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Global Epidemiology

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B.S. in Public Health, University of South Florida, 2022

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Abstract

Temporal Trends in Risk Profiles and Outcomes of Non-Outbreak legionellosis Cases in Georgia (2013-2023): A Sociodemographic and Regional Analysis

By Maria Paula Ibarcena Woll

Legionellosis is typically associated with outbreaks, but a significant portion of cases occur sporadically, contributing to the overall disease burden. This study examines non-outbreak-associated legionellosis cases in Georgia from 2013 to 2023, focusing on disease trends, social vulnerability, and associated factors A total of 1,617 unique cases were reported, with 29% (n = 471) occurring among White, non-Hispanic or Latino males, primarily aged 50–65 years.

Case counts increased from 69 in 2013 to 199 in 2023. Average lag times between symptom onset and date of report to public health ranged from 19.1 days in 2013 to 8.4 days in 2019 with the highest calculated lag time being 48.7 days in 2020 during the COVID-19 pandemic. Brooks County, which had no reported incidence at the start of the study, reached 6.2 cases per 100,000 by the end of the period, while Fulton County experienced a 300% increase in incidence rates.

When examining the impact of social vulnerability, as measured by the Social Vulnerability Index (SVI), on legionellosis-related hospitalization or death, we found no significant association between higher SVI and hospitalization (Risk Ratio [RR] = 1.03, 95% CI: 0.87–1.22) or death (Odds Ratio [OR] = 1.92, 95% CI: 0.86–4.26) when controlling for age, occupation, and gender. However, we did find a statistically significant association between death and higher SVI when only controlling for age, with an odds ratio of 1.04 per year increase (95% CI: 1.03–1.06). These findings suggest that structural inequities, such as housing quality and healthcare access, may amplify risks for vulnerable populations.

Despite limitations, including missing data and possible geographic misclassification, the study underscores the importance of closer examination of social vulnerability on legionellosis risk and severity. Increased environmental monitoring, improved healthcare access, and public infrastructure investments are likely essential for reducing legionellosis risks. Furthermore, as climate change exacerbates environmental conditions favorable to *Legionella* growth, these efforts are crucial in mitigating future disease burdens and protecting vulnerable populations.

Keywords: legionellosis, non-outbreak cases, social vulnerability, geographic disparities, disease burden

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Introduction

Overview of legionellosis

Legionellosis is a respiratory disease caused by *Legionella pneumophila*, a bacterium that primarily affects individuals over 50, those who are immunocompromised, smokers, and those with lung conditions.[1,2] Although *L. pneumophila* is the most common cause, other species of *Legionella* can also lead to the disease.[1] legionellosis includes Legionnaires' disease (LD), a severe pneumonia with a 2–10-day incubation period and Pontiac fever, a milder, self-limiting illness with a 1–3-day incubation period. [1,2,3] In the United States, LD affects about 6,000 people annually and has a mortality rate of 10–15%, which can rise to 25–50% in immunocompromised individuals. [2,4] Its true incidence is likely underreported due to diagnostic challenges. [1,5]

Legionella thrives in various freshwater sources, particularly those that are warm and often stagnant, such as municipal water systems, cooling towers, and air conditioning systems.[6,7] It becomes problematic when humans inhale water that contains *Legionella* bacteria. [8-10] *Legionella* can form biofilms within piping systems, regardless of pipes' age or frequency of use; however, biofilms pose a higher risk when disrupted, such as during construction or plumbing repairs, which can introduce the bacteria into the water supply and increase the risk of human exposure.[7]

Both outbreak-related and community-acquired cases of legionellosis exist. An outbreak-related case of legionellosis refers to an infection that is determined to be epidemiologically linked to other cases and to a common source of exposure.[11] A community-acquired case is often considered "a sporadic infection" with no clear relationship to other cases or to an identifiable source.[12] An individual considered a sporadic case likely contracted the *Legionella* bacteria from a source in the community where they reside or work. [12] Current literature focuses primarily on outbreak-related legionellosis, but community-acquired legionellosis remains understudied, with much of the literature being outdated. This is due to challenges in underreporting, diagnostic difficulties, and environmental monitoring, all of which impede the tracking and diagnosis of community-acquired infections, making it more difficult to define the risk profiles and outcomes of such exposures. [5, 13, 14]

These aforementioned challenges highlight how broader systemic factors influence the detection and prevention of legionellosis, particularly in community settings. Social determinants of health (SDOH), as defined by the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC), include non-medical factors like economic status, education, healthcare access, the built environment, and social context, all of which impact health outcomes, including the incidence of diseases like legionellosis.[15,16]

Social Determinants of Health and legionellosis

SDOH, such as access to clean water and well-maintained plumbing, significantly influence exposure risks to *Legionella* bacteria. [15, 17] People living in low-income areas often experience poor infrastructure, delayed plumbing repairs, and limited access to healthcare, all of which increase their vulnerability to *Legionella* infections. [13, 17] In contrast, individuals in higher socioeconomic groups typically have more reliable access to healthcare services and greater health literacy, enabling them to navigate the healthcare system more effectively. [18] These social and environmental disadvantages compound the risk of infection, especially in communities that lack resources to adequately maintain water systems. [19]

The impact of SDOH on legionellosis is multidimensional, as it affects individuals' susceptibility based on their socioeconomic status, access to care, and quality of housing. [15,20-22] Indices such as the Social Vulnerability Index (SVI) capture these variables and are used to identify and map areas at greater risk for certain diseases subject to SDOH disparities, such as LD and Pontiac fever. [20,23]

Epidemiology of legionellosis: National and Georgia Context

In the United States, the incidence of LD has increased over the last two decades, peaking at a crude incidence rate of 3.04 cases per 100,000 people in 2018. [13,24] Approximately 80% of Legionnaires' disease cases are not linked to any known outbreaks, suggesting that community-acquired infections are the more common type of case. [13] In 2019, legionellosis incidence rates were disproportionately higher among Black or African American individuals (3.77 per 100,000) compared to White individuals (2.15 per 100,000). [11,13,24] These community-acquired cases represent a significant public health challenge due to underdiagnosis and difficulty tracing the source of infection. [11] While known outbreaks allow for targeted interventions, sporadic cases require enhanced surveillance and prevention strategies to reduce risk in vulnerable populations. [23,25,26]

Georgia provides a valuable setting to study the influence of SDOH on legionellosis due to its diverse population and health disparities. [16, 21,27,28] According to the most recent legionellosis case data publicly available for Georgia, in 2019, there were 172 reported cases in the state, resulting in a crude incidence rate of 1.72 per 100,000 people. [24,29] Although Georgia's incidence rate was lower than the national average at that time, the state's urban and rural areas present varying risks based on differences in infrastructure, climate, and health access. For example, counties like Forsyth and Cobb tend to have lower SVI scores, reflecting greater access to resources, whereas counties such as Muscogee have higher SVI scores, indicating greater vulnerability related to housing and socio-economic status – both of which could impact legionellosis risk. [30-33]

Investigating community-acquired legionellosis in Georgia is particularly relevant given the role that SDOH play in disease exposure, diagnosis, and outcomes. Populations with lower income often face barriers to timely diagnosis and healthcare access, which may contribute to worse health outcomes. [17,34] The state's socioeconomic diversity, urbanization, and environmental conditions favorable to *Legionella* proliferation make it an ideal context for examining how risk profiles and disease outcomes have evolved from 2013 to 2023. [16, 21,27,28,35] This research aims to characterize the burden of LD in Georgia between 2013 and 2023, with a specific exploration of the association between social vulnerability and severe outcomes following a legionellosis diagnosis.

Methods

Data Source

Data used in this analysis were obtained from the Georgia State Electronic Notifiable Disease Surveillance System (SENDSS), maintained by the Georgia Department of Public Health (DPH). The dataset consisted of non-outbreak associated legionellosis cases reported in the state of Georgia from 2013 to 2023. Prior to receipt, the dataset was de-identified by DPH staff to ensure that protected health information (PHI) from case report forms remained confidential. The dataset was formally requested from

PH following DPH and Emory University IRB approvals, and a state epidemiologist oversaw the de-identification process. This process ensured HIPAA compliance and ethical guidelines for handling public health data. The final dataset received for analysis was structured as an anonymized case-level dataset, with each row representing an individual case of legionellosis.

<u>Variables Received</u>

The dataset included a variety of demographic and clinical variables reported in the case surveillance system, including age, race, ethnicity, occupation, and ZIP code. Case-related variables included case status (confirmed or suspected), smoking status (yes, no, or unknown), hospitalization status (yes, no, or unknown), underlying health conditions (asthma, heart disease or congestive heart failure, diabetes, weakened immune system, chronic kidney disease, liver disease, and chronic lung disease), symptom onset date, and outcome (still ill, survived, or died). Additionally, environmental risk factors and probable exposure sources were included in the dataset, such as potential sources of *Legionella* exposure, travel history, recent hospital stays (unrelated to legionellosis infection), and reported water sources linked to cases.

<u>Outcome and Exposure Variables</u>

Two outcomes were examined in this analysis: (1) mortality among confirmed legionellosis cases (binary variable: died vs. survived), and (2) hospitalization among confirmed cases (binary variable: hospitalized vs. not hospitalized). The main exposure of interest was social vulnerability as measured by the SVI score of each case's county of residence at the time of legionellosis diagnosis. The SVI score (described below) is a composite measure of socioeconomic vulnerability based upon factors like socioeconomic status, household composition, minority status, housing, and transportation. The SVI values were linked back to individuals in our line list based on residential ZIP code and then geocoded to the county level using tidygeocoder package in R.

<u>Additional Data Sources and Data Integration</u>

To enhance the robustness of the dataset, additional open-source data were obtained and incorporated. Data from the United States Census Bureau, accessed through the American Community

Survey Census (ACS) Application Programming Interface (API), were used to estimate yearly county-level populations, serving as denominators for calculating case rates and accounting for population differences.[36] Additionally, the GDPH website was consulted to identify county-level health district boundaries for a regional analysis.[37] Lastly, the CDC's Social Vulnerability Index (SVI) database was used to assign the most recent available SVI scores to each case based on the individual's geocoded county of residence at the time the case was reported to GDPH. This assignment was performed in R studio using an R package developed by Drexel University called findSVI.[20,38]

Descriptive Analysis and Mapping

Descriptive statistics were calculated to summarize case characteristics by gender, age group, race/ethnicity, and outcome status. Frequencies and percentages were reported for categorical variables, and rates were calculated using annual county-level population estimates from ACS census data. In instances where population estimates were unavailable for 2022 and 2023, 2021 population data were carried forward to calculate rates per 100,000 population.

Choropleth maps were generated using the geomap and tigris packages in R Studio to visualize the spatial and temporal distribution of legionellosis cases across Georgia. ZIP codes were geocoded to counties, and cases were aggregated by county and year. Static maps were created for each individual year, and an animated map was produced to display the evolution of county-level legionellosis incidence from 2013 to 2023. The maps in the annex allow for intuitive visualization of geographic and temporal trends, highlighting areas with persistently high or increasing incidence rates over time.

Statistical Analysis

Regression Modeling

To assess associations between social vulnerability and legionellosis health outcomes, two regression models were constructed:

Mortality: Logistic regression was used to estimate odds ratios (ORs) and 95% confidence intervals (CIs). Mortality was modeled as a dichotomous outcome, coded as 1 if the case died and 0 if the case survived or remained ill.

$$\ln(Odds\ of\ Mortality) = \alpha + \beta_1 SVI + \beta_2 Age + \beta_3 Occupation + \beta_4 Gender$$

Hospitalization: Log-binomial regression was used to estimate risk ratios (RRs) and 95% CIs. Hospitalization status was modeled as a dichotomous outcome, coded as 1 if the case was hospitalized and 0 if the case was not hospitalized.

$$\log(P(hospitalized = 1)) = \beta_0 + \beta_1 SVI$$

Given that mortality was a rare outcome in the dataset (<10% of individuals died following their legionellosis diagnosis), logistic regression was selected as the appropriate model. In contrast, hospitalization was more common, with 48.0% of cases hospitalized due to their legionellosis infection.

Both models initially included SVI, age, gender, occupation, and comorbidity status as covariates. Comorbidity status was incorporated as a dichotomous variable (presence or absence of any comorbidity). Underlying health conditions considered as comorbidities included asthma, heart disease or congestive heart failure, diabetes, weakened immune system, chronic kidney disease, liver disease, and chronic lung disease. Model building followed standard epidemiologic procedures, including assessment of collinearity, evaluation of confounding, and testing for effect measure modification (statistical interaction).

Collinearity Assessment

Collinearity among covariates was evaluated using variance decomposition proportions (VDP). In the logistic regression model for mortality, high collinearity was detected in the comorbidities covariate (VDP = 0.66) and the interaction term between SVI and comorbidities (VDP = 0.71), exceeding the threshold of 0.5. This indicated instability in estimating the joint effect of these variables. As a result, the comorbidities and the interaction term were excluded from the final mortality model. No collinearity was observed among model covariates (VDP < 0.5) in the log-binomial regression model for hospitalization status. This allowed the inclusion of the interaction term between SVI and comorbidities and later asses for effect measure modification (EMM) and statistical interaction as the interaction term was able to be retained in the model.

EMM and Statistical Interaction Assessment

In the logistic regression model assessing mortality, comorbidity status and its interaction terms with

SVI were excluded due to collinearity, and therefore EMM and statistical interaction were not assessed for this outcome. For the model assessing hospitalization status as the outcome, EMM by comorbidity status was evaluated through the inclusion of an interaction term (SVI × comorbidity). Stratified estimates and likelihood ratio tests (LRTs) were used to assess statistical interaction. No statistically significant interaction was detected (LRT p = 0.4881), and the risk ratios for SVI were not meaningfully different between strata (with comorbidities: RR = 0.95, 95% CI: 0.73–1.24; without comorbidities: RR = 1.08, 95% CI: 0.78–1.49), suggesting no evidence of EMM.

Confounding Assessment

A change-in-estimate approach was used to evaluate confounding. Covariates were considered confounders if their removal from the full model changed the effect estimate for the main exposure (SVI) by 10% or more. In the model assessing mortality as the outcome, age, gender, and occupation met the confounding criterion and were retained in the final model. In contrast, in the model assessing hospitalization status as the outcome, the removal of individual covariates changed the estimated risk ratio for SVI by less than 10%, indicating no evidence of confounding.

Results

Descriptive Statistics

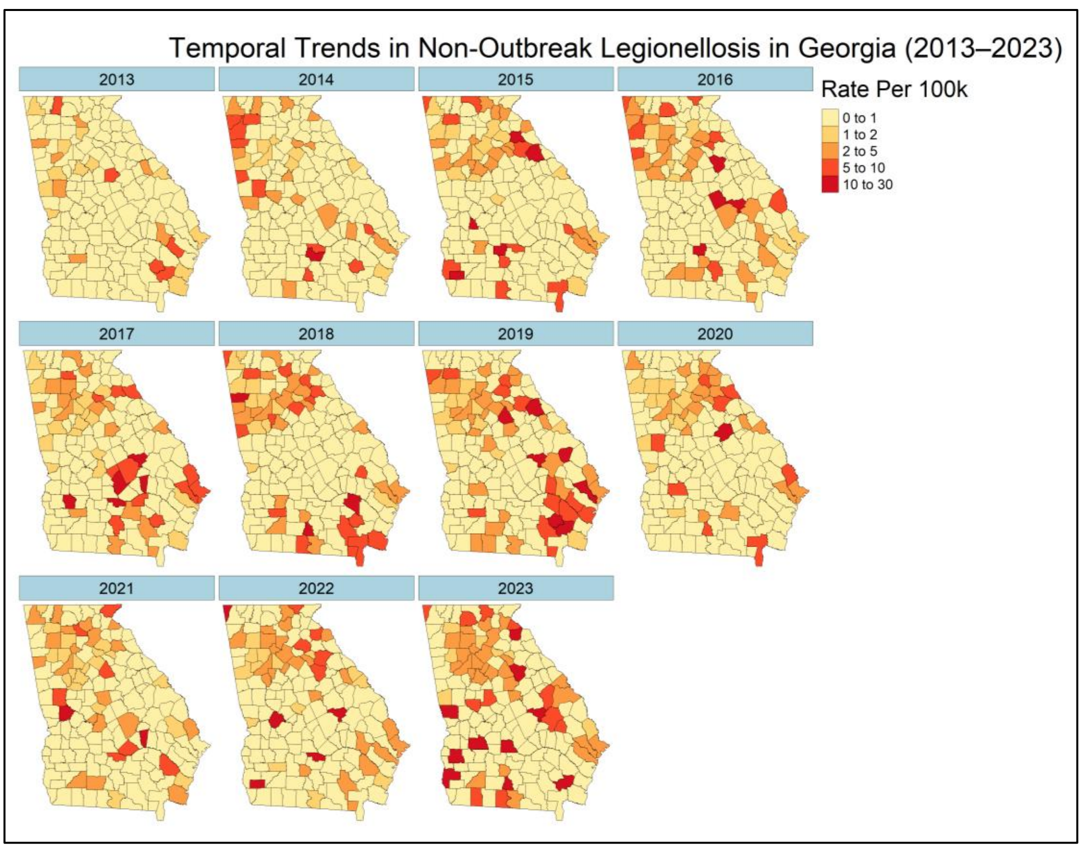
Between 2013 and 2023, a total of 1,617 non-outbreak-associated legionellosis cases were reported in Georgia. The mean age of cases was 58.5 years (SD = ±14.7). [Table 1] Approximately 63% of individuals diagnosed were male and 37% were female. Over half of the cases (50.5%) identified as White, while 42.4% identified as Black or African American. Most individuals (91.4%) were non-Hispanic, whereas 2.4% identified as Hispanic or Latino; ethnicity data were unavailable for 6.2% of cases. Occupation data showed that among those with a reported occupation, Transportation/Logistics (7.2%), Construction/Maintenance/Engineering (4.8%), and Government/Public Services (4.5%) were the most frequently represented sectors. Outcomes varied across cases: 6.9% of individuals died due to their legionellosis infection, 11.9% remained ill at the time of data collection, and 52.9% survived.

Table 1. Baseline demographic characteristics of reported legionellosis cases in Georgia, 2013–2023

Characteristic	Overall (N=1617)
Age	
<30	44 (2.7%)
30–49	357 (22.1%)
50–64	644 (39.8%)
65–74	353 (21.8%)
≥75	218 (13.5%)
Unknown	1 (0.1%)
Gender	
Female	593 (36.7%)
Male	1022 (63.2%)
Other	1 (0.1%)
Unknown	1 (0.1%)
Race	
White	816 (50.5%)
Black or African American	685 (42.4%)
American Indian/Alaska Native	3 (0.2%)
Asian	21 (1.3%)
Native Hawaiian/Pacific Islander	1 (0.1%)
Multiracial	6 (0.4%)
Not Available	65 (4.0%)
Other	20 (1.2%)
Ethnicity	
Hispanic or Latino	39 (2.4%)
Non-Hispanic or Latino	1478 (91.4%)
Not Available	100 (6.2%)
Occupation	
Construction/Maintenance/Engineering	77 (4.8%)
Environmental/Outdoor Labor	44 (2.7%)
Finance/Business	53 (3.3%)
Government/Public Services	73 (4.5%)
Healthcare	32 (2.0%)
Transportation/Logistics	117 (7.2%)
Retail/Hospitality	61 (3.8%)
Not in Labor Force	465 (28.8%)
Unknown/Not Otherwise Classified	695 (43.0%)
Outcome	
Died	111 (6.9%)
Still Ill	192 (11.9%)
Survived	856 (52.9%)
Unknown	458 (28.3%)

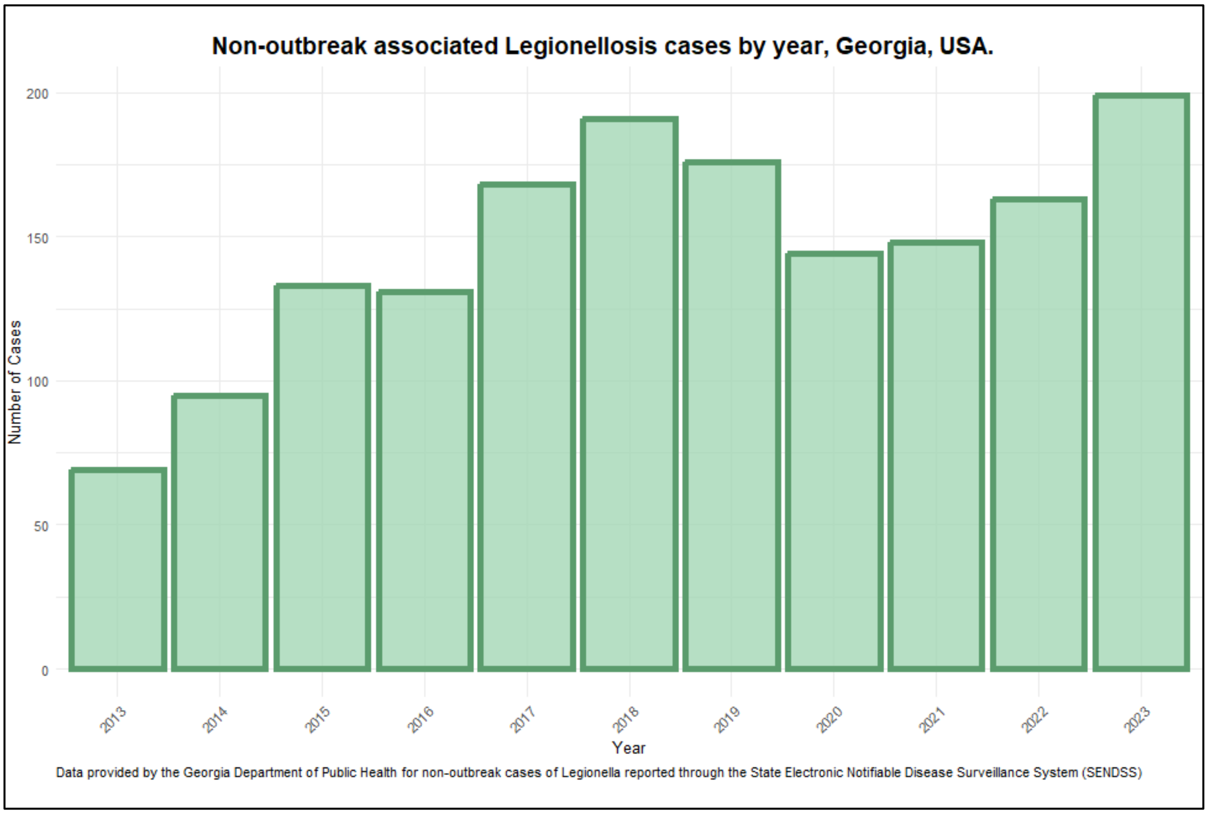
When examining the incidence rates of legionellosis across counties, differences in population sizebecome apparent. [Figure 1] For example, Baldwin County in 2023 reported a rate of 2.3 cases per 100,000 population, with only one case in that year. In contrast, DeKalb County, with a significantly larger population, reported 28 cases in 2023, yielding a rate of 3.7 cases per 100,000. Starting in 2016, a trend of elevated incidence rates emerged in north-central and southern Georgia. Counties such as Wilkinson County saw rates as high as 11.4 per 100,000. By 2018, several counties, including Camden County, reported incidence rates ranging from 5 to 10 per 100,000, with a few counties—such as Polk County—exceeding 10 cases per 100,000. In 2020, elevated incidence rates persisted, particularly in Hancock County, which reported an incidence rate of 11.6 per 100,000, while Effingham County and Clarke County had incidence rates of 9.3 and 3.9 per 100,000, respectively. Notably, in 2023, Fulton County experienced its highest number of cases in the last decade, with 39 cases reported to the GDPH, resulting in an incidence rate of 3.6 per 100,000 population.

Figure 1. Temporal trends in-non-outbreak legionellosis in Georgia (2013-2023)



Temporal trends in reported cases varied over time, with peaks observed in 2018 and 2023. [Figure 2] A marked decline in reported cases was observed in 2020, coinciding with widespread disruptions in healthcare access and public health operations during the COVID-19 pandemic.

Figure 2. Annual number of non-outbreak-associated legionellosis cases reported in Georgia, 2013–2023



The analysis of reporting delays revealed a mean lag of 14.9 days between symptom onset and case entry into Georgia's state electronic disease surveillance system (SENDSS). [Figure 3] The year 2020 exhibited the most prolonged reporting delays, with an average lag of 48.7 days, ranging from 0 days to 540 days. In contrast, 2018 experienced the shortest delays, with an average of 7.2 days. This stark difference highlights the significant impact of external factors, such as the COVID-19 pandemic, on the timeliness of public health reporting.

Figure 3. Average time from symptom onset to case entry in SENDSS, Georgia, 2013–2023

Year	Average Days	Missing Dates
2013	19.1	0
2014	21.0	0
2015	12.2	0
2016	11.7	1
2017	11.5	0
2018	7.2	0
2019	8.4	0
2020	48.7	2
2021	15.9	6
2022	10.6	11
2023	8.7	6

Among cases with complete data on comorbidities, 24.3% (n = 781) had at least one underlying comorbid condition [Table 2]. The most commonly reported comorbidities included diabetes (20.3%), and immunosuppressive conditions (18.7%) heart disease or congenital heart failure (17.3%). Eleven percent of patients (n = 177) had three or more comorbidities, while 27.7% (n = 488) had no reported comorbidities. Additionally, 24.0% (n = 388) had missing data on comorbidities.

Table 2. Number of reported comorbidities among legionellosis cases, Georgia, 2013–2023

Patient Comorbidity Summary		
Comorbidity Status	Number of Patients (n=1617)	Percent (%)
No Comorbidities	488	27.7%
1 Comorbidity	393	24.3%
2 Comorbidities	211	13.0%
3+ Comorbidities	177	10.9%
Missing	388	24.0%

Analysis I: Mortality

From 2013 to 2023, 192 deaths were reported among 1,617 individuals diagnosed with non-outbreak associated legionellosis in Georgia, yielding a case fatality proportion of 11.9%. In the full logistic regression model including SVI, age, occupation, and gender, higher SVI was associated with increased odds of death (OR = 1.92; 95% CI: 0.86–4.26), although not statistically significant. [Table 3] Age emerged as the only statistically significant predictor, with each one-year increase associated with a 4% increase in the odds of death (OR = 1.04; 95% CI: 1.03–1.06). Female gender was associated with elevated, but non-significant, odds of death compared to males (OR = 1.45; 95% CI: 0.97–2.17). Occupation was not significantly associated with mortality, and no single occupational group had a statistically significant difference in mortality risk when compared to individuals not in the labor force.

Table 3. Adjusted odds ratios for death due to legionellosis by SVI, age, gender, and occupation, Georgia, 2013–2023

Covariate	Adjusted Odds Ratio (OR)	95% Confidence Interval
SVI	1.92	0.86–4.26
Age	1.04	1.03–1.06
Gender		
Male (reference)	–	–
Female	1.45	0.97–2.17
Occupation		
Not in the labor force (reference)	–	–
Healthcare	0.93	0.26–3.32
Retail/Hospitality	0.37	0.09–1.60
Transportation/Logistics	0.94	0.45–1.96
Construction/Maintenance/Engineering	0.36	0.09–1.56
Government/Public Services	0.65	0.22–1.90
Finance/Business	0.83	0.24–2.87
Environmental/Outdoor Labor	1.44	0.52–3.96
Unknown/Not Otherwise Classified	1.07	0.67–1.71

Analysis II: Hospitalization Status

Hospitalization occurred in 1,225 of the 1,617 legionellosis cases (75.8%), indicating substantial clinical severity in this population. [Table 4] In the adjusted model that included SVI as the only predictor, a non-significant association between higher SVI and hospitalization (RR = 1.03; 95% CI: 0.87–1.22) was observed.

Table 4. Adjusted odds ratios for hospitalization status due to legionellosis by SVI, 2013–2023

Covariate	Adjusted Risk Ratio (RR)	95% Confidence Interval
SVI	1.03	0.87–1.22

Discussion

Although legionellosis is commonly associated with outbreak scenarios, a significant proportion of cases contribute to the overall disease burden outside of recognized outbreaks. As noted in the literature, most legionellosis cases occur sporadically, with environmental factors and community vulnerabilities playing critical roles in shaping disease dynamics. [11, 12, 15] The findings of this study underscore the recognition that non-outbreak legionellosis constitutes a significant portion of the overall disease burden. Furthermore, social determinants of health, as captured by the SVI, may play a role in shaping health outcomes. [11, 21, 23]

Over a period of 10 years, 1,617 unique cases of non-outbreak associated legionellosis were reported across multiple counties in Georgia. The majority of cases, 39.8% (n = 644) were found in white non-Hispanic or Latino males, with a high proportion of cases occurring in individuals aged 50-65. This pattern highlights the need for increased awareness and targeted prevention efforts among middle-aged and older adults who may be more susceptible due to age-related vulnerabilities or existing health conditions.

Annual case counts of non-outbreak associated legionellosis cases rose from 69 in 2013 to 199 in 2023, potentially suggesting an increasing burden of the disease for Georgia. In addition to being characterized by number of cases, this burden is also borne by the public health system that strives to investigate each and every case. When the public health system was strained – such as occurred in 2020 and 2021 due to the COVID-19 pandemic – reporting lags got longer. The average number of days between symptom onset and case report to public health increased nearly 6-fold between 2019 and 2020. This is worth noting when examining the impact COVID-19 had on the reporting of other reportable diseases and considering resource or personnel management in future instances when public health capacity is strained extraordinarily. Additionally, delays in diagnosis and reporting can exacerbate illness severity, as delayed access to healthcare makes individuals more vulnerable to poor health outcomes, especially those with preexisting comorbidities.[14,19,21]

A noticeable increase in case counts was observed in the final two years of the study period (2022–2023), aligning with national trends of rising legionellosis incidence in recent years. At the county level, there was considerable geographic variation in reported legionellosis incidence. While the majority of counties reported fewer than 10 cases annually, certain counties saw notable spikes in case counts, exceeding 25 cases per year. These regional disparities highlight the variability in disease burden across the state. [16, 21,27,28] The sustained increases in certain counties may reflect localized outbreaks or other environmental risk factors that warrant further investigation.

Between 2013 and 2023, Georgia counties reported varying numbers of non-outbreak-associated legionellosis cases, with some counties experiencing significant fluctuations in incidence rates. For example, southern counties like Brooks County saw an increase from an incidence rate of 0 per 100,000 in 2013 to 6.2 per 100,000 in 2023. Similarly, Fulton County experienced a 300% increase in its incidence rate, rising from 0.9 per 100,000 in 2013 to 3.6 per 100,000 in 2023. These increases indicate that the disease burden is rising across different geographic and demographic settings, not just in specific regions. This highlights the dynamic nature of legionellosis incidence rates in Georgia and suggests a need for targeted interventions in counties with higher incidence rates.

Previous studies have emphasized the role of comorbidities—particularly chronic respiratory diseases, diabetes, and immunosuppression—in increasing susceptibility to severe legionellosis outcomes. [1,2] However, fewer studies have examined how neighborhood-level vulnerability may independently contribute to these risks.

In this study, although the adjusted odds of death were elevated among individuals with higher social vulnerability, the wide confidence interval and lack of statistical significance limit the interpretation of these findings. Taken together, these results suggest that while older age significantly increased the risk of mortality, community-level vulnerability and occupation did not demonstrate clear associations with death following legionellosis diagnosis.

Despite the limitations encountered, the analysis of hospitalization status and associated covariates revealed important insights. While hospitalization status was not statistically significantly associated with SVI, and proposed covariates (age, occupation, and gender) did not emerge as confounders nor comorbidities as effect modifiers, the model still highlights the relevance of structural determinants. These determinants—such as housing disrepair and limited healthcare access—act as amplifiers of risk, particularly in the absence of targeted prevention or early intervention. [18-21]

Furthermore, as climate change continues to intensify rainfall patterns and raise ambient temperatures, environmental conditions favorable to *Legionella* growth may become more widespread. This could further increase the risk of infection in vulnerable communities. [6,7,9,35]

Overall, these findings suggest that structural inequities, particularly those related to socio-economic status and education, may interact with environmental exposures—such as deteriorating housing infrastructure, water system degradation, and inadequate maintenance of building water systems—to amplify the risks for already marginalized populations.

Limitations

Several limitations must be considered when interpreting these findings. First, the comorbidity variable used in this study was dichotomized for ease of use given the large amounts of missing values in the dataset and the fact these data were derived from case report forms (as opposed to clinical records), which may underrepresent or misclassify the presence of certain health conditions. Second, while our geocoding approach used ZIP codes to assign counties, some degree of geographic misclassification is possible, particularly in border regions or among transient populations. Additionally, missing data presented an ongoing challenge during. A large proportion of missing values were observed in the occupation category (n = 695, 43.0%), outcome status (n = 458, 28.3%), and response to health conditions (n = 388, 24.0%), which were used to create the comorbidity variable and associated categories. Third, the analyses used population estimates for 2021 to calculate county-level rates for 2022 and 2023, which may have introduced slight inaccuracies in rate estimation for those years.

Moreover, the use of the SVI at the county level, while useful for examining structural disparities, may obscure within-county heterogeneity in vulnerability—particularly in larger metropolitan areas. Finally, while the associations between social vulnerability and legionellosis outcomes are noteworthy, the lack of statistical significance and the presence of missing data in the dataset remain important limitations and merit further investigation.

Conclusion

This study highlights interesting trends in legionellosis cases and case reporting in Georgia between 2013 – 2023. It also explores the role social and structural determinants of health may have in shaping the severity of legionellosis outcomes in Georgia. While traditional risk factors such as age and comorbidities remain important, community-level vulnerability—captured through the SVI—may play an important role in hospitalization and death for legionellosis patients. Moreover, these findings call for more targeted prevention strategies, particularly in communities with high social vulnerability. Interventions might include expanded environmental monitoring, increased access to healthcare, and investment in public infrastructure to reduce exposure risks.

As public health surveillance systems continue to improve, integrating geospatial data, social vulnerability indices, and health outcomes can help refine our understanding of disease ecology and support equitable disease prevention efforts. In the context of a changing climate and persistent health inequities, these approaches are vital to protecting populations most at risk from severe infectious diseases, including legionellosis.

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