Epidemiology of Undiagnosed Trichomoniasis in a Probability Sample of Urban Young Adults

Susan M. Rogers1*, Charles F. Turner1,2, Marcia Hobbs3, William C. Miller3, Sylvia Tan1, Anthony M. Roman4, Elizabeth Eggleston1, Maria A. Villarreal1,5, Laxminarayana Ganapathi6, James R. Chromy7, Emily Erbelding8

1 Statistics and Epidemiology, Research Triangle Institute, Washington, District of Columbia, United States of America, 2 Program in Data Analytics and Applied Social Research, City University of New York (Queens College and the Graduate Center), Flushing, New York, United States of America, 3 School of Medicine and Gillings School of Public Health, University of North Carolina, Chapel Hill, North Carolina, United States of America, 4 Center for Survey Research, University of Massachusetts, Boston, Massachusetts, United States of America, 5 Department of Epidemiology, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland, United States of America, 6 Research Computing Division, Research Triangle Institute, Research Triangle Park, North Carolina, United States of America, 7 Statistics and Epidemiology Division, Research Triangle Institute, Research Triangle Park, North Carolina, United States of America, 8 Division of Infectious Diseases, Johns Hopkins Bayview Medical Center, Baltimore, Maryland, United States of America

Abstract

*T. vaginalis* infection (trichomoniasis) is the most common curable sexually transmitted infection (STI) in the U.S. It is associated with increased HIV risk and adverse pregnancy outcomes. Trichomoniasis surveillance data do not exist for either national or local populations. The Monitoring STIs Survey Program (MSSP) collected survey data and specimens which were tested using nucleic acid amplification tests to monitor trichomoniasis and other STIs in 2006–09 among a probability sample of young adults (N = 2,936) in Baltimore, Maryland — an urban area with high rates of reported STIs. The estimated prevalence of trichomoniasis was 7.5% (95% CI 6.3, 9.1) in the overall population and 16.1% (95% CI 13.0, 19.8) among Black women. The overwhelming majority of infected men (98.5%) and women (73.3%) were asymptomatic. Infections were more common in both women (OR = 3.6, 95% CI 1.6, 8.2) and men (OR = 9.0, 95% CI 1.8, 44.3) with concurrent chlamydial infection. Trichomoniasis did not vary significantly by age for either men or women. Women with two or more partners in the past year and women with a history of personal or partner incarceration were more likely to have an infection. Overall, these results suggest that routine *T. vaginalis* screening in populations at elevated risk of infection should be considered.

Introduction

*Trichomonas vaginalis* is the most common curable sexually transmitted infection (STI) in the United States [1,2]. Untreated trichomoniasis is associated with pelvic inflammatory disease, low birth weight, preterm delivery, and increased susceptibility to HIV [3–6]. Comorbidity with other STIs is commonly observed [7–8]. Despite increasing recognition of the harmful health effects of trichomoniasis [9], many infections go undetected because symptoms are often mild or absent [10]. However, the burden of disease is largely unknown as national surveillance data are not available for trichomoniasis.

Until recently, most studies of trichomoniasis were confined primarily to specialized or clinic populations which do not adequately characterize the incidence or prevalence in the population at large. Clinical detection of trichomoniasis traditionally has relied upon diagnostic techniques with relatively low sensitivity, such as wet mount or culture. The availability of sensitive molecular diagnostics, e.g., trans cription mediated amplification (TMA) and polymerase chain reaction (PCR), expanded opportunities for detection of trichomoniasis within broad populations. Using a urine-based PCR, the trichomoniasis prevalence was 2.3% (95% CI 1.8, 2.7) in the 2001–2002 National Longitudinal Study of Adolescent Health (Add Health), a cohort of 18 to 26 year-olds who were U.S. students in grades 7 through 12 in 1994–95 [11]. In the 2001–2004 National Health and Nutrition Examination Survey (NHANES), the prevalence of trichomoniasis was 3.1% (95% CI 2.3, 4.3) of U.S. women aged 14 to 49 years based on PCR of vaginal swabs [12]. Both surveys reported few symptoms among those infected and estimated substantially higher prevalence of infection among Black women [Add Health: 10.5%, 95% CI 8.3, 13.3; NHANES: 13.3%, 95% CI 10.0, 17.7].

While these two surveys provide important data on national prevalence of trichomoniasis, information on the local epidemiology of these infections is sparse. STI epidemics are local phenomena, evolving within communities. National estimates of prevalence obscure variations that arise in subpopulations due to local differences in behavior patterns, sexual networking, screening and case-management. In this paper, we report trichomoniasis prevalence and associated demographic and behavioral charac-
teristics from the 2006–2009 Monitoring STIs Survey Program (MSSP). The MSSP was designed to monitor the epidemiology of sexually transmitted infections across a three-year period among adolescents and young adults residing in Baltimore, Maryland—a metropolitan area with both a historically high incidence of diagnosed STIs based on reports to public health authorities and a high prevalence of undiagnosed STIs based on evidence from past population surveys [13–14].

Methods

Study sample

The MSSP collected telephone survey data and biospecimens for continuous monitoring of three STIs—gonorrhea, chlamydial infection, and trichomoniasis—among probability samples of adolescents and young adults residing in Baltimore, MD. Recruitment for the MSSP began in September 2006 and ended in June 2009. A stratified, list-assisted, probability sampling design was used to maximize sample efficiency in identifying our target population of English-speaking males and females between 15 and 35 years of age residing in Baltimore households with landline telephones. Over the course of the survey, we estimate that approximately 15% of Baltimore households did not have a landline telephone (see Text S1).

In this design, all households with a landline telephone had a known probability of selection into the sample. Our probability sample included four strata. We sampled the first three strata using commercially-available, regularly updated information on Baltimore households [15]. These strata include (1) households believed to contain someone aged 15–35 years, (2) households with no one aged 15–35, and (3) households with residents of unknown age. The fourth stratum was constructed by selecting all known landline telephone numbers in Baltimore, and removing numbers on the original commercial list. Inclusion of this fourth stratum ensures that the probability sample includes all households with landline telephones, and that each telephone number is in one and only one stratum. Errors in list-sample information (e.g., households that were erroneously thought to have a resident aged 15 to 35) were eliminated during survey screening.

Survey execution

All sampled households with a known address were sent a lead letter describing the study. Interview staff at the University of Massachusetts, Boston conducted telephone screening and recruitment. Household screening was completed with an adult (18 years of age or older) household member. In screened residences with more than one person aged 15 to 35 years, one member was probabilistically selected (see Text S2). Minors (<18 years of age) were recruited with parental permission. Parents were informed that their child’s survey and test results were confidential and that they would not be shared with parents.

T-ACASI interview

After obtaining informed consent for the survey interview, interviewers transferred respondents to a T-ACASI system [16–17]. T-ACASI increases reporting of sensitive and stigmatized behaviors compared to traditional telephone surveys conducted by human interviewers [18–21]. The survey included questions on respondents’ demographic characteristics, sexual behaviors, previous STIs, and other health behaviors and took 13 minutes on average to complete. Respondents were compensated $10 to $20 for completing the interview [22].

Specimen collection

Upon completion of the survey interview, respondents were invited to participate in the STI-testing phase of the study. Participants were informed that they would be re-contacted for a positive gonorrhea or chlamydial infection result and that, as required by law, names and contact information of persons who tested positive would be reported to the local health department. Since at the time the study was initiated the trichomoniasis assay had not been evaluated or cleared by the FDA, participants were informed that they would not be re-contacted regarding their trichomoniasis results [23–24]. During year two of the study — following further testing and validation of the test assay by the study’s laboratory — the study protocol was amended. During the consent process under the amended protocol, all participants were informed that they would be re-contacted for positive trichomoniasis, gonorrhea, and/or chlamydial infection test result and referred to one of Baltimore’s local public health clinics or their own private physician for repeat testing and/or presumptive therapy. (These amended procedures were reviewed and approved by all four IRBs and described in the informed consent documents that were signed by all participants recruited under the amended protocol.)

Participants who agreed to provide a biospecimen for STI testing were mailed a collection kit with instructions, a consent form, and monetary compensation for completing the telephone survey. Most specimens were urine; a small number of women in 2009 (n = 46) provided self-collected vaginal swabs in addition to urine specimens. Specimens were collected in containers with DNA/RNA Protect™ (Sierra Diagnostics, Sonora, CA), designed to prevent nucleic acid degradation for 7–10 days without refrigeration. Participants mailed specimens in pre-addressed postage-paid shipping cartons to the University of North Carolina-Chapel Hill (UNC) Hospitals’ McLendon Clinical Laboratories via U.S. Postal Service first class mail. Only specimens submitted with a signed consent form were tested. Participants received $40 to $100 US dollars for mailing in the specimen. (Payments for survey participation and specimens were increased over the course of the study in order to increase the survey response rate and return of specimens for STI testing. The incentive for respondents who agreed to provide a specimen but failed to mail-in their specimen after repeated reminders was increased from $40 to $100 in a final attempt to obtain a specimen. See Text S3 for additional details.)

Laboratory testing

Specimen handling. Urine specimens (2 mL) were transferred to APTIMA Combo 2 Assay urine specimen transport tubes (Gen-Probe, Inc., San Diego, CA) upon receipt at the UNC Hospitals laboratory. T vaginalis nucleic acids were detected by transcription-mediated amplification (TMA) using Gen-Probe analyte-specific reagents (TV ASR) using interpretive criteria previously established with vaginal swabs [25]. TV ASR TMA results <10 000 relative light units (RLU) were considered negative, and specimens with ≥30 000 RLU were considered positive. Results from 10 000 to <30 000 RLU were considered equivocal, and specimens were retested. Initially equivocal specimens with repeat test results <10 000 RLU were considered negative; those with repeat results ≥10 000 RLU were considered positive. Trichomoniasis was defined as a repeatedly positive test result. Using these interpretive criteria, TV ASR is 98.2% sensitive and 98.0% specific in latent class analysis compared to wet mount, culture, and a rapid antigen test [25]. The same processed urine specimen was used to detect N. gonorrhoeae and C. trachomatis nucleic acids.
acids using the FDA-cleared APTIMA Combo2 assay (Gen-Probe, Inc., San Diego, CA).

To verify that specimen collection, mailing and processing procedures were acceptable for APTIMA testing, we spiked negative urine specimens (60 mL) in study containers with T. vaginalis (n = 10) or GC (n = 12) at or near the limits of detection of the assays (10 trichomonads/mL and 250 GC colony-forming units/mL). APTIMA T. vaginalis ASR results from these spiked specimens and 12 negative control urines that were mailed to the UNC Hospitals laboratory were similar to test results obtained from the same specimens prior to mailing. Quantitative assay outputs in relative light units were not statistically different, and qualitative (negative or positive) results were identical.

Ethics statement
Participants in the telephone survey provided oral consent. Minors aged 15–17 years were recruited with parental/guardian permission and minor assent; parents were informed that their child’s survey and test results were confidential and that they would not be shared with parents. Respondents who agreed to provide a specimen for STI testing were mailed a collection kit (a maximum of three days after the T-ACASI interview) with instructions and a consent form. Only specimens submitted to the laboratory with a signed consent form were tested. All study procedures – including the foregoing consent procedures – were approved by the Institutional Review Boards (IRBs) of Research Triangle Institute, the University of North Carolina at Chapel Hill, the University of Massachusetts-Boston, and the Johns Hopkins Medical Institutions.

Data Access
The data required to replicate our substantive analyses will be available to authorized researchers under a restricted data use agreement with the Inter-University Consortium for Political and Social Research (ICPSR) at the University of Michigan. Because of the sensitive nature of these data and the risk of deductive disclosure of respondents’ identity, researchers must agree to the ICPSR’s terms of use which require, in part, compliance with the repository’s access regulations and codes of scientific conduct.

Sample Weighting
Two sets of sample weights were constructed to adjust for the unequal probabilities of selection based on our stratified sample design and survey nonresponse. Initial weights were developed reflecting the inverse probability of selection within each stratum with adjustments for the differing probabilities of selection within households, the number of landline telephones within the household, and survey nonresponse. A post-stratification adjustment was applied to align the sample distribution with the 2006–09 U.S. Census estimates of the Baltimore City population by age, gender, and race/ethnicity [26]. A second set of weights was constructed to compensate for additional differences in the provision of a urine specimen for STI testing among respondents who completed the survey interview.

Statistical Analyses
Survey estimates of infection prevalence by gender and race/ethnicity were derived using the sample weights described above. Estimated prevalence rates are period rates and represent estimates of infection detected during the 33-month study period. Odds ratios for associations of demographic and behavioral characteristics of respondents with infection status by sex were estimated using logistic regression. Adjusted odds ratios were calculated from multivariable logistic regression models controlling for the effects of race/ethnicity, age, and marital status. Models were estimated separately for men and women. All statistical analyses accounted for the complex sample design of the MSSP using the svy algorithms of Stata, version 12 [27].

Multiple Imputation for Missing Specimens and Survey Data
Multiple imputation models using chained equations (MICE) were used to impute the substantial number of missing TV infection tests (n = 816) and education measurements (n = 777) plus a small number of missing observations for some demographic variables. [The education variable was missing in 777 cases because the question – “highest grade completed” – was not asked (nor was it meaningful) for many respondents under age 20.] Predictor variables used in MICE imputations included age, education, four race-and-gender combinations (Black Female, Black Male, NonBlack Female, and NonBlack Male), STI symptoms in past 3 months (dysuria and discharge), plus 11 other sexual behavior and technical variables. Logit models were used for all imputations except education for which we used an ordered logit model. Using the chained equation multiple imputation procedure we generated 60 sets of imputed data after a burn-in period of 100 iterations.

Results
Survey execution
A sample of 73,318 telephone numbers was released over the survey period. 48,136 (65.6%) of these numbers were non-residential (out of service numbers, business telephones, faxes, etc.), 20,435 (27.9%) were residential, and the status of 4,747 (6.5%) numbers was undetermined after repeated attempts. Of the residential numbers, 14,199 (69.5%) were screened and 4998 included one or more eligible household members aged 15 to 35 years. Interviews were completed with 2,936 (58.7%) eligible respondents and 2,136 (72.8%) mailed in specimens for testing.

Estimated prevalence of trichomoniasis
The estimated prevalence of trichomoniasis was 7.5% (95% CI 6.2, 9.1; Table 1, Left Panel). Accounting for missing specimens with multiple imputation, the prevalence estimate was 7.4% (95% CI 6.0, 8.9), virtually equivalent to that obtained from the tested specimens alone. Similarly equivalent results were obtained for subpopulations defined by race and gender (Table 1, Right Panel). Given these results, our subsequent analyses only present estimates derived from participants providing specimens for testing.

Subpopulation variations in trichomoniasis prevalence
Nearly one in six Black females tested positive for trichomoniasis (16.1%, 95% CI 13.0, 19.8). Estimates were significantly lower among other racial/ethnic and gender subgroups (Table 1). Overall, women were more likely than men to be infected (11.8% vs 2.9%, OR = 4.4, 95% CI 2.4, 8.3) and estimates of infection were significantly higher among Black compared to non-Black men and women in both unadjusted and adjusted analyses (Table 2). Age was not associated with trichomoniasis among men or women when treated as a categorical variable in unadjusted or adjusted analyses.

Figure 1 shows the association of trichomoniasis with age using fractional polynomial plots for men and women. No association was observed for males, but females show a seemingly curvilinear relationship between age and infection prevalence that peaks at approximately age 21. This relationship is not, however,
statistically significant. Logistic regression models including linear, quadratic, and cubic age variables as predictors of the odds of infection for females had p values of 0.256 or higher.

Unmarried men and women were more likely to have trichomoniasis than married persons, but these effects were diminished in adjusted analyses (Table 2). Among women, but not men, having less than a high school education was associated with infection (OR = 3.3, 95% CI 1.8, 6.1) and the association remained after adjusting for race, age, and marital status (adj OR = 2.2, 95% CI 1.2, 4.3). Part-time employment was associated with infection among men (adj OR = 10.3, 95% CI 1.4, 77.2), but there was no association between any employment status and infection prevalence for women (p = 0.154).

In considering our results for males, it should be noted that detection of subpopulation variation in trichomoniasis infection among men is compromised by their low rate of observed infection (2.9%, 95% CI 1.7, 5.1). This results in low statistical power and large standard errors for estimates of infection prevalence among subpopulations men.

Variation by sexual and social behaviors
The number of recent sexual partners was significantly associated with the likelihood of infection among women but not men (Table 3). Women reporting two or more partners in the past year were more likely than women with fewer partners to test positive for trichomoniasis (OR = 2.3, 95% CI 1.8, 4.5). The effect was attenuated somewhat after adjusting for race/ethnicity, age, sex, and marital status but remained statistically significant (adj OR = 2.1, 95% CI 1.3, 3.5). Men and women who reported both opposite and same gender lifetime sex partners were more likely to test positive for trichomoniasis. The effects were weakened after adjusting for race/ethnicity, age, and marital status although the result for females had borderline statistical significance (adj OR = 1.8, 95% CI 1.0, 3.3). The prevalence of trichomoniasis was significantly higher among women (OR = 1.8, 95% CI 1.1, 2.9) and men (OR = 4.7, 95% CI 1.5, 15.2) who reported having a new sex partner in the past three months. After adjustment for demographic characteristics, these effects decreased and were no longer statistically significant for females (adj OR = 1.5, 95% CI 0.9, 2.5) but they were significant for males (adj OR = 3.1, 95% CI 1.1, 9.0).

Women, but not men, with a history of personal or partner incarceration were more likely to have trichomoniasis (OR = 2.7, 95% CI 1.7, 4.3) and the association remained significant after adjustment (adj OR = 2.0, 95% CI 1.2, 3.4). A formal test for gender interaction does not reject the null hypothesis that the pattern of association between incarceration and infection prevalence was equivalent for males and female (p>0.50).

Women with a self-reported history of STIs (OR = 1.9, 95% CI 1.2, 3.0) or a previous diagnosis with trichomoniasis (OR = 2.1, 95% CI 1.2, 3.3) were more likely to have trichomoniasis although the effects did not persist after adjustment (Table 4). Infection with trichomoniasis was not associated with recent antibiotic use in our sample, although men who reported a health care visit in the past three months were significantly less likely to test positive for trichomoniasis (adj OR = 0.3, 95% CI 0.1, 1.0).

Co-morbidity with chlamydial infection
Both women and men who had a current chlamydial infection were much more likely to also have trichomoniasis. Among women, 31% of those with chlamydial infection also had a trichomoniasis infection compared to 11.1% of women with no chlamydial infection (OR = 3.6, 95% CI 1.6, 8.2). Similarly for men, 17.1% of those with an undiagnosed chlamydial infection also had undiagnosed trichomoniasis compared to 2.3% of other men (OR = 9.0, 95% CI 1.8, 44.3). These effects persisted after adjusting for race, age, and marital status (adj OR = 2.8, 95% CI 1.2, 6.3 for women, and OR = 5.3, 95% CI 1.1, 26.6 for men).

Gender Interactions
We had anticipated that there would be many associations between infection prevalence and respondents’ characteristics that would vary significantly by gender. However, none of the tests for gender by sociodemographic variable interaction were significant at the 0.05 level (Table 2). We also found only one significant gender interaction for respondent sexual or health behavioral characteristics (p = 0.049) — for presence of symptoms in the past 5 months (Table 4). Women reporting symptoms in the past three months were more likely than other women to have trichomoniasis (19.7% vs. 10.2%, adj OR = 2.0, 95% CI 1.2, 3.5) while for men the reverse was true but not statistically significant (0.8% vs. 3.0%, adj OR = 0.3, 95% CI 0.0, 2.5).

Symptomatic and asymptomatic trichomoniasis
Only one of 18 men (unweighted) with trichomoniasis reported symptoms in the past three months. Most men (94.2%) and women (84.1%) reported neither discharge nor dysuria in the three months prior to the survey (Table 5). Furthermore, most
| Subpopulation: | FEMALES | | | | | MALES | | | | | Gender | | Interaction |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Tv % (95% CI) | Base N | OR (95% CI) | p | AOR (95% CI) | p | | | | | | | |
| ALL | 11.8 (9.6, 14.3) | 1,322 | — | — | — | — | 2.9 (1.7, 5.1) | 798 | — | — | — | — | <0.001 |
| Race | | | | | | | | | | | | | |
| Black | 16.1 (13.0, 19.8) | 845 | 4.6 (2.4, 8.5) | <0.001 | 4.4 (2.3, 8.5) | <0.001 | 5.0 (2.8, 8.8) | 454 | 36.1 (4.6, 281.6) | 0.001 | 26.6 (3.3, 217.4) | 0.002 | 0.059 |
| Non-Black | 4.1 (23.70) | 477 | ref | ref | 0.2 (0.0, 1.0) | 344 | Ref | ref | | | | |
| Age (in years) | | | | | | | | | | | | | |
| 15–19 | 11.4 (7.1, 17.7) | 316 | 1.1 (0.6, 2.1) | >0.50 | 0.8 (0.4, 1.6) | 0.456 | 3.7 (1.4, 9.8) | 260 | 2.0 (0.4, 9.1) | 0.392 | 0.9 (0.2, 4.2) | >0.50 | >0.50 |
| 20–24 | 15.2 (10.8, 20.9) | 308 | 1.5 (0.8, 2.7) | 0.163 | 1.3 (0.7, 2.4) | 0.479 | 3.9 (1.2, 11.7) | 152 | 2.1 (0.4, 10.6) | 0.385 | 1.1 (0.2, 5.7) | >0.50 | |
| 25–29 | 9.3 (6.0, 14.3) | 311 | 0.9 (0.5, 1.7) | >0.50 | 0.8 (0.4, 1.5) | 0.411 | 2.1 (0.7, 6.6) | 190 | 1.1 (0.2, 5.7) | >0.50 | 0.8 (0.2, 4.2) | >0.50 | |
| 30–35 | 10.6 (7.1, 15.5) | 387 | ref | ref | 1.9 (0.6, 5.8) | 196 | Ref | ref | | | | |
| Marital Status | | | | | | | | | | | | | |
| Not Married | 12.9 (10.4, 15.9) | 1,090 | ref | ref | 3.6 (2.0, 6.3) | 650 | Ref | ref | | | 0.095 | |
| Married | 6.3 (3.3, 11.7) | 231 | 0.5 (0.2, 0.9) | 0.031 | 0.7 (0.3, 1.5) | 0.335 | 0.3 (0.0, 1.9) | 148 | 0.1 (0.1, 0.6) | 0.012 | 0.2 (0.0, 1.9) | 0.165 | |
| Educationb | | | | | | | | | | | | | |
| <High school | 21.9 (15.1, 30.6) | 139 | 3.3 (1.8, 6.1) | <0.001 | 2.2 (1.2, 4.3) | 0.015 | 3.5 (1.1, 11.0) | 77 | 3.9 (0.6, 23.8) | 0.143 | 2.6 (0.4, 18.0) | 0.337 | 0.402 |
| High school | 14.6 (9.9, 20.9) | 253 | 2.0 (1.1, 3.7) | 0.025 | 1.4 (0.7, 2.5) | 0.324 | 5.2 (2.0, 12.9) | 144 | 5.9 (1.1, 30.9) | 0.037 | 4.3 (0.9, 21.2) | 0.070 | |
| >High school | 7.8 (5.2, 11.5) | 613 | ref | ref | 0.9 (0.3, 3.4) | 317 | Ref | ref | | | | |
| Employmentb | | | | | | | | | | | | | |
| Full-time | 9.6 (6.5, 13.8) | 557 | 0.6 (0.3, 1.0) | 0.068 | 0.7 (0.4, 1.2) | 0.181 | 2.3 (1.0, 5.4) | 329 | 2.8 (0.5, 15.4) | 0.226 | 4.4 (0.8, 24.4) | 0.091 | 0.069 |
| Part-time | 13.5 (8.5, 20.8) | 177 | 0.9 (0.5, 1.7) | >0.50 | 0.9 (0.5, 1.8) | >0.50 | 7.8 (2.1, 25.0) | 70 | 10.0 (1.4, 74.0) | 0.024 | 10.3 (1.4, 77.2) | 0.023 | |
| Unemployed | 15.2 (10.9, 20.8) | 272 | ref | ref | 0.8 (0.2, 3.5) | 138 | Ref | ref | | | | |

Estimates based on respondents who provided urine specimens for testing. Estimates are weighted to account for differing probabilities of selection and post-stratification adjustment to match Census (ACS) marginals for Baltimore, Maryland (see text). Base Ns are unweighted. Odds ratios (ORs) calculated using logistic regression. Gender-specific adjusted ORs (AOR) calculated from multivariable models controlling for race (Black; Non-Black), age (4 categories: 15–19, 20–24, 25–29, 30–35), and marital status (married vs. not married, including widowed, divorced, and separated). Black was omitted in calculation of adjusted ORs for males for education and employment since there were zero TV infections among non-Black respondents in the age range for these variables (20 to 35). P-values shown in column of prevalence estimates are for test of hypothesis that estimates of TV prevalence are independent across categories of the independent variable (e.g., marital status). Variance estimates and confidence intervals (CI) were calculated using statistical algorithms that take account of the complex sample design used in the MSSP surveys. P-values for ORs and adjusted ORs are for test of independence of TV prevalence across categories of socio-demographic variables taking account of weighting, complex sample design, and covariates (for adjusted ORs).

\*Persons describing themselves as Hispanic are coded as Non-Black.

\*Ages 20 to 35 only.

\*The difference in infection prevalence among men and women is statistically significant (OR = 4.4, 95% CI = 2.4, 8.3, p < 0.001).

doi:10.1371/journal.pone.0090548.t002

Table 2. Estimated prevalence of T. vaginalis (TV) infection and odds ratios by gender and sociodemographic characteristics.
participants with undiagnosed infections were asymptomatic. Of persons with trichomoniasis, 98.5% of men (95% CI: 89.1, 99.8) and 73.3% of women (95% CI: 62.6, 82.0) reported neither dysuria nor discharge in the three months prior to the survey.

Discussion

The MSSP was designed to monitor the prevalence of trichomoniasis and other STIs in a population typically identified as being at high risk of sexually transmitted infections – young adults residing in an urban center with high rates of diagnosed STIs and HIV. In this population, female gender, Black race, and having less than a high school education were significantly associated with likelihood of trichomoniasis. Estimates of infection were particularly troublesome among Black women. Our results suggest that routine screening should be considered to prevent the morbidity associated with trichomoniasis in populations at elevated risk of infection, including sexually active young women in Baltimore and similar venues [1,28–30].

Trichomoniasis poses two major difficulties for public health strategies that seek to contain the disease in the general population. First, unlike other STIs such as chlamydial infection, trichomoniasis was not consistently observed in a particular age group. We found no association between age and infection prevalence across the age range 15 to 35 for either women or men. Second, the overwhelming majority of infections were asymptomatic and symptoms were common among uninfected persons. The latter finding renders self-referral for treatment ineffective as a strategy for controlling trichomoniasis in the general population. Population screening is a logical alternative, but the lack of an association with age in the age group studied implies that screening may not be effectively targeted on a narrow age range, e.g., adolescents and young adults.

Among women, multiple sexual partners, experiences of forced sex, a history of self or partner incarceration, and concomitant chlamydial infection were risk markers for prevalent trichomoniasis. Among men, current chlamydial infection and new sex partners remained significantly associated with trichomoniasis in multivariable analyses while recent doctor or clinic visits were associated with a lower prevalence of infection. (Smaller sample sizes may have limited our ability to detect associations with other characteristics among men.)

These results are consistent with findings from other large-scale population-based surveys. The Wave III Add Health study observed substantial overlap of trichomoniasis with chlamydial infection, although the effects were most pronounced among women [11]. Among women in the 2001–04 NHANES, prevalence of chlamydial infection was higher among women under 26 years of age with trichomoniasis. They observed no differences among older women.

Study Limitations

Our results should be interpreted with awareness of the limitations of our research. The first limitation arises from the locale of our research. This research studied the adolescent and young adult population of the city of Baltimore, MD. Numerous studies have demonstrated that Baltimore city has a high incidence of both diagnosed STIs [31] and undiagnosed STIs that persist in this population [14]. While results from this venue may generalize to other urban locales with similar characteristics, it is unlikely that our findings will generalize to non-urban populations with a low incidence of diagnosed STIs and a low prevalence of undiagnosed STIs.

The second limitation arises from the substantial level of non-response to the telephone survey including a greater proportion of females than males who responded to the survey and to the subsequent request for biospecimens for STI assay. Following typical survey practice, we used poststratification weights to align our survey samples to the demographic composition of the Baltimore population, and we employed covariate adjustments for gender, age, race, and marital status to provide further control in our statistical analyses. It should be recognized, however, that neither poststratification weights nor the covariate adjustments employed in our statistical analyses can guarantee sample equivalence.

The non-response problem in telephone surveys is a well recognized and growing problem. The MSSP did much better...
Table 3. Estimated prevalence of T. vaginalis (TV) and odds ratios by gender and sexual behaviors.

| Lifetime partners include both Males & Females<sup>b</sup> | Females | Males |
|--------------------------------------------------------|---------|-------|
| TV % | Base N | OR (95% CI)<sup>a</sup> | p | Adj. OR (95% CI)<sup>a</sup> | p | TV % | Base N | OR (95% CI)<sup>a</sup> | p | Adj. OR (95% CI)<sup>a</sup> | p | p<sup>a</sup> |
| Yes | 19.5% | 124 | 2.0 (1.1, 3.7) | 0.030 | 1.8 (1.0, 3.3) | 0.067 | 9.3% | 36 | 3.8 (0.5, 30.7) | 0.210 | 5.3 (0.6, 45.0) | 0.130 | >0.50 |
| No | 10.9% | 1,1198 | ref | ref | 2.6% | 761 | ref | ref | 3.3 (1.0, 11.5) | 0.060 | 1.6 (0.5, 5.6) | 0.450 | >0.50 |
| Had > 2 partners last year<sup>c</sup> | Females | Males |
| Yes | 19.2% | 433 | 2.8 (1.8, 4.5) | <0.001 | 2.1 (1.3, 3.5) | 0.003 | 4.9% | 323 | 3.3 (1.0, 11.5) | 0.060 | 1.6 (0.5, 5.6) | 0.450 | >0.50 |
| No | 7.8% | 888 | ref | ref | 1.5% | 475 | ref | ref | 0.50 |
| Had a new partner past 3 months<sup>d</sup> | Females | Males |
| Yes | 17.1% | 228 | 1.8 (1.1, 2.9) | 0.029 | 1.5 (0.9, 2.5) | 0.158 | 7.2% | 207 | 4.7 (1.5, 15.2) | 0.009 | 3.1 (1.1, 9.0) | 0.040 | 0.130 |
| No | 10.5% | 1,070 | ref | ref | 1.6% | 587 | ref | ref | 0.50 |
| Partner had STI in past year<sup>e</sup> | Females | Males |
| Yes | 10.2% | 66 | 0.8 (0.3, 2) | >0.50 | 0.7 (0.3, 1.8) | 0.444 | 8.3% | 25 | 3.2 (0.4, 22.5) | 0.247 | 2.2 (0.3, 15.2) | 0.441 | 0.234 |
| No | 11.8% | 1,256 | ref | ref | 2.8% | 773 | ref | ref | 0.50 |
| Don’t know if partner had STI in past year<sup>e</sup> | Females | Males |
| Yes | 13.7% | 127 | 1.2 (0.6, 2.3) | >0.50 | 1.1 (0.5, 2.2) | >0.50 | 6.2% | 67 | 2.5 (0.4, 13.8) | 0.305 | 1.7 (0.3, 10.7) | >0.50 | 0.453 |
| No | 11.5% | 1,195 | ref | ref | 2.6% | 731 | ref | ref | 0.50 |
| Ever forced to have sex<sup>f</sup> | Females | Males |
| Yes | 17.5% | 206 | 1.7 (1.0, 3.0) | 0.038 | 1.8 (1.1, 3.1) | 0.028 | 0.0% | 18 | 0% | 0% | >0.50 |
| No | 10.8% | 1,111 | ref | ref | 3.0% | 766 | ref | ref | 0.50 |
| Respondent or partner ever incarcerated<sup>g</sup> | Females | Males |
| Yes | 17.8% | 527 | 2.7 (1.7, 4.3) | <0.001 | 2.0 (1.2, 3.4) | 0.012 | 4.5% | 218 | 2.0 (0.6, 6.2) | 0.24 | 1.3 (0.5, 3.7) | >0.50 | >0.50 |
| No | 7.3% | 793 | ref | ref | 2.3% | 578 | ref | ref | 0.50 |

<sup>a</sup>Odds ratios (ORs) calculated using logistic regression. Gender-specific adjusted ORs (AORs) calculated from multivariable models controlling for race (Black; Non-Black), age (4 categories: 15–19, 20–24, 25–29, 30–35), and marital status (married vs. not married, including widowed, divorced, and separated). Gender Interaction tests equivalence of unadjusted ORs for males and females (i.e., logistic regression models odds of Tv as a function of Female, Behavioral variable, and Female-by-Behavioral variable).

<sup>b</sup>Gender specific adjusted ORs (AORs) calculated from multivariable models controlling for race (Black; Non-Black), age (4 categories: 15–19, 20–24, 25–29, 30–35), and marital status (married vs. not married, including widowed, divorced, and separated). Gender Interaction tests equivalence of unadjusted ORs for males and females (i.e., logistic regression models odds of Tv as a function of Female, Behavioral variable, and Female-by-Behavioral variable).

<sup>c</sup>Referent group includes respondents who reported solely either male or female lifetime sexual partners. Respondents with no lifetime partners recoded as ‘no’.

<sup>d</sup>Respondents with no lifetime partners recoded as ‘no’.

<sup>e</sup>Referent group includes respondents who reported knowing whether or not their partner(s) in the past year had an STI. Respondents with no lifetime partners or no partners in the past year recoded as ‘knowing’.

<sup>f</sup>Referent group includes respondents who reported never being forced to have sex with someone when they didn’t want to. Respondents with no lifetime partners recoded as never having forced sex.

<sup>g</sup>Respondents with no lifetime partners recoded as never having partners who were incarcerated.

<sup>h</sup>ORs not calculated because none of the 32 men who reported forced sex also tested positive for Tv.

DOI: 10.1371/journal.pone.0090548.t003
### Table 4. Estimated prevalence of T. vaginalis (Tv) and odds ratios by gender and health behaviors.

|                              | FEMALES                                                                 | MALES                                                                 | Gender Interaction |
|------------------------------|-------------------------------------------------------------------------|----------------------------------------------------------------------|-------------------|
|                              | Base N | Tv %   | OR (95% CI)* | p       | Adj. OR (95% CI)* | p       | Base N | Tv (%)  | OR (95% CI)* | p       | Adj. OR (95% CI)* | p       | p*       |
| Previously had an STI\(b\)   |        |        |              |         |                    |         |        |        |        |              |         |                    |         |          |
| Yes                          | 411    | 16.8%  | 1.9 (1.2, 3.0) | 0.006  | 1.4 (0.8, 2.3)    | 0.254  | 92     | 2.9%   | 0.9 (0.2, 3.7)  | >0.50  | 0.5 (0.1, 1.9)    | 0.283  | 0.309    |
| No                           | 910    | 9.6%   | ref          | ref     | ref                | ref     | 706    | 3.0%   | ref          | ref     | ref                | ref     |          |
| Previously had T. vaginalis\(c\) |        |        |              |         |                    |         |        |        |        |              |         |                    |         |          |
| Yes                          | 185    | 19.7%  | 2.1 (1.2, 3.5) | 0.005  | 1.6 (0.9, 2.9)    | 0.094  | 16     | 0.0%   | ref          | ref     | ref                | ref     |          |
| No                           | 1,136  | 10.5%  | ref          | ref     | ref                | ref     | 782    | 3.0%   | ref          | ref     | ref                | ref     |          |
| Current chlamydial infection |        |        |              |         |                    |         |        |        |        |              |         |                    |         |          |
| Yes                          | 44     | 31.0%  | 3.6 (1.6, 8.2) | 0.002  | 2.8 (1.2, 6.3)    | 0.013  | 26     | 17.1%  | 9.0 (1.8, 44.3) | 0.007  | 5.3 (1.1, 26.6) | 0.043  | 0.319    |
| No                           | 1,278  | 11.1%  | ref          | ref     | ref                | ref     | 772    | 2.3%   | ref          | ref     | ref                | ref     |          |
| Symptoms in past 3 months\(d\) |        |        |              |         |                    |         |        |        |        |              |         |                    |         |          |
| Yes                          | 224    | 19.7%  | 2.2 (1.3, 3.7) | 0.005  | 2.0 (1.2, 3.5)    | 0.012  | 49     | 0.8%   | 0.2 (0.0, 2.0)  | 0.189  | 0.3 (0.0, 2.3)    | 0.237  | 0.049    |
| No                           | 1,097  | 10.2%  | ref          | ref     | ref                | ref     | 749    | 3.0%   | ref          | ref     | ref                | ref     |          |
| Doctor or clinic visit in past 3 months\(e\) |        |        |              |         |                    |         |        |        |        |              |         |                    |         |          |
| Yes                          | 870    | 11.6%  | 1.0 (0.6, 1.5) | >0.50  | 0.9 (0.5, 1.4)    | 0.499  | 367    | 1.4%   | 0.3 (0.1, 1.1)  | 0.081  | 0.3 (0.1, 1.0)    | 0.051  | 0.119    |
| No                           | 447    | 12.1%  | ref          | ref     | ref                | ref     | 429    | 4.1%   | ref          | ref     | ref                | ref     |          |
| Antibiotic use in past month |        |        |              |         |                    |         |        |        |        |              |         |                    |         |          |
| Yes                          | 209    | 12.7%  | 1.1 (0.6, 1.9) | >0.50  | 1.0 (0.5, 1.7)    | >0.50  | 93     | 1.4%   | 0.5 (0.1, 2.6)  | 0.427  | 0.6 (0.1, 3.0)    | >0.50  | 0.388    |
| No                           | 1,112  | 11.6%  | ref          | ref     | ref                | ref     | 702    | 2.7%   | ref          | ref     | ref                | ref     |          |

*Odds ratios (ORs) calculated using logistic regression. Gender-specific adjusted ORs (AORs) calculated from multivariable models controlling for race (Black; Non-Black), age (4 categories: 15–19, 20–24, 25–29, 30–35), and marital status (married vs. not married, including widowed, divorced, and separated). Gender Interaction tests equivalence of unadjusted ORs for males and females (i.e., logistic regression models odds of Tv as a function of Female, Behavioral variable, and Female-by-Behavioral variable).

\(b\)Previous STI includes self-reported diagnoses of C. trachomatis, N. gonorrhea, and/or T. vaginalis.

\(c\)Self-reported previous diagnosis of T. vaginalis infection.

\(d\)Self-reported symptoms of dysuria and/or discharge.

\(e\)ORs not calculated because none of the 16 men with a prior diagnosis of Tv also tested positive for Tv in the survey.

doi:10.1371/journal.pone.0090548.t004
than many telephone surveys in obtaining household and respondent cooperation. (Survey screening was completed with 69.5% of households identified as residential, and interviews were completed with 58.7% of screened respondents who were identified as eligible for interview.) While MSSP may have done better than the average telephone survey [32], there is ample room for concern that non-response bias may distort our results. The available evidence suggests that the impact of this non-response may be less substantial than one might fear [32,33]. However, we cannot know with certainty what impact this non-response would have for the findings of the MSSP.

The third limitation arises from the fact that only 2,136 of 2,936 (72.8%) of survey respondents provided biospecimens for STI testing. Multiple imputation suggests that this biospecimen non-response had a trivial impact on STI prevalence (see Table 1). A similar conclusion was reached regarding STI biospecimen non-response in a national survey of adolescent males [34] and an earlier in-person study of Baltimore adults [14]. We cannot, nonetheless, be certain that biospecimen non-response does not affect our conclusions.

Conclusion

Data from the MSSP confirm findings from other population-based and clinical studies that suggest trichomoniasis is highly prevalent in the general population — particularly among Black women. Vigorous public health interventions to reduce this prevalence and to potentially avoid the complications associated with infection are clearly warranted. The MSSP research model and similar population survey programs provide a much-needed paradigm for monitoring the impact of such interventions on the prevalence of untreated and largely asymptomatic infections that persist in the population, both nationally and locally. A key challenge for future research will be adapting this paradigm so that it can be implemented at a cost that is affordable to local public health departments.

Supporting Information

Text S1 (DOC)

Text S2 (DOC)

Text S3 (DOC)

Text S4 (DOC)

Author Contributions

Conceived and designed the experiments: SMR CFT WCM MH AMR E. Eggleston. Performed the experiments: SMR CFT WCM ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. Eggleston. Performed the experiments: SMR CFT WCM MH ST E. Erbelding ST MV JRC LG. Analyzed the data: SMR CFT WCM ST JRC. Contributed reagents/materials/analysis tools: SMR E. EG.

References

1. Schwebke JR (2002) Update of trichomoniasis. Sex Trans Inf 78:378.

2. Weinstock H, Berman S, Cates W Jr (2004) Sexually transmitted diseases among American youth: incidence and prevalence estimates. Persp on Sexual Reprod Health 36:6–10.

3. Cotch MF, Fastoeke JG, Nugent RP (1997) Trichomonas vaginalis associated with low birth weight and preterm delivery. Sex Trans Dis 24:361.

4. Van der Pol B, Kwok C, Pierre-Louis B (2008) Trichomonas vaginalis infection and human immunodeficiency virus acquisition in African women. J Infect Dis 197(4):548–554.

5. McGrelland RS, Sangare L, Hassan WM, Lavres L, Mandaliva K, et al (2007) Infection with Trichomonas vaginalis increases the risk of HIV-1 acquisition. J Infect Dis 195(5):698–702.

6. Mavedzenge SN, Pol BY, Ching H, Montgomery ET, Blanchard K, et al (2010) Epidemiological synergy of Trichomonas vaginalis and HIV in Zimbabwean and South African women. Sex Trans Dis 37(7):460–466.

7. Steckler J, Bachman L, Brozman R (2005) Concurrent sexually transmitted infections (STIs) in sex partners of patients with selected STIs: Implications for patient-delivered partner therapy. Clin Infect Dis 40:787–703.

8. Allsworth J, Ratner JA, Popert J (2009) Trichomoniasis and other sexually transmitted infections: Results from the 2001–04 NHANES surveys. Sex Transm Dis 6(12): 738–744. doi:10.1097/OLQ.0b013e3181818954.

9. Bachman L, Hobbs M, Sena A, Sobel JD, Schwebke JR, et al (2011) Trichomonas vaginalis genital infections: Progress and challenges. Clin Inf Dis 53 (Suppl 3):S160.

10. Roth AM, Williams JA, Ly R, Card K, Brooks D, et al (2011) Changing sexually transmitted infection screening protocol will result in improved case finding for Trichomonas vaginalis among high-risk female populations. Sex Trans Dis 38(12): DOI: 10.1097/OLQ.0b013e318200035c.

11. Miller WC, Swaygard H, Hobbs M, Ford CA, Handcock MS, et al. (2005) The prevalence of trichomoniasis in young adults in the United States. Sex Trans Dis 32(10):593–598.
12. Sutton M, Sternberg M, Koumans E, McQuillan G, Berman S, et al (2007) Markowitz L. The prevalence of Trichomonas vaginalis infection among reproductive-age women in the United States, 2001-2004. Clin Infect Dis 45(10):1319-26.

13. Centers for Disease Control and Prevention (2007) Sexually Transmitted Disease Surveillance 2006. Atlanta, GA: U.S. Division of Health and Human Services, November 2007.

14. Turner CF, Rogers SM, Miller HG, Miller WC, Gribble J, et al. (2002) Untreated Gonococcal and Chlamydial infection in a probability sample of Baltimore adults. JAMA 287(6):726-733.

15. Cooley PC, Miller HG, Gribble JN, Turner CF (2008) Automating telephone surveys: Using T-ACASI to obtain data on sensitive topics. Comput and Human Behav 6:1-11.

16. Cooley PC, Turner CF (1998) Implementing audio-CASI on Windows platforms. Comput and Human Behav 14(2):195-207.

17. Gribble JN, Miller HG, Catania JA, Pollack L, Turner CF (2000) The impact of T-ACASI interviewing on reported drug use among men who have sex with men. Substance Use and Misuse 35:869-890.

18. Turner CF, Villarreal MA, Rogers SM, Eggleston E, Ganagathi L, et al. (2005) Reducing bias in telephone survey estimates of the prevalence of drug use: A randomized trial of telephone audio-CASI. Addiction 100:1432-1444.

19. Villarreal MA, Turner CF, Rogers SM, Roman A, Cooley PC, et al. (2008) T-ACASI reduces bias in STD measurements: The National STD and Behavior Measurement Experiment. Sex Trans Dis 35(4):499-506.

20. Villarreal MA, Turner CF, Eggleston EE, Al-Tayyib, Rogers SM, et al. (2006) Same-gender sex in the USA: Impact of T-ACASI on prevalence estimates. Pub Opin Quarterly 70:166-196.

21. Roman AM, Eggleston EE, Turner CF, Rogers SM, Crow R, et al. (2008) Effects of sampling and screening strategies in an RDD survey. Proceedings of the 2008 Joint Statistical Meetings, Denver CO, August 4-7.

22. Zerulman J, Miller WC, Gaydos C, Rogers SM, Turner CF (2003) Chlamydia in population surveys and other screenings of low prevalence populations: Coping with decreased positive predictive value. Sex Trans Inf 79(5):94-97.

23. Nigel F, Tanton C, Mercer CH, Nicholson S, Soldan K, et al. (2012) Testing for sexually transmitted infections in a population-based sexual health survey: development of an acceptable ethical approach. Ethics 2012 38: 380–382 originally published online January 17, doi: 10.1136/medethics-2011-10006.

25. Hupert JN, Mortenson JE, Reed JL, Kahn JA, Rich KD, et al. (2007) Rapid antigen testing compares favorably with transcription-mediated amplification assay for the detection of Trichomonas vaginalis in young women. Clin Infect Dis 45(2):194-198.

26. U.S. Bureau of the Census (2006) American Community Survey, Baltimore City, Maryland.

27. StataCorp (2011) Stata Statistical Software: Releases 10 to 12. College Station, TX: StataCorp LP 2007-2011.

28. Helms DJ, Mouser DJ, Metcalf CA, Douglas JM, Malotte CK, et al. (2008) Risk factors for prevalent and incident Trichomonas vaginalis among women attending three sexually transmitted disease clinics. Sex Trans Dis 2008; 35 (5): 484-488.

29. Van der Pol B, Williams JA, Orr DP, Bitteriger BE, Fortenberry JD (2005) Prevalence, incidence, natural history, and response to treatment of Trichomonas vaginalis infection among adolescent women. J Infect Dis 192:2039–44.

30. Van der Pol B (2007) Trichomonas vaginalis infection: the most prevalent nonviral sexually transmitted infection receives the least public health attention. Clin Infect Dis 44:23-25.

31. Centers for Disease Control and Prevention (2011) Sexually Transmitted Disease Surveillance 2010. Atlanta: U.S. Department of Health and Human Services.

32. Pew Research Center for the People and the Press (2012). Assessing the Representativeness of Public Opinion Surveys. May 15, 2012, Washington DC: Pew Center. (Published online at www.people-press.org/files/legacy-pdf/Assessing the Representativeness of Public Opinion Surveys.pdf accessed online on September 29, 2013).

33. Biener L, Garrett CA, Gilpin EA, Roman AM, Currivan DB (2004) Consequences of declining survey response rates for smoking prevalence estimates. Am J Prev Med Oct, 27(3):254-7.

34. Ku L, St Louis M, Farshy C, Aral S, Turner CF, et al (2002) Risk behaviors, medical care, and chlamydial infection among young men in the United States. Am J Public Health 92(7):1140-3.