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MAJOR ARTICLE

# Knowledge of Human Immunodeficiency Virus Status and Seropositivity After a Recently Negative Test in Malawi

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***Background.*** Awareness of human immunodeficiency virus (HIV) status among all people with HIV is critical for epidemic control. We aimed to assess accurate knowledge of HIV status, defined as concordance with serosurvey test results from the 2010 Malawi Demographic Health Survey (MDHS), and to identify risk factors for seropositivity among adults (aged 15–49) reporting a most recently negative test within 12 months.

***Methods.*** Data were analyzed from the 2010 MDHS. A logistic regression model was constructed to determine factors independently associated with HIV seropositivity after a recently negative test. All analyses controlled for the survey's complex design.

***Results.*** A total of 11 649 adults tested for HIV during this MDHS reported ever being sexually active. Among these, HIV seroprevalence was 12.0%, but only 61.7% had accurate knowledge of their status. Forty percent (40.3%; 95% confidence interval [CI], 36.8–43.8) of seropositive respondents reported a most recently negative test. Of those reporting that this negative test was within 12 months (n = 3630), seroprevalence was 7.2% for women (95% CI, 5.7–9.2), 5.2% for men (95% CI, 3.9–6.9), higher in the South, and higher in rural areas for men. Women with higher education and men in the richest quintile were at higher risk. More than 1 lifetime union was significantly associated with recent HIV infection, whereas never being married was significantly protective.

***Conclusions.*** Self-reported HIV status based on prior test results can underestimate seroprevalence. These results highlight the need for posttest risk assessment and support for people who test negative for HIV and repeat testing in people at high risk for HIV infection.

**Keywords.** awareness of HIV status; HIV/AIDS; Malawi; recent HIV seropositivity.

Human immunodeficiency virus (HIV) continues to present a major challenge to global public health, with almost 37 million people living with HIV (PLHIV) worldwide in 2015 and 1.1 million people who died from acquired immune deficiency syndrome (AIDS)-related causes [1, 2]. In light of recent evidence that early antiretroviral therapy (ART) reduces HIV-related morbidity and mortality [3, 4], the World Health Organization (WHO) recently released guidelines for the initiation of ART for all PLHIV regardless of CD4 count [5]. To end the AIDS epidemic in accordance with UNAIDS 90-90-90 treatment scale-up targets, 90% of PLHIV should know their status by 2020, so they can receive sustained ART and achieve viral suppression [6–8]. Knowing one's HIV status has additionally been validated as an effective prevention measure in high HIV burden settings, with multiple studies demonstrating that it can result in positive behavior changes [9–17]. Yet, although HIV testing and counseling (HTC) has increased dramatically over the past decade, less than half of adult PLHIV in sub-Saharan Africa are estimated to know their status [1].

Malawi is among 15 countries collectively accounting for 75% of the global HIV burden [1]. In 2015, it had an estimated 980 000 PLHIV, a prevalence of 9.1% among adults aged 15–49, and 27 000 AIDS-related deaths [18]. The 2004 Malawi Demographic Health Survey (MDHS) indicated that 83% of adults had never been previously tested for HIV, and among those, HIV prevalence was 12.6% [19]. Since 2004, the Government of Malawi, with support from the United States President's Emergency Plan for AIDS Relief (PEPFAR), has dramatically scaled-up HTC capacity, with female and male respondents from the 2010 MDHS reporting prior HIV testing rates of 73% and 53%, respectively. Unfortunately, self-reported HIV status based on prior testing was poorly correlated with actual serostatus determined by the survey [20].

Other studies have defined awareness of HIV status as having received the result of a prior HIV test [17, 21]; however, recent seroprevalence testing conducted in conjunction with DHS or AIDS Indicator Surveys (AIS) provide an opportunity to compare self-reported previous test results with current serostatus [22–25]. Thus, the number of "undiagnosed infections" expands

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from those never receiving an HIV test result to include PLHIV who inaccurately consider themselves to be HIV-negative based on prior testing. Of the 59% and 53% of PLHIV unaware they were HIV positive per the 2011 Uganda AIS and 2012 Kenya AIS, respectively, 46% and 69% fit this latter category, although specific risk factors for seroconversion since testing negative were not reported [22, 25]. Given recent scale-up of HTC in Malawi, we analyzed data from adults aged 15–49 from the most recent MDHS (1) to assess accurate knowledge of HIV status and (2) to identify risk factors for current seropositivity among those who reported most recently negative results.

## METHODS

### Malawi Demographic Health Survey Design

We analyzed data from the 2010 MDHS, a large nationally representative, cross-sectional survey of adults from 27 307 households. Using the 2008 Malawi Population and Housing Census as a sampling frame, the MDHS sample was selected using a stratified, 2-stage cluster design to provide population and health indicator estimates at national, regional, and district levels. All eligible women aged 15–49 in selected households and men aged 15–54 in a subsample of one third of households were interviewed, as is DHS convention, totaling 23 748 women and 7783 men. A detailed description of MDHS methods is described elsewhere [20, 26].

### Malawi Demographic Health Survey Human Immunodeficiency Virus Testing

A subsample of 1 in 3 households was selected for HIV testing, and blood specimens were collected from all consenting adults. Interviewers explained testing and data confidentiality procedures, and respondents were made aware that they would not have access to HIV test results because testing was anonymous. However, all households were provided information about HIV and nearby HTC services. Eighty-seven percent of eligible MDHS respondents were interviewed and consented to HIV testing, with 91% testing coverage for women and 84% for men. Dried blood spot samples were tested using the Vironostika HIV Uni-Form I Plus-O (bioMerieux) enzyme-linked immunosorbent assay (ELISA) test. A nonreactive result was considered negative, whereas positive results were confirmed by a second ELISA assay, Enzygnost Anti-HIV ½ Plus (Dade Behring). Discordant results were retested by both methods, and, if again discordant, Western Blot 2.2 (Abbott Laboratories) was used. Test results were linked with sociodemographic data from individual questionnaires [20].

### Malawi Demographic Health Survey Ethical Review

Survey protocols were approved by the Malawi Health Sciences Research Committee, the ICF Macro Institutional Review Board (IRB), and the US Centers for Disease Control and Prevention IRB. Informed consent was obtained from all eligible persons [20].

### Data Management and Statistical Analysis

Survey questionnaire response datasets from the 2010 MDHS were merged with the HIV laboratory dataset to produce a final dataset for analysis. All analyses were performed using survey procedures in STATA 13.0 to account for stratification, sample weighting, and clustering within the MDHS' complex survey design. Survey data were weighted using female and male survey sampling weights, and analyses involving HIV serostatus were weighted using HIV survey sampling weights. Domain analysis was performed on the subpopulation of patients aged 15–49 who were ever sexually active.

We calculated frequencies and weighted proportions with 95% confidence intervals (CIs) for variables including HIV prevalence and prior testing. Accurate knowledge of HIV status was defined as concordance between a self-reported result from a most recent prior HIV test and the MDHS HIV test result. Exposure variables of interest were chosen from those available within the MDHS based on a literature review of comparable studies from sub-Saharan Africa [16, 20–25], and these were used to characterize sexually active adults aged 15–49 who reported a negative HIV test within 12 months and those found to be HIV-positive during the MDHS survey, stratified by gender. Statistical significance for cross tabulations was conducted using the Rao-Scott $\chi^2$ test. Multivariable logistic regression models were constructed using purposeful selection to determine factors independently associated with being HIV-positive after reporting a most recently negative test result within 12 months [27, 28]. Predictor variables were screened using single variable logistic regression models. Variables with $P < .25$ were included in the initial multivariable model, which was refitted, excluding variables with the largest $P$ values one at a time, until all variables had a $P < .05$. Interactions between age, wealth index, and residence were assessed for each strata but were nonsignificant. Model fit was assessed using the svylogitgof package in Stata [29].

## RESULTS

Of 13 910 adults tested for HIV, 11 649 of the unweighted sample (83.7%) were aged 15–49 and ever sexually active. Within this subpopulation, HIV prevalence was 12.0% (95% CI, 11.1–13.0).

### Prior Human Immunodeficiency Virus Testing

Sixty-nine percent (95% CI, 67.8–70.3) of respondents within this subpopulation reported ever having a prior HIV test, 97.9% (95% CI, 97.5–98.1) of whom said they received their result. Their estimated HIV seroprevalence was 13.3% (95% CI, 12.1–14.5), whereas seroprevalence among those reporting never testing was 8.9% (95% CI, 7.8–10.2). Of those who reported never being previously tested, 93.2% (95% CI, 92.0–94.2) said they knew where to get tested.

### Accurate Knowledge of Human Immunodeficiency Virus Status

Prior studies have defined awareness of HIV status as having had a prior HIV test and received the result [17, 21]. Using this definition, 68.1% (95% CI, 66.7–69.4) of our subpopulation were potentially aware of their HIV status, as described above. However, using 2010 MDHS data on HIV serostatus and

**Table 1. A Comparison of "Awareness" Versus "Accurate Knowledge"[a] of HIV Status Among Sexually Active Adults Aged 15–49 in Malawi**

| Awareness (denoted in italics) | % | 95% CI |
|---|---|---|
| Reports a previous HIV test and receipt of the result | *68.1* | 66.7–69.4 |
| Reports a previous HIV test but no receipt of the result | 1.0 | 0.8–1.3 |
| Reports never having a previous HIV test | 30.8 | 29.5–32.2 |
| Previous testing status unknown | 0.1 | 0–0.1 |
| Total | 100 | – |
| Accurate Knowledge (denoted in italics) | % | 95% CI |
| HIV-positive and previous test reported to be positive | *4.1* | 3.7–4.7 |
| HIV-negative and previous test reported to be negative | *57.6* | 56.2–9.0 |
| HIV-positive and previous test reported to be negative | 4.7 | 4.2–5.4 |
| HIV-negative and previous test reported to be positive | 0.2 | 0.1–0.3 |
| Reports never having a previous HIV test | 32.2 | 30.9–33.6 |
| Previous test result unknown | 1.1 | 0.8–1.4 |
| Total | 100 | – |

Abbreviations: CI, confidence interval; HIV, human immunodeficiency virus; MDHS, Malawi Demographic Health Survey.

[a]Awareness of HIV status is defined as having had a prior HIV test and received the result. Accurate knowledge is defined as concordance between a self-reported most recent prior HIV result and the MDHS HIV test result.

self-reported prior results, we were able to examine whether awareness of HIV status from prior testing reflected actual serostatus at the time of the survey. Assuming that serostatus as determined by MDHS DBS testing was correct and that respondents truthfully disclosed their prior HIV testing results, "accurate knowledge" of HIV status in our subpopulation was actually only 61.7%, with only 4.1% (95% CI, 3.7–4.7) of respondents accurately aware they were HIV-positive and 57.6% (95% CI, 56.2–59.0) accurately aware they were HIV-negative (Table 1).

More importantly, of those with a prior HIV test result documented, 7.1% (95% CI, 6.3–8.0) were now seropositive but inaccurately thought they were HIV-negative based on their last test. Only 35.2% (95% CI, 32.1–38.6) of those found in the 2010 MDHS to be HIV-positive on DBS testing reported a previously positive HIV test, whereas 23.5% (95% CI, 20.7–26.5) reported no prior testing, and 40.3% (95% CI, 36.8–43.8) reported a most recently negative test result. Of those PLHIV with a previously negative HIV test who reported the timing of this test, 49.7% (95% CI, 43.1–56.3) were tested within the last year.

### Human Immunodeficiency Virus Seropositivity Within 12 Months of a Reportedly Negative Test

Characteristics and risk behaviors of sexually active adults aged 15–49 who reported a most recently negative HIV test within 12 months of the MDHS survey (unweighted, n = 3630), stratified by gender and baseline variables of interest, are presented in Table 2. The HIV prevalence within this group was 6.2% (95% CI, 5.2–7.5).

Factors independently associated with recent HIV seropositivity within 12 months are presented in Table 3. Residing in the Southern region was associated with recent seropositivity, with adjusted odds ratios (AORs) of 3.17 (95% CI, 1.46–6.88) compared with the Northern region for women and 2.21 (95% CI, 1.01–4.80) for men, and being from a rural area was protective for men (AOR 0.45; 95% CI, 0.20–0.99). Women with more education had higher odds of recent seropositivity (AOR 2.58; 95% CI, 1.37–3.85), as did men in the richest wealth quintile (AOR 3.44; 95% CI, 1.15–10.26). Regardless of gender, never being married or living with a partner was protective, with AORs of 0.29 (95% CI, 0.08–1.00) in women and 0.05 (95% CI, 0.01–0.25) in men.

Women who reported knowing that condom use reduces the risk of HIV transmission had a lower odds of recent seropositivity, whereas men who knew that monogamy reduces transmission had higher odds. Delayed sexual debut was protective for men, whereas for women, lifetime number of sexual partners was associated with recent HIV seropositivity. Finally, more than 1 lifetime union (marriage or living with a significant other) was a significant risk factor regardless of gender. Of note, men who reported no sexual activity within 4 weeks preceding the survey had a higher odds of recent HIV seropositivity within 12 months (Table 3).

## DISCUSSION

Between 2004 and 2010, there was a dramatic increase in reported HIV testing among men and women aged 15–49 in Malawi, from 15.1% and 12.9%, respectively, in 2004 to 51.2% and 71.6% in 2010, corresponding with major scale-up of HIV prevention, care, and treatment services [19, 20]. However, further improvement was still needed at that time to achieve the UNAIDS target for 90% of PLHIV to know their HIV status [6]. As demonstrated by our study, only 69% of sexually active adults reported ever testing for HIV before the 2010 MDHS, even though 93% of those who never tested reported that they knew where to get tested. Of those found to be HIV-positive, one quarter reportedly had never been previously tested. This missed opportunity reinforces the need for continued scale-up of HTC to reduce the number of undiagnosed HIV infections in Malawi, increase the number of PLHIV on ART, and align with universal test and treat strategies for HIV prevention [6, 30, 31].

However, despite benefits of HTC, one-time testing for HIV is inadequate in areas and among populations of high disease burden. Although other studies often define knowledge of HIV status as having previously received a test result [17, 21], our data indicate that reported prior testing overestimates accurate knowledge of current serostatus. This aligns with findings from similar analyses in Uganda and Kenya; however, these analyzed factors associated with "undiagnosed HIV infections" overall, which combined HIV-positive patients reporting previously negative results with those who never previously tested, and found associations with factors including youth, education, marital status, incomplete HIV knowledge, multiple sexual partners, and inconsistent condom use [22–25]. By contrast, we examined specific risk factors for seropositivity since a

**Table 2. Characteristics of Sexually Active Adults Aged 15–49 Who Reported a Previously Negative HIV Test Within 12 Months of the MDHS**

| Variable (unweighted n) | Total (n = 3630) % [95% CI] | Female (n = 1884) % [95% CI] | Male (n = 1746) % [95% CI] |
|---|---|---|---|
| Age Group (n = 3630) | | | |
| 15–24 (n = 1320) | 36.9 [34.8–39.1] | 36.7 [33.9–39.6] | 37.1 [34.1–40.3] |
| 25–34 (n = 1366) | 37.6 [35.5–39.9] | 38.8 [35.9–41.7] | 36.5 [33.5–39.6] |
| 35–49 (n = 944) | 25.4 [23.6–27.4] | 24.5 [22.2–27.1] | 26.3 [23.6–29.3] |
| Region (n = 3630) | | | |
| Northern (n = 702) | 11.9 [9.8–14.5] | 11.7 [9.3–14.7] | 12.2 [9.4–15.7] |
| Central (n = 1309) | 46.1 [43.0–49.3] | 45.5 [41.6–49.6] | 46.8 [42.0–51.6] |
| Southern (n = 1619) | 41.9 [38.9–44.9] | 42.8 [39.1–46.6] | 41 [36.7–45.5] |
| Residence (n = 3630) | | | |
| Urban (n = 489) | 20.2 [17.0–24.0] | 18.4 [15.4–21.8] | 22 [17.0–28.1] |
| Rural (n = 3141) | 79.8 [76.0–83.0] | 81.6 [78.2–84.6] | 78 [71.9–83.0] |
| Education (n = 3630) | | | |
| Primary or lower (n = 2543) | 68.2 [65.8–70.6] | 77.6 [75.0–80.1] | 58.9 [55.4–62.2] |
| Secondary or higher (n = 1087) | 31.8 [29.4–34.2] | 22.4 [19.9–25.0] | 41.1 [37.8–44.6] |
| Marital Status (n = 3630) | | | |
| Never married (n = 674) | 19.1 [17.3–21.0] | 8.3 [6.8–10.1] | 29.8 [26.9–32.8] |
| Married or living together (n = 2637) | 72.1 [69.9–74.2] | 78.1 [75.5–80.5] | 66 [62.9–69.1] |
| Widow, divorced, not living tog (n = 319) | 8.9 [7.7–10.1] | 13.6[11.7–15.6] | 4.2 [3.1–5.7] |
| Wealth Index Quintile (n = 3630) | | | |
| Poorest (n = 592) | 14.8 [13.2–16.7] | 16.7[14.4–19.1] | 13 [11.0–15.4] |
| Poorer (n = 708) | 18.5 [16.6–20.7] | 19.5 [17.1–22.1] | 17.6 [15.2–20.2] |
| Middle (n = 759) | 19.8 [18.0–21.7] | 19.7 [17.5–22.1] | 19.9 [17.4–22.5] |
| Richer (n = 774) | 20.7 [18.6–22.8] | 19.6 [17.3–22.3] | 21.7 [18.9–24.7] |
| Richest (n = 797) | 26.2 [23.4–29.2] | 24.5[21.2–28.1] | 27.9 [24.2–31.9] |
| Why Last HIV Test Was Done (n = 3608) | | | |
| Asked for it of own accord (n = 1982) | 53.4 [50.9–56.0] | 56.7 [53.5–59.9] | 50.2 [46.4–53.9] |
| Offered it (n = 652) | 19.6 [17.8–21.6] | 21.1 [18.6–23.8] | 18.2 [15.5–21.2] |
| Required to test (n = 974) | 26.9 [24.6–29.3] | 22.2 [19.7–24.9] | 31.7 [27.8–35.7] |
| Knows Condoms Reduce Risk (n = 3623) | | | |
| No (n = 928) | 26.2 [24.2–28.3] | 27.7 [24.9–30.6] | 24.7 [21.7–27.9] |
| Yes (n = 2695) | 73.8 [71.7–75.8] | 72.3 [69.4–75.1] | 75.3 [72.1–78.3] |
| Knows Monogamy Reduces Risk (n = 3623) | | | |
| No (n = 454) | 13.1 [11.5–14.8] | 13.3 [11.2–15.7] | 12.9 [10.6–15.6] |
| Yes (n = 3169) | 86.9 [85.2–88.5] | 86.7 [84.3–88.8] | 87.1 [84.4–89.4] |
| Age at First Intercourse (n = 3630) | | | |
| ≤15 (n = 1005) | 28.3 [26.4–30.4] | 25.5[22.8–28.5] | 31.1 [28.2–34.2] |
| 16–17 (n = 680) | 18.2[16.7–19.9] | 19 [16.8–21.5] | 17.5 [15.2–20.0] |
| 18–19 (n = 646) | 18.2 [16.6–20.0] | 15.5 [13.3–17.9] | 21 [18.6–23.6] |
| ≥20 (n = 1299) | 35.2 [32.8–37.6] | 39.9 [36.7–43.2] | 30.4 [27.3–33.8] |
| Lifetime Sexual Partners (n = 3609) | | | |
| 1–2 (n = 2473) | 67.2 [64.7–69.7] | 87 [84.9–88.8] | 47.4 [43.6–51.1] |
| 3–4 (n = 740) | 21.7 [19.4–24.1] | 11.2 [9.6–13.1] | 32.2 [28.4–36.2] |
| ≥5 (n = 396) | 11.1 [9.8–12.6] | 1.8 [1.1–2.9] | 20.5 [17.9–23.3] |
| Lifetime Unions (n = 3618) | | | |
| 0–1 unions (n = 2959) | 81.6 [79.8–83.2] | 79.5 [77.0–81.9] | 83.6 [81.1–85.9] |
| >1 union (n = 659) | 18.4 [16.8–20.2] | 20.5[18.1–23.0] | 16.4 [14.1–18.9] |
| Recent Sexual Activity (n = 3630) | | | |
| Active within 4 weeks (n = 2268) | 61.7 [59.3–64.0] | 63.2 [60.5–65.8] | 60.2 [56.7–63.5] |
| Inactive within 4 weeks (n = 1362) | 38.3 [36.0–40.7] | 36.8 [34.2–39.5] | 39.8 [36.5–43.3] |
| Who Has Final Say On Healthcare (n = 1466) | | | |
| Self (n = 271) | — | 18.1 [15.4–21.1] | — |
| Together with spouse or partner (n = 558) | — | 38.9 [35.4–42.5] | — |
| Husband or other (n = 637) | — | 43.0 [39.4–46.8] | — |
| Risk Factors Within 12 Months | | | |
| No. Sexual Partners Including Spouse (n = 3630) | | | |
| No sex in 12 months (n = 436) | 12.5 [11.1–14.1] | 12.5 [10.6–14.6] | 12.6 [10.6–14.9] |

**Table 2. Continued**

| Variable (unweighted n) | Total (n = 3630) % [95% CI] | Female (n = 1884) % [95% CI] | Male (n = 1746) % [95% CI] |
|---|---|---|---|
| 1 partner (n = 2946) | 80.2 [78.4–81.9] | 86.1 [83.9–88.0] | 74.3 [71.6–76.8] |
| 2+ partners (n = 248) | 7.3 [6.3–8.4] | 1.4 [0.9–2.3] | 13.1 [11.3–15.3] |
| No. Extramarital Partners (n = 3630) | | | |
| 0 (n = 3017) | 83.1 [81.3–84.7] | 91.6 [89.6–93.2] | 74.6 [71.6–77.3] |
| ≥1 (n = 613) | 16.9 [15.3–18.7] | 8.4 [6.8–10.4] | 25.4 [22.7–28.4] |
| Condom Use During Last Sex (n = 3627) | | | |
| No (n = 2663) | 73.7 [71.5–75.7] | 80.5 [78.0–82.8] | 66.8 [63.6–69.9] |
| Yes (n = 528) | 13.8 [12.3–15.5] | 7.0 [5.6–8.8] | 20.6 [18.1–23.4] |
| No sex in 12 months (n = 436) | 12.5 [11.1–14.1] | 12.5 [10.6–14.6] | 12.6 [10.6–14.9] |
| Condom Each Time, Last Partner (n = 3640) | | | |
| No (n = 2834) | 78.1 [76.1–79.9] | 83 [80.7–85.2] | 73.1 [70.1–75.9] |
| Yes (n = 334) | 9.3 [8.1–10.7] | 4.4 [3.3–5.9] | 14.3 [12.2–16.6] |
| No sex in 12 months (n = 436) | 12.6 [11.2–14.2] | 12.6 [10.7–14.7] | 12.6 [10.6–14.9] |
| Last Sexual Partner Type (n = 3626) | | | |
| Spouse (n = 2655) | 72.7 [70.5–74.8] | 79.6 [77.0–82.0] | 65.8 [62.6–68.9] |
| Not live-in significant other (n = 497) | 13.2 [11.7–14.9] | 7.7 [6.1–9.7] | 18.7 [16.3–21.4] |
| Casual acquaintance or sex worker (n = 38) | 1.5 [1.0–2.2] | 0.2 [0.1–0.5] | 2.8 [1.9–4.3] |
| No sex in 12 months (n = 436) | 12.5 [11.1–14.1] | 12.5 [10.6–14.6] | 12.6 [10.6–14.9] |
| Trips Away From Home (n = 3620) | | | |
| 0 (n = 1804) | 49.8 [47.5–52.1] | 55.2 [52.3–58.0] | 44.4 [41.0–47.9] |
| 1–2 (n = 1053) | 29 27.2-30.9] | 31.2 [28.6–33.8] | 26.9 [24.4–29.5] |
| >2 (n = 763) | 21.2 [19.3–23.3] | 13.7 [11.6–16.1] | 28.7 [25.8–31.8] |
| Injections (n = 3629) | | | |
| 0 (n = 2565) | 69.6 [67.5–71.7] | 56.6 [53.6–59.6] | 82.5 [80.1–84.7] |
| 1–2 (n = 668) | 19.4 [17.8–21.1] | 25.4 [22.9–28.1] | 13.4 [11.5–15.6] |
| >2 (n = 396) | 11.0 [9.6–12.5] | 17.9 [15.6–20.5] | 4.1 [3.1–5.4] |
| Any Reported STD (n = 3622) | | | |
| No (n = 3568) | 98.7 [98.2–99.1] | 99.0 [98.4–99.4] | 98.5 [97.5–99.0] |
| Yes (n = 54) | 1.3 [0.9–1.8] | 1.0 [0.6–1.6] | 1.5 [1.0–2.5] |

Abbreviations: CI, confidence interval; HIV, human immunodeficiency virus; STD, sexually transmitted disease.

reportedly negative test. Of note, undiagnosed HIV infections "discovered" during the 2010 MDHS were not shared with survey participants due to the common practice of using anonymous testing for HIV surveillance at the time [20]. This practice has now fallen out of favor given ethical concerns and 2013 WHO guidance that participants in HIV surveillance should have the opportunity to learn their status [32]. The need for this opportunity is reinforced by unequivocal evidence that earlier HIV diagnosis and treatment improve outcomes [3–5], and doing so will allow future DHS endeavors to increase knowledge of HIV status among survey populations.

Per recent WHO guidelines, all patients testing negative for HIV should receive condoms, linkage to HIV prevention services, and quality posttest counseling to reduce behaviors that put them at risk for future acquisition of HIV [33, 34]. For those admitting high recent or ongoing risk of exposure, retesting can be considered within 6 to 8 weeks and is recommended at least annually while at continued high risk. People defined by these guidelines as high-risk include those who inject drugs, commercial sex workers, men who have sex with men, and people with recent sexually transmitted infections or high-risk or HIV-positive partners [35]. However, we found that 12% of sexually active, reproductive age adults in the general population who were tested for HIV during the 2010 MDHS survey were HIV-positive, and that, notably, 40% of these reported a most recently negative HIV test, approximately half of which were within 12 months. Furthermore, among those with a negative HIV test reported within 12 months, HIV seroprevalence was as high as 6.2%. Assuming that respondents truthfully reported their prior results, that MDHS DBS testing was accurate, and that previously negative tests represented truly HIV-negative status (each of these assumptions is subject to limitations as outlined below), some of these "newly positive" cases may represent a crude proxy for HIV incidence. For this reason, we built a unique model to identify risk factors for this "recent" seropositivity.

Human immunodeficiency virus seroprevalence in this subpopulation with a reportedly negative HIV test within 12 months was higher in women than in men and in the Southern region; however, this is in accordance with findings that HIV prevalence in the overall DHS population was significantly higher in women than men (13% versus 8%, respectively) and twice

**Table 3. Factors[a] Associated With Seropositivity Among Sexually Active Adults Reporting a Negative HIV Test Within 12 Months**

| | Female | | | Male | | |
|---|---|---|---|---|---|---|
| Variable | HIV Prevalence | OR [CI] | AOR [CI] | HIV Prevalence | OR [CI] | AOR [CI] |
| Age Group | | | | | | |
| 15–24 (n = 1320) | 6.1 [3.9–9.3] | Reference | — | 1.7 [0.8–3.5] | Reference | — |
| 25–34 (n = 1366) | 8.2 [5.7–11.6] | 1.38 [0.79–2.40] | — | 4.9 [3.2–7.4] | **3.00 [1.26–7.14]** | 1.30 [0.48–3.53] |
| 35–49 (n = 944) | 7.4 [4.9–11.2] | 1.24 [0.65–2.36] | — | 10.7 [6.7–16.6] | **7.00 [2.81–17.40]** | 2.00 [0.73–5.47] |
| Region | | | | | | |
| Northern (n = 702) | 3.3 [1.7–6.4] | Reference | — | 3 [1.6–5.4] | Reference | — |
| Central (n = 1309) | 5 [3.2–7.7] | 1.55 [0.68–3.56] | 1.53 [0.65–3.57] | 4.8 [2.9–7.9] | 1.64 [0.73–3.71] | 1.43 [0.62–3.31] |
| Southern (n = 1619) | 10.7 [7.9–14.4] | **3.51 [1.63–7.56]** | **3.17 [1.46–6.88]** | 6.4 [4.5–9.0] | **2.21 [1.07–4.57]** | **2.21 [1.01–4.80]** |
| Residence | | | | | | |
| Urban (n = 489) | 15.9 [10.1–24.3] | Reference | — | 9 [5.6–14.2] | Reference | — |
| Rural (n = 3141) | 5.3 [4.1–6.9] | **0.29 [0.16–0.53]** | 0.57 [0.29–1.11] | 4.1 [3.0–5.6] | **0.44 [0.24–0.80]** | **0.45 [0.20–0.99]** |
| Education | | | | | | |
| Primary or less (n = 2543) | 5.1 [3.8–6.8] | Reference | — | 6.3 [4.3–9.1] | Reference | — |
| Secondary or more (n = 1087) | 14.7 [10.0–21.1] | 3.20 [1.89–5.41] | **2.58 [1.37–3.85]** | 3.7 [2.3–5.8] | 0.57 [0.29–1.10] | 0.48 [0.21–1.10] |
| Marital Status | | | | | | |
| Married or living together (n = 2637) | 8.3 [4.5–14.7] | Reference | — | 0.6 [0.3–1.5] | Reference | — |
| Never married (n = 674) | 6.2 [4.5–8.5] | 1.37 [0.65–2.87] | **0.29 [0.08–1.00]** | 6.8 [5.0–9.3] | **0.09 [0.03–0.22]** | **0.05 [0.01–0.25]** |
| Widow, divorced, not living together (n = 319) | 12.7 [7.9–19.9] | **2.20 [1.18–4.11]** | 1.10 [0.48–2.53] | 12.2 [5.4–25.3] | 1.88 [0.73–4.85] | 1.78 [0.53–5.90] |
| Wealth Index Quintile | | | | | | |
| Poorest (n = 592) | 4.3 [2.1–8.5] | Reference | — | 3.7 [1.8–7.3] | Reference | — |
| Poorer (n = 708) | 2.9 [1.5–5.5] | 0.68 [0.25–1.83] | 0.71 [0.25–2.03] | 3.8 [2.1–6.7] | 1.03 [0.40–2.67] | 0.92 [0.32–2.61] |
| Middle (n = 759) | 4.7 [2.8–7.8] | 1.11 [0.45–2.75] | 1.29 [0.50–3.31] | 5.8 [3.1–10.5] | 1.62 [0.61–4.28] | 1.41 [0.54–3.65] |
| Richer (n = 774) | 7 [4.0–11.8] | 1.69 [0.66–4.30] | 1.45 [0.57–3.69] | 3.3 [1.7–6.0] | 0.89 [0.36–2.17] | 0.94 [0.31–2.28] |
| Richest (n = 797) | 15 [10.9–20.3] | **3.96 [1.74–9.00]** | 2.49 [0.95–6.53] | 7.9 [4.7–13.2] | 2.27 [0.90–5.70] | **3.44 [1.15–10.26]** |
| Knows Condoms Reduce HIV Risk | | | | | | |
| No (n = 928) | 8.9 [5.8–13.3] | Reference | — | 3.6 [2.0–6.3] | Reference | — |
| Yes (n = 2695) | 6.6 [5.1–8.5] | 0.73 [0.45–1.17] | **0.62 [0.39–0.99]** | 5.8 [4.2–7.8] | 1.65 [0.84–3.23] | 1.68 [0.83–3.43] |
| Knows Monogamy Reduces Risk | | | | | | |
| No (n = 454) | 5 [2.6–9.6] | Reference | — | 1.9 [0.7–5.2] | Reference | — |
| Yes (n = 3169) | 7.5 [5.8–9.8] | 1.54 [0.72–3.31] | — | 5.7 [4.3–7.6] | **3.06 [1.07–8.73]** | **2.95 [1.02–8.55]** |
| Age at First Intercourse | | | | | | |
| ≤15 (n = 1005) | 7.6 [4.8–11.7] | Reference | | 7.4 [4.2–12.6] | Reference | — |
| 16–17 (n = 680) | 9.2 [5.8–14.3] | 1.24 [0.61–2.50] | — | 5 [2.7–9.0] | 0.66 [0.26–1.69] | 0.69 [0.31–1.55] |
| 18–19 (n = 646) | 8.2 [4.6–14.4] | 1.09 [0.49–2.43] | — | 4.6 [2.7–7.8] | 0.61 [0.26–1.46] | **0.37 [0.16–0.88]** |
| ≥20 (n = 1299) | 5.7 [3.9–8.4] | 0.74 [0.39–1.40] | — | 3.6 [2.3–5.6] | **0.47 [0.22–1.00]** | **0.32 [0.14–0.72]** |
| Lifetime Sexual Partners | | | | | | |
| 1–2 (n = 2473) | 5.7 [4.4–7.5] | Reference | | 3.5 [2.2–5.4] | | |
| 3–4 (n = 740) | 15 [9.3–23.3] | **2.89 [1.66–5.04]** | **1.80 [1.01–3.21]** | 7.3 [4.6–11.3] | **2.18 [1.11–4.29]** | 1.31 [0.62–2.78] |
| ≥5 (n = 396) | 32.9 [12.7–62.5] | **8.06 [2.27–28.63]** | **4.44 [1.17–16.88]** | 6.1 [3.6–10.1] | 1.82 [0.89–3.72] | 1.13 [0.47–2.73] |
| Lifetime Unions | | | | | | |
| 0–1 unions (n = 2959) | 5.8 [4.4–7.7] | Reference | — | 4 [2.7–5.8] | Reference | — |
| >1 union (n = 659) | 12.4 [8.3–18.0] | **2.28 [1.40–3.71]** | **2.64 [1.59–4.39]** | 11.7 [7.8–17.2] | **3.21 [1.76–5.84]** | **2.23 [1.23–4.02]** |
| Recent Sexual Activity | | | | | | |
| Active within 4 weeks (n = 2268) | 5.4 [3.9–7.3] | Reference | — | 4.9 [3.5–6.7] | Reference | — |
| Not active within 4 weeks (n = 1362) | 10.4 [7.6–14.2] | **2.05 [1.33–3.17]** | 1.72 [0.94–3.14] | 5.7 [3.4–9.5] | 1.18 [0.61–2.27] | **2.14 [1.13–4.06]** |
| No. Extramarital Partners in 12 Months | | | | | | |
| 0 (n = 3017) | 7.2 [5.5–9.3] | Reference | — | 6.3 [4.7–8.3] | Reference | — |
| ≥1 (n = 613) | 8.2 [4.1–15.8] | 1.17 [0.53–2.59] | — | 2.2 [1.0–4.7] | **0.33 [0.14–0.77]** | 1.07 [0.37–3.14] |
| Condom Each Time, Last Partner | | | | | | |
| No (n = 2834) | 6.1 [4.5–8.3] | Reference | — | 6.2 [4.5–8.4] | Reference | — |
| Yes (n = 334) | 14.5 [7.3–26.6] | **2.60 [1.12–6.00]** | 2.61 [0.86–7.91] | 1.7 [0.6–4.3] | **0.26 [0.09–0.73]** | 0.63 [0.20–1.96] |
| No sex in 12 months (n = 436) | 12.5 [7.7–19.5] | **2.19 [1.18–4.07]** | 1.75 [0.79–3.89] | 3.8 [1.7–8.4] | 0.61 [0.24–1.52] | 2.12 [0.57–7.86] |

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; HIV, human immunodeficiency virus. Bold text indicates a confidence interval that does not include 1.

[a]Candidate predictors variables screened but not eligible for inclusion in the multivariable model include type of relationship with last sexual partner, condom use at last intercourse within 12 months, number of trips away from home within 12 months, number of injections received within 12 months, having a sexually transmitted infection within 12 months, the reason why the last HIV test was done, and who has the final say on healthcare decisions (for women only).

as high in the South [20]. Likewise, a greater risk of new HIV infection among (1) rich and urban men and (2) women with more education and lifetime sexual partners is reflected by patterns seen in the general DHS population, as is the protective effect of never being married [20]. Several other findings could also be expected based on well known risk factors for HIV acquisition: HIV seroprevalence within 12 months of a negative test was associated with more than 1 lifetime union, whereas women knowing the benefits of condoms and men with delayed sexual debut were protected. Thus, our analyses did not reveal additional factors that distinguish people more likely to acquire HIV after a recently negative test above and beyond those suggested by the general adult population in Malawi. Nevertheless, they do suggest that WHO recommendations for annual HIV retesting could be extended to patients who fall outside of the traditional definition of "high-risk", if HIV incidence within the general population is high enough.

This study was subject to limitations including possible survey response bias. Men reporting no sexual activity within 4 weeks had a higher adjusted odds of new HIV seropositivity; this could be due to behavioral compensation for previously high-risk encounters, but it could also indicate intentionally inaccurate reporting of sexual behavior. In future surveys, biologic testing of HIV-positive samples for the presence of antiretroviral drug metabolites might better quantify self-reporting bias. In addition to false reporting, discrepancies between MDHS serosurvey data and reported prior test results could reflect poor quality of HIV tests available at the time [33]. Without CD4 counts or HIV viral loads available (or newer population-based HIV incidence assays) [36], we were unable to distinguish between truly incident HIV and seropositivity in a person with a previously false negative result. However, we suggest that, given low ART coverage in Malawi in 2010 [37], many seropositive cases reporting a previously negative test could represent the former scenario.

Another important limitation is that results reflect conditions in Malawi in 2010, but much has since changed. Per the 2014 Malawi Millennium Development Goals Endline Survey, 43% of women and 40% of men aged 15–49 were tested for HIV within 12 months and knew their results [38]. The impact of this on accurate awareness of their HIV status remains unknown until results from the 2015–2016 MDHS and upcoming Malawi Population-based HIV Impact Assessment (MPHIA) become available. The MPHIA I particular will include HIV recency assays to allow determination of HIV incidence [39]. A third study limitation is that the MDHS was population-based and not designed to assess HIV prevalence and risk factors among small but high-risk populations. Although we attempted to assess variables such as injection use, sex with commercial sex workers, and trips away from home, these and others were too infrequent to make any meaningful inferences [22].

## CONCLUSIONS

Despite these limitations, our results highlight a dramatic increase in knowledge of HIV status among Malawian adults from 2004 to 2010. However, as of the last MDHS, there still remained a high rate of undiagnosed HIV, requiring intensified scale-up and uptake of HTC to reach 90-90-90 targets. By delineating the difference between "receiving a prior HIV test result" and "accurate knowledge of HIV status based on this result", we demonstrate the importance of serotesting for accurate HIV surveillance. Although our analyses did not elucidate surprising risk factors for recent HIV infection among those with a previously reported negative test, our results do suggest that annual retesting may be necessary even in people not traditionally defined as high-risk by recent WHO retesting guidelines. Finally, the high prevalence of newly identified HIV infection among the survey population with a most recently negative HIV test, as soon as within 12 months, reinforces the importance of high-quality posttest prevention counseling for patients who test negative. As we move more resources towards universal test and treat strategies, it will be important to maintain focus on preventing and diagnosing disease among those who remain at high, ongoing risk for infection.


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