex or exchange partner (last person had sex with)** | No     | 0.66 (0.54, 0.80)         | 0.68 (0.52, 0.89)         | 0.74 (0.57, 0.97)         |
| Yes               |                           |                           |                           |                           |
| **Ever have unprotected sex (no condom) with last sex partner** | No     | 1.28 (1.06, 1.54)         | 0.52 (0.38, 0.69)         | 2.43 (1.93, 3.07)         |
| Yes               |                           |                           |                           |                           |
| **Never asked partner about HIV status when have sex** | No     | 0.49 (0.40, 0.57)         | 0.32 (0.25, 0.41)         | 0.85 (0.67, 1.07)         |
| Yes               |                           |                           |                           |                           |
| **Having STI in the past 12 month** | No     | 1.82 (1.49, 2.22)         | 2.15 (1.55, 3.06)         | 2.13 (1.48, 3.06)         |
| Yes               |                           |                           |                           |                           |
| **Drug use**      |                           |                           |                           |                           |
| No                | 0.48 (0.34, 0.70)         | 0.50 (0.27, 0.95)         | 0.49 (0.23, 1.06)         | 0.36 (0.20, 0.65)         |
| Yes               |                           |                           |                           |                           |
| **Score: Knowledge about HIV** | 0.84 (0.80, 0.89)     | 0.88 (0.83, 0.93)         | 0.80 (0.74, 0.85)         | 0.88 (0.82, 0.95)         |
| Yes               |                           |                           |                           |                           |
| **Score: believe of ARV** | 0.89 (0.85, 0.93) | 0.88 (0.83, 0.93)         | 0.83 (0.79, 0.88)         | 0.81 (0.76, 0.86)         |
| **Score: stigma** | 1.05 (0.99, 1.09)         | 1.11 (1.02, 1.18)         | 1.11 (1.06, 1.17)         | 1.10 (1.03, 1.19)         |
| **Interaction: age and gender** | Age<18 and male | 3.65 (2.44, 5.45)         | 2.82 (1.69, 4.70)         | 13.40 (5.58, 32.02)       |
|                   | Age<18 and female         | 4.91 (3.16, 7.63)         | 6.23 (4.02, 9.64)         | 16.17 (6.86, 38.16)       |
|                   | Age≥18 and male           | 3.64 (2.88, 4.61)         | 3.62 (2.52, 5.20)         | 3.29 (2.17, 5.00)         |
|                   | Age≥18 and female         | 1                         | 1                         | 1                         |
| **Interaction: age and ever have sex** | Age<18 and never have sex | 13.46 (8.90, 20.37)       |                           |                           |
|                   | Age<18 and have sex       | 3.21 (2.07, 4.98)         |                           |                           |
|                   | Age≥18 and never have sex |                           |                           |                           |
|                   | Age≥18 and have sex       | 0.66 (0.15, 2.93)         |                           |                           |

No evidence of lack of fit for all models.
| Reasons for never tested | 2014 n=743, 25% N (%) | 2015 n=363, 12% N (%) | 2016 n=373, 7% N (%) | 2017 n=313, 7% N (%) |
|--------------------------|----------------------|-----------------------|----------------------|----------------------|
| Risk Perceptions         |                      |                       |                      |                      |
| Not at risk for HIV (1)  | 244 (33)             | 58 (16)               | 73 (20)              | 67 (21)              |
| Too young, need consent (11) | 5            | 12                    | 22                   | 17                   |
| Fear                     | 69 (9)               | 25 (7)                | 58 (16)              | 37 (12)              |
| Afraid to learn HIV positive(2) | 64      | 21                    | 48                   | 27                   |
| Afraid of blood, needle or pain (18,24) | 7    | 4                     | 10                   | 10                   |
| Indifference             | 144 (19)             | 75 (21)               | 73 (20)              | 52 (17)              |
| Do not want/care (12, 22) | 29     | 22                    | 26                   | 9                    |
| Do not know/think (16,19) | 112    | 53                    | 49                   | 43                   |
| Discrimination (26)      | 25 (3)               | 5 (1)                 | 11 (3)               | 8 (3)                |
| If HIV+, will lose partner/family friends (3) | 3     | 0                     | 1                    | 1                    |
| If HIV+, will be beaten/hurt by partner (4) | 4          | 2                     | 2                    | 3                    |
| Partner does not want me to test (5) | 10  | 2                     | 6                    | 3                    |
| Family/friends do not want me to test (6) | 7     | 1                     | 1                    | 1                    |
| Wait for partner to test together (17) | 3    | 0                     | 1                    | 0                    |
| Access/Time              | 195 (26)             | 127 (35)              | 92 (25)              | 86 (27)              |
| Live too far from testing site(7) | 34 | 5                     | 9                    | 1                    |
| Cost too much money to test (8) | 5    | 0                     | 0                    | 1                    |
| Did not know where to test for HIV (10) | 53   | 31                    | 40                   | 30                   |
| Lack of time (13)        | 51                   | 42                    | 14                   | 22                   |
| Lack of access, opportunity (14, 21) | 49          | 50                    | 29                   | 25                   |
| Lack of knowledge/information (23) | 10 | 0                     | 1                    | 0                    |
| Support                  | 87 (12)              | 43 (12)               | 64 (17)              | 70 (22)              |
| Health provider never offered test (9) | 79 | 43                    | 64                   | 70                   |
| Need encouragement (25)  | 8                    | 0                     | 0                    | 0                    |
| Intend to test for HIV in the next 12 months | Yes | 661 (89)             | 313 (87)             | 307 (85)             | 269 (87)             |
|                          | No                   | 81 (11)               | 47 (13)              | 53 (15)              | 41 (13)              |

Participants were allowed to choose more than one reason.
Table 4: HBHTC acceptance and HBHTC positive among persons who have not tested before

|                        | Never had HIV test before | Accept HBHTS N= 1570 (88 %) | HIV positive by HBHTS N=154 (10 %) |
|------------------------|---------------------------|-----------------------------|-----------------------------------|
| Time                   |                           |                             |                                   |
| 2014                   | 743                       | 668 (90)                    | 85 (13)                           |
| 2015                   | 360                       | 312 (87)                    | 36 (11)                           |
| 2016                   | 365                       | 320 (88)                    | 28 (9)                            |
| 2017                   | 308                       | 270 (88)                    | 5 (2)                             |
| Sex                    |                           |                             |                                   |
| Male                   | 862                       | 752 (87)                    | 64 (9)                            |
| Female                 | 914                       | 818 (89)                    | 86 (11)                           |
| Age                    |                           |                             |                                   |
| <18                    | 839                       | 768 (92)                    | 11 (1)                            |
| 18-24                  | 336                       | 304 (90)                    | 28 (9)                            |
| ≥ 25                   | 601                       | 498 (83)                    | 111 (23)                          |
| Ever have sex          |                           |                             |                                   |
| Yes                    | 1128                      | 985 (87)                    | 139 (14)                          |
| No                     | 642                       | 580 (90)                    | 10 (2)                            |
| Never asked partner about HIV status when have sex |                        |                             |                                   |
| Yes                    | 744                       | 657 (88)                    | 87 (13)                           |
| No                     | 936                       | 828 (88)                    | 51 (6)                            |
| Reasons for not test   |                           |                             |                                   |
| Not at risk            |                           |                             |                                   |
| Yes                    | 437                       | 389 (89)                    | 26 (7)                            |
| No                     | 1339                      | 1181 (88)                   | 124 (10)                          |
| Fear                   |                           |                             |                                   |
| Yes                    | 185                       | 131 (71)                    | 12 (9)                            |
| No                     | 1591                      | 1439 (90)                   | 138 (10)                          |
| Indifference           |                           |                             |                                   |
| Yes                    | 340                       | 291 (86)                    | 28 (10)                           |
| No                     | 1436                      | 1279 (90)                   | 122 (10)                          |
| discrimination         |                           |                             |                                   |
| Yes                    | 48                        | 42 (88)                     | 5 (12)                            |
| No                     | 1728                      | 1528 (88)                   | 145 (10)                          |
| Lack of access/Time    |                           |                             |                                   |
| Yes                    | 498                       | 470 (94)                    | 54 (11)                           |
| No                     | 1278                      | 1100 (86)                   | 96 (9)                            |
| Lack of Support        |                           |                             |                                   |
| Yes                    | 264                       | 237 (90)                    | 25 (11)                           |
| No                     | 1512                      | 1333 (88)                   | 125 (9)                           |

There were 14 never testers who participated in HPS for 2 years and 1 who participated for 3 yrs. Only the first observation is included in this analysis.
Supporting information:

S1: Composite variables

Knowledge about HIV included the following 9 items:

- A healthy-looking person can have HIV.
- HIV can be transmitted from a mother to her baby during pregnancy.
- HIV can be transmitted from a mother to her baby during delivery.
- HIV can be transmitted from a mother to her baby during breast feeding.
- Condom use can reduce HIV risk.
- Circumcision for an HIV-negative man can reduce the risk of getting HIV.
- Circumcision for an HIV-positive man can reduce the risk of giving HIV.
- Antiretroviral therapy (ART) is available for treating HIV infection.
- ART has benefits for HIV-infected persons and reduces their risk for transmitting HIV to their partner.

Each item received 1 point for a correct response and 0 points for an incorrect or do-not-know response; thus, the maximum score was 9. The Cronbach alpha coefficient for this measure was 0.65.

Beliefs about ART included the following 6 items:

- HIV-infected persons can live a long, normal life if they take ART.
- Traditional medicine is as good as ART.
- Persons taking ARV medicines need to hide the medicines so that other people won’t find out.
- ART is only given to HIV-infected persons who are feeling really bad.
- After testing HIV-positive, immediate HIV care is not needed if the person is feeling good.
Special kinds of drugs can be given by a doctor or nurse to HIV-infected pregnant women to reduce the risk for HIV transmission to the baby.

Each item received 1 point for a correct response and 0 points for an incorrect or do-not-know response; thus, the maximum score was 6. The Cronbach alpha coefficient for this measure was 0.85.

HIV stigma included the following 8 items:

- Family members of persons living with HIV/AIDS should be ashamed.
- Persons with AIDS should be isolated from other people.
- Persons living with HIV/AIDS deserve to be punished.
- Persons living with HIV/AIDS should be ashamed.
- Persons living with HIV/AIDS in this community face rejection from their peers.
- Persons living with HIV/AIDS in this community face verbal abuse or teasing.
- Persons living with HIV/AIDS in this community face rejection from their home by their family.
- Persons living with HIV/AIDS in this community face neglect from their family.

Each item was scored on a 2-point scale: disagree = 0; neutral = 1; agree = 2; thus, the maximum score was 16. The Cronbach alpha coefficient for this measure was 0.66.
Table S2: Demographic and behavioral factors associated with never tested for HIV before by weighted approach

|                        | 2014 Crude OR (95% CI) | 2015 Crude OR (95% CI) | 2016 Crude OR (95% CI) | 2017 Crude OR (95% CI) |
|------------------------|------------------------|------------------------|------------------------|------------------------|
| **Sex**                |                        |                        |                        |                        |
| Male                   | 2.58 (2.15, 3.10)      | 2.12 (1.66, 2.73)      | 2.16 (1.69, 2.76)      | 1.52 (1.15, 2.02)      |
| Female                 | 1                      | 1                      | 1                      | 1                      |
| **Age**                |                        |                        |                        |                        |
| <18                    | 4.41 (3.49, 5.60)      | 4.93 (3.64, 6.67)      | 7.51 (5.55, 10.16)     | 16.47 (10.63, 25.54)   |
| 18-24                  | 1.50 (1.21, 1.85)      | 1.20 (0.84, 1.71)      | 1.19 (0.80, 1.76)      | 0.84 (0.46, 1.55)      |
| ≥25                    | 1                      | 1                      | 1                      | 1                      |
| **Relationship**       |                        |                        |                        |                        |
| Other                  | 2.16 (1.81, 2.60)      | 2.70 (2.04, 3.57)      | 2.57 (1.94, 3.41)      | 5.78 (3.81, 8.79)      |
| Married/marital union | 1                      | 1                      | 1                      | 1                      |
| **Knowing people died with AIDS** | 1 | 1 | 1 | 1 |
| No                     | 1.69 (1.38, 2.08)      | 1.61 (1.10, 2.32)      | 1.22 (0.82, 1.81)      | 2.02 (1.16, 3.51)      |
| Yes                    | 1                      | 1                      | 1                      | 1                      |
| **Ever have sex**      |                        |                        |                        |                        |
| No                     | 3.93 (3.01, 5.12)      | 6.28 (3.98, 9.90)      | 5.11 (3.81, 6.87)      | 5.85 (3.56, 9.63)      |
| Yes                    | 1                      | 1                      | 1                      | 1                      |
| **Having casual sex or exchange partner (last person had sex with)** | 1 | 1 | 1 | 1 |
| No                     | 0.68 (0.55, 0.83)      | 0.69 (0.54, 0.90)      | 0.76 (0.56, 1.03)      | 0.60 (0.39, 0.92)      |
| Yes                    | 1                      | 1                      | 1                      | 1                      |
| **Having unprotected sex (no condom) with last sex partner** | 1 | 1 | 1 | 1 |
| No                     | 1.27 (1.04, 1.55)      | 0.52 (0.39, 0.69)      | 2.08 (1.60, 2.72)      | 2.26 (1.74, 2.93)      |
| Yes                    | 1                      | 1                      | 1                      | 1                      |
| **Never asked partner about HIV status when have sex** | 1 | 1 | 1 | 1 |
| No                     | 0.47 (0.39, 0.56)      | 0.32 (0.25, 0.41)      | 0.79 (0.61, 1.04)      | 0.35 (0.23, 0.53)      |
| Yes                    | 1                      | 1                      | 1                      | 1                      |
| **Having STI in the past 12 month** | 1 | 1 | 1 | 1 |
| No                     | 1.84 (1.48, 2.29)      | 1.92 (1.29, 2.85)      | 1.55 (1.00, 2.39)      | 5.40 (2.21, 13.17)     |
| Yes                    | 1                      | 1                      | 1                      | 1                      |
| **Drug use**           |                        |                        |                        |                        |
| No                     | 0.53 (0.36, 0.78)      | 0.53 (0.25, 1.11)      | 0.47 (0.20, 1.11)      | 0.46 (0.23, 0.91)      |
| Yes                    | 1                      | 1                      | 1                      | 1                      |
| **Score: knowledge about HIV** | 0.84 (0.80, 0.89) | 0.88 (0.83, 0.94) | 0.81 (0.75, 0.87) | 0.89 (0.82, 0.97) |
| **Score: believe of ARV** | 0.88 (0.84, 0.92) | 0.87 (0.82, 0.93) | 0.87 (0.81, 0.93) | 0.83 (0.76, 0.90) |
| **Score: stigma**      | 1.02 (0.98, 1.08)      | 1.13 (1.05, 1.21)      | 1.11 (1.06, 1.18)      | 1.10 (1.03, 1.18)      |
| **Interaction: age and gender** | 1.06 (1.01, 1.11) | 1.11 (1.06, 1.18) | 1.10 (1.03, 1.18) | 1.01 (0.90, 1.14) |
| Age<18 and male        | 3.54 (2.32, 5.40)      | 2.42 (1.42, 4.12)      | 13.67 (5.46, 34.26)    |                        |
| Age<18 and female      | 5.15 (3.30, 8.04)      | 5.41 (3.46, 8.48)      | 13.06 (5.26, 32.38)    |                        |
| Age=18 and male        | 3.48 (2.70, 4.50)      | 3.12 (2.07, 4.72)      | 3.31 (2.07, 5.31)      |                        |
| Age=18 and female      | 1                      | 1                      | 1                      | 1                      |
| Interaction: age and ever have sex |          |          |
|-----------------------------------|----------|----------|
| Age<18 and never have sex         | 12.00 (7.56, 19.05) |          |
| Age<18 and have sex               | 3.26 (2.00, 5.32)   |          |
| Age>=18 and never have sex        | 0.73 (0.16, 3.28)   |          |
| Age>=18 and have sex              | 1         |          |
Table S3: Reasons for never tested for HIV before and intention to have HIV test in the next 12 month among never testers (by weighted approach)

| Reasons for never tested                              | 2014 weighted n=720, 24% N (%) | 2015 weighted n=387, 12% N (%) | 2016 Weighted n=424, 8% N (%) | 2017 weighted n=309, 7% N (%) |
|-------------------------------------------------------|--------------------------------|--------------------------------|-------------------------------|-------------------------------|
| Risk Perceptions                                      | 240 (33)                       | 61 (16)                        | 85 (20)                       | 74 (24)                       |
| Not at risk for HIV (1)                               | 240                            | 50                             | 65                            | 61                            |
| Too young, need consent (11)                          | 4                              | 14                             | 20                            | 13                            |
| Fear                                                  | 76 (10)                        | 34 (9)                         | 81 (12)                       | 36 (12)                       |
| Afraid to learn HIV positive (2)                      | 70                             | 29                             | 72                            | 27                            |
| Afraid of blood, needle or pain (18, 24)              | 9                              | 5                              | 10                            | 9                             |
| Indifference                                          | 141 (20)                       | 82 (21)                        | 76 (18)                       | 48 (16)                       |
| Do not want/care (12, 22)                             | 35                             | 25                             | 33                            | 7                             |
| Do not know/think (16, 19)                            | 107                            | 57                             | 43                            | 41                            |
| Discrimination (26)                                   | 26 (3)                         | 7 (2)                          | 10 (2)                        | 9 (3)                         |
| If HIV+, will lose partner/family friends (3)         | 3                              | 0                              | 1                             | 1                             |
| If HIV+, will be beaten/hurt by partner (4)           | 4                              | 3                              | 2                             | 4                             |
| Partner does not want me to test (5)                  | 11                             | 3                              | 6                             | 3                             |
| Family/friends do not want me to test (6)             | 8                              | 2                              | 1                             | 1                             |
| Wait for partner to test together (17)                | 0                              | 0                              | 0                             | 0                             |
| Access/Time                                           | 191 (26)                       | 140 (36)                       | 92 (22)                       | 78 (25)                       |
| Live too far from testing site (7)                    | 32                             | 7                              | 6                             | 2                             |
| Cost too much money to test (8)                       | 5                              | 0                              | 0                             | 1                             |
| Did not know where to test for HIV (10)               | 47                             | 33                             | 38                            | 30                            |
| Lack of time (13)                                     | 56                             | 52                             | 21                            | 25                            |
| Lack of access, opportunity (14, 21)                  | 48                             | 50                             | 28                            | 19                            |
| Lack of knowledge/information (23)                    | 10                             | 0                              | 2                             | 0                             |
| Support                                               | 83 (12)                        | 37 (9)                         | 76 (18)                       | 70 (23)                       |
| Health provider never offered test (9)                | 79                             | 37                             | 76                            | 70                            |
| Need encouragement (25)                               | 9                              | 0                              | 0                             | 0                             |
| Intend to test for HIV in the next 12 months          |                                 |                                |                               |                               |
| Yes                                                   | 632 (88)                       | 337 (88)                       | 339 (83)                      | 260 (85)                      |
| No                                                    | 79 (11)                        | 44 (12)                        | 70 (17)                       | 46 (15)                       |

There were 15 never tester participated in more than 1 years.

Participants were allowed to choose more than one reason.
Table S4: HBHTC acceptance and HBHTC positive among persons who have not tested before (by weighted approach)

|                      | Never had HIV test before weighted N=1826 | Accept HBHTS weighted N=1578 (86 %) | HIV positive by HBHTS weighted N=150 (9 %) |
|----------------------|------------------------------------------|-------------------------------------|------------------------------------------|
| **Time**             |                                          |                                     |                                          |
| 2014                 | 720                                      | 641 (89)                            | 82 (13)                                  |
| 2015                 | 383                                      | 332 (87)                            | 36 (11)                                  |
| 2016                 | 418                                      | 344 (82)                            | 25 (7)                                   |
| 2017                 | 305                                      | 261 (86)                            | 6 (2)                                    |
| **Sex**              |                                          |                                     |                                          |
| Male                 | 992                                      | 839 (85)                            | 76 (9)                                   |
| Female               | 834                                      | 740 (89)                            | 73 (10)                                  |
| **Age**              |                                          |                                     |                                          |
| <18                  | 826                                      | 754 (91)                            | 10 (1)                                   |
| 18-24                | 344                                      | 312 (91)                            | 26 (8)                                   |
| ≥ 25                 | 655                                      | 512 (78)                            | 113 (22)                                 |
| **Ever have sex**    |                                          |                                     |                                          |
| Yes                  | 1187                                     | 1005 (85)                           | 141 (14)                                 |
| No                   | 632                                      | 568 (90)                            | 8 (1)                                    |
| **Never asked partner about HIV status when have sex** | | | |
| Yes                  | 770                                      | 659 (86)                            | 90 (14)                                  |
| No                   | 962                                      | 836 (90)                            | 47 (6)                                   |
| **Reasons for not test** |                                       |                                     |                                          |
| **Not at risk**      |                                          |                                     |                                          |
| Yes                  | 456                                      | 397 (87)                            | 24 (6)                                   |
| No                   | 1370                                     | 1181 (86)                           | 125 (11)                                 |
| **Fear**             |                                          |                                     |                                          |
| Yes                  | 223                                      | 146 (65)                            | 18 (8)                                   |
| No                   | 1604                                     | 1432 (89)                           | 132 (9)                                  |
| **Indifference**     |                                          |                                     |                                          |
| Yes                  | 344                                      | 283 (82)                            | 22 (8)                                   |
| No                   | 1482                                     | 1295 (87)                           | 127 (10)                                 |
| **discrimination**   |                                          |                                     |                                          |
| Yes                  | 52                                       | 45 (87)                             | 4 (9)                                    |
| No                   | 1774                                     | 1533 (86)                           | 145 (9)                                  |
| **Lack of access/Time** |                                       |                                     |                                          |
| Yes                  | 503                                      | 473 (94)                            | 57 (12)                                  |
| No                   | 1323                                     | 1105 (84)                           | 93 (8)                                   |
| **Lack of Support**  |                                          |                                     |                                          |
| Yes                  | 266                                      | 241 (91)                            | 29 (12)                                  |
| No                   | 1560                                     | 1337 (86)                           | 121 (9)                                  |

There were 14 never testers who participated in HPS for 2 year and 1 who participated for 3 yrs. Only the first observation is included in this analysis.
Click here to access/download Supporting Information time2.xls
Click here to access/download

Supporting Information
time3.xls
