AIDS Mortality May Have Contributed to the Decline in Syphilis Rates in the United States in the 1990s

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Background: **The mortality associated with AIDS among men may have had an influence on primary and secondary syphilis trends among men in the United States, through the loss of men at high risk for acquisition or transmission of syphilis in this population and/or by prompting safer sexual behaviors in response to the threat of AIDS.**

Goal: **The goal of this study was to examine the association between AIDS mortality rates and primary and secondary syphilis incidence rates among men in the United States from 1984 to 1997.**

Study Design: **We used a fixed-effects regression analysis of state-level AIDS mortality rates and primary and secondary syphilis incidence rates for men.**

Results: **Our analysis showed a significant association between higher AIDS mortality and lower rates of syphilis incidence, after we controlled for confounding factors. Our model estimates suggested that every 20 AIDS deaths per 100,000 adult men are associated with declines of about 7% to 12% in syphilis incidence rates among men.**

Conclusion: **Increases in AIDS-associated mortality may have accounted for one-third to one-half of the decline in syphilis rates among men in the early 1990s. Recent declines in AIDS mortality in the United States may have contributed to the recent outbreaks of syphilis, particularly among men who have sex with men. Our findings underscore the importance of providing STD prevention services to men with HIV infection and the need for STD surveillance in communities at risk for syphilis outbreaks.**

SYPHILIS RATES IN THE UNITED STATES have declined dramatically since peaking in 1990. The 5979 cases of primary and secondary (P&S) syphilis reported in 2000 represent an almost 90% decline from 1990.[1] P&S syphilis rates in recent years are the lowest ever reported, prompting a nationwide syphilis elimination campaign.[2]

Although the reasons for this unprecedented decrease in syphilis are not fully understood, at least four important factors may have contributed to the decline: (1) increased support of syphilis control programs and HIV prevention activities,[3,4] (2) acquired immunity to syphilis in the population at risk for syphilis,[3,4] (3) declines in crack cocaine use, a major contributor to the syphilis epidemic of the late 1980s,[3] and (4) sexual behavioral changes in response to the HIV/AIDS epidemic.[4–8]

Examples of sexual behavioral responses to the HIV/AIDS epidemic include increases in condom use and reductions in number of sex partners. For example, increased condom use in response to increasing local AIDS prevalence has been observed,[9] and mathematical models have suggested that a decline in the rate of partner change as a result of AIDS awareness could explain the dramatic declines in STD rates among men who have sex with men (MSM) following the advent of the AIDS epidemic.[10]

In addition to prompting safer sexual behaviors, the HIV/AIDS epidemic may have contributed to the decline in syphilis through a more direct mechanism: AIDS-associated mortality. It is likely that people at high risk for syphilis acquisition (and, more important, syphilis transmission) were disproportionately included among the hundreds of thousands who have died of AIDS-related causes in the United States, because syphilis is much more common in people with HIV infection than in the general U.S. population, and risk factors for syphilis (such as having unprotected sex or having numerous sex partners) are also risk factors for sexual acquisition of HIV.[11,12]

A recent report showed that at least 30% of MSM and 5% of heterosexual men with diagnosed gonorrhea in Colorado Springs, Colorado, in 1981 died in the ensuing 2 decades, and HIV infection likely was the main cause for the higher death rates among MSM.[13]

Mathematical modeling has illustrated the possibility that high AIDS death rates among the people at greatest risk for STD acquisition and particularly transmission may influence STD incidence rates. One model showed that the loss of sexually active people from the population through AIDS-related mortality can reduce the rate of partner change in the population, thereby reducing STD rates.[14] Another such model suggested that substantial declines in STDs in MSM since the advent of AIDS could be attributable to sickness and deaths due to AIDS, even if AIDS affected only a relatively small fraction of the population.[15]

Theoretical studies also have demonstrated that differential AIDS mortality in a cohort can account for some of the observed reductions in risky sexual behavior in that cohort over time.[16]

Thus, HIV/AIDS may have contributed to the decline in syphilis directly (through the loss of people at high risk for acquisition and particularly transmission of syphilis) and/or indirectly (by prompting safer sexual behaviors). In this study we use national STD surveillance data to explore the association between AIDS mortality and syphilis incidence in the United States in more detail, focusing on syphilis incidence rates and AIDS death rates among men.

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TABLE 1. Variables: Mean, Standard Deviation, Description, and Source

Variable	Mean (SD)	Description	Source
Syphilis	1.91 (1.35)	Log of syphilis rate among males (new cases of primary and secondary syphilis reported per 100,000 population) in year t. If a state reported no syphilis cases in a given year, 1 case was assumed.	CDC Surveillance Data*
AIDS deaths	14.9 (23.8)	Average number of deaths of men with AIDS aged 18 y and older per 100,000 male population in years t, t-1, t-2, t-3	CDC Surveillance Data*
Sociodemographic variables			
Poverty	0.14 (0.04)	Proportion of state population who live in poverty	U.S. Bureau of the Census†
Income	23.8 (3.9)	Per-capita income, 1998 dollars (thousands)	U.S. Department of Commerce‡§
Robbery	19.6 (17.1)	Number of robberies committed per 10,000 state population	U.S. Department of Justice‖
Health spending	3.09 (0.88)	Per-capita health expenditures, 1998 dollars (thousands)	Centers for Medicare and Medicaid Services§¶
Density	0.43 (1.50)	State population (thousands) per square mile of land area	U.S. Bureau of the Census, Statistical Abstracts#**
African American	6.10 (5.56)	Percentage of state population that is African American male	U.S. Bureau of the Census**
Hispanic	3.24 (4.16)	Percentage of state population that is Hispanic male	U.S. Bureau of the Census**
Youth	15.0 (1.53)	Percentage of state population aged 15 y to 24 y	U.S. Bureau of the Census**
Alcohol	2.49 (0.67)	Per-capita alcohol consumption (gallons of ethanol), based on population aged 14 y and older	National Institute on Alcohol Abuse and Alcoholism (NIAAA)††
Lagged syphilis	2.03 (1.30)	Log of syphilis rate among men in year t-1 (the lagged value of *Syphilis*)	CDC Surveillance Data*
Fixed-effects variables			
State		State indicator variables	Created
Year		Year indicator variables	Created
State-specific trend variables		State-specific trend variables were created by multiplying each state indicator variable by the variable Trend, where Trend = 1 in 1984, 2 in 1985, 3 in 1986, etc.	Created

*Sources and limitations of syphilis surveillance data are described more thoroughly elsewhere.[1]
†Poverty data obtained via Internet (http://www.census.gov/hhes/poverty/histpov/hstpov21.html).
‡Income data obtained via Internet (http://www.bea.doc.gov/bea/regional/spi/).
§Adjusted to 1998 dollars with the Consumer Price Index from the Bureau of Labor Statistics, obtained via Internet (ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt).
‖Robbery data obtained via Internet (http://www.ojp.usdoj.gov/bjs/datast.htm).
¶Health spending data obtained via Internet (http://www.hcfa.gov/stats/nhe-oact/stateestimates/States98/).
#Population density data calculated from population estimates from the Census Bureau, divided by square miles of land area (based on 1990 estimates) obtained from Statistical Abstracts.[42]
**Population estimates were obtained from various Bureau of the Census publications maintained by the Division of STD Prevention, as described in annual STD surveillance reports.[1]
††Alcohol consumption data obtained via Internet (http://www.niaaa.nih.gov/publications/pcyr7097.txt) and from published reports.[43]

Methods

This analysis is based on state-level data of annual syphilis rates and AIDS death rates in the United States from 1984 to 1997. Primary and secondary syphilis rates and AIDS-related death rates were obtained from state surveillance reports maintained by the Centers for Disease Control and Prevention, and additional state-level sociodemographic data were obtained from a variety of sources (Table 1). Because some states historically have low rates of syphilis, our analysis excluded the 10 states with the lowest syphilis rates, based on 1990 incidence. Our sample therefore included 574 observations: 40 states and the District of Columbia over a 14-year period.

Fixed-Effects Model

We used ordinary least squares regression (OLS) analysis to examine the association between the syphilis rate among men in a given year and AIDS-related mortality among men in the given year and preceding years. Specifically, the dependent variable in our model was syphilis and the control variable of interest was AIDS deaths (Table 1). The variable *AIDS deaths* in year t is a state-specific average of AIDS death rates among men over the most recent 4 years (years t-3, t-2, t-1, and t).

The unobserved or unmeasured determinants of the incidence of syphilis vary considerably both across states as well as over time. Our regression models included fixed effects for both state and year. The state variables control for the state-specific determinants of syphilis that do not vary by time, whereas the year variables control for determinants of syphilis shared by all states that do vary by time.[17,18] However, the use of these fixed effects does not eliminate possible biases introduced by omitted confounding variables. In particular, omitting the unobserved determinants of syphilis that vary within states over time could result in overstating or understating the true association between AIDS-related mortality and syphilis rates.

For example, studies of the epidemiology of syphilis in the United States indicate that syphilis rates may be influenced by differences in socioeconomic status, community well-being, availability of health care, and degree of urbanization.[8,19] Any within-state changes in these traits might also influence AIDS mortality rates. In order to separate the effects of AIDS mortality from the effects associated with these characteristics, we estimated models that included several additional, potentially confounding variables (Table 1). These additional variables include *poverty* and *income* (socioeconomic status variables), *robbery* (community well-being variable), *health spending* (health care availability variable), and *density* (degree of urbanization variable).

Syphilis rates are typically higher among some minority groups than among whites, and syphilis rates are typically higher among teenagers and young adults than among older adults.[1,8] To control for differences in racial and age distributions in state populations, we also included *African-American*, *Hispanic*, and *Youth* as potential confounding variables. Syphilis has also been associated with alcohol and illicit drug use, particularly crack cocaine.[3,20,21] We therefore included in our model a measure of alcohol consumption (*alcohol*). In addition, we note that the variable *robbery* serves as a proxy for crack cocaine use, because robbery rates have been shown to be highly correlated with illegal drug use.[22]

Statistical Analyses

We estimated the relation between AIDS mortality rates and primary and secondary syphilis rates, using eight different models. All of the models included a constant and the variables *AIDS deaths*, *state*, and *year*. Models 2, 4, 6, and 8 included the additional sociodemographic variables described above, and models 3, 4, 7, and 8 included the state-specific trend variables (Table 1), which control for state-specific trends in unobserved factors that may influence syphilis rates. Because a state's syphilis rate in year t is influenced by that state's syphilis rate in the previous year (t-1), we included the *lagged syphilis* value (the syphilis rate for men in year t-1) as a control variable in models 5 to 8. All regressions were performed with RATS, version 5.[23] We used OLS with standard errors calculated with the white correction for heteroskedasticity.[23,24]

Robustness Tests

In addition to using OLS, we repeated the analysis of models 5 to 8 with several modifications. We performed two-stage least-squares regression analyses, using the syphilis rate for men in year t-2 as well as the other variables listed for each model as instruments.[17,18,23] To address the statistical problem of autocorrelation, we (1) repeated the analysis with the Newey–West procedure for autocorrelation-consistent standard errors,[25] and (2) repeated the analysis with generalized least-squares regression analysis, applying the Hildreth–Lu procedure for estimating the autocorrelation coefficient.[17,23]

Results

Higher AIDS death rates were associated with declines in syphilis rates among men, as shown by the negative coefficient for *AIDS deaths* in all models (Tables 2 and 3). Specifically, states with higher AIDS mortality among men in years t, t-1, t-2, and t-3 had lower syphilis rates among men in year t. The AIDS death coefficient estimates reported in Tables 2 and 3 ranged from −0.004 (Table 2, model 5) to −0.035 (Table 2, model 4). These estimates were quite similar, differing by less than one standard error in models that relied on two-stage least squares (Table 3) instead of ordinary least squares (Table 2). In models that included the lagged syphilis rate and other potentially confounding variables (models 6 and 8), the coefficient estimates ranged from only −0.014 and −0.024.

The AIDS deaths coefficient can be interpreted as the approximate percentage change in syphilis incidence rates per 100,000 associated with a one-unit change in the AIDS deaths variable. A one-unit change in the AIDS deaths variable is an increase of one, in absolute terms, in the average number of AIDS deaths among men per 100,000 over a 4-year period (Table 1).[42,43] Because the AIDS deaths variable is a 4-year average of AIDS mortality rates among men, each additional AIDS death per 100,000 will increase the AIDS deaths variable by 0.25 units. Similarly, every 20 AIDS deaths per 100,000 (for example, 5 AIDS deaths per year in each of the years t, t-1, t-2, and t-3) would increase the AIDS deaths variable by 5 units. Thus, the AIDS deaths coefficients of −0.014 and −0.024 (when multiplied by 5) suggest that every 20 AIDS deaths of men per 100,000 population is associated with a reduction in the rate of primary and secondary syphilis in men of about 7% to 12%.

Another way to interpret the AIDS deaths coefficient is to examine how changes in AIDS mortality are associated with changes in primary and secondary syphilis rates. For example, from 1990 to 1995, the average state-level decrease in primary and secondary syphilis rates among men was 51%. Over the same period, the average value of *AIDS deaths* increased by 10.2 in absolute terms, which (when multiplied by the AIDS deaths coefficient estimates of −0.014 to −0.024) would be associated with a decline in syphilis of about 15% to 25%. Thus, our model estimates suggest that the increase in AIDS mortality may have accounted for about one third to one half of the decline in primary and secondary syphilis in men from 1990 to 1995.

Robustness Tests

The statistical significance of the AIDS mortality variable decreased somewhat when we calculated Newey–West standard errors and when we used generalized least squares. In general, however, the results with use of alternative methods (available upon request from the authors) were consistent with the presented results.

Discussion

We found a strong association between AIDS death rates and primary and secondary syphilis rates among men. Our estimates suggested that every 20 AIDS deaths of men per 100,000 population is associated with a decline in the rate of primary and secondary syphilis in men of about 7% to 12%. The declines in syphilis rates associated with increases in AIDS mortality may represent a substantial portion of the overall decline in syphilis in the early 1990s. In fact, our model estimates suggested that the increase in AIDS mortality rates may have accounted for about one third to one half of the decline in primary and secondary syphilis rates among men from 1990 to 1995.

The association between AIDS death rates and syphilis rates was statistically significant over a range of model specifications, suggesting that the association is not spurious. Furthermore, the

TABLE 2. Relation of Selected Factors with Syphilis Rates in 40 States and District of Columbia, 1984–1997, Based on Ordinary Least-Squares Regression Results*

	Model							
Factor	1	2	3	4	5	6	7	8
AIDS deaths	−0.011† (0.003)	−0.029† (0.005)	−0.011‡ (0.005)	−0.035† (0.009)	−0.004 † (0.001)	−0.014† (0.004)	−0.012† (0.003)	−0.018† (0.007)
Poverty	—	−3.978† (1.481)	—	−0.979 (1.178)	—	−1.126 (1.128)	—	−0.526 (1.059)
Income	—	0.014 (0.037)	—	0.075 (0.058)	—	−0.016 (0.029)	—	0.048 (0.054)
Robbery	—	0.034† (0.007)	—	0.024† (0.007)	—	0.014† (0.005)	—	0.015‡ (0.006)
Health spending	—	0.839† (0.275)	—	−0.186 (0.365)	—	0.258 (0.215)	—	−0.586 (0.336)
Density	—	−2.133† (0.451)	—	1.100 (0.722)	—	−1.286† (0.343)	—	0.699 (0.687)
African American	—	0.242 (0.230)	—	0.184 (0.246)	—	0.223 (0.154)	—	0.335 (0.223)
Hispanic	—	−0.429† (0.150)	—	−0.044 (0.167)	—	−0.001 (0.106)	—	0.261 (0.152)
Youth	—	0.056 (0.068)	—	0.344† (0.110)	—	0.004 (0.058)	—	0.160 (0.119)
Alcohol	—	0.560‡ (0.243)	—	0.782‡ (0.395)	—	0.195 (0.218)	—	0.389 (0.373)
Lagged syphilis	—	—	—	—	0.758† (0.032)	0.683† (0.038)	0.527† (0.041)	0.490† (0.045)
Adjusted R^2	0.786	0.839	0.886	0.896	0.908	0.911	0.918	0.920

*Values not in parentheses are regression coefficients. Values in parentheses are standard errors. Regression coefficients for each variable can be interpreted as the approximate percentage change in syphilis rates associated with a one-unit change in the given variable. Models 3,4,7,8 included the state-specific trend variables described in Table 1.
†$P < 0.01$.
‡$P < 0.05$.

temporal order of the association between AIDS death rates and declining syphilis rates was consistent with (but does not prove) a causal link between AIDS death rates and declining syphilis rates, as higher AIDS mortality rates preceded declines in syphilis rates.

The observed association between higher AIDS mortality rates and decreased syphilis incidence may reflect an actual effect of AIDS mortality on the epidemiology of syphilis. If so, this effect of AIDS mortality on syphilis could be direct (through the loss of men at high risk for acquisition and transmission of syphilis from the population) and/or indirect (by prompting safer sexual behaviors in response to the AIDS deaths).

Our analysis cannot distinguish between the direct and indirect effects of AIDS mortality. If AIDS deaths do influence STD rates through direct and indirect effects, then the availability of highly active antiretroviral therapy might also influence STD rates directly (by preventing sickness and death among people with HIV who may be at high risk for acquisition and particularly transmission of syphilis) and/or indirectly (through increases in risky sexual behavior by people who are less concerned about transmitting or acquiring the virus because they perceive HIV as less threatening).[26–32] In fact, recent outbreaks of STDs among MSM have been reported from several cities across the nation, and a decreased fear of acquiring HIV may have contributed to these outbreaks.[33–35]

Although a decreased fear of acquiring HIV might affect HIV-uninfected MSM and possibly HIV-infected MSM who are unaware of their infection, HIV-infected MSM who are aware of their HIV infection would not be expected to experience a decreased fear of acquiring HIV. However, high rates of HIV infection in the men affected by the recent STD outbreaks were reported,[33,34] and recent studies have indicated that people with known HIV infection are at high risk of acquiring an STD.[33,36–38]

We note that there are limitations to the surveillance data.[1] Although syphilis cases are reportable by law to state health departments, not all diagnosed cases are reported. There are state-specific differences in the methods of identifying cases and collecting surveillance information, so comparisons of incidence rates between states should be interpreted with caution. Within a given state, however, the surveillance methods are more stable, so trends in syphilis incidence should be more reliable.[1]

We focused on AIDS mortality and syphilis rates among men only. We chose this focus on the basis of surveillance data indicating that about two thirds of the AIDS cases involving men reported in the United States through 1998 have occurred in MSM,[39] and in a recent literature review it was reported that 64% to 90% of MSM with syphilis were also infected with HIV.[12]

Our analysis is subject to the usual statistical problems associated with the analysis of state-level mortality and morbidity data over multiple time periods.[18] To address these issues, we estimated a range of model specifications using a variety of estimation procedures and found a consistent association between AIDS mortality rates and syphilis incidence rates. This association was quite robust to the inclusion of several potential confounding variables, suggesting that this relationship does not reflect merely the influence of confounding variables omitted from the analysis.

Despite the limitations of our study, our analysis demonstrated a strong association between increases in reported AIDS mortality rates and decreases in reported syphilis rates among men. This association may be attributable at least in part to the loss of men

TABLE 3. Relation of Selected Factors with Syphilis Rates in 40 States and District of Columbia, 1984–1997, Based on Two-Stage Least-Squares Regression Results*

	Model			
Factor	5	6	7	8
AIDS deaths	−0.005†	−0.016†	−0.011†	−0.024†
	(0.001)	(0.004)	(0.004)	(0.008)
Poverty	—	−1.416	—	−0.677
		(1.136)		(1.070)
Income	—	−0.013	—	0.057
		(0.029)		(0.056)
Robbery	—	0.016†	—	0.018†
		(0.005)		(0.007)
Health spending	—	0.317	—	−0.452
		(0.212)		(0.325)
Density	—	−1.372†	—	0.833
		(0.356)		(0.681)
African American	—	0.225	—	0.285
		(0.158)		(0.223)
Hispanic	—	−0.044	—	0.159
		(0.113)		(0.161)
Youth	—	0.009	—	0.221‡
		(0.058)		(0.112)
Alcohol	—	0.232	—	0.520
		(0.212)		(0.361)
Lagged syphilis	0.730†	0.614†	0.390†	0.326†
	(0.042)	(0.058)	(0.070)	(0.087)
Adjusted R^2	0.908	0.910	0.916	0.917

*Values not in parentheses are regression coefficients. Values in parentheses are standard errors. Regression coefficients for each variable can be interpreted as the approximate percentage change in syphilis rates associated with a one-unit change in the given variable. Models 3,4,7,8 included the State-specific trend variables described in Table 1.
†$P < 0.01$.
‡$P < 0.05$.

from the population at high risk for syphilis, including those who are the most effective transmitters of syphilis.

Our findings underscore the importance of providing STD prevention services to men with HIV infection. Our results also suggest that declining AIDS death rates can increase the likelihood of future outbreaks of syphilis and other STDs, highlighting the need for enhanced STD surveillance in communities at risk for such outbreaks.[34,40,41]

References

1. Centers for Disease Control and Prevention. Sexually Transmitted Disease Surveillance, 2000. Atlanta: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2001.
2. Division of STD Prevention. The National Plan to Eliminate Syphilis from the United States. Atlanta: Centers for Disease Control and Prevention, 1999.
3. Centers for Disease Control and Prevention. Primary and secondary syphilis: United States, 1997. MMWR Morb Mortal Wkly Rep 1998; 47:493–497.
4. Kilmarx PH, St. Louis ME. The evolving epidemiology of syphilis. Am J Public Health 1995; 85:1053–1054.
5. Becker MH, Joseph JG. AIDS and behavioral change to reduce risk: a review. Am J Public Health 1988; 78:394–410.
6. Winkelstein WJ, Wiley JA, Padian NS, et al. The San Francisco Men's Health Study: continued decline in HIV seroconversion rates among homosexual/bisexual men. Am J Public Health 1988; 78:1472–1474.
7. Williams LA, Klausner JD, Whittington WL, Handsfield HH, Celum C, Holmes KK. Elimination and reintroduction of primary and secondary syphilis. Am J Public Health 1999; 89:1093–1097.
8. Nakashima AK, Rolfs RT, Flock ML, Kilmarx P, Greenspan JR. Epidemiology of syphilis in the United States, 1941–1993. Sex Transm Dis 1996; 23:16–23.
9. Ahituv A, Hotz VJ, Philipson T. The responsiveness of the demand for condoms to the local prevalence of AIDS. J Hum Resour 1996; 31:869–897.
10. Kramer I, Yorke JA, Yorke ED. The AIDS epidemic's influence on New York City's gay sexual contact rate from an analysis of gonorrhea incidence. Math Comput Model 1990; 13:21–25.
11. Wasserheit JN. Epidemiological synergy. Interrelationships between human immunodeficiency virus infection and other sexually transmitted diseases. Sex Transm Dis 1992; 19:61–77.
12. Blocker ME, Levine WC, St. Louis ME. HIV prevalence in patients with syphilis, United States. Sex Transm Dis 2000; 27:53–59.
13. Potterat JJ, Muth SQ, Stites HK. Twenty-year mortality in a 1981 cohort of homosexuals with gonorrhoea: a preliminary estimate. Int J STD AIDS 2001; 12:414–415.
14. Boily MC, Brunham RC. The impact of HIV and other STDs on human populations: are predictions possible? Infect Dis Clin North Am 1993; 7:771–792.
15. Kault DA. Modelling the effects of AIDS on gonorrhea epidemiology. Math Comput Model 1992; 16:3–14.
16. Blower SM, van Griensven GJ. Effect of differential mortality on risk behavior change in cohort studies. J Acquir Immun Defic Syndr 1993; 6:1364–1367.
17. Kennedy P. A Guide to Econometrics. Cambridge, MA: The MIT Press, 1998.
18. Wooldridge JM. Econometric Analysis of Cross Section and Panel Data. Cambridge, MA: The MIT Press, 2002.
19. Rolfs RT, Nakashima AK. Epidemiology of primary and secondary syphilis in the United States, 1981 through 1989. JAMA 1990; 264:1432–1437.
20. Zenilman JM, Hook EW, Shepherd M, Smith P, Rompalo AM, Celentano DD. Alcohol and other substance use in STD clinic patients: relationships with STDs and prevalent HIV infection. Sex Transm Dis 1994; 21:220–225.
21. Marx R, Aral SO, Rolfs RT, Sterk CE, Kahn JG. Crack, sex, and STD. Sex Transm Dis 1991; 18:92–101.
22. Corman H, Mocan HN. A time-series analysis of crime, deterrence, and drug abuse in New York City. Am Econ Rev 2000; 90:584–604.
23. Estima. RATS Version 5 Reference Manual. Evanston, IL: Estima, 2000.
24. White H. A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. Econometrica 1980; 48:817–838.
25. Newey W, West K. A simple positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. Econometrica 1987; 55:703–708.
26. Dukers NH, Goudsmit J, de Wit JB, Prins M, Weverling GJ, Coutinho RA. Sexual risk behaviour relates to the virological and immunological improvements during highly active antiretroviral therapy in HIV-1 infection. AIDS 2001; 15:369–378.
27. Kalichman SCR. Viral load, perceived infectivity, and unprotected intercourse. J Acquir Immun Defic Syndr 2001; 28:303–305.
28. Miller M, Meyer L, Boufassa F, et al. Sexual behavior changes and protease inhibitor therapy. SEROCO Study Group. AIDS 2000; 14:F33–F39.
29. Kelly JA, Hoffman RG, Rompa D, Gray M. Protease inhibitor combination therapies and perceptions of gay men regarding AIDS severity and the need to maintain safer sex. AIDS 1998; 12:F91–F95.
30. Kravcik S, Victor G, Houston S, et al. Effect of antiretroviral therapy and viral load on the perceived risk of HIV transmission and the need for safer sexual practices. J Acquir Immun Defic Syndr 1998; 19: 124–129.
31. Dilley JW, Woods WJ, McFarland W. Are advances in treatment changing views about high-risk sex? N Engl J Med 1997; 337:501–502.
32. Katz MH, Schwarcz SK, Kellogg TA, et al. Impact of highly active antiretroviral treatment on HIV seroincidence among men who have sex with men: San Francisco. Am J Public Health 2002; 92:388–394.
33. Centers for Disease Control and Prevention. Resurgent bacterial sex-

ually transmitted disease among men who have sex with men–King County, Washington, 1997–1999. MMWR Morb Mortal Wkly Rep 1999; 48:773–777.
34. Centers for Disease Control and Prevention. Outbreak of syphilis among men who have sex with men–Southern California, 2000. MMWR Morb Mortal Wkly Rep 2001; 50:117–120.
35. Wolitski RJ, Valdiserri RO, Denning PH, Levine WC. Are we headed for a resurgence of the HIV epidemic among men who have sex with men? Am J Public Health 2001; 91:883–888.
36. Scheer S, Chu PL, Klausner JD, Katz MH, Schwarcz SK. Effect of highly active antiretroviral therapy on diagnoses of sexually transmitted diseases in people with AIDS. Lancet 2001; 357:432–435.
37. Belongia EA, Danila RN, Angamuthu V, et al. A population-based study of sexually transmitted disease incidence and risk factors in human immunodeficiency virus-infected people. Sex Transm Dis 1997; 24:251–256.
38. Kalichman SC, Rompa D, Cage M. Sexually transmitted infections among HIV seropositive men and women. Sex Transm Infect 2000; 76:350–354.
39. Centers for Disease Control and Prevention. HIV/AIDS Surveillance Report. Atlanta: Centers for Disease Control and Prevention, 1999:10.
40. Golden MR, Rompalo AM, Fantry L, et al. Early intervention for human immunodeficiency virus in Baltimore sexually transmitted disease clinics: impact on gonorrhea incidence in patients infected with HIV. Sex Transm Dis 1996; 23:370–7.
41. Aral SK, Berman SM, Aral S0. Anticipating outbreaks: a prevention role for integrated information systems. Sex Transm Dis 2002; 29:6–12.
42. U.S. Census Bureau. Statistical Abstract of the United States. Washington, DC: U.S. Government Printing Office, 2000.
43. Nephew TM, Williams GD, Stinson FS, Nguyen K, Dufour MC. Surveillance Report #55: Apparent Per Capita Alcohol Consumption: National, State, and Regional Trends, 1977–98. Bethesda, MD: National Institute on Alcohol Abuse and Alcoholism, Division of Biometry and Epidemiology, Alcohol Epidemiology Data System, 2000.