Effects of Screening and Partner Notification on Chlamydia Positivity in the United States: A Modeling Study

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Objectives: Model impact of increasing screening and partner notification (PN) on chlamydia positivity.

Methods: We used a stochastic simulation model describing pair formation and dissolution in an age-structured heterosexual population. The model accounts for steady, casual, and concurrent partnerships and a highly sexually active core group. The model used existing sexual behavior data from the United States and was validated using chlamydia positivity data from Region X (Alaska, Idaho, Oregon, Washington). A screening program with a coverage rate of 20% was implemented among women aged 15 to 24 years. After 10 years, we increased screening coverage to 35%, 50%, and 65% and partner treatment rates from 20% to 40% and 55%. Finally, we included male screening (aged 15–24, screening coverage: 20% and 35%, partner treatment: 25% and 40%). We analyzed the effects on chlamydia positivity in women and the frequency of reinfection 6 months after treatment.

Results: The model described the decline in positivity observed from 1988 to 1997 in Region X, given screening coverage of 20% and a 25% partner treatment rate. Increasing screening coverage from 35% to 65% resulted in incremental decreases in positivity as did increasing the PN rate; a 23% reduction in positivity was achieved by either increasing screening by 3-fold or PN by 2-fold. Adding male screening to the program had less impact than increasing screening coverage or PN among women. Increased PN and treatment reduced reinfection rates considerably.

Conclusions: Increasing efforts in PN may contribute at least as much to control of chlamydia infection as increasing screening coverage rates.

Genital infection with *Chlamydia trachomatis* is the most commonly reported bacterial sexually transmitted infection in the United States.[1] A large proportion of chlamydial infections remain asymptomatic.[2] In women, chlamydia can cause pelvic inflammatory disease and can lead to ectopic pregnancy and infertility. *C. trachomatis* infections do not confer long-lasting immunity; therefore, persons who have been infected and treated can be reinfected. In up to 20% of young women treated for chlamydia, reinfection can be identified within 1 year.[3] Starting in 1988, chlamydia screening of sexually active women under the age of 25 years was implemented in Region X (Alaska, Idaho, Oregon, Washington) and later expanded across the country.[4]

After screening was implemented, chlamydia positivity decreased in Region X through 1996,[5] but has been increasing since 1997. Policy decisions are required if chlamydia prevalence is to be reduced further, but how are reductions in prevalence to be achieved most effectively? Screening participation rates of women seeking health care or family planning advice have remained relatively low (<50%).[6] If prevalence is to be decreased, should efforts focus on increasing screening participation or might other strategies, such as increasing partner treatment rates or including screening of males, be more effective?

Here, we report on results from a modeling study to assess the impact on chlamydia positivity of variety of potential changes to the present chlamydia prevention program in the United States. We used an existing individual-based model described elsewhere[7,8] and modified to reflect the situation in the United States, starting with the implementation of population-based screening programs in 1988. Our aim was to assess the effects of increasing chlamydia screening coverage among women aged 15 to 24 years, of increasing partner notification (PN) and treatment, and of including men aged 15 to 24 years in the screening program. Our aim is not to make quantitative predictions, but to compare the possible effects of various prevention strategies with each other.

The modeling results raise questions about programmatic and practical choices for improving services for testing and treatment of chlamydia. How should scarce resource be used most effectively to reduce chlamydia positivity in young women? We briefly discuss implications for programmatic decisions to draw attention to these issues for future discussion among policy makers.

METHODS

Model Structure

For modeling chlamydia transmission dynamics, a simulation model was used that describes pair formation and dissolution as well as transmission of infection as stochastic processes. Full details on the model structure and assumptions are available in the Technical Appendix (Supplemental Digital Content, online only, available at: http://links.lww.com/OLQ/A38) and in earlier publi-

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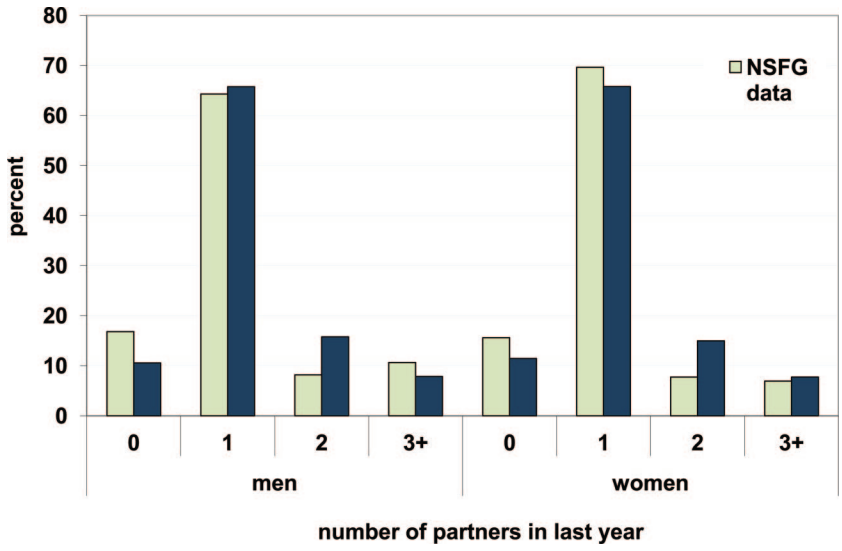

Figure 1. Number of partners in the last year as observed in the NSFG 2002 and as simulated by the model.
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cations.[7–9] Briefly, the model describes a heterosexual population aged 15 to 64 years. Individuals are characterized by age, sex, sexual activity (high/low), status of infection (not infected/symptomatic infection/asymptomatic infection), time since infection, and number and identities of partners. A distinction is made between steady and casual partners regarding the duration of the relationship and the frequency of sexual contacts during the relationship. In the younger age-groups (15–34 years), a subset of the population is defined as the "core group," with higher numbers of partners. The transmission probability of chlamydia is assumed to be equal between males and females. The recovery rate differs between the 2 sexes and depends on whether the infection is symptomatic or not.

Sexual Behavior Data

To parameterize the pair formation and separation process, we used data collected in 2002 from the National Survey of Family Growth (NSFG), a nationally representative multistage area probability sample.[10] Although more recent NSFG data are available, we used these older data as representing the midpoint of our study time frame. Survey data are based on 12,571 in-person interviews; 4928 with men and 7643 with women. Participants were 15 to 44 years of age and in US households. We used information about the number of (opposite sex) sex partners in the last year stratified by age. We calibrated the model such that the numbers of partners in the last year in the model population reflected those reported in NSFG (Fig. 1). To estimate partnership durations, we used results from a telephone survey conducted in Seattle, WA, in 2003–2004.[11]

Chlamydia Positivity and Screening Coverage

We used positivity data collected from family planning clinics participating in the Infertility Prevention Project (IPP) from 1988 to 2009.[4] In view of the fact that the most complete set of information about a variety of parameters was available for Region X, we focused on positivity data from that area and compared model simulation results with estimates from that area. A pilot project for chlamydia screening among young women was initiated in Region X in 1988. Chlamydia positivity declined rapidly from 1988 to 1997. We assumed that positivity in females was the same as positivity in males; national prevalence data from 1999 to 2002 support this assumption, showing that prevalence in males and females is not different.[12] In 1993, the first national chlamydia screening recommendations were implemented. At present, these recommendations include screening (*a*) all sexually active females aged ≤25 annually and (*b*) sexually active females aged ≥26 with risk factors (e.g., new sex partner or multiple sex partners).[13]

For estimating the present chlamydia screening coverage rate, we used figures from 2 data sources. The first was the Health Employer Data and Information Set published by the National Committee for Quality Insurance.[14] Health Employer Data and Information Set estimates are available at the national level. In commercial care settings (private settings), the 2005 screening coverage rate among sexually active women seeking family planning or STD-related health care was 34.4% for females aged 16 to 20 years and 35.2% for females aged 21 to 25 years. Among those with Medicaid, publicly funded care, the 2005 screening coverage rate among women seeking care was 49.1% among females aged 16 to 20 years and 52.4% among females aged 21 to 25 years. The second data source was the Family Planning Annual Report from the Office of Population Affairs.[15] Family Planning Annual Report includes regional screening coverage estimates for women seeking care at participating, federally funded family planning clinics (Title X). Nationally, 50% of all female family planning users under the age of 25 years were tested for chlamydia. In Region X, the screening coverage rate in 2005 was 35% for this group.

PN and treatment includes all activities designed to find and treat sexual partners of individuals diagnosed with chlamydial infection. PN may include traditional partner referral managed by state and local STD program staff, such as disease intervention specialists, expedited partner therapy (EPT) in either prescription, or medication form provided to the diagnosed patient to deliver to his or her sexual partners, clinic-specific efforts such as encouraging diagnosed patients to "bring your own partner (BYOP)" to the clinic to receive concurrent treatment, and other initiatives.

Scenarios

At baseline (i.e., before implementation of screening), we assumed that there was an endemic equilibrium with a chlamydia positivity in females of 13.0% among those aged 15

TABLE 1. Alternative Scenarios

Scenario	Target Group (yr)	Screening Coverage (%)	Partner Notification (%)
1 (baseline)	Women 15–24	20	25
2	Women 15–24	35	25
3	Women 15–24	50	25
4	Women 15–24	65	25
5	Women 15–24	20	40
6	Women 15–24	20	55
7	Women 15–24	35	40
8	Women and men 15–24	20	25
9	Women and men 15–24	35	25
10	Women and men 15–24	35	40

to 24 years. Before screening, only symptomatically infected individuals are treated, and PN is not performed. Our initial screening scenario assumed a screening coverage of 20% for women aged 15 to 24 years and a PN and treatment rate of 25% (25% of all current partners of chlamydia-infected women at the moment of screening are treated). When screening is implemented, PN and treatment activities are also begun among those diagnosed and treated because of a symptomatic infection. Using 25% as a baseline for the proportion of partners treated was motivated by the wide range of estimates found in the literature ranging from around 10%[16] up to 79%.[17–19]

After 10 years of screening under the initial scenario, we considered alternative scenarios (Table 1). We investigated the impact of (*a*) increasing screening coverage among women aged 15 to 24 years; (*b*) increasing partner treatment; and (*c*) increasing both screening and partner treatment. We also investigated the effect of screening men aged 15 to 24 years for chlamydia, using the same age range as for females. For comparison and sensitivity analyses, we also ran simulations with lower than baseline coverage and PN rates; alternatively, we ran scenarios with increased coverage and decreased PN rates (Technical Appendix, Supplemental Digital Content, online only, available at: http://links.lww.com/OLQ/A38). For all scenarios, the primary outcome was chlamydia positivity among women aged 15 to 19 years, 20 to 24 years, and 25 to 29 years after the scenario had been implemented for 10 years. Furthermore, we assessed the proportion of persons positive at screening or treated via PN who became reinfected within 6 months of treatment. For all scenarios, screening was first implemented at baseline for 10 years, then switched to an alternative scenario for another 10 years. For every scenario, 100 simulation runs were performed, and averages were computed. We report results on prevalence of asymptomatic infections in women in the age-groups under screening and in one additional age-group to demonstrate indirect effects of screening.

RESULTS

In the endemic steady state before screening was implemented, chlamydia positivity was 12.5% in women aged 15 to 19 years and 13.5% in women aged 20 to 24 years. In the first 5 years after introduction of screening, positivity decreased rapidly and then reached a plateau at around 9% for both screened age-groups (Fig. 2). Indirect effects on those age-groups not included in the screening are visible; positivity decreased by approximately 3% in the 25 to 29 year age-group. In the model simulations, we did not observe an increase in positivity as was observed in Region X starting in 1998.

The effects of alternative intervention strategies on the positivity of chlamydia in different age-groups of women are shown in Figure 3. Decreases in chlamydia positivity can be achieved by either increasing screening coverage or increasing the percentage of partners notified and treated. Increasing screening coverage from 20% to 65% (3-fold increase) while keeping the partner treatment rate at 25% led to a decrease of 22.5% in positivity for women aged 15 to 19 years; a similar decrease was achieved by increasing partner treatment from 25% to 55% (2-fold increase). Increasing both chlamydia screening coverage and partner treatment by 15% (screening: 35%, partner treatment: 40%) also decreased positivity among women aged 15 to 19 years by 22.5% (from 8.9% to 6.9%).

Adding male chlamydia screening at a coverage rate of 20% had the same effect as increasing screening coverage of women by 15% (from 20% to 35%); similarly, screening 35%

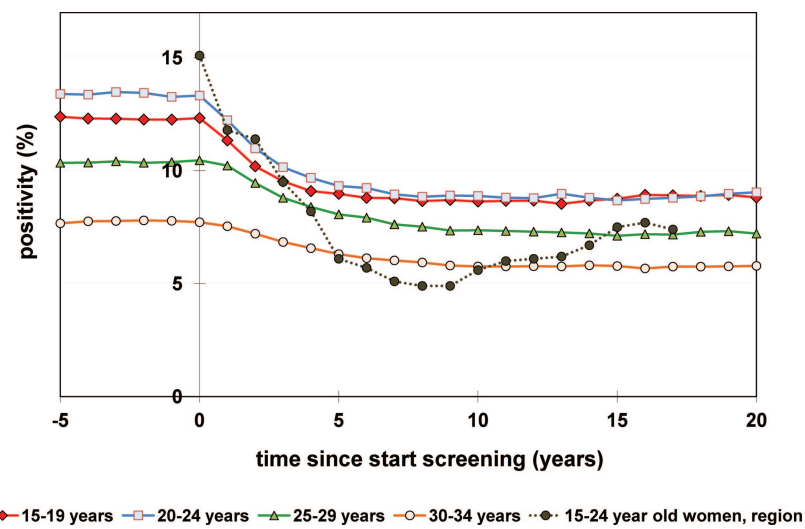

Figure 2. Prevalence among women decreases to about 60% of prescreening levels after 20 years of screening in the baseline scenario (20% screening coverage* and 25% PN and treatment). For comparison positivity rates of women aged 15 to 24 from region X are shown. *Among women aged 15 to 24 years.

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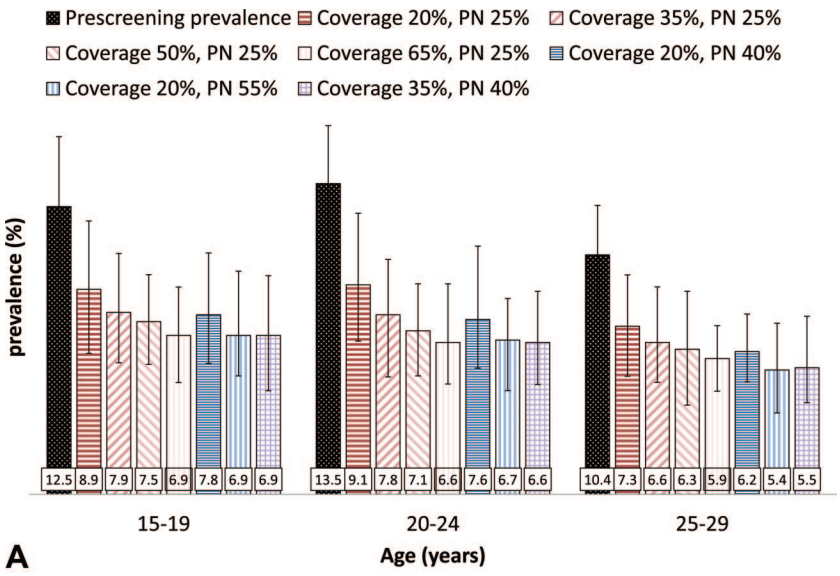

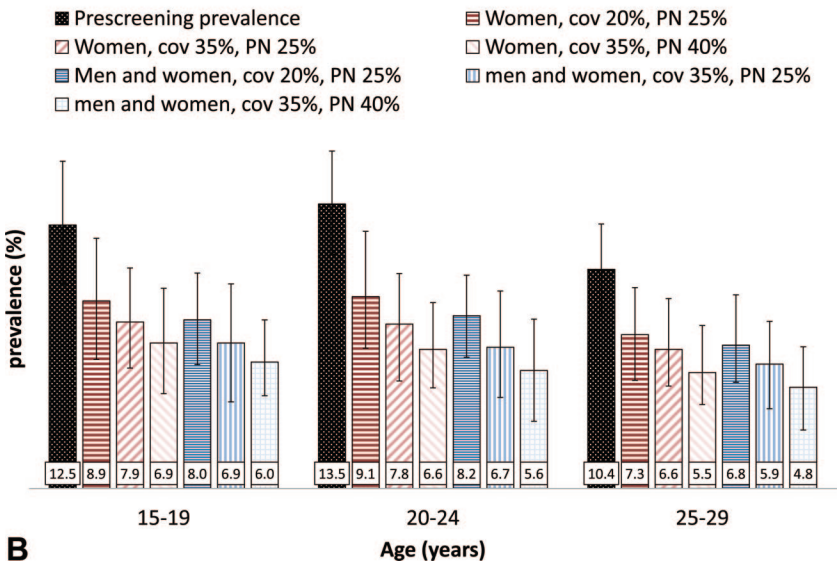

Figure 3. A, Effect of different screening* strategies on prevalence after 10 years of screening with a coverage of 20% and PN and treatment rate of 25% and then 10 years of screening with coverage and PN and treatment. Note the strong indirect effects in the age-group 25 to 29 years. The error bars indicate the minimum and maximum values observed among the 100 simulations runs performed for each scenario. *Screening women aged 15 to 24 years. B, The effect of adding screening of men aged 15 to 24* with different coverages and PN and treatment rates. The error bars indicate the minimum and maximum values observed among the 100 simulations runs performed for each scenario. *In addition to screening women aged 15 to 24 years.

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of men and 35% of women had the same impact as screening 65% of women (partner treatment: 25%). The most effective of all scenarios was screening 35% of women and men with a partner treatment rate of 40%. In that case, chlamydia positivity among women aged 15 to 19 years could be reduced by around 33%, as compared with positivity associated with 20% coverage and 25% PN. Overall, we find that all strategies result in rather minimal impact on chlamydia prevalence considering the major efforts required to implement and achieve those coverage rates.

To observe how a decrease in coverage and partner treatment rates, respectively, would affect existing screening programs, we ran simulations with lower than baseline values of these parameters. First, in a scenario where screening coverage decreased to 20% after the first 10 years of screening, positivity started increasing again, especially among females aged 15 to 19 years. After 10 more years of screening with 20% coverage, positivity had increased by around 1%. If only PN and treatment drops to 10% after 10 years of screening, positivity also went up by approximately 1.5% after 10 years. In a scenario where coverage goes up to 35%, but PN drops to 10% after 10 years of screening, positivity went up by 0.5%. The latter means that a 15% increase in coverage could not counteract the adverse impact of decreasing partner treatment rates by 15%. The differences were small, but the directions of the effects were clear.

The rate of reinfection among women treated for chlamydia was approximately 45% at 6 months and was relatively constant over time. For men who were identified and treated due to PN, the reinfection rate was around 15%. Increasing screening coverage had minimal impact on reinfection rates, while increasing partner treatment led to a decrease in reinfection rates. An increase in partner treatment rates by 15% resulted in approximately a 7% decrease in reinfection rates among women. The reinfection rate among men was unchanged and shows that a substantial fraction of reinfections are due to new infected partners. When including men in screening, the observed reinfection rates in men increased to

36%. This is due to the selection of persons for whom reinfection rates are measured. When only women were screened, reinfection in men was observed after PN and treatment only, while in the male screening scenarios, they were also included via the screening procedure. With increasing partner treatment, reinfection rates in men decreased by 7%.

DISCUSSION

Main Findings

Chlamydia positivity has not been decreasing over the past decade. In this modeling study, we aimed to give guidance for deciding on what interventions would be most effective to decrease chlamydia prevalence in the future. Our main finding is that increasing rates of PN and treatment potentially has a larger impact on positivity than increasing the screening coverage among women, when one intervention was implemented holding the other stable. We compared the effects of similar percentage increases in screening coverage and partner treatment rates. However, an increase in screening coverage by 15% requires testing and treating many more women than a similar increase in PN and treatment. In addition, increasing partner treatment reduces reinfection rates and therefore can be viewed as a more targeted intervention measure. Earlier results based on different assumptions about the fraction of asymptomatic infections and baseline coverage rates support these conclusions.[20,21] Also, a recently published study based on a deterministic modeling framework showed that the effectiveness of screening is improved when reinfection within partnerships can be prevented.[22]

Overall, one can say that gains in decreasing prevalence are relatively small in view of the major efforts needed to improve coverage to higher levels. Some of the pertinent parameters we used are uncertain. However, a recent study showed that some determinants of the natural history of chlamydial infection like the duration of infection do not greatly affect the effectiveness of screening at the coverage rates considered here.[23] Therefore, it seems that more creative strategies are called for than just increasing coverage if substantial impact is to be achieved. Our results support insights from intervention trials that conclude that focusing intervention to avoiding reinfection within partnerships and increasing PN services might be the road to go.

The model presented here described prescreening chlamydia positivity that mirrored positivity observed in Region X in 1988 and showed a strong decline in positivity in the first 5 years after the introduction of chlamydia screening among sexually active young women. After that, positivity leveled off and remained on a constant endemic level for the remaining 15 years that were modeled. Other factors not included in the model are likely responsible for the difference between observed chlamydia positivity and modeled positivity. These could be sexual behavior changes, changes in immunity, or changes in testing behavior. Therefore, our results should not be interpreted as quantitative predictions, but they should be interpreted in terms of a qualitative comparison between different screening strategies. These results are obtained with a model that has been used for many other studies into the effectiveness of screening and partner treatment, and results reported here are consistent with earlier studies.[7,8,24] In a comparative study, it was shown that the model used here performs well in describing essential features of the sexual network and chlamydia transmission.[25]

Positivity and Prevalence in Other Regions and on National Level

Positivity levels in the model in the prescreening period exceed 10% in younger women. This is consistent with positivity data among sexually active young women reported from Region X but is higher than observed in general population surveys, such as the National Health and Examination Survey, which found a prevalence of 4.7% among all females aged 14 to 19 years from 1999 to 2002.[12] In 1988, prevalence may have been higher, but no national estimates are available from this time. Therefore, we used available positivity data for our simulations. In the combined intervention scenario (35% screening, 40% PN), the resulting positivity among females aged 15 to 19 years was 6.9% after 10 years of screening, which is more consistent with the National Health and Examination Survey prevalence among sexually active females aged 15 to 19 years for years 2003–2004 (7.1%).[26] Using a model based on a population prevalence of around 4% would lead to different quantitative but not qualitative conclusions, as comparison with the study by Andersen et al shows.[24] We used data from Region X because the longest time series of positivity values was available for this region. In view of the model's generality, our qualitative results are likely also applicable to other regions with similar screening coverage. A recent study showed that overall IPP positivity in family planning clinics was stable from 2004 to 2008.[27] Screening could be enhanced by targeting specific risk groups like detention centers and jails; these effects cannot be incorporated into the model in its present form.

Reinfection rates found in the model were higher than reported in most observational studies.[28–30] In the study by Peterman et al,[30] reinfection rates in women were 11% to 15% at 3 to 4 months after treatment, while in the model, we found reinfection rates of around 45% after 6 months. Batteiger et al[31] reported that 84% of repeated positive tests were due to reinfection, while 14% could be attributed to treatment failure and 2% to unexplained persistence. This would lead to the conclusion that increased partner treatment may be able to prevent a large fraction of all reinfections, which agrees with our findings that demonstrate a substantial decrease in reinfection rates with increasing partner treatment. It is difficult to compare the reinfection rates found in the literature with the reinfection rates observed in the model because the selection of persons included in the studies and the model observations were not the same. Furthermore, in reality, persons who have tested positive for chlamydia might change their behavior in the months after the positive test, either by taking fewer risks or by ending the partnership. Also, short-term immunity may play a role, which was not included in the model. Finally, the model might overestimate the number of sex acts in ongoing partnerships. In a recent modeling study,[22] it was shown that models that do not take reinfection into account may overestimate the impact of screening on chlamydia prevalence. The model used in that article was a deterministic and simplified version of the stochastic simulation model we used here. Our results on reinfection shown here provide further support for the conclusion that reinfection in partnerships plays an important role in the endemic persistence of chlamydia infection.

The model showed that for a given screening coverage and rate of partner treatment and no changes over time in sexual behavior, chlamydia positivity will plateau after 5 to 10 years. There is no reason to expect further decreases unless more effective intervention measures are implemented. Furthermore, our study showed that screening women aged 15 to 24 years affects not only those age-groups but has a substantial

indirect effect on women of older age-groups and on men (data not shown). Expanding screening to men aged 15 to 24 years did have some additional effect on top of the indirect effects obtained by screening women. However, when considering screening men, additional effort and costs in setting up screening for a different target group need to be considered. For instance, men seek care less frequently than women. Given the potential effort it takes to set up a new screening program for men or to increase screening among women, cost-effectiveness is a critical consideration. More data are needed about health care uptake by men and ways to include men in screening programs before we can assess the possible impact of male screening in more detail. Ongoing population-based screening programs in England and in the Netherlands have shown that it is difficult to achieve screening coverages exceeding 20%.[32,33] Possibly, targeted screening of populations at high risk, such as incarcerated women and men or focusing efforts on adolescents and young adults (aged <20 years), and eliminating screening of women older than 25 could improve the effectiveness of broad population screening and may serve as a more cost-effective intervention.

Limitations of the Study

Our study has several limitations. First, there are large differences in screening coverage rates from different regions, by different implementing organizations, and in different time periods. We have just used rough estimates of coverage, which we assumed are constant over time. However, recent studies have revealed that screening participation may be low and may decrease with time.[34] However, we wanted to implement screening strategies as future goals for programmatic changes, and implementing regular screening is done with the aim of reaching a given regular uptake by the target population. Screening uptake rates in other regular programs such as cervical cancer screening show that higher coverage and regular uptake is not impossible to reach.[35] Furthermore, there is limited empirical information concerning the partner treatment coverage.[16] Where possible, we used geographically related data (Region X); however, it was also necessary to use national data sources where regional data were not available. Such national data may not have been representative of the region. The model we use is not sufficiently detailed to incorporate differences in coverage between different regions and other population heterogeneity on regional levels. Possibly, screening could be made more efficient by focusing on improving current programs in those regions that have low coverage at present or by targeting the existing program toward more sexually active persons. Second, partner treatment was modeled fairly simply (inclusion of current partners only). Actual patterns of partner treatment with and without PN might be different from those modeled, with implications for the effectiveness of PN and treatment when compared with other approaches. Finally, although the model's positivity matched the positivity in IPP family planning clinics, both estimates may be higher than those in the general population. More detailed data about time dependent uptake rates of screening are needed to understand the exact relationship between population prevalence and positivity. There is an inherent uncertainty in how well a model structure will reflect actual transmission processes in the population.[9]

CONCLUSIONS

Our findings that increasing partner treatment alone is slightly more effective than increasing screening coverage of women alone is consistent with other results obtained in modeling studies.[24] It is also in line with other results showing that sexual network structure is an important consideration in the success of sexually transmitted infection prevention. In practice, this means that patients cannot be viewed as isolated individuals; partnership dyads and sexual behaviors should be assessed and targeted. Although increasing coverage of screening may be costly and hard to put into practice, corresponding PN and treatment is a critical component to successful chlamydia prevention and control efforts. It may be necessary to explore innovative ways of implementing screening and partner treatment in practice if these prevention goals are to be reached within present budget limitations. For example, research has shown that EPT is more effective and has a lower societal and health care system cost than traditional PN.[36] With diminishing health department resources and competing demands, expanding traditional (disease intervention specialists) PN and treatment activities may not be feasible. However, community outreach efforts to promote EPT have the opportunity to reach a large audience and increase a low-cost intervention. Such prevention efforts, whether increasing screening coverage or partner treatment, are applicable to all public health partners, including health departments, physicians, and insurance providers; reducing the burden of chlamydia serves not only to directly protect individual patients (prevent initial infection and reduce reinfection risk) but also to reduce overall population costs, both in terms of expenditures and adverse reproductive outcomes.

REFERENCES

1. CDC. Sexually Transmitted Disease Surveillance, 2008. Atlanta, GA: Centers for Disease Control and Prevention, U.S. Department of Health and Human Services, 2009.
2. Johnson RE, Berman S. Sexual transmission: *Chlamydia trachomatis*. In: Krämer A, Kretzschmar M, Krickeberg K, eds. Modern Infectious Disease Epidemiology: Concepts, Methods, Mathematical Models, and Public Health. New York, NY: Springer Verlag, 2010:359–382.
3. Hosenfeld CB, Workowski KA, Berman S, et al. Repeat infection with Chlamydia and gonorrhea among females: A systematic review of the literature. Sex Transm Dis 2009; 36:478–489.
4. CDC. Chlamydia prevalence monitoring project annual report 2005. In: Sexually Transmitted Disease Surveillance 2005 Supplement. Atlanta, GA: Centers for Disease Control and Prevention, 2006.
5. CDC. Sexually Transmitted Disease Surveillance 2007 Supplement, Chlamydia Prevalence Monitoring Project Annual Report 2007. Atlanta, GA: Centers for Disease Control and Prevention. U.S. Department of Health and Human Services, 2009.
6. CDC. Chlamydia screening among sexually active young female enrollees of health plans–United States, 2000–2007. Morb Mortal Wkly Rep 2009; 58:362–365.
7. Kretzschmar M, van Duynhoven YT, Severijnen AJ. Modeling prevention strategies for gonorrhea and Chlamydia using stochastic network simulations. Am J Epidemiol 1996; 144:306–317.
8. Kretzschmar M, Welte R, van den Hoek A, et al. Comparative model-based analysis of screening programs for *Chlamydia trachomatis* infections. Am J Epidemiol 2001; 153:90–101.
9. Kretzschmar M, Turner KM, Barton PM, et al. Predicting the population impact of chlamydia screening programmes: Comparative mathematical modelling study. Sex Transm Infect 2009; 85:359–366.
10. Mosher WD, Chandra A, Jones J. Sexual behavior and selected health measures: men and women 15–44 years of age, United States, 2002. In: *Advance Data from Vital and Health Statistics.* Hyattsville, MD: National Center for Health Statistics, 2005.

11. Foxman B, Newman M, Percha B, et al. Measures of sexual partnerships: Lengths, gaps, overlaps, and sexually transmitted infection. Sex Transm Dis 2006; 33:209–214.
12. Datta SD, Sternberg M, Johnson RE, et al. Gonorrhea and chlamydia in the United States among persons 14 to 39 years of age, 1999 to 2002. Ann Intern Med 2007; 147:89–96.
13. CDC. Sexually transmitted disease treatment guidelines, 2006. Morb Mortal Wkly Rep 2006; 55:38.
14. National Center for Quality Assurance (NCQA). The State of Healthcare Quality 2009. Washington, DC: National Committee for Quality Assurance, 2009.
15. RTI International. Family Planning Annual Report: 2005 National Summary. Research Triangle Park, NC: RTI, 2006.
16. Golden MR, Hogben M, Handsfield HH, et al. Partner notification for HIV and STD in the United States: Low coverage for gonorrhea, chlamydial infection, and HIV. Sex Transm Dis 2003; 30:490–496.
17. Kissinger P, Mohammed H, Richardson-Alston G, et al. Patient-delivered partner treatment for male urethritis: A randomized, controlled trial. Clin Infect Dis 2005; 41:623–629.
18. Hogben M. Partner notification for sexually transmitted diseases. Clin Infect Dis 2007; 44(suppl 3):S160–S174.
19. Hogben M, Kissinger P. A review of partner notification for sex partners of men infected with Chlamydia. Sex Transm Dis 2008; 35:S34–S39.
20. Kretzschmar M, Satterwhite C, Leichliter J, et al. Analysis of Chlamydia screening in the United States using a stochastic simulation model. Presented at: ISSTDR; 2007; Seattle, WA.
21. Kretzschmar M, Satterwhite C, Leichliter J, et al. Effects of screening and partner notification on chlamydia prevalence in the United States: A modeling study. Presented at: ASTA/BASSH meeting; 2008; Washington, DC.
22. Heijne JC, Althaus CL, Herzog SA, et al. The role of reinfection and partner notification in the efficacy of Chlamydia screening programs. J Infect Dis 2011; 203:372–377.
23. Althaus CL, Heijne JC, Roellin A, et al. Transmission dynamics of *Chlamydia trachomatis* affect the impact of screening programmes. Epidemics 2010; 2:123–131.
24. Andersen B, Gundgaard J, Kretzschmar M, et al. Prediction of costs, effectiveness, and disease control of a population-based program using home sampling for diagnosis of urogenital *Chlamydia trachomatis* infections. Sex Transm Dis 2006; 33:407–415.
25. Althaus CL, Turner KM, Schmid BV, et al. Transmission of *Chlamydia trachomatis* through sexual partnerships: A comparison between three individual-based models and empirical data. J R Soc Interface 2012; 9:136–146.
26. Forhan SE, Gottlieb SL, Sternberg MR, et al. Prevalence of sexually transmitted infections among female adolescents aged 14 to 19 in the United States. Pediatrics 2009; 124:1505–1512.
27. Satterwhite CL, Grier L, Patzer R, et al. Chlamydia positivity trends among women attending family planning clinics: United States, 2004–2008. Sex Transm Dis 2011; 38:989–994.
28. Fung M, Scott KC, Kent CK, et al. Chlamydial and gonococcal reinfection among men: A systematic review of data to evaluate the need for retesting. Sex Transm Infect 2007; 83:304–309.
29. Golden MR, Whittington WL, Handsfield HH, et al. Effect of expedited treatment of sex partners on recurrent or persistent gonorrhea or chlamydial infection. N Engl J Med 2005; 352:676–685.
30. Peterman TA, Tian LH, Metcalf CA, et al. High incidence of new sexually transmitted infections in the year following a sexually transmitted infection: A case for rescreening. Ann Intern Med 2006; 145:564–572.
31. Batteiger BE, Tu W, Ofner S, et al. Repeated *Chlamydia trachomatis* genital infections in adolescent women. J Infect Dis 2010; 201:42–51.
32. van den Broek IV, Hoebe CJ, van Bergen JE, et al. Evaluation design of a systematic, selective, internet-based, Chlamydia screening implementation in the Netherlands, 2008–2010: Implications of first results for the analysis. BMC Infect Dis 2010; 10:89.
33. Health Protection Agency. NCSP: Five years. The Fifth Annual Report of the National Chlamydia Screening Programme 2007/08. In: National Chlamydia Screening Programme. London, United Kingdom, 2008.
34. Heijne JCM, Tao G, Kent C, et al. Uptake of regular chlamydia testing by US women: Longitudinal study. Am J Prev Med 2010; 39:243–250.
35. Gohmann SF. A comparison of health care in Canada and the United States: The case of Pap smears. Med Care 2010; 48:1036–1040.
36. Gift TL, Kissinger P, Mohammed H, et al. The cost and cost-effectiveness of expedited partner therapy compared with standard partner referral for the treatment of chlamydia or gonorrhea. Sex Transm Dis 2011; 38:1067–1073.