Published in final edited form as:

Ann Epidemiol. 2017 September ; 27(9): 606–610.e2. doi:10.1016/j.annepidem.2017.08.018.

Rural Counties Chlamydia and Gonorrhea Rates in Pennsylvania Among Adolescents and Young Adults

Casey Pinto, MS, CRNP¹, Lorah D. Dorn, PhD, CRNP², Vernon M. Chinchilli, PhD³, Ping Du, MD, PhD⁴, and Guangqing Chi, PhD⁵

¹Assistant Professor, Department of Public Health Sciences, The Pennsylvania State University, College of Medicine, Hershey, PA, USA

²Professor, College of Nursing & Department of Pediatrics, The Pennsylvania State University, University Park, PA, USA

³Distinguished Professor, Department of Public Health Science, The Pennsylvania State University College of Medicine, Hershey, PA, USA

⁴Associate Professor, Department of Public Health Science, The Pennsylvania State University College of Medicine, Hershey, PA, USA

⁵Associate Professor, Department of Agricultural Economics, Sociology, and Education, The Pennsylvania State University, University Park, PA, USA

Abstract

Background—American adolescents and young adults between the ages of 15-24 account for 50% of all sexually transmitted diseases (STDs) annually. Rural populations in this age group are often understudied, despite having factors that place them at higher risk for STDs.

Objective—To evaluate the utility of time-series analysis in the assessment of rural PA county-level chlamydia and gonorrhea rates overtime (2004-2014) for 15-19 and 20-24-year-old age groups by gender.

Design—An exploratory analysis was completed using PA STD surveillance case report, and census data, to develop a linear mixed effects model of the STD rate for each Pennsylvania county for the years 2004 through 2014 using three-month increments. A cubic polynomial spline regression model was assumed over the 44 time points for each county to account for possible oscillations in the STD rate during the 11-year period.

Results—Eight out of twelve rural counties had a significant increase in chlamydia or gonorrhea rates, and five rural counties had significant decreases in chlamydia or gonorrhea rates from 2004-2014.

Conclusions—Results from this study provide the first analysis of change in rates of STDs in rural settings and demonstrates the utility of time-series analysis for populations with small sample sizes.

Keywords

Time-series; Chlamydia; Gonorrhea; Rural

Introduction

High morbidity of chlamydia and gonorrhea presents an important US public health problem with annual costs estimated at \$516.7 million and \$162.1 million, respectively.¹ Combined with the high cost burden, those infected are often asymptomatic, resulting in adverse outcomes when left untreated. Outcomes of these STDs include pelvic inflammatory disease and infertility in females, epididymitis in men, and increasing the risk for HIV acquisition for both genders.² Among the US population, adolescents and young adults account for more than 50% of chlamydia and gonorrhea cases annually,¹ placing them at a higher risk for sequelae from these infections than any other age group.

Analyses to better understand trends of STDs like chlamydia and gonorrhea are often performed at the state level, overshadowing trends in smaller subsets of the population that could be informative for research, prevention, or intervention strategies. Using Pennsylvania (PA) as an example case, 71% of counties are considered rural, containing 27% of the population, yet analyses on PA STD data are only completed at the state level. Recent statewide PA analysis identified a decrease in gonorrhea rates and a marginal increase in chlamydia rates from 2004-2014 in urban areas, while rural areas of the state have seen significant increases in both chlamydia and gonorrhea among 20-24 year old populations (Figure 1).^{3,4} Local assessments in PA do report percent change in the number of STD cases, however, this has historically not provided enough justification to implement interventions, or garner support for more clinical or research funding. Better understanding and identification of significant change in STD rates in rural areas is important not only to highlight concerning areas, but to justify the need for funding such underserved rural populations.

Identifying low-population or rural areas with significant increases in STD rates overtime is important to help identify areas at risk for outbreaks, and justify funding requests. Time-series analyses have been used for chlamydia, gonorrhea, and syphilis analysis,^{5,6,7,8} as well as syndromic surveillance to identify bioterrorism,⁹ hand foot and mouth disease,¹⁰ hospital acquired infections,¹¹ tuberculosis,¹² and many other diseases. Yet no research to date has completed an analysis at a rural level, due to low case counts or small population sizes resulting in high variation of disease.¹³ Thus, rural populations are often understudied when analyzing infectious diseases, even when case counts are high.

To fully evaluate the trend of STD rates among adolescent and young adult populations in Pennsylvania, an analysis should be completed. The purpose of this study is to demonstrate the utility of time-series analysis to assess rural PA county-level chlamydia and gonorrhea rates overtime (2004-2014) for 15-19 and 20-24-year-old age groups by gender. This analysis will not only identify chlamydia and gonorrhea trends in these rural, low-population counties, but will assist researchers to better understand if time-series analyses can be applied to STD data in areas with few cases to detect significant changes overtime. These

changes can help identify areas with outbreaks, as well as potential areas of outbreak and in turn, implement treatment and prevention strategies.

Methods

The data for this study were gathered from two datasets; gonorrhea and chlamydia case reports (2004-2014) from the Pennsylvania Department of Health's National Electronic Disease Surveillance System (PA-NEDSS) excluding Philadelphia, and US census data. Gonorrhea and chlamydia surveillance data from PA-NEDSS included pertinent demographic characteristics such as age, gender, county, specific STD, and week of reporting. Census information obtained for this research included population estimates for the years 2004-2014 by county in Pennsylvania.

Designation of Counties for Analysis

The county-level census data¹⁴ was used to determine rural status for each county. However, many counties were not uniformly rural so rural designation was based on the percentage of people living in a rural area. The quantified percentage was calculated by dividing the number of citizens that live in rural areas by the total population for each respective county. Counties selected for analysis were defined as rural, and needed to have greater than 75% of the population living in a rural area.

Seasonal Variation

Seasonal variation is expected in sexually transmitted disease rates and has been documented at a variety of time periods over the year. In all age groups, higher rates are documented in the second and third quarter of the year,¹⁵ coinciding with summer and early fall. Specific to young adults and adolescents, seasonal variation results in higher STD rates during the school year, or when there is a greater frequency of intermingling with other students.¹⁶ The present analysis was conducted at the quarter level, thus the authors opted to control for seasonal variation to remove its confounding effects.

Analysis

The final data set consisted of the number of diagnosed cases, relative to the number of individuals at risk, from 2004 through 2014 (44 time points). The arcsine-square-root transformation was applied to the proportional response to approximate normality. A cubic polynomial spline regression model, with nodes at 3.75 years and 7.5 years, was assumed over the 44 time points for each county to account for oscillations in the STD rate during the 11-year period.¹⁷ The cubic polynomial spline regression model was structured to be continuous and differentiable at the nodes, and the model included (1) terms to account for seasonal variation and (2) an autoregressive process to account for correlation. The Ng-Perron test was applied to investigate stationarity, and Akaike's information corrected criteria (AICC) statistics were calculated to assess goodness-of-fit, determining that the 6-lag model was sufficient for the autoregressive correlation structure.¹⁸ For each county, the change in the model-based STD rates between 2004 and 2014 was estimated and its statistical significance determined. This statistical analysis was applied to the eight combinations of age group (15-19, 20-24-year-olds), gender (female, male), and STD

(chlamydia, gonorrhea) within each of the 66 counties. The false discovery rate (FDR) process was applied to assess statistical significance of these 528 time-series analyses.¹⁹ All analyses were performed via proc autoreg in SAS, Version 9.4.²⁰

Results

Descriptive Statistics

Twelve counties were defined as rural meeting the rural criterion of greater than 75% of their population according to the Census Bureau: Bedford, Clarion, Forest, Fulton, Juniata, Perry, Potter, Sullivan, Susquehanna, Tioga, Wayne, and Wyoming. Chlamydia and gonorrhea cases in the rural counties totaled 3,721 with the number of cases per county ranging from 106 to 677 (Table 1).

Chlamydia by Age Group and Gender

During 2004-2014, chlamydia rates for females aged 15-19 years, increased significantly in one of the 12 counties, and decreased in none. Chlamydia rates for males aged 15-19 years significantly increased in two counties, and decreased in one. Chlamydia rates for females aged 20-24 years, significantly increased in two counties and decreased in none. Males aged 20-24 years, experienced a significant increase in chlamydia rates in two counties and decreased in one.

Gonorrhea by Age Group and Gender

Among females aged 15-19 years, there was a decrease in gonorrhea rates for two counties for the years 2004 until 2014. Males aged 15-19 years had a significant increase in one county and a decrease in one county. Females and males aged 20-24 years both saw a significant increase in gonorrhea rates in one county and a decrease in one county.

Discussion

This study was initiated based on increased STD reports from public health nurses in adolescents and young adults among several rural counties (Tioga, Perry, Potter, and Sullivan) since 2009. Time-series studies had been previously completed in infectious disease populations,⁵⁻¹² but none had been completed in such a small population. This paper demonstrates the utility of this analysis specifically in small rural counties such as Perry and Potter County.

Specifically analyzing the counties of interest (Tioga, Perry, Potter, and Sullivan), Perry County had a significant increase in chlamydia rates for females aged 15-19 and males aged 20-24, with a decrease in gonorrhea rates for females of both age groups. This corresponds with previous anecdotal evidence. Among 15-19 year old males, Potter County had a significant increase in chlamydia, while Sullivan had an increase in gonorrhea and Tioga County had a decrease in gonorrhea. These three counties neighbor Bradford County (figure 2), which has a rural population percentage of 72%. While Bradford County was not included in the initial analysis, a subsequent analysis was run that documented this county also had a significant increase in Chlamydia rates, among all age groups except 15-19 year

old males and no change in gonorrhea rates. Demonstrating that rates of chlamydia are increasing which matches anecdotal evidence, but the gonorrhea results need more assessment due to the low number of cases (<30) of gonorrhea in areas where there was documented significance. Two counties (Potter and Tioga) where the FDR significance criteria was not met, but the unadjusted p-value was significant, corresponded with the anecdotal evidence, and may denote a trend towards significance in increasing chlamydia rates among 20-24-year-old females. This analysis shows that these counties should be examined further to determine potential causes for the increased rates of chlamydia since both anecdotal and statistically significant evidence were noted.

Other counties that were not anecdotally listed as counties of concern (Bedford, Clarion, and Forest) were noted to have a significant increase in chlamydia or gonorrhea rates. Thus, the time-series analysis helped to identify other areas of concern in Pennsylvania. Identifying these counties early could better inform prevention and intervention programs to help prevent STD outbreaks.

Identifying rural counties with increasing chlamydia or gonorrhea rates is not the only important outcome of this study. Rural communities have significant barriers to STD prevention and care, specifically access to health centers, lack of funding, and more conservative policies.²¹ Highlighting a significant increase of STDs in a rural county may help eliminate some of these barriers by providing opportunities and justification for increasing funding, opening additional clinics, and even changing policies that are a barrier to STD prevention. After changes are made, follow-up evaluation for changes in rates of chlamydia and gonorrhea are also important. A decrease in rates of STDs can identify interventions that are successful, and justify government spending and policy changes, especially in populations that may otherwise be hidden in state-wide statistics.

Identifying counties with increasing rates may not only help to identify outbreaks, but also help to discover populations at risk. These populations at risk may have other underlying factors increasing the STD burden such as drug use and higher rates of alcohol use. Identifying these populations and implementing prevention early can also assist in tailored prevention programs, and decreasing the spread beyond rural areas due to a spillover effect.

Limitations

Several limitations are relevant when interpreting the results. First, the small quarterly sample sizes of the selected counties made it difficult to achieve sufficient statistical power, resulting in counties that may have had increased or decreased rates overtime, but lacked significance in this study. Other factors impacting the results were the various behavioral and social environmental characteristics specific to STD acquisition. Factors such as alcohol, drug, and tobacco use, race, access to care, and screening practices vary from rural to urban settings, impact STD acquisition, and thus should be controlled for in future analysis,²¹ using spatio-temporal regression modeling to better control for the aforementioned factors.

Overall, our study provided evidence of the utility of time-series analysis to study chlamydia and gonorrhea rates in smaller geographic units of the population. The study findings will contribute to a better understanding of the trends of chlamydia and gonorrhea in the state of

Pennsylvania and can serve as a guide to other states. This study also confirmed that time-series analyses are useful for public health professionals and clinicians when assessing STD rates. More research is needed before this methodology is adopted, but time-series should be considered a useful tool in more focused community-based assessment of STDs.

References

1. Owusu-Edusei K, Chesson HW, Gift TL, Tao G, Mahajan R, Ocfemia MC, Kent CK. The estimated direct medical cost of selected sexually transmitted infection in the United States, 2008. *Sex Transm Dis.* 2013 Mar; 40(3):197–201. DOI: 10.1097/OLQ.0b013e318285c6d2 [PubMed: 23403600]
2. Cohen MS. Sexually transmitted diseases enhance HIV transmission: no longer a hypothesis. *Lancet.* 1998; 351:5–7. DOI: 10.1016/S0140-6736(98)90002-2
3. EpiQMS: epidemiologic query and mapping system for Commonwealth of PA Department of Health. <https://apps.health.pa.gov/EpiQMS/asp/ChooseDataset.asp>
4. Pinto CN, Dorn LD, Chinchilli VM, Du P. Chlamydia and gonorrhea acquisition among adolescents and young adults in Pennsylvania: A rural and urban comparison. *Sex Transm Dis.* Accepted, pending publication.
5. Tian LT, Satterwhite CL, Braxton JR, Groseclose SL. Application of the time-series approach to assess the temporal trend of racial disparity in chlamydia prevalence in the US National Job Training Program. *Am J Epidemiol.* 2010; doi: 10.1093/aje/kwq344placeholder
6. Zaidi AA, Schnell DJ, Reynolds GH. Time series analysis of syphilis surveillance data. *Stat Med.* 1989; 8:353–62. DOI: 10.1002/sim.4780080316 [PubMed: 2711066]
7. Schnell DJ, Zaidi AA, Reynolds G. A time series analysis of gonorrhea surveillance data. *Stat Med.* 1989 Mar; 8(3):343–53. DOI: 10.1002/sim.4780080315 [PubMed: 2711065]
8. Passos MR, Arze WN, Mauricio C, Barreto NA, Varella Rde Q, Cavalcanti SM, et al. Is there increase of STDs during Carnival? Time series of diagnoses in a STD clinic. *Rev Assoc Med Bras.* 2010; 56:420–7. DOI: 10.1590/S0104-42302010000400014 [PubMed: 20835638]
9. Reis BY, Mandl KD. Time series modeling for syndromic surveillance. *BMC Medical Informatics and Decision Making.* 2003 Jan 23.3(1):1.doi: 10.1186/1472-6947-3-2 [PubMed: 12525262]
10. Feng H, Duan G, Zhang R, Zhang W. Time series analysis of hand-foot-mouth disease hospitalization in Zhengzhou: establishment of forecasting models using climate variables as predictors. *PLoS One.* 2014 Jan 31.9(1):e87916.doi: 10.1371/journal.pone.0087916 [PubMed: 24498221]
11. Fernández-Pérez C, Tejada J, Carrasco M. Multivariate time series analysis in nosocomial infection surveillance: a case study. *International journal of epidemiology.* 1998 Apr 1; 27(2):282–8. DOI: 10.1093/ije/27.2.282 [PubMed: 9602411]
12. Wah W, Das S, Earnest A, Lim LK, Chee CB, Cook AR, Wang YT, Win KM, Ong ME, Hsu LY. Time series analysis of demographic and temporal trends of tuberculosis in Singapore. *BMC public health.* 2014 Oct 31.14(1):1.doi: 10.1186/1471-2458-14-1121 [PubMed: 24383435]
13. Allard R. Use of time-series analysis in infectious disease surveillance. *Bulletin of the World Health Organization.* 1998; 76(4):327. [PubMed: 9803583]
14. Pennsylvania State Data Center. Census Data: PA Counties Urban and Rural Populations. 2010. <https://pasdc.hbg.psu.edu/Data/Census2010/tabid/1489/Default.aspx> Accessed January 25, 2016
15. Fortenberry JD, Orr DP, Zimet GD, Blythe MJ. Weekly and seasonal variation in sexual behaviors among adolescent women with sexually transmitted diseases. *J Adolesc Health.* 1997; 20(6):420–425. DOI: 10.1016/S1054-139X(96)00275-3 [PubMed: 9178078]
16. Sattenspiel, L. The geographic spread of infectious diseases: models and applications. Princeton University Press; 2009.
17. Vonesh, EF., Chinchilli, VM. Linear and Nonlinear Models for the Analysis of Repeated Measurements. New York, NY: Marcel Dekker, Inc; 1997.
18. Ng S, Perron P. Lag length selection and the construction of unit root tests with good size and power. *Econometrica.* 2001; 69:1519–1554. DOI: 10.1111/1468-0262.00256

19. Benjamini Y, Hochberg Y. Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society, Series B.* 1995; 57:289–300. DOI: 10.2307/2346101
20. SAS (9.4). Cary, NC
21. Crosby, RA., Wendel, ML., Vanderpool, RC., Casey, BR. Rural populations and health: Determinants, disparities, and solutions. John Wiley & Sons; 2012 Jul 30.

Figure 1.
Percent Change in STD Incidence Density from 2004-2014 with Pennsylvania Map of Residency Status by School District

Figure 2.
Pennsylvania Counties with >75% - of the population designated rural

Table 1

Results from the cubic polynomial spline regression model controlled for seasonal variation.

County	% rural	STD	Total # Cases	Female 15-19	Male 15-19	Female 20-24	Male 20-24
Clarion	76.6	CHL	639	↑	↑ * ✓	↑	↑ *
		GC	38	↓	↓	↓	↓
Juniata	82.3	CHL	169	↑	↑	↑ *	↑
		GC	8	↓ *	No convergence	↓ *	↑
Wyoming	83.5	CHL	257	↑	↑ *	↑	↑
		GC	16	↑ *	↓ *	↓	↓ * ✓
Bedford	83.8	CHL	231	↑	↓	↑ * ✓	↑
		GC	16	↑	↑	↑ * ✓	↓
Susquehanna	84.0	CHL	292	↓	↓	↑	↑
		GC	20	↓	No convergence	↑	↑
Wayne	88.1	CHL	335	↓	↑	↓	↓
		GC	22	↓ *	No convergence	↑	↑ * ✓
Perry	88.5	CHL	581	↓ * ✓	↓	↑	↓ * ✓
		GC	68	↓ * ✓	↑ *	↓ * ✓	↑
Tioga	90.1	CHL	561	↑	↑	↑ *	↑
		GC	23	↑	↓ * ✓	↑	↓
Forest	100	CHL	98	↓	↓	↑	↑ * ✓
		GC	8	↓	↓	No convergence	↓
Fulton	100	CHL	122	↑	↓	↑	↓ * ✓
		GC	17	↓	No convergence	↑	↑
Potter	100	CHL	176	↑	↑ * ✓	↑ *	↑
		GC	4	↓ * ✓	No convergence	↓	↑
Sullivan	100	CHL	192	↓	↑	↑	↑

County	% rural	STD	Total # Cases	Female 15-19	Male 15-19	Female 20-24	Male 20-24
GC				↓ *	↓ *	↑	↑
29				↑ *	✓	Trend	Trend

* denotes significant p-values;
✓ denotes that the FDR criterion for statistical significance has been met