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Impacts of changing sexual behavior on chlamydia and gonorrhea burden among US high school students, 2007–2017

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Abstract

Background: Rates of adolescent sexual activity have long been declining in the United States. We sought to estimate the number of cases of gonorrhea and chlamydia averted over one decade associated with these declines, and associated costs saved.

Methods: We analyzed data from the CDC's Youth Risk Behavior Survey of US high-school students from 2007–2017 and combined it with epidemiological estimates drawn from the literature to parameterize a dynamic population transmission model. We compared transmissions from observed behavioral trends to a counterfactual scenario that assumed sexual behaviors from 2007 remained constant over 10 years. We calculated outcomes by age and for three racial/ ethnic groups (Hispanic, non-Hispanic Black, and non-Hispanic White adolescents) who vary on underlying burden and amount of behavioral change.

Results: We estimated 1,118,483 cases of chlamydia and 214,762 cases of gonorrhea were averted (19.5% of burden across all ages). This yielded $474 million (2017 dollars) savings in medical costs over the decade. The largest number of averted cases (767,543) was among Black adolescents, but the largest proportion (28.7%) was among Hispanic adolescents.

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Ethics approval: this is a modeling study without human subjects; no ethical approval is required.

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Conclusions: Whatever its origins, changing sexual behavior among adolescents results in large estimated reductions in STI burden and medical costs relative to previous cohorts. Although diagnoses among adolescents have not declined at this rate, multiple explanations could make these apparently divergent trends consistent. Efforts to continue supporting effective sex education in and out of school along with STI screening for adolescents should reinforce these gains.

Summary:

A modeling study estimated that changes in sexual behavior among US high school students helped avert >1.3 million cases of gonorrhea and chlamydia and save nearly a billion dollars

Keywords

gonorrhea; chlamydia; adolescents; sexual behavior; modeling

Introduction.

Overall rates of sexual intercourse among adolescents, and of specific behaviors that may increase the risk of exposure to sexually transmitted infections, are on the decline in the United States (1–3). This phenomenon has captured widespread popular attention (4, 5), and has numerous hypothesized causes (6). A recent report covering the 2007–2017 waves of CDC's Youth Risk Behavior Survey (YRBS) provides detailed numbers for these trends (7). For instance, the percent of high school (HS) students who reported having ever had sexual intercourse (SI) declined over 2007–2017 from 47.8% to 39.5%, while those reporting 4+ lifetime partners declined from 14.9% to 9.7%. In contrast, other measures indicate increasing risk over time; e.g. among sexually active respondents, condom use at last sex declined from 61.5% to 53.8%. Although this may be associated with increased use of long-acting reversible contraceptives and other forms of birth control, these alternatives do not also provide protection for sexually transmitted infections (STIs).

These trends include important heterogeneity by race/ethnicity. The proportion of individuals who report having ever had SI declined by 11.7% for White students (43.7% to 38.6%), but 21.0% for Hispanic students (52.0% to 41.1%), and 31.1% for Black students (66.5% to 45.8%, 7). Similarly, the percentage reporting 4+ lifetime sexual partners declined by 25% for White students (11.5% to 8.6%), but 46% for both Hispanic and Black students (17.3% to 9.4% and 27.6% to 14.8%, respectively).

Adolescents bear large burdens of both chlamydia and gonorrhea infections. In 2017, for instance, ~438,000 cases of chlamydia and ~93,000 of gonorrhea were reported among 15–19-year-olds, reflecting 26% and 17% of all diagnoses, respectively (8). Some natural questions arise then: how much larger would chlamydia and gonorrhea burden have been, overall and by race/ethnicity, had reported cumulative shifts in rates of sexual activity over this period not occurred? Or is the decline in condom use sufficient to negate the epidemiological impact of overall declines in intercourse? To what extent are changes in diagnoses expected from these behaviors consistent with observed diagnoses, given that the latter also reflect diagnostic changes?

Answering these questions creates multiple challenges. First, it requires precisely defining a counterfactual scenario with no behavior change, and estimating expected incidence therein. Second, incidence—observed or counterfactual—is a complex function of many interacting parts, including current prevalence, sexual networks, diagnosis, treatment, and pathogen biology. Isolating the impact of any one—here, behavioral change—means holding the others constant in that counterfactual, even if they also underwent some change. Finally, given the underlying epidemiology, any reasonable model must consider behavioral heterogeneity and STI risk across at least four dimensions: sex, age, race/ethnicity, and time. Mathematical modeling allows us to address all of these challenges.

In this paper, we extend a previously published modeling framework (9) to assess the interplay of changes in behaviors detailed in the 2007–2017 YRBS trends report on estimated incidence overall and by demographic categories. We then estimate medical cost savings from cases of STI averted. As YRBS represents a stratified sample of adolescents in HS, our model reflects this population. Finally, we consider observed trends in reported adolescent STI diagnoses over the same timeframe, interpreting our results and these trends in mutual context to see what they collectively reveal about the evolving dynamics of STI burden and detection among US adolescents.

Methods

Our analysis extends the single-generation Bernoulli modeling framework in *teen-SPARC* (www.emorycamp.org/teensparc, 9) to cover behavior change over 10 years and include race/ethnicity. Methods and motivation for this underlying model are described in detail in the User Manual on the *teen-SPARC* website, and code is at https://github.com/statnet/CAMP_Adol_GC_CT_10yr. We focus here on the three races/ethnicities explored in the CDC's trend report (non-Hispanic Black, Hispanic, non-Hispanic White; henceforth Black/Hispanic/White).

Model structure.

Annual incident cases for high-school-attending students of female sex ($s=F$), age a and race/ethnicity r in year y ($I_{s=F,a,r,y}$) are estimated as:

$$I_{s=F,a,r,y} = \sum_{r'=\{B,H,W\}} E_{s=F,a,r} D_{s=F,a,r,y} \left(1 - p_{s=F,a,r,y}\right) \left(1 - \left(1 - \beta_{s=F} p_{s=M,\cdot,r',y} \tau_{s=F,r}\right)^{c_{s=F,a,r,y}} \varphi_{s=F,r,r'}\right)$$

with variables defined and derived in Tables S1 and S2 (Supplemental Digital Content 1). Briefly, the indices (*s, a, y, r*) stand for sex (*F*=female and *M*=male), age, race/ethnicity and year, while *r'* reflects partner race/ethnicity. *I* is incidence, *E* is HS population size, *D* is proportion having ever had sex, *p* is prevalence, *β* is transmission probability per condomless discordant act, **τ** is the partner prevalence ratio (described below), *c* is number of condomless acts/person/year, and *φ* is the proportion of partners by race/ethnicity. The expression inside the summation represents a traditional Bernoulli probability for repeated exposures, with transmission probabilities in the base and number of exposures in the exponent, limited to exposures from a specific race/ethnic group; these are then summed. Male incidence follows an analogous equation. We analyzed and modeled adolescents ages 14–18, covering the vast majority of HS students. Because YRBS did not ascertain sex of partners until recently, we use penile-vaginal transmission probabilities throughout, knowing that these represent the vast majority of acts of intercourse, and yield conservative estimates since they are lower than penile-anal transmission.

Model inputs.

Table S1 lists parameter data sources. Main behavioral inputs were derived from the National YRBS 2017 Combined Dataset (10), which includes previous years' data. Analyses were conducted using survey procedures in SASv9.4 (SAS Institute, Inc., Cary, NC) to address YRBS's complex sampling design and weights. For each biennial survey year 2007–2017, we calculated weighted numbers of respondents, proportion of respondents reporting having ever had SI, and proportion reporting condom use at last SI, all by sex, race/ethnicity and age. We then tabulated age of first SI by sex, race/ethnicity, and current age; and mean number of lifetime partners among sexually experienced respondents by sex, race/ethnicity, current age, and age at first sex. Following *teen-SPARC*, we used lifetime partner counts and the difference between current age and age at first sex to estimate mean number of new partners/year.

Behavioral inputs.—For the three behaviors—proportion having ever had SI, condom use at last SI, and number of new partners/year—we conducted regressions to ascertain predicted values to use in the model for each combination in the four-way (sex, age, year, race/ethnicity) stratification. These values smooth the stochasticity across individual cells by assessing trends across numerical predictors (details in Supplemental Digital Content 1).

Simulation model.

We compared two scenarios: a baseline counterfactual with no behavior change—i.e. in which predicted values for 2007 behaviors continued for the decade—and a second modeling observed trends. We chose 2007 to coincide with CDC's trends report. Key outcomes include the estimated number and percent of incident cases averted (NIA, PIA) in the second scenario relative to the first.

To make scenarios interpretable, we calibrated our model to produce stable incidence in the absence of behavior change. We did so using a "partner prevalence ratio" (PPR), representing the ratio between STI prevalence for a given group's actual sexual partners to that of the overall HS population of the appropriate sex and same race/ethnicity composition as those partners. For instance, the PPR for Hispanic females for gonorrhea is 1.52, meaning that gonorrhea prevalence among their partner pool is 52% higher than among the HS-attending males in the model, weighted by the proportion of male students by race/ethnicity in Hispanic females' reported partner pool. Such discrepancies can result from violations of our assumption of random age mixing among a closed population of adolescents (e.g. if some partners are >18) or if high variations in activity rates within and across locales mean that some individuals are over-represented in the partner pool and this correlates with their infection probability; both are reasonable hypotheses on which we lack complete data.

Additional details of the model calibration process are in the Supplemental Digital Content 1.

We ran both models and calculated NIA and PIA overall and disaggregated by infection, sex, race/ethnicity, and year. We then drew 100 sets of input parameters from a multivariate-normal distribution using the regression variance/covariance matrices, reran the base and behavior-change models, and recalculated NIA and PIA, constructing credible intervals (CrI) as the central 95% of results (details in Supplemental Digital Content 1).

Finally, we used published estimates of the direct medical cost of chlamydia and gonorrhea to calculate medical costs saved from averted cases. We used gender-specific estimates of lifetime cost/case (11) and adjusted them to 2017 dollars using the Medical Care component of the Consumer Price Index for All Urban Consumers (12). We used a 3% annual compound rate to calculate future (2017) value of costs saved/case averted for each year. We calculated total costs saved as the product of the NIA and compounded cost saved/case averted. To provide a measure of cost uncertainty, we also performed best- and worst-case scenario analyses by using +/− 50% of the compounded costs. Table S3 lists uncompounded and compounded costs, with best- and worst-case scenario values.

Results

Table S4 lists the regression coefficients generating the predictions for modeled sexual behaviors, while Table S5 provides the predicted values. Figure 1 shows these values for the proportion of female HS students reporting having ever had SI, overlaid on the data (other measures shown in Figure S1). Regression results confirm previous findings (7) of declining proportions over time of adolescents reporting having ever had SI and using condoms at last SI, with significant trend differences by race/ethnicity. Our analysis provides additional disaggregation by age that enables our prediction models and simulations. Table S6 lists the PPR values needed to calibrate the model.

Incidence reductions.

When comparing observed behavioral trends from 2007–2017 to a counterfactual assuming no behavior change, the estimated NIA over 10 years is 214,762 cases for gonorrhea (CrI=18,406–924,307), reflecting a PIA of 19.5% (CrI=2.1%–35.8%). Chlamydia has an NIA of 1,118,483 cases (CrI=567,495–2,548,280) and PIA of 19.5% (CrI=11.7%–26.6%). Table 1 further disaggregates these by sex and year, and calculates corresponding costs averted (with credible intervals in Table S7). Across both infections, we estimate $474 million saved in medical costs over the decade associated with reported behavior change (range $237–$711 million for worst- to best-case scenarios). Infections averted among female students are the overwhelming proportion (~$454 million, range $227–$682 million), with chlamydia representing 84.0% of costs averted ($398 million, range $199–$597 million). Both infections averted and costs saved grow substantially over time, given the compounding effects of additional behavior change and reducing background prevalence. The effect is not exponential, however, with dampening in later years.

Figure 2 shows NIA and PIA by race/ethnicity. Most cases averted are among Black students (767,543), including 602,712 cases of chlamydia and 164,830 cases of gonorrhea (numbers do not add due to rounding). Hispanics follow, at 378,292 (348,761 of chlamydia and 29,531 of gonorrhea). With their lower initial burden and smaller behavior change, Whites see only 187,410 total cases averted (167,010 of chlamydia and 20,400 of gonorrhea). In contrast, the *percent* of infections averted is highest among Hispanic students (28.7% overall, comprising 28.9% for chlamydia and 27.4% for gonorrhea), intermediate for Blacks (19.7% overall, 19.6% chlamydia, 20.2% gonorrhea), and again lowest for Whites (11.4%, 11.4%, 11.7%, respectively).

Figure 3 shows the NIA and PIA by age. The NIA reflects the distribution of the sexually active HS population, with ages 16–18 collectively representing 87.8% of all STI cases. Note that the total number for 18-year-olds is less than 16- or 17-year-olds, despite a greater proportion sexually active, since many 18-year-olds have graduated HS and left the population. The PIA shows a slow but steady decline across ages.

Discussion

We modeled the estimated effect of previously reported behavioral change among adolescents in US high schools on STI incidence, focusing on 2007–2017 to match a recent YRBS behavioral trends report (7). We estimate that this behavior change, relative to a scenario in which both behaviors reported in 2007 and all other factors had persisted over 10 years, results in a predicted reduction of >1.1 million incident cases of chlamydia and >200,000 cases of gonorrhea. The combined medical costs saved are estimated at nearly half a billion dollars over the decade. For perspective, the medical costs of all chlamydia and gonorrhea infections incident in one year across all ages in the US have been estimated at $680 million (2010 dollars, $830 million in 2017 dollars, 11).

Our model predicted the greatest percent decline in STI incidence in Hispanic students, reflecting temporal trends in both proportion having ever had SI and using condoms. For the former, time trends suggested declining transmission for all race/ethnicity populations, with Blacks having the steepest decline, followed by Hispanics, then Whites. However, these benefits were partly offset by declining rates of condom use—and here, Hispanics showed by far the least risk increase, particularly as reported by males. Our model also predicted that PIA declines with age, which may reflect the fact that populations with smaller underlying burden (here, younger ages) are closer to the epidemic threshold and can see larger proportional reductions from similar levels of behavior change.

It is, of course, useful to compare our findings to trends in reported rates of adolescent diagnoses over the same decade. These increased by 16% for chlamydia (1,779.3 to 2,072.4/100,000 persons) and decreased by 5% for gonorrhea (462.3 to 438.3/100,000 persons, 8, 13). Notably, these numbers are both small relative to changes in diagnoses across all ages: an increase of 44% for chlamydia (367.5 to 528.8 reported cases/100,000 persons) and 46% for gonorrhea (118.0 to 171.9/100,000 persons, 8).

One possible explanation for the apparent discrepancy between our model and observed trends reflects the fact that we estimated incident cases, while the latter reflect reported cases, which depend on diagnosis. We assumed constant screening rates in our model to isolate the effects of sexual behavior, and because the effects of screening changes are not straightforward. A given increase in screening will not simply increase diagnoses by that same amount, but it can also reduce incidence by shortening the duration of diagnosed infections through treatment. And indeed the last decade has seen multiple improvements in screening coverage, test sensitivity, and reporting completeness (8), with specific efforts targeting adolescent screening (14). For example, the Healthcare Effectiveness Data and Information Set reveals increases in chlamydia screening over this period among women across a range of insurance types (e.g. from 50.7% to 57.6% of sexually active women aged 16–24 with Medicaid, 15). Such changes in screening complicate the relationship between numbers of diagnoses (as seen empirically) and incident cases (as estimated by our model).

Two additional data types can help assess changes in the relationship between reported diagnoses and incident cases and therefore clarify true changes in incidence. One is measures of positivity, the percent of tests that are positive. Data here are murky: CDC recently began reporting positivity rates for STI clinics from selected jurisdictions (8, 16–18), but these fluctuate widely between years, and are difficult to interpret since the proportion of cases diagnosed in STI clinics has shrunk considerably over this interval, potentially making it a more highly selected population with time. The second data type is population-based studies, in particular the National Health and Nutrition Examination Survey (NHANES), which measures chlamydia prevalence in each nationally representative wave. A recent report found that 14–19-year-old females in NHANES saw a significant decline in prevalence from 3.9% (2001–2004) to 2.3% (2013–2016); among Black female adolescents the decline was even steeper, from 10.9% (2001–2004) and 12.0% (2009–2012) down to 4.4% (2013–2016, 19). This suggests that relatively flat diagnoses among adolescents could combine two positive developments: the declining incidence predicted by our model along with increasing detection. Additional modeling and analysis of future NHANES waves will be crucial in assessing these possibilities further; tracking and reporting of positivity rates by a range of testing entities would also help.

Another explanation for the divergence between our predicted incidence and reported cases is that incidence rates in the absence of adolescent behavior change would have increased substantially, but behavior change helped to keep that increase relatively small (chlamydia) or eliminate it (gonorrhea). One factor supporting this is the rapidly rising rates of both infections among older cohorts, including 20–24-year-olds, especially among men (8). Sexual partnerships that cross cohort boundaries could, then, fuel higher incidence among adolescents even as the latter's number of sexual contacts remains steady or falls. This effect could be especially strong if there is an increase over time in the proportion of partnerships that are with older partners. Our method of model calibration excluded these possibilities, given a lack of robust data on age mixing across cohorts and a desire to focus on adolescent behaviors specifically. We note that this explanation, if true, still implies that adolescent behavior change reduced adolescent incidence considerably from what it otherwise would have been.

Other possible explanations include a variety of measurement issues, e.g. adolescents might have begun to increasingly underreport risk behaviors in YRBS. However, this explanation requires a motivation for underreporting that increases with time but yields consistent patterns across longitudinal studies (1, 3). Another possibility is divergent trends for 19-year-olds compared to 14–18-year-olds, since the former are included in many published adolescent diagnosis reports, but not our high-school-based behavioral analyses. Indeed, earlier analyses of both the National Survey of Family Growth and NHANES that included 19-year-olds did not find significant changes in key adolescent sexual behaviors (20, 21). However, for each the time period also ended earlier than our analysis (2012 and 2014, respectively), and our data indicate considerable change since then. Given how rapidly sexual behavior changes over these ages, both within and across cohorts, we encourage the publication of adolescent data by single-year age bands, permitting more detailed disaggregation of trends.

Our model includes multiple additional limitations related to both structure and parameterization. We extended a pre-existing single-step one-year model to 10 years; however, the resulting dynamics are still relatively simple, especially regarding sexual network structure, and involve a 1-year timestep with possible artifacts (see *teen-SPARC* user manual for further consideration). T*een-SPARC*'s design reflected a desire to produce tools accessible to users without specialized modeling training, and the network simplicity reflects both this philosophy and the relative sparseness of data on adolescent sexual network structure. More data on features such as age mixing and heterogeneity in relationship counts and timing would motivate enhancements to model structure for this and additional questions. Moreover, there is considerable regional and local variation in STI burden, demographic composition, and care access that this model averages across. Behavior change was occurring before 2007, so use of a counterfactual that assumed 2007 behaviors would continue thereafter was arbitrary; however, counterfactuals by definition cannot be perfectly realistic, and this choice provided a convenient benchmark given the high quality of documentation for 2007–2017 behavioral trends (7). Our model excluded male-male sex since YRBS did not ascertain partner sex until recently. However, according to our calculations, male-male sex comprised only 2.1% of acts in YRBS 2015; moreover, although adolescent MSM have higher rates of gonorrhea than their peers, the reverse may be true for chlamydia, reducing the overall epidemiological impact of their exclusion (8). Our calculation of credible intervals by simulating new parameter sets after calibration likely overstates uncertainty, although this is partly counteracted by other forms of uncertainty not considered; while we also considered uncertainty on costs, we did so independently. We did not attempt to ensure consistency between male and female behavioral reports, since inconsistencies may result from sex-specific misreporting (thus requiring balance) or reflect different rates of sexual contact outside the focus population (not requiring balance). Predicting the direction of effect on our outcomes is difficult without knowing the true cause for the discrepancy. Perhaps most importantly, we assumed fixed rates of diagnosis and mean infection durations, with the latter implying fixed treatment probabilities. This reflected our desire to isolate the effects of behavior change. Increasing diagnosis rates, especially among males with asymptomatic infection, would have led to higher treatment, shorter infection durations, and additional incidence declines. This additional determinant is consistent with our model either over- or underestimating the amount of change attributable to behavior change specifically. Future modeling should consider also these dynamics, although this requires additional data collection to rigorously estimate temporal change in all relevant parameters for our specific ages of interest.

The full implications of this work depend on what is driving behavior changes. Many explanations have been suggested, ranging from expanding medically accurate sex education (22) to “helicopter” parenting (23) to declining nonconsensual sex (24), with researchers noting similar parallel declines in other “adult” activities like smoking and driving (25). Scholars have considered both benefits and costs associated with these explanations; the latter include concerns about declining opportunities for age-appropriate psychosocial development. Further research to precisely determine the impact of each potential cause is crucial for supporting adolescents in making healthy choices, including but not limited to STI prevention. Regardless of other successes, one clear area for improvement entails reversing declines in condom use at last intercourse, without which averted cases of STIs would have been greater. Numerous medically-accurate sex education programs—within and outside schools, online and off—have been shown to be efficacious at increasing condom use (26), and could be expanded.

Implications for individual health and education departments are further driven by local trends. Although we analyzed national data to determine national trends, many state and local jurisdictions also participate individually within the Youth Risk Behavior Surveillance System (YRBSS). Health departments in these areas can assess their own behavioral trends, identifying points similar to or divergent from national ones, including both areas of progress and for improvement. Our code may be adapted to provide state or local estimates of cases averted. Those jurisdictions not currently participating in YRBSS could use local behavioral surveillance systems (if these exist and include adolescents) or consider joining YRBSS. In both cases, engagement with education departments, a major partner in promoting adolescent health, could help develop actionable strategies that are responsive to positive behavior change at the local level.

This analysis quantifies the expected reduction in adolescent STI incidence in the US from 2007 to 2017 when combining multiple forms of reported declines in adolescent sexual health risks. Whatever the causes of the behavior change, or its other consequences, its existence suggests that US youth are collectively reducing their exposure to STIs, resulting in large cost savings to the health care system relative to previous cohorts. This is especially true for Black and Hispanic adolescents. Efforts to continue supporting effective sex education in and out of school along with STI screening for adolescents should reinforce these trends, while enhancing the ability for adolescents to make choices that support their own sexual health.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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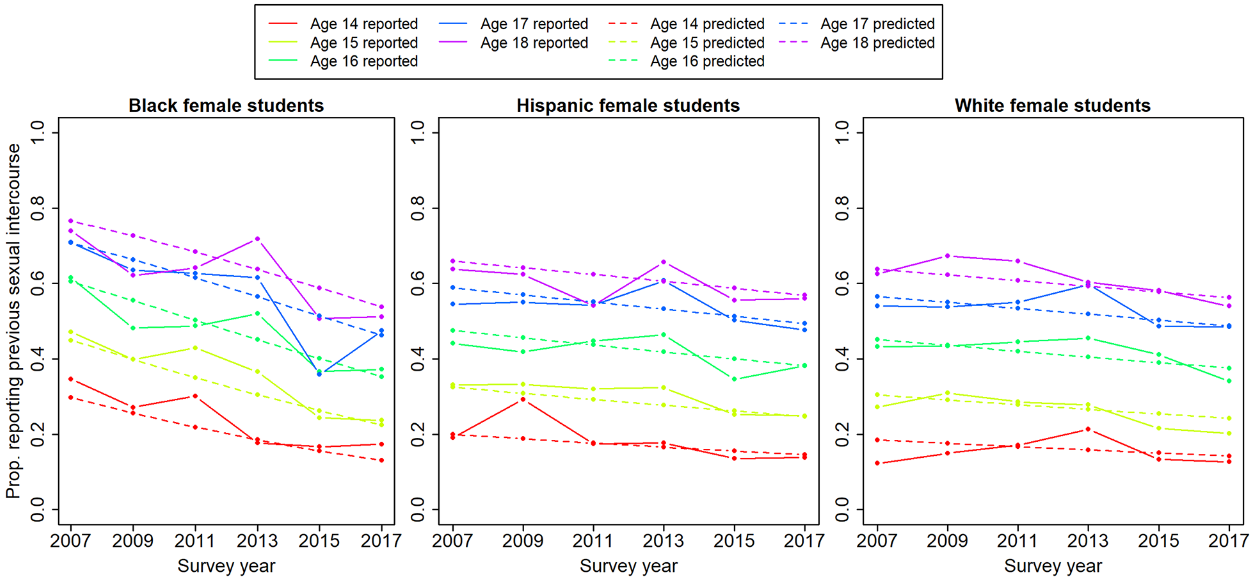

Figure 1:

Reported vs. predicted values for the proportion of female students reporting having ever had sexual intercourse (SI), by race/ethnicity. Reported values are from the CDC's Youth Risk Behavior Survey (YRBS) as described in the text. Predicted values are drawn from the model specified in Table S4.

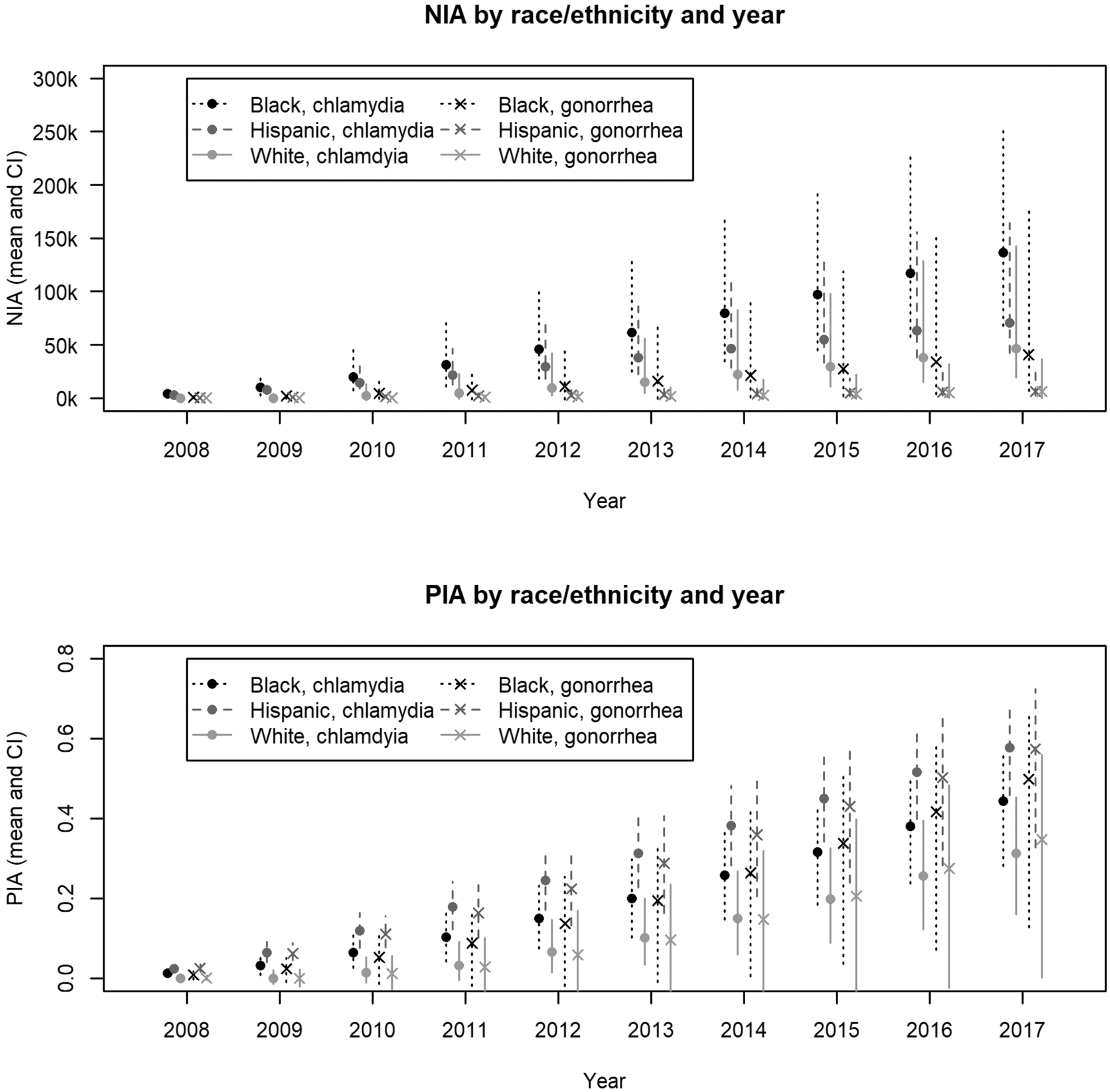

Figure 2:

Infections averted by race/ethnicity and year. NIA = number of infections averted. PIA = percent of infections averted. All figure values reflect differences between a scenario with observed (but smoothed) behaviors and one in which behaviors observed at the beginning of the decade (2007) continued throughout. Symbols represent model results using predicted values obtained using the point estimates from the regressions of behavioral change. Bars represent credible intervals (CrI; central 95% of results) when drawing new parameters sets by using the regression variance/covariance matrix.

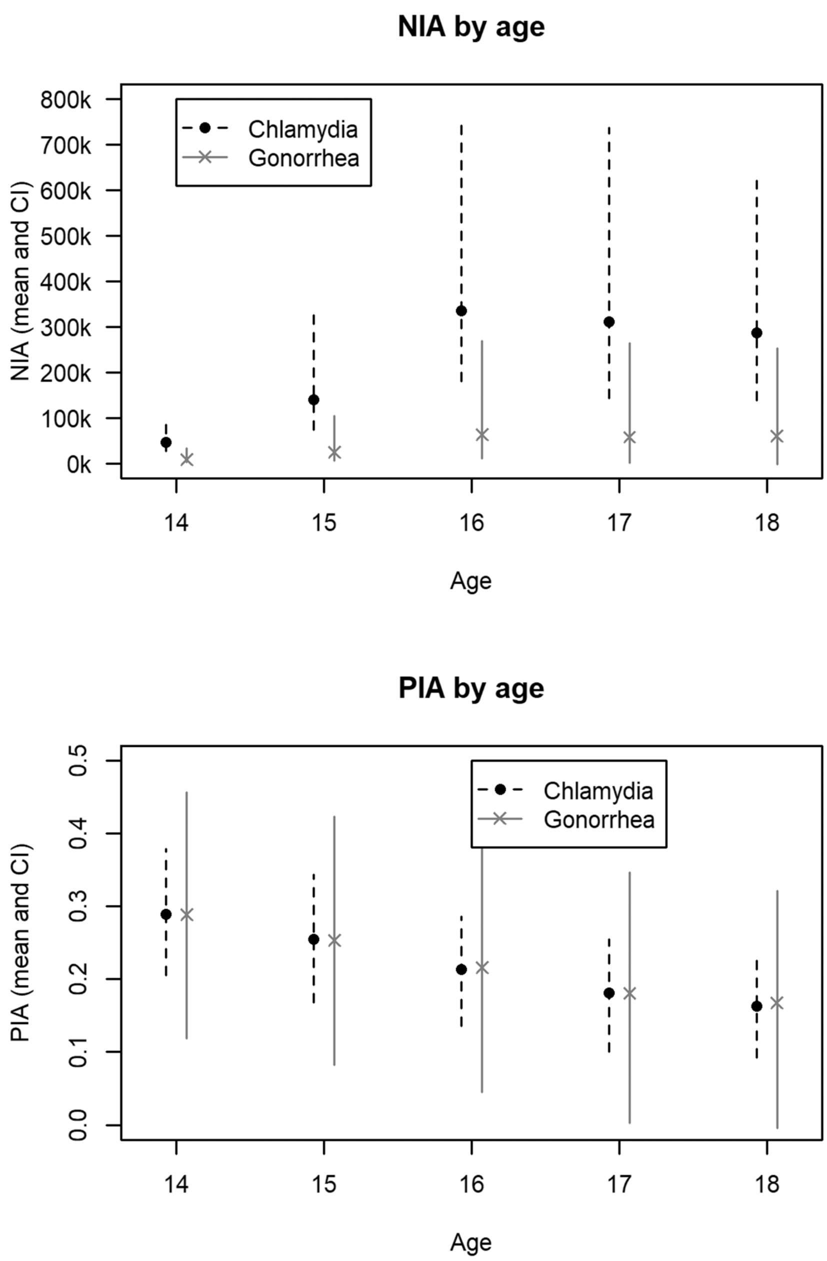

Figure 3:
Infections averted by age. NIA = number of infections averted. PIA = percent of infections averted. All figure values reflect differences between a scenario with observed (but smoothed) behaviors and one in which behaviors observed at the beginning of the decade (2007) continued throughout. Symbols represent model results using parameters from Table S4; bars represent credible intervals (CrI; central 95% of results) when drawing new parameters sets by using the regression variance/covariance matrix.

Table 1:

Estimated cases and medical costs averted (2017 dollars) through behavior change among US high school students, 2007–2017

	Chlamydia									
	Female students					Male students				
	Cases averted	Costs saved per case averted*	Costs saved	Costs saved (worst case scenario)	Costs saved (best case scenario)	Cases averted	Costs saved per case averted*	Costs saved	Costs saved (worst case scenario)	Costs saved (best case scenario)
2008	6,117	$581.20	$ 3,555,200	$1,777,600	$5,332,801	567	$47.90	$27,159	$13,580	$40,739
2009	13,238	$564.28	$ 7,469,939	$3,734,969	$11,204,908	4,356	$46.51	$202,598	$101,299	$303,896
2010	27,527	$547.84	$ 15,080,392	$7,540,196	$22,620,588	8,544	$45.15	$385,762	$192,881	$578,642
2011	41,750	$531.88	$ 22,205,990	$11,102,995	$33,308,985	15,779	$43.84	$691,751	$345,876	$1,037,627
2012	62,531	$516.39	$ 32,290,383	$16,145,192	$48,435,575	22,792	$42.56	$970,028	$485,014	$1,455,041
2013	81,735	$501.35	$ 40,977,842	$20,488,921	$61,466,763	32,504	$41.32	$1,343,065	$671,533	$2,014,598
2014	106,748	$486.75	$ 51,959,589	$25,979,795	$77,939,384	41,354	$40.12	$1,659,122	$829,561	$2,488,684
2015	128,797	$472.57	$ 60,865,598	$30,432,799	$91,298,397	52,568	$38.95	$2,047,524	$1,023,762	$3,071,285
2016	155,984	$458.81	$ 71,567,019	$35,783,510	$107,350,529	62,353	$37.81	$2,357,567	$1,178,783	$3,536,350
2017	179,022	$445.45	$ 79,745,350	$39,872,675	$119,618,025	74,217	$36.71	$2,724,506	$1,362,253	$4,086,759
Total	803,449		$ 385,717,302	$192,858,651	$578,575,953	315,034		$12,409,082	$6,204,541	$18,613,623

	Gonorrhea									
	Female students					Male students				
	Cases averted	Costs saved per case averted*	Costs saved	Costs saved (worst case scenario)	Costs saved (best case scenario)	Cases averted	Costs saved per case averted*	Costs saved	Costs saved (worst case scenario)	Costs saved (best case scenario)
2008	965	$565.24	$545,457	$272,728	$818,185	2	$126.14	$252	$126	$378
2009	1,961	$548.77	$1,076,138	$538,069	$1,614,207	634	$122.47	$77,646	$38,823	$116,469
2010	4,238	$532.79	$2,257,964	$1,128,982	$3,386,946	1,325	$118.90	$157,543	$78,771	$236,314
2011	6,666	$517.27	$3,448,122	$1,724,061	$5,172,183	2,715	$115.44	$313,420	$156,710	$470,129
2012	10,385	$502.21	$5,215,451	$2,607,725	$7,823,176	4,214	$112.07	$472,263	$236,131	$708,394
2013	14,272	$487.58	$6,958,742	$3,479,371	$10,438,113	6,383	$108.81	$694,534	$347,267	$1,041,801
2014	19,265	$473.38	$9,119,666	$4,559,833	$13,679,499	8,645	$105.64	$913,258	$456,629	$1,369,887
2015	24,301	$459.59	$11,168,497	$5,584,248	$16,752,745	11,444	$102.56	$1,173,697	$586,848	$1,760,545
2016	30,085	$446.20	$13,423,927	$6,711,964	$20,135,891	14,240	$99.58	$1,418,019	$709,010	$2,127,029

2017	35,667	$433.21	$15,451,301	$7,725,651	$23,176,952	17,355	$96.68	$1,677,881	$838,941	$2,516,822
Total	147,805		$68,665,263	$34,332,632	$102,997,895	66,957		$6,898,513	$3,449,256	$10,347,769

All table values reflect differences between a scenario with observed (but smoothed) behaviors and one in which behaviors observed at the beginning of the decade (2007) continued throughout.

Cases averted are rounded to whole numbers, and costs saved are rounded to nearest dollar. Presented numbers do not always add to presented totals due to rounding.

* Medical costs saved per case averted are the future (2017) value of the medical costs saved per case averted in a given year and compounded at 3% annually. For more detail, see Table S3 in the Supplement.