ASSESSING THE IMPACT OF THE 1918/1919 INFLUENZA PANDEMIC IN MISSOURI COUNTIES HEAVILY INVOLVED IN LEAD-ZINC MINING

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The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

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ABSTRACT

Occupational concentrations within regions have the capability to influence infectious disease transmission as they shape the way humans interact within a community. The 1918 influenza pandemic is widely discussed as the "World's Most Deadly Pandemic" (Feehan & Apostolopoulos, 2021), but little is known about how rural communities were impacted by the pandemic. Through historical data collection and analysis, this project assesses the impact of the occupational risk of mining on influenza transmission and severity during the pandemic within three rural mining districts in the state of Missouri, USA: the Tri-State District, Central District, and Old Lead Belt. Missouri mines supplied much of the lead produced during this time, with many Missourians working in closed workspaces in close proximity to each other within the mining operations. Although each district had similar high prevalences of the same occupation, they varied substantially in socioeconomic and demographic characteristics such as population density and access to healthcare. This study suggests that factors such as these allowed for variation in disease burden between mining districts to develop. The Tri-State District experienced the largest disease burden of all mining districts, followed by the Old Lead Belt. The Central District experienced the least and was the only mining district to have lower standardized mortality outcomes on average compared to the state of Missouri. These results indicate that the presence of mining may have increased disease prevalence in certain areas, in conjunction with additional demographic factors that influence disease spread. The results and methodologies from this study have the potential to be applied to other real-world situations, such as the ongoing COVID-19 pandemic, and provide insight for public health officials to make informed decisions that have the potential to improve population-level health outcomes.

CHAPTER 1: INTRODUCTION

Infectious diseases are often described using the epidemiological triad model comprised of three main components: agent, host, and environment. The first two components primarily describe the biology of the disease, while the third component focuses on how ecological interactions influence transmission and severity of disease. The latter considers all possible physical, social, behavioral, cultural, political, and economic factors (van Seventer & Hochberg, 2017). From the moment of pathogen exposure to potential recovery, each component of the epidemiological triad is influencing the disease progression. This structure can be utilized in assessing and predicting the impact of a variety of diseases, including those that may lead to epidemics or pandemics, such as the 1918 influenza pandemic.

The 1918 influenza pandemic maintains the title “World’s Most Deadly Pandemic” as approximately 50 million people died from the disease (Feehan & Apostolopoulos, 2021; Johnson & Mueller, 2002; Taubenberger & Morens, 2006). Furthermore, an estimated 500 million people (a third of the world’s population at the time) became infected with the disease. The entire world was impacted by the pandemic, as the influenza virus infected as many susceptible hosts as possible. Three distinct pandemic waves within an approximate one-year period from 1918-1919 are recognized in most regions of the world (Crosby, 2003; Taubenberger & Morens, 2006). An additional fourth wave occurred in several locations in 1920 (Ansart et al., 2009; Crosby, 2003; Johnson & Mueller, 2002; Sattenspiel, 2011; Yang et al., 2014). It is important to note that many locations did not experience the pandemic in the same manner in terms of timing of waves and severity of outcomes.

The state of Missouri is one of these locations, primarily experiencing two peaks within the main wave from October 1918 to May 1919 and an echo wave from January 1920 to April 1920. An additional third peak may have occurred within the main wave in late March 1919; however, its impact was significantly lower in terms of mortality compared to those prior. Based on a detailed analysis of reported deaths, it is clear that epidemic patterns varied throughout the state (Orbann et al., in preparation; Sattenspiel et al., in preparation). These outcomes may reflect how various characteristics of different regions influence disease transmission and severity. In an attempt to uncover more geographical variation in disease impact, this study will examine the impact of the 1918 influenza pandemic within three mining districts in Missouri. Mining activity peaked in Missouri during this time period with a large proportion of residents engaging in related occupational activities; an analysis of mortality could provide further insight on how the average Missourian was impacted by the 1918 influenza pandemic. This study is unique as it is focusing on districts of Missouri that are not primarily urban; previous research focusing on the impact of the 1918 influenza pandemic in Missouri primarily analyzed urban areas, likely due to these regions having more detailed historical documentation of the event (Hoffman, 2011; Kalnins, 2006).

Missouri's official state mineral is galena, the major source of lead ore, due to its important influence on the economy and historical development of the state. Missouri was a global leader in lead production in the late 19th and early 20th centuries due to the many lead deposits located in the state; reaching record production in 1916 with 155,527 tons of zinc and 30,827 tons of lead valuing approximately 46 million dollars (Kiilsgaard et al., 1967; Missouri Department of Natural Resources, 2021). Barium and zinc mining were common as well, often located in the same areas as lead. There were three primary mining districts in Missouri during the time being investigated: Southeast Missouri Lead District, Tri-State District, and Central District. The Tri-State District was the largest in size, as this district included 14 southwestern counties in Missouri, continuing into Kansas and Oklahoma (Missouri Department of Natural Resources, 2021). The Southeast Missouri Lead District, commonly known as the Old Lead Belt, produced a significant amount of lead at the time and continues to do so today. The Central District produced the least compared to the other districts; however, the amount was still considerable compared to other states' production efforts (Kiilsgaard et al., 1967). The specific characteristics of each of these districts will be discussed in more detail in the next chapter.

The goal of this project is to assess the impact of a specific occupational risk on influenza transmission and severity. The primary hypothesis that will be tested in this project is that these three mining districts experienced a greater impact in terms of mortality compared to the state during the 1918 influenza pandemic. Although much of the territory encompassed by these districts is not comprised of urban areas, which are often associated with higher disease transmission rates due to increased population density, the occupational risk due to working in a closed workspace in close proximity to other workers likely substantially increased miners' risk of transmitting and acquiring disease. Individuals that were not miners themselves but were members of the same social network would also be at an increased risk of disease. A secondary hypothesis will be tested in this study as well, which is that the Tri-State District experienced the greatest impact and the Central District experienced the least based on the average rurality and population density of the counties comprised in each mining district.

Important insights can be gained by studying past pandemics, as history tends to repeat itself. Prevention, containment, and treatment strategies may be altered to improve health outcomes due to this gained knowledge. The 1918 influenza is extremely influential in particular;

this specific virus can be thought of as the "mother" of influenza pandemics (Taubenberger & Morens, 2006), as the majority of influenza pandemics in recent past have been caused by descendants of the 1918 virus that have made slight genetic modifications via antigenic shift and antigenic drift[1] (Treanor, 2004). The 1918 influenza was also the last great pandemic of respiratory disease prior to COVID-19 which is currently unfolding; therefore, it naturally serves as a mental model for the idea of a pandemic.

In order to achieve the goal of this project, this thesis will be comprised of four main sections. First, important characteristics of the study populations will be described. Demographic variables and geographic locations will be explored in detail at both the county and state level. Second, the biological characteristics of influenza viruses and the clinical manifestations of influenza will be described. A more extensive description of the 1918 influenza pandemic on a global scale and within the state of Missouri will be provided as well. Third, the methods for data collection and analysis will be outlined. Emphasis will be placed on constraints associated with studying historical pandemics. Finally, this thesis will conclude with a discussion of results produced from this project and their implications for understanding the impact of infectious disease pandemics on different sectors of a population.

[1] Antigenic shift involves two separate viruses exchanging genetic material. Antigenic drift involves the accumulation of a series of minor genetic mutations.

CHAPTER 2: STUDY REGIONS AND POPULATIONS

This chapter reviews demographic information from the entire state and each mining district to provide a lens into the life of an everyday Missourian living in these regions during the early 20th century. Differing variables will be discussed to highlight possible influences on disease transmission. The data presented here was primarily taken from the 1910 Missouri Decennial Census; however, additional archival, historical, and ethnographic source materials were utilized. Each mining district is comprised of varying numbers of counties, with four counties from each district chosen as representatives. Counties with the highest number of employees and mines were chosen based on available information; Chapter 3 provides a detailed explanation of the county selection process. Table 2.1 lists each county per district that will be discussed in further detail; the locations of each of these counties are shown in Figure 2.1. Complete demographic data for each representative mining county can be found in Appendix A.

Table 2.1. Counties representing each mining district.

Mining District	Counties
Tri-State District	Greene, Jasper, Lawrence, Newton
Central District	Cole, Miller, Moniteau, Morgan
Old Lead Belt	Franklin, Jefferson, Madison, St. Francois

The State of Missouri

Missouri was the 7th most populated US state in 1910 with a total of 3,293,335 inhabitants. The state was subdivided into 114 counties and the independent City of St. Louis which functioned as its own county/city unit (U.S. Census Bureau, 1913b). Of the 295 cities in Missouri, only five cities had over 25,000 inhabitants: St. Louis City, Kansas City, St. Joseph, Springfield, and Joplin. None of those cities were located in northeastern, southeastern, or central Missouri. Five cities had a population over 10,000 but less than 25,000: Hannibal, Sedalia, Jefferson City, Webb City, and Moberly. In contrast to the more populated cities, these are located in either central or northeastern Missouri with the exception of Webb City which is adjacent to Joplin. Figure 2.1 shows the geographical location of these cities.

The majority of the state lived in rural areas, with 57.53% of the population living in cities/towns/villages with less than 2,500 inhabitants or other smaller rural territories. Of the 114 counties, 67 were considered to be completely rural. All other counties were comprised of both urban and rural populations, seven of those having less than 50% of the population living in rural areas: Pettis, Cole, Greene, Marion, Jasper, Buchanan, and Jackson. All cities with 10,000 inhabitants or more are located in these counties, with the exception of the city of Moberly, located in Randolph County. St. Louis City was completely urban (U.S. Census Bureau, 1913b).

The predominant ethnicity of the state was Caucasian, as 95.19% of the population identified as White (U.S. Census Bureau, 1913b). Individuals classified as Black were relatively common in the state; no state outside of the US census-defined South Atlantic and South Central Regions had a higher percentage of individuals of Black ethnicity than Missouri which had 4.78% (U.S. Census Bureau, 1913a). The remaining 0.03% of the population's ethnic makeup consisted of Chinese, Japanese, Indian, and 'other' individuals. More men than women comprised the state, with 51.25% of the population being male (U.S. Census Bureau, 1913b). The ratio of men actually present in the state in 1918 was somewhat lower, however, as over 156,000 Missouri men served in all branches of the armed forces during World War I (Missouri Secretary of State, 2021). The literacy rate for men of voting age for the entire state was 94.7% (U.S. Census Bureau, 1913b). No more than 39.1% of the population maintained consistent formal employment (U.S. Census Bureau, 1914). It is plausible that not all farm work is included in this estimate, as some farm work may not fall into the definition of formal employment which is a contractual arrangement between a business and an individual. Agricultural employment was the most common type of formal employment, which is not surprising as 78.6% of Missouri land consisted of farmland (U.S. Census Bureau, 1913b; U.S. Census Bureau, 1914). Manufacturing/mechanical industry and trade employment were the second and third most common, likely due to those occupations' support of the agricultural industry (U.S. Census Bureau, 1914). It should be noted that Missouri had a large number of factories compared to other places within the U.S. as well, likely due to the availability and ease of shipping by way of the Missouri and Mississippi Rivers.

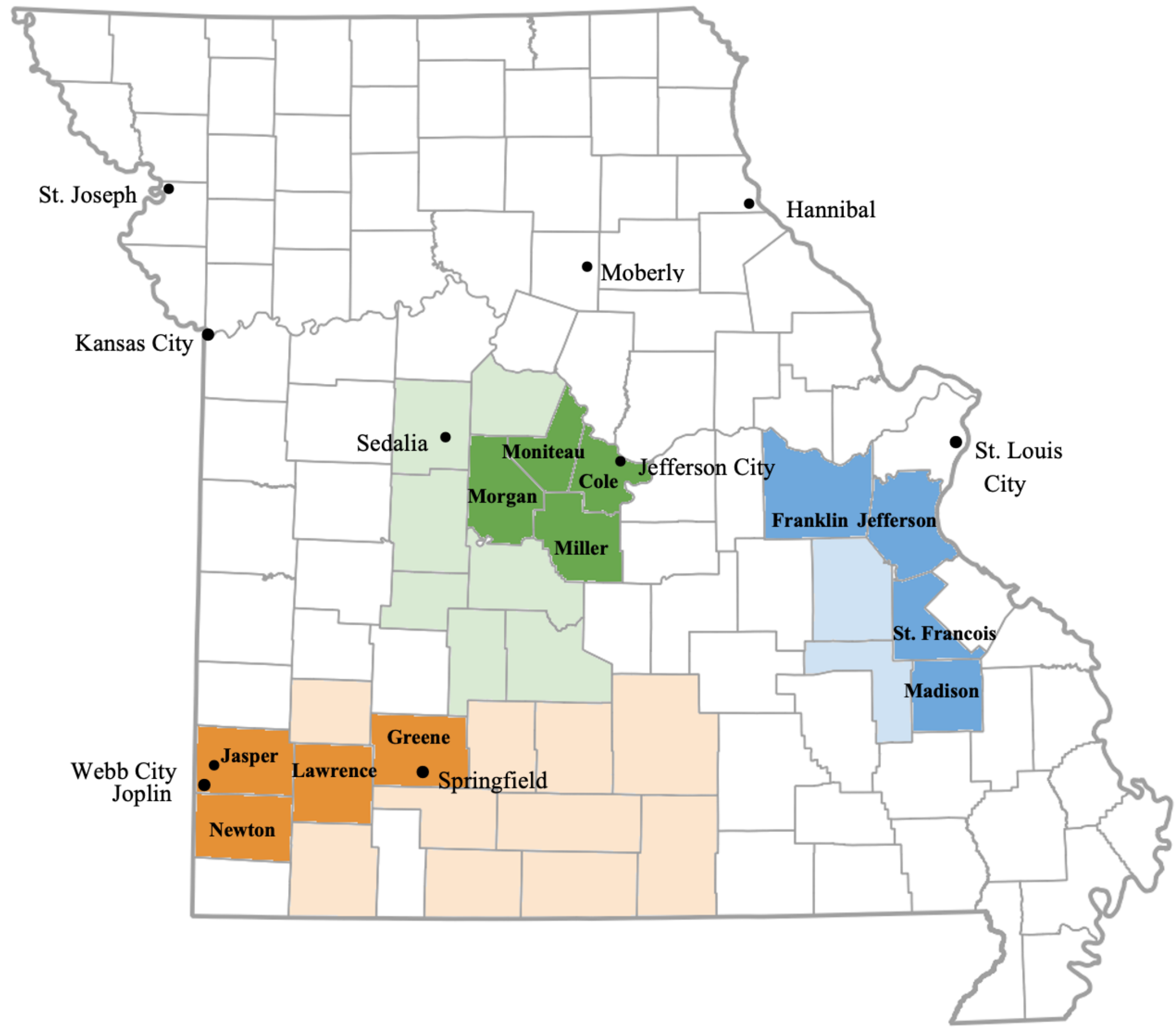


Figure 2.1. Map of Missouri with individual counties outlined. Cities with 10,000 or more inhabitants in 1910 are labeled. Counties representing each mining district are labeled and heavily shaded. Counties lightly shaded are included in the corresponding district but not analyzed within this study. Tri-State District – orange, Central District – green, Old Lead Belt – blue.

Tri-State District

The Tri-State District for lead and zinc mining includes 14 southwestern counties in Missouri, continuing into Kansas and Oklahoma (Missouri Department of Natural Resources, 2021). The majority of mining occurred in Greene, Jasper, Lawrence, and Newton counties (Figure 2.1). Lesser satellite deposits extended as far east as Howell and Texas counties (Missouri Department of Natural Resources, 2021). The city of Joplin, located in Jasper County, was considered to be the headquarters of the Missouri portion of the Tri-State District, as large lead deposits found there in 1870 prompted initial mining operations (Kiilsgaard et al., 1967).

Greene, Jasper, Lawrence, and Newton County Demographics

Greene and Jasper counties, with 63,831 and 89,673 total inhabitants, respectively, had significantly larger populations than the two other Tri-State District counties included in the study; Lawrence and Newton counties had less than half with 26,583 and 27,136 inhabitants, respectively (U.S. Census Bureau, 1913b). More than half of the population of Greene and Jasper counties lived in urban areas, while the vast majority of Lawrence and Newton County residents lived in rural areas. All four counties had approximately the same area, ranging from 609 – 667 square miles. Over 90% of Greene and Lawrence counties were considered to be farmland; Jasper (79.77%) and Newton (76.49%) were slightly lower. Newton had the lowest literacy (93.5%), while Jasper had the highest (97.4%) (U.S. Census Bureau, 1913b). Access to healthcare varied across counties, ranging from 84.76 – 175.46 physicians per 100,000 inhabitants (Polk's Medical Register, 1917).

As described in the overall state demographics, the primary ethnicity in all counties is White (U.S. Census Bureau, 1913b). Of these four counties Greene had the largest proportion of

Black individuals (4.11%), while Lawrence had the least (0.34%). Newton had the highest percent of individuals recognized in the 'other' ethnicity category (0.13%) followed by Miller (0.08%), all other counties had less than 0.05%. Newton County had the largest sex bias with 53.46% of the population male, while the other three counties ranged from 50.20 – 50.81% (U.S. Census Bureau, 1913b).

Central District

Major lead and minor zinc production occurred in the Central District from 1830 to 1910; (Missouri Department of Natural Resources, 2021). After 1910, the Central District primarily produced barite with lead as a byproduct (Kiilsgaard et al., 1967; Brobst & Wagner, 1967). Some zinc mining occurred as well. This district was primarily northeast of what is now the Lake of the Ozarks, with the majority of mining operations occurring in Cole, Cooper, Miller, Moniteau and Morgan counties (Missouri Department of Natural Resources, 2021). Figure 2.1 shows the geographical location of the Central District counties included in this study. Lesser mining operations were found in Camden, Benton, Maries, and Osage counties as well (Interstate Historical Society, 1917).

Cole, Miller, Moniteau, and Morgan County Demographics

Cole County had the largest population with 21,957 total inhabitants; slightly more than half of these individuals lived in urban areas within the county, likely within or near the Jefferson City limits (U.S. Census Bureau, 1913b). The total population of all other counties ranged from 12,863 – 16,717 inhabitants with Morgan County having the least. The entire population of Miller, Moniteau, and Morgan Counties lived in rural areas. The total area of each county varied substantially, ranging from 380 – 614 square miles with Cole being the smallest county and Morgan the largest. The total percent of land dedicated to farming for each county varied substantially as well, ranging from 71.12 – 95.99% with Morgan County comprised of the least and Moniteau comprised of the most. Miller had the lowest literacy rate (93.6%) and Moniteau had the highest (95.4%) (U.S. Census Bureau, 1913b). Access to healthcare varied slightly across counties, ranging from 83.45 – 118.26 physicians per 100,000 inhabitants (Polk's Medical Register, 1917).

Cole County had the largest percentage of Black individuals in the population (9.82%), Miller had the least (0.57%) (U.S. Census Bureau, 1913b). The percentage of Black individuals in Moniteau and Morgan counties was slightly lower than the state average with 3.50% and 3.19%, respectively. Neither Cole nor Morgan County had a single individual of 'other' ethnicity, Miller and Moniteau counties had less than 0.1%. Cole County had the largest sex difference with 54.86% of the population being male, while Moniteau County had the least (50.12%) (U.S. Census Bureau, 1913b).

Old Lead Belt

The Southeast Missouri Lead District, commonly known as the Old Lead Belt, is located southwest of St. Louis City. The majority of this district's operations occurred in St. Francois County in addition to smaller operations in Franklin, Jefferson, Madison, and Washington counties (Missouri Department of Natural Resources, 2021; Kiilsgaard et al., 1967). Figure 2.1 shows the geographical location of these counties. Zinc and barite mining occurred in lesser amounts as well, primarily in Washington County (Mugel, 2017).

Franklin, Jefferson, Madison, and St. Francois County Demographics

Of these four counties, St. Francois County had the largest population with 35,738 inhabitants while Madison had the smallest with 11,273 (U.S. Census Bureau, 1913b). The total population of Franklin and Jefferson counties fell roughly in the middle, with 29,830 and 27,878 inhabitants. In all counties the majority of the population lived in rural areas. Franklin County was the most rural as only 12.3% of the population lived in urban areas; the other three counties' populations ranged from 21.6 – 26.1% urban. The total area of each county varied substantially, ranging between 458 and 879 square miles with St. Francois the smallest and Franklin County the largest. The total percent of land dedicated to farming for each county varied substantially as well, ranging from 40.23 – 84.76% with Madison County comprised of the least and Franklin comprised of the most farmland. St. Francois County had the lowest literacy rate (86.5%) and Franklin County had the highest (94.3%) (U.S. Census Bureau, 1913b). Access to healthcare varied across counties, ranging from 71.74 – 115.32 physicians per 100,000 inhabitants (Polk's Medical Register, 1917).

Franklin and Jefferson counties had a higher percentage of Black individuals compared to the state average with 4.58% and 5.61% (U.S. Census Bureau, 1913b). In contrast, Madison and St. Francois counties had a lower percentage of Black individuals compared to the state average with 2.48% and 1.56%. St. Francois County was the only county with individuals in the 'other' category of ethnicity, comprising 0.01% of the population (U.S. Census Bureau, 1913b).

A Comparison of All Districts

Of all regions, the Tri-State District was the most urban with Greene and Jasper counties having the largest populations of all counties discussed and the majority of inhabitants of those counties living in urban areas (U.S. Census Bureau, 1913b). The Central District was the least urban as three out of the four counties' total populations completely lived in rural areas; however, slightly over half of Cole County's population lived in urban areas. All counties in the Old Lead Belt were primarily rural, with some of the total population living in urban areas. The Central District was the smallest mining district analyzed and was comprised of 1,997 total square miles; the Tri-State District and Old Lead Belt were approximately the same size at 2,533 and 2,517 total square miles. The Old Lead Belt was the least rural district in terms of agricultural status with 67.23% of the total area dedicated to farmland. This may be due to the district's proximity to the growing city of St. Louis. The Tri-State District had the most area comprised of farmland (84.49%) followed by the Central District (86.23%). The Tri-State District had the highest literacy rate (95.43%); the Central District and Old Lead Belt fell below the state average at 94.25% and 90.88% (U.S. Census Bureau, 1913b). Access to healthcare varied between districts ranging from 98.34 – 127.28 number of physicians per 100,000, the Old Lead Belt with the least and Tri-State District with the most (Polk's Medical Register, 1917).

The Tri-State District had the highest percentage of 'other' ethnic individuals (0.04%) but had the lowest percentage of Black individuals (1.99%) (U.S. Census Bureau, 1913b). In contrast, the Central District had the highest percentage of Black individuals (4.27%) of all districts. The Old Lead Belt had a slightly lower percentage of Black individuals (3.56%) in its total population. All districts had a higher proportion of men to women than the state average, ranging from 51.26 – 52.20% (U.S. Census Bureau, 1913b).

This information provides a deeper understanding of the everyday Missourian within each district. In addition, these variables provide information regarding potential disease transmission and prevalence. The number of physicians per 100,000 provides a measurement of access to healthcare as does total area dedicated to farmland because it allows for an estimate of rurality. It is widely known that access to healthcare influences health outcomes, as does rurality since it directly influences access to healthcare itself (Smith et al., 2006). Socioeconomic status (SES) influences access to healthcare, as individuals with low SES may not be able to afford care and receive more poor-quality health care. Literacy rate provides an indication of SES within this study, as individuals with low SES tend to receive lower-quality education compared to individuals with high SES. Ethnicity provides insight on healthcare access as well, as the vast majority of non-White individuals during this time period had a low SES due to unequal human rights; the Civil Rights Act outlawing discrimination based on race, color, religion, sex, and national origin was not enacted until 1964. Shifting discussion from socioeconomic status, the largest non-biological factor that influences influenza transmission within a community is population density. The greater the number of people in one area, the more person to person contact will occur – which is the main infection pathway for influenza (Tarwater & Martin, 2001). Each mining district consists of unique characteristics that influence the spread of infectious disease, specifically the 1918 influenza pandemic which will be discussed in depth in the following chapter.

CHAPTER 3: THE 1918 INFLUENZA PANDEMIC

The influenza virus responsible for the 1918 pandemic was especially virulent, as the case-fatality rates were >2.5% compared to <0.1% in previous influenza pandemics (Taubenberger & Morens, 2006). While this pandemic continues to have the highest mortality of any global event, it is important to note that the pandemic occurred during World War 1, which greatly impacted everyday life itself with approximately 20 million deaths and 21 million individuals wounded (Mougel, 2011). This chapter will cover the pathology of influenza, provide a brief summary of the 1918 influenza pandemic on a global scale, discuss the impact of the pandemic on the entire state of Missouri, and briefly review previous research on the impact of the pandemic within the mining industry.

Influenza and the Influenza Virus

Influenza is transmitted by droplets containing the influenza virus. These droplets are mainly spread by direct person-to-person contact, with the infected sneezing or coughing while in close proximity to a non-infected individual. Another possible route of transmission is through indirect contact, such as touching the surface sneezed or coughed on by an infected person. Either way, the droplets must find their way into the mucosal membranes of the eyes, nose, or mouth of healthy individuals to infect them. Once the virus makes its way into the body, it enters healthy cells within which its reproduction occurs (Centers for Disease Control and Prevention [CDC], 2022). A major advantage of the virus is the large window of time for influenza transmission to occur; healthy adults are contagious 1 day prior to symptom onset until 5-7 days after, while children and immunocompromised individuals may remain contagious over 7 days (CDC, 2022).

Influenza is typically diagnosed by the establishment of common symptoms associated with the disease; the diagnosis is strengthened if influenza was already reported in the area. Symptoms typically begin to occur 1-4 days after exposure and have an abrupt onset (CDC, 2022). They can include fever, chills, cough, sore throat, runny or stuffy nose, muscle/body aches, headaches, and tiredness. It is important to note that not all individuals with influenza develop a fever and other less common symptoms may also occur. These include vomiting and diarrhea. Fever and other symptoms that affect the entire body rather than a specific area last 2-5 days after onset (CDC, 2022). All other symptoms, particularly respiratory symptoms, take more time to diminish and can last up to several weeks after onset. The severity of symptoms depends mainly on the type of influenza virus and medical history of the patient (CDC, 2022). Like all diseases, individuals that are at a higher risk for developing more severe symptoms are those with weakened immune systems. This includes but is not limited to infants and young children, pregnant women, older adults over the age of 65, obese persons, and individuals with autoimmune disorders.

Three influenza viruses occur in humans: A, B, and C (CDC, 2022). All are single-stranded RNA viruses classified in the Orthomyxovirus family that are spherical in shape and have spikes which are used to attach to healthy cells within the body (Reid & Taubenberger, 2003; Taubenberger et al., 2005). Each virus can be determined by its genetic material; envelope proteins and length of genome are commonly used to differentiate types (Bouvier & Palese, 2008). Additionally, each virus has its own general clinical characteristics.

Influenza A viruses are the most common and are the only influenza viruses known to cause pandemics. These viruses infect all humans and some animals, causing moderate to severe illness. Type A has multiple subtypes because it is constantly altering its genetic material when reproducing in the cells of the infected individual (Treanor, 2004; Crawford, 2018). Influenza A viruses are divided into two subtypes based on two proteins found on the surface of the virus: hemagglutinin (H) and neuraminidase (N) (CDC, 2022). There are 18 hemagglutinin subtypes and 11 neuraminidase subtypes. The 1918 influenza virus was type A and denoted as H1N1 (CDC, 2022).

Influenza B is the second most common influenza virus and primarily affects children, causing mild to moderate illness (Bhat, 2020). Both influenza A and B cause seasonal influenza epidemics (CDC, 2022). Recent data shows that seals can be infected by influenza B viruses as well (Bodewes et al., 2013). Influenza C affects humans, pigs, dogs and cattle; however, it is rarely reported among humans due to the lack of disease severity and is not thought to be of major public health concern (Manuguerra & Hannoun, 1992; WHO, 2018a; Yuanji et al., 1983; Zhang et al., 2018).

Influenza occurs throughout the world, affecting up to a billion people per year (Girard et al., 2005). It is considered a seasonal disease in temperate regions, typically occurring at high frequencies in the winter; heavily affecting the northern hemisphere from November-April and the southern hemisphere from April-September (WHO, 2018b). This is not to say that individuals cannot be diagnosed with influenza outside of these time frames in their respective geographic location, only that there is a higher probability of an individual contracting the disease during the winter. There is no clear seasonal pattern of influenza prevalence in tropical regions as there is in temperate regions (WHO, 2018b). The disease is prevalent year-round, typically having several peaks during rainy/wet seasons. Rainy seasons typically occur during the summer months, while dry seasons occur during the winter.

Bedford et al. (2015) state that global circulation patterns of seasonal influenza viruses occurring simultaneously vary with antigenic drift (random small changes in the virus), as faster antigenic drift results in greater disease incidence and more adult infections. Additionally, evidence supports the hypothesis that less geographical movement of influenza A and B viruses correspond with slower rates of antigenic drift, lower ages of infection, and less frequent, smaller-scale epidemics (Bedford et al., 2015). Kenah et al. (2011) discuss how varying patterns of influenza seasonality in different regions of the world directly affect global influenza transmission, particularly in regard to vaccination timing and effort. Tamerius et al. (2011) continued similar research, concluding that future research is needed for tropical regions due to insufficient understanding of influenza seasonality in those particular areas.

To fully understand the geographical distribution of a disease, it is important to consider how disease spreads at the community level. Influenza viruses do not choose which individuals they infect; however, there are outside factors that influence disease spread. As with most diseases, individuals that have lower socioeconomic status have higher influenza morbidity and mortality rates (Hadler et al., 2016). Access to healthcare in 1918 may have been limited for individuals with lower socioeconomic status due to the inability to pay physician fees or lack of reliable transportation. Health insurance was not common at this time either (Institute of Medicine, 1993). Poor nutritional status lowers the immune system's ability to fight infection (Maggini, et al., 2018). Frontline jobs, such as cashiers and clerks, that require workers to be in close proximity to customers, tend to be occupied by individuals with low socioeconomic status. These individuals typically live in denser populated areas as well. An increase of indirect and direct contact with various germs corresponds with increased population density (Tarwater & Martin, 2001). Furthermore, areas with high population densities and/or low socioeconomic individuals tend to be less sanitary, likely due to lack of investment in and development of infrastructure (Moore et al., 2003). While these conditions are primarily referring to present populations, it is assumed individuals in 1918 also experienced these kinds of risks.

The largest non-biological factor that influences influenza transmission within a community is population density. The greater the number of people in one area, the more person to person contact will occur – which is the main infection pathway (Tarwater & Martin, 2001). This argument can be used for any area that had high human traffic in 1918, such as train stations, schools, grocery stores, etc. Mass travel via boat and train had a large impact on disease transmission, allowing organisms to reach locations and new environments that would not have been plausible otherwise. This includes the wartime use of mass transit due to WW1 during this time, as war facilitated the dissemination of influenza due to crowded conditions of military camps and trenches, followed by surviving members of war returning home and potentially spreading disease to civilians (Byerly, 2010). This disease spread has the potential to be extremely harmful, as a community might not have any immunity to a novel strain of influenza virus.

It is important to acknowledge the involvement of other species when discussing geographic distribution and transmission factors, as approximately 60% of emerging infectious diseases are zoonotic, meaning that the pathogen originated in animals then spilled over into the human population (Jones et al., 2008). The most commonly recognized zoonotic influenza hosts include pig, bird, and bat. The origin of many zoonotic diseases is traced to geographic locations that have high consumption rates of these animal hosts along with decreased sanitation levels

(Institute of Medicine & National Research Council, 2009). These factors are directly related to cultural differences between populations, which is a main driver for the geographic variability of zoonotic influenza once the disease is introduced into the population. Ecological factors influence for the geographic variability of zoonotic influenza as well, as research indicates that avian influenza virus H5N1 outbreaks are closely associated with known bird migration routes (Tian et al., 2014).

Reperant et al. (2012) list three sets of barriers that must be crossed by a zoonotic influenza virus: animal-to-human transmission barriers, virus-cell interaction barriers, and human-to-human transmission barriers. In order to cross these barriers, adaptive changes within the virus must occur. Overall, increased exposure to various animals increases the probability that a zoonotic disease will be transmitted. Peiris et al. (2016) discuss how live poultry markets in China promoted the spread of avian influenza A H7N9. Consistent close contact with birds and their bodily fluids allowed these areas to become hotspots for influenza transmission. The same is seen within the swine industry; workers have an increased risk of infection due to their close proximity with pigs (Myers et al., 2006). This concentration of infections can lead to increased geographic variability, with certain areas and/or populations having higher concentrations of animals and more human-animal interaction.

The 1918 Influenza Pandemic Globally

The term "Spanish flu" is often used for the 1918 pandemic, but both it and the term "1918 influenza pandemic" are misnomers. The 1918 influenza pandemic occurred over several years—initial cases occurred in Spring 1918 and continued until Spring 1919 or 1920 depending on location (Ansart et al., 2009; Crosby, 2003; Johnson & Mueller, 2002; Sattenspiel, 2011;

Yang et al., 2014). The alternate name "Spanish Flu" gained popularity at the time as Spain remained neutral during World War 1 and did not impose wartime news censorship, causing Spanish news to become the most reliable outlet to provide information about the ongoing pandemic (Taubenberger et al., 2005). The exact origin of the 1918 influenza remains unknown; different theories, however, have proposed that the 1918 influenza began in France, China, Vietnam, or in the U.S. (Barry, 2004).

It is important to note that many geographical locations experienced the pandemic differently when compared to each other in terms of mortality rates and timing/absence of certain waves. This is likely due to differences in wartime involvement, public health infrastructure, and cultural customs that affect health outcomes. For example, mortality rates ranged from 12 per 10,000 individuals in Argentina to 4,450 per 10,000 individuals in Cameroon (Johnson & Mueller, 2002).

The global 1918 influenza pandemic has most often been thought to occur in three rapid waves (Crosby, 2003; Taubenberger & Morens, 2006). The first wave began in March of 1918 and lasted throughout the spring; this wave was the least lethal wave and exhibited relatively low mortality rates; however, many locations did not experience the first wave until the summer of 1918 (Sattenspiel, 2011; Andreasen et al., 2008). The second and most significant wave occurred in the fall of 1918, beginning in September and often ending around the end of 1918, although it extended into 1919 in many locations. The majority of deaths during the pandemic were associated with this wave. The third wave, which was not experienced everywhere, generally occurred in the late winter beginning in February and ending in April 1919. This wave was less virulent than the second and more variable in appearance, but more fatal than the first wave (Taubenberger & Morens, 2006). A growing body of recent research suggests that many regions, including the U.S. State of Missouri, experienced a fourth wave of the pandemic in 1920 (Ansart et al., 2009; Crosby, 2003; Johnson & Mueller, 2002; Sattenspiel, 2011; Yang et al., 2014); however, it remains unclear whether this later peak in influenza mortality was actually a fourth wave of the 1918 strain or another epidemic associated with a different strain of the influenza virus (Johnson & Mueller, 2002).

While influenza was a known disease at the time, physicians did not diagnose initial cases as influenza since no influenza strain prior to the 1918 pandemic was as virulent with such high mortality rates. Initial speculation for disease diagnoses included trench fever, dengue, anthrax, cholera, and plague (Crosby, 2003; Johnson, 2006; Tognotti, 2003). With so many individuals infected and dying in rapid succession, the healthcare and funerary industries experienced an overwhelming demand for services (Hobday & Cason, 2009). A large number of doctors and nurses were called into the military service due to World War 1 and/or became sick themselves, further increasing the burden of stress on the healthcare industry for civilians (Crosby, 2003). Many hospitals had to turn away patients due to already reaching their maximum capacity (Hobday & Cason, 2009).

There was no standard treatment for those that came down with this influenza strain. Many healthcare providers experimented with a variety of remedies including aspirin, mustard poultice, quinine, tobacco, beef tea, zinc sulfate, opium, salt water, and alcohol (Rice & Palmer, 1993; Johnson, 2006; Starko, 2009; Keeling, 2010; Short et al., 2018). Nursing care greatly improved the recovery of patients (Robinson 1990), likely due to sufficient supportive care being provided, such as fluid replacement. No ventilation machines or intensive care units existed at this time. Non-pharmaceutical interventions for the pandemic included isolation of those infected, restrictions on mass gatherings (including closures of churches and schools), implementation of facemask requirements, and increased hygiene efforts at the city and county levels (Crosby, 2003; Johnson, 2006; Short et al., 2018).

In a typical influenza epidemic, the age-specific death rates tend to produce a U-shaped curve, with the highest mortality occurring in young children and older individuals with weak immune systems that could not overcome the virus. All other age categories experience a comparatively low rate of deaths. The 1918 pandemic is unique among influenza outbreaks – the age-specific mortality curve was W-shaped. This curve is similar to the U-shaped curve with high mortality in young and old individuals, but has an additional third mortality peak in young adults approximately 20-40 years of age (Taubenberger & Morens, 2006). This mortality peak was striking, as influenza and pneumonia[2] death rates for this age range were more than 20 times higher than previous years and accounted for approximately half of all influenza deaths within the pandemic (Taubenberger et al., 2000; Taubenberger & Morens, 2006). Additionally, individuals 65 years and under accounted for the vast majority (99%) of excess influenza mortality in the 1918 pandemic (Taubenberger & Morens, 2006). This was shocking, as individuals 65 years and older experienced the majority of excess influenza deaths in typical pandemics. Some have suggested this third mortality peak may be caused by these individuals, now 20-40 years old, being infected by a the 1889-1892 influenza pandemic strain which predisposed them to a more severe outcome in the 1918 influenza pandemic (Gagnon et al., 2013; Shanks et al., 2012).

[2] Pneumonia deaths should be included when discussing influenza mortality during this time period as many individuals died from secondary pneumonia infection caused by opportunistic bacteria (Morens et al., 2008).

Missouri and the 1918 Influenza Pandemic

The pandemic pattern in Missouri differed from the standard 3-wave pattern described by Crosby (2003), but was similar to several other regions around the world. The presence of influenza in the Spring of 1918 is apparent in Missouri; however, the excess influenza mortality at this time was minimal, suggesting little impact on the everyday life of a Missourian. The main wave struck Missouri in September 1918, causing mandatory social distancing and closures of many non-essential businesses in major cities (McKinsey et al., 2018). The main wave for the entire state was bimodal; the first peak occurred in November followed by a slightly higher second peak in December (Figure 3.1). There may have been a third peak occurring in the main wave in late March, although it had a significantly lower impact compared to those before. An echo wave occurred between January and April 1920.

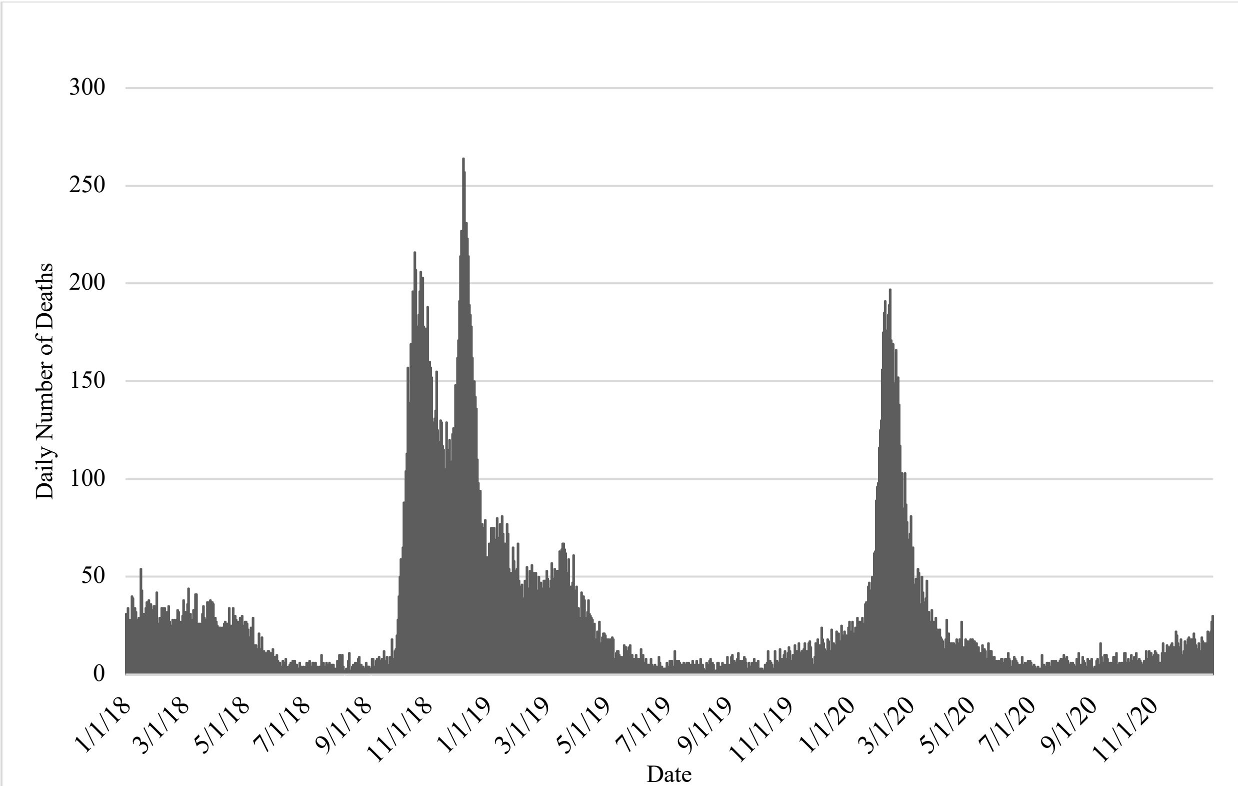


Figure 3.1. Daily number of deaths due to influenza and pneumonia in Missouri for 1918-1920.

All districts within Missouri experienced increased disease burden throughout the pandemic and felt the pressure to provide care while resources were limited (McKinsey et al., 2018). Nurses were in short supply specifically, as some were overseas helping in the ongoing war and others contracted the disease themselves from patients. Schools and universities were heavily impacted as well (McKinsey et al., 2018). The three medical schools of the time all graduated their classes early to increase the healthcare workforce. Public school systems cancelled classes for weeks at a time. The University of Missouri was quarantined twice, along with cancelling the entire 1918 football season (McKinsey et al., 2018).

Similar to other parts of the world, Missouri experienced a W-shaped age-specific mortality curve with high mortality in young children, young adults approximately 20-40 years of age, and individuals 65 years and older. St. Louis and Kansas City had the highest number of deaths within any city in Missouri, likely due to the high population density for each municipality promoting disease transmission. More detailed analysis of the pandemic in Missouri will be discussed in Chapter 5 in order to have a better understanding of how mining districts in Missouri were impacted by the 1918 influenza pandemic.

Mining and the 1918 Influenza Pandemic

Little research focusing on the impact of the 1918 influenza pandemic on mining can be found, likely due to the lack of historical documentation associated with the occupation during this time. One notable study was that of Starr (1920), who analyzed the impact of the 1918 influenza pandemic within coal miners in Ohio, USA. The influenza mortality rate among miners almost doubled in 1918 (19.2 per 1,000) compared to the year prior (11.1). Additionally, 83% of the total deaths from influenza and pneumonia among coal miners in 1917 and 1918 occurred within the 15-44 age range. Tuberculosis was the only infectious disease that had a higher number of total deaths within Ohio coal miners (Starr, 1920). Phimister (1973) found that the influenza-related mortality rate was approximately four times higher in mining compounds (9.2%) than in villages (2.3%) in Rhodesia. These findings are not surprising, as the mortality peak in young adults aged approximately 20-44 is well documented in the 1918 influenza pandemic (Taubenberger & Morens, 2006).

Miners -consumption, -con, -lungs, -puff, and -asthma are all terms used to describe lung-related illnesses due to constant inhalation of mineral particles or dust (Huffman, 1910). It is important to note that influenza was not the only respiratory illness within the mining community that had symptoms which could have been described as miners consumption. Tuberculosis usually affects the lungs and was likely called by these terms within the mining industry as well. It is probable that individuals infected with tuberculosis assumed they had simply developed miners consumption rather than an infectious disease and continued to spread the disease in the workplace, explaining the high rates of tuberculosis among miners. Tuberculosis was extremely prevalent within mining operations in Missouri specifically. After a steady increase in tuberculosis prevalence, Dr. Anthony J. Lanza, an assistant surgeon of the United States Public Health Service, joined Edwin Higgins, a mining engineer from the Bureau of Mines, to investigate health disparities in miners working within the Tri-State District in 1914 (Lanza & Higgens, 1915). Ethnographic records described the working conditions in the mines as small and cramped, providing an excellent environment for the transmission for infectious diseases such as influenza and tuberculosis.

No information regarding the exact ages or age range of miners are available, limiting the amount of age-specific analyses that could be conducted within this project. It can be assumed the youngest age of hire within the mining industry after 1916 was 16, as the Keating-Owen Act of 1916 banned the sale of products from any mine that employed children under the age of 16. Additionally, mining is extremely labor-intensive. Physically mature men are capable of developing much more muscle mass than boys that have not reached maturity, causing mature men to be of more value within mining operations. No women worked in the mines (Lanza & Higgens, 1915).

Possible Influence of Lead Exposure on Mortality

Lead can negatively affect almost all organs and systems within the human body. Those most susceptible to the effects of lead are children six years old and younger (U.S. Environmental Protection Agency [EPA], 2022). Low levels of lead found in blood can result in behavioral and learning problems, lower IQ and hyperactivity, slowed growth, hearing problems, and anemia. More severe cases can result in seizures, coma, and death. Pregnant women and the developing fetus are at a high risk of experiencing the negative side effects of lead exposure, and in addition, the baby may be born prematurely. Other consequences include an increased likelihood of behavioral and learning problems in the child, compromised development of the baby's brain and nervous system, and an increased likelihood of the mother having a miscarriage. It is important to note that a mother can expose her child to lead both in utero and via breastfeeding. Adults exposed to lead can experience hypertension, decreased kidney function, and reproductive problems (EPA, 2022).

Lead exposure was not monitored or controlled during the time of the 1918 influenza pandemic. Restrictions and efforts to reduce lead concentration in gasoline, paint, toys and other consumer goods, foods, and water did not begin until the 1930s (Dignam et al., 2019). It was not until 1971, through the Occupational Safety and Health Administration (OSHA) Act of 1970, that an exposure limit for the workplace was created (Dignam et al., 2019). Additionally, lead pipes were commonly used in the early 1900s due to the material's pliability and relative resistance to corrosion (Costa, 2007). The CDC did not begin monitoring blood lead levels in individuals until 1976 using the most advanced technology for the time (CDC, 2021).

It is plausible that communities living within the Tri-State District, Central District, and Old Lead Belt were exposed to higher levels of lead compared to regions within Missouri that did not have a high concentration of lead-zinc mining. Furthermore, it is plausible that increased levels of lead exposure within the mining districts may have weakened the immune systems of residents – specifically miners who were often working in enclosed spaces surrounded by dust that may have contained lead. No further analysis regarding the potential influence of lead exposure on mortality among miners and residents within these mining communities was conducted due to the lack of historical documentation on the subject; however, it is important to note the possibility that such influence may have occurred.

CHAPTER 4: METHODS

As stated in previous chapters, the objective of this study is to examine the impact of the 1918 influenza pandemic in lead/zinc mining districts in Missouri. In order to execute this, demographic information and mortality data were collected. The results for each district will be analyzed and compared to each other in Chapter 5. Additionally, these results will be used to evaluate the study's hypothesis. This chapter will describe the data collection efforts and evaluation methods utilized for this study.

Data Collection

Primary data was collected for 1918 – 1920 influenza mortality from publicly available death records in the Missouri Digital Heritage Project (https://s1.sos.mo.gov/records/Archives/ArchivesMvc/DeathCertificates). Information on death certificates was input manually into a database that included all deaths from influenza and pneumonia occurring in the state of Missouri between 1918 and 1920. Variations for influenza as a cause of death include flu, Spanish influenza/flu, enfluenza, and La Grippe. Deaths from pneumonia that do not mention influenza were only collected if they listed no other infectious cause of death. Hypostatic and surgery pneumonias were also not included as these categories represent non-infectious pneumonias and are outside the scope of this study. Deaths caused by pneumonia and tuberculosis simultaneously were included due to the established association between pneumonia and tuberculosis mortality within the 1918 influenza pandemic (Noymer, 2009; Mamelund & Dimka, 2019). Baseline deaths for 1910 were collected in the same manner, with the exception of including deaths caused by pneumonia and tuberculosis simultaneously.

The selection of socioeconomic variables was driven by the goal to investigate how the experiences of individuals living in various mining districts during a major pandemic differ from those living in other districts within the state. Demographic and socioeconomic data for each district was needed to better understand/quantify characteristics that may underlie observed patterns of spread of a pandemic. This information was primarily collected from the 1910 Missouri Supplemental Census. Physician counts were collected from the 1917 Polk's Medical Register and Directory. The number of physicians per 100,000 for each county was calculated by dividing the number of number of physicians in the county by the county population then multiplied by 100,000 to allow for easier comparison of data. Information regarding mining operations was collected from the Missouri Department of Natural Resources and the 1918 Annual Report of the Bureau of Mines.

Constraints

The largest challenge associated with the 1918 data was the limited number of reliable resources available due to the lack of historical documentation of relevance to infectious disease transmission that was retained from this time period. The information used to describe the demographic structure of Missouri in 1918 was collected from the 1910 Missouri census as this document is the closest census prior to the pandemic. The United States Census Bureau only produces decennial censuses for each state. The 1920 Census was closer in time to the pandemic, but it was not chosen to represent this time period as it reflects major demographic changes caused by the 1918 influenza pandemic and World War I.

Death certificates were not required by law in Missouri until 1909 (Missouri Secretary of State, 2022). While this law was enacted at the time of the 1918 influenza pandemic, it is likely that compliance was not universal throughout the state at the time. Some deaths during this time period may not have been assigned a death certificate and would not have been included in this study.

County level data was especially sparse for this time period. State level data was more easily accessible, but could not provide enough information to understand how the experiences of individuals living in various mining districts differ as the data available is aggregated. Counties containing cities with inhabitants of 25,000 or more had more detailed data available, likely due to the larger populations presenting higher variability compared to the rest of the state and more resources available to support historical documentation within the region.

It is probable that census data regarding Black Americans is biased/skewed as Black individuals did not have the same rights or treatment as White individuals during this time; the Civil Rights Act outlawing discrimination based on race, color, religion, sex, and national origin was not enacted until 1964. Similar issues may have impacted data on other underrepresented groups. It is likely that death counts of underrepresented groups were underestimated for similar reasons, and in addition, regulations requiring death registration were just becoming widespread at the time of the pandemic, so that deaths of young individuals especially may have been under-recorded (Missouri Department of Health & Senior Services, 2021). Another type of bias is illustrated by the literacy rate — estimates provided by the 1910 Missouri census only took men of voting age into consideration, which may be problematic as a vast majority of the population was not taken into account.

Polk's Medical Register and Directory (1917) was the only document available containing data that could be used to quantify healthcare accessibility for this time period. These results may be inflated as all types of healthcare providers were conflated into the umbrella terms of physician or surgeon compared to major specializations seen in the current day (e.g., nurse practitioners, dietitians, etc.). No documents describing the economy of Missouri in detail were available; the only applicable economic information discovered was the average value of all farm property per county provided by the 1910 Missouri Census. Limited information regarding transportation usage was available. While it may have been possible to examine the influence of transportation on disease transmission as done in previous studies (Palmer et al., 2007; Muley et al., 2020), this idea was not pursued as the Missouri Department of Transportation was unable to access their physical archives due to COVID-19 social distancing mandates. The main mode of public transportation in the beginning of the 1900s was by train; however, railroads were not used publicly during 1917– 1920 as they were seized by the federal government for World War 1 efforts (Association of American Railroads, 2021).

County Selection

Each district is comprised of varying numbers of counties; four counties from each district were chosen as representatives to ensure each district was compared appropriately. The Department of Natural Resources (2021) and the 1918 *Mining and Mine Inspection of the State of Missouri* were utilized to make this selection. The 1918 Annual Report of the Bureau of Mines provided a list of lead-zinc mining operations by county for the Western and Eastern districts, including the number of employees for each mining operation. The Western District indicated by the report was for the Tri-State District and the Eastern District was for the Old Lead Belt. Four counties with the highest number of employees were chosen to represent the district as this indicated these counties had the most involvement in mining operations. The 1918 Annual Report of the Bureau of Mines did not include the Central District; no explanation for this was provided. A likely reason for this exclusion is that the Tri-State District and Old Lead Belt were of primary concern by inspectors, as these districts produced much more lead-zinc product than the Central District (Park, 2005). The four counties chosen to represent the Central District were determined using a map illustrating historical mining operations provided by the Department of Natural Resources (2021).

Due to the variation in demographics between mining districts, a comparison group of four clustered non-mining counties that was similar demographically and socioeconomically (other than major occupation) could not be identified. For example, all three mining districts have different proportions of individuals living in urban/rural counties. Thus, the three mining districts are discussed in comparison to each other and to the state as a whole.

Data Analysis

Counties were considered to be either urban or rural based on whether or not the majority (50%) of the population within the county lived in urban areas as defined by the Census (places of 2,500 or more inhabitants). Estimation of rurality for each county was determined by dividing the area of farmland by total area.

All mining district comparisons included all four mining representative counties for each district as listed in Table 2.1. Weekly deaths were evaluated as both counts and rates. Rates were calculated by dividing the total death count by total population for the entire district and multiplying the result by 100,000. The age distribution of deaths was calculated by dividing the total number of deaths within the age group by the total number of deaths of the entire district then multiplied by 100 in order to be viewed as a percent.

Age specific death rates were calculated by dividing the total number of deaths per age category by the expected number of individuals within the population, then multiplied by 100,000 to allow for easier comparison. As the census did not provide counts of individuals within each age group per county, these values were calculated using the age breakdown for the entire state. The total expected urban and rural inhabitants within each county were calculated by multiplying the percentage of inhabitants living in urban and rural areas by the total county population. Urban and rural expected age proportions per age category for the state were then multiplied by the total expected urban and rural inhabitants within each county, and the urban and rural numbers for each age group were then added together to provide the final estimated number of individuals within each age group per county. This procedure minimized the degree of assumption utilized within this calculation while recognizing the high level of variability in county composition.

The 1910 age breakdown for the state was utilized for both the 1910 and 1918 ASDRs. The 1910 ASDRs utilized deaths that occurred within 1910, while the 1918 ASDRs utilized deaths that occurred in 1918-1920. Excess ASDRs were calculated by subtracting the 1910 ASDR values from the 1918 ASDR values.

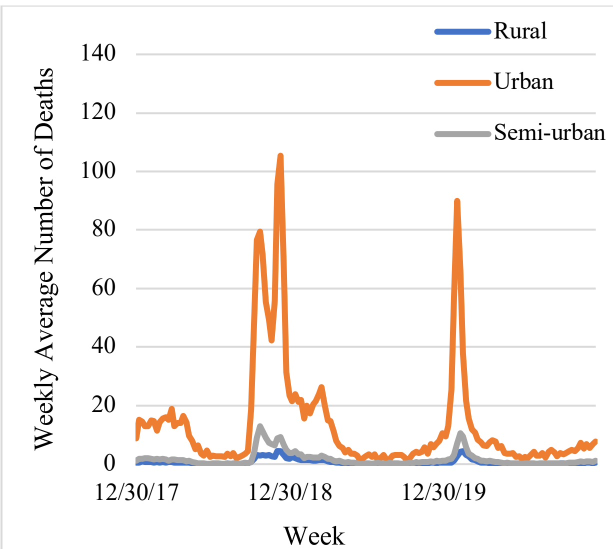
CHAPTER 5: RESULTS & DISCUSSION

The main goal of this project was to assess the impact of a specific occupational risk, mining of lead and other minerals, on influenza transmission and severity during the 1918 influenza pandemic. This chapter begins by analyzing the impact of the 1918 influenza pandemic in Missouri as a whole, comparing mortality data for urban, rural, and semi-urban counties. Mortality data for the Tri-State District, Central District, and Old Lead Belt are then compared to each other, followed by an overall comparison to state statistics. The following chapter will provide a discussion of these results in relation to the hypotheses mentioned in Chapter 1, including a brief conclusion regarding the potential implications of such results. Appendix B provides the mortality data for each representative mining county, each mining district, and the state of Missouri.

Missouri and the 1918 Influenza Pandemic in Detail

As discussed in Chapter 3, Missouri differed from the common 3-wave pattern described by Crosby (2003). Missouri experienced a bimodal main wave, with the first peak in late October and a slightly higher second peak in early December (Figure 3.1). An echo wave occurred between January and April 1920. Substantial variation across counties was seen, as 26.32% of counties had a larger echo wave compared to the main wave. It is important to note that the echo wave in these counties have a higher peak but are narrower in width compared to the main wave.

The average number of deaths in entirely urban counties was approximately 20 times higher than in entirely rural counties throughout the pandemic (Figure 5.1a). Counties that were comprised of both urban and rural areas (labeled "semi-urban") experienced slightly higher average number of deaths compared to counties that were completely rural. This is not surprising, as urban areas have much larger population sizes compared to rural areas. Once standardized (Figure 5.1b), it is clear that urban counties experienced a higher disease burden on average compared to semi-urban and rural counties. This is clearly seen in the second peak of the bimodal wave in early December 1918 and the echo wave in early February 1920. Rural counties experienced the least mortality burden.



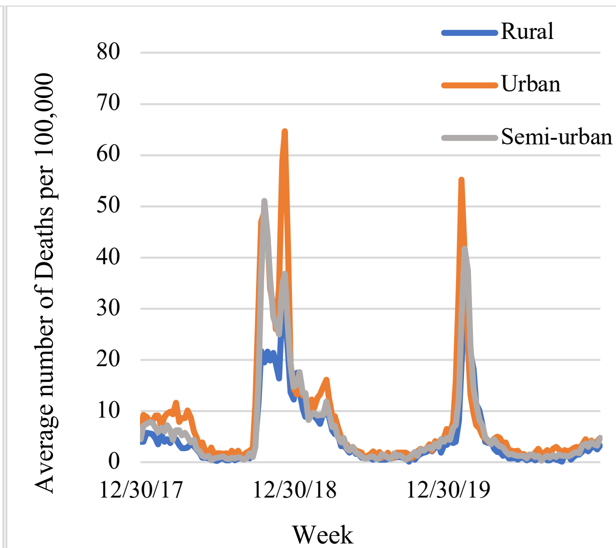


Figure 5.1. Weekly average number of deaths separated into rural, urban, and semi-urban categories: a) absolute numbers of deaths, b) deaths per 100,000 population.

Minimal variation of overall age specific mortality can be seen between urban, semi-urban, and rural counties (Figure 5.2); 0-4 years ranged 19.02-22.01%, 25-34 years ranged 16.02-21.59%, and 65 years and older ranged 13.08-19.44% of deaths. Rural counties experienced less mortality in the 20-44 year age categories, but had the highest in individuals 0-4 years and 65 years and older. This may be due to rural areas having less access to healthcare and the latter age categories having weaker immune systems on average. Semi-urban counties experienced slightly higher mortality in the 5-15 year age categories. Urban counties had the lowest mortality in the 0-19 year age categories, but experienced the highest in the 25-34 year age category. The latter may be explained by urban areas having a larger proportion of adults aged 25-34 years due to more work opportunities and opportunities for these individuals to congregate within larger cities.

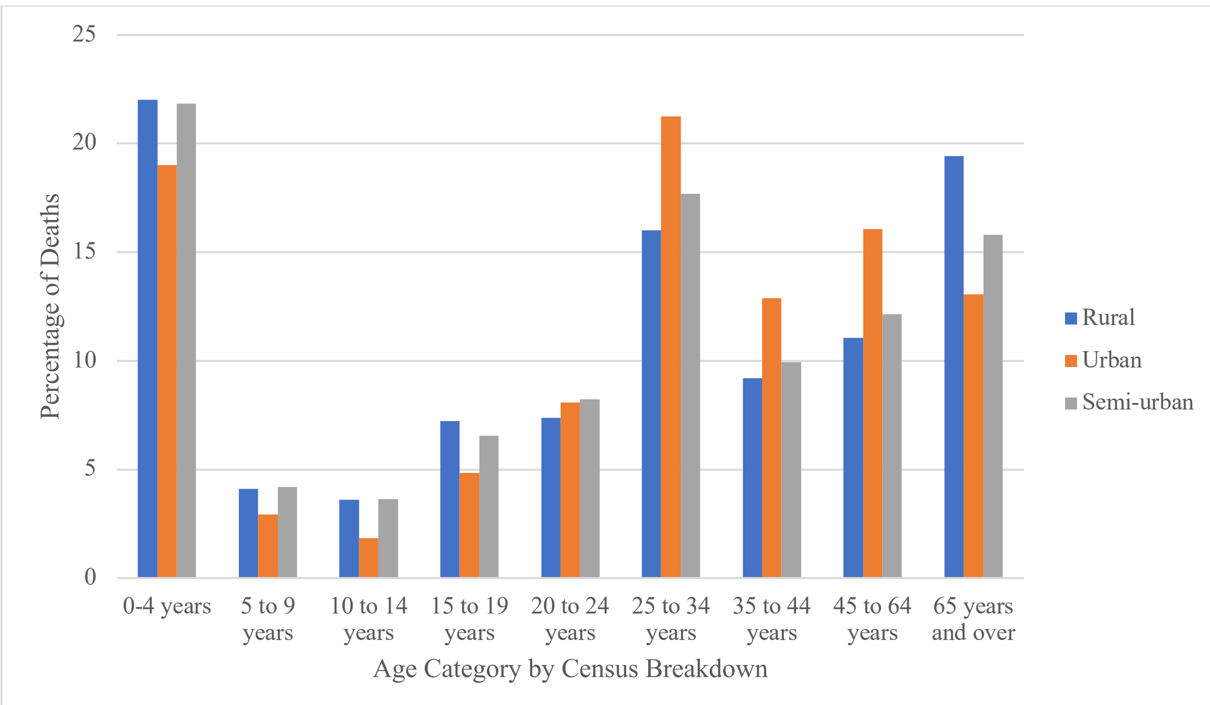


Figure 5.2. Age specific mortality percentages in rural, urban, and semi-urban counties in Missouri 1918-1920.

Excess age specific mortality rates, found by subtracting the 1910 baseline ASDRs from those of 1918, increased at least five-fold in all age categories (Figure 5.3). Overall, the age specific excess death rates for the entire state of Missouri followed the same distinctly W-shape observed in the age-specific influenza-related mortality curve; 0-4, 25-34, and 65 years and older had comparatively higher death rates. The largest difference between the baseline year and pandemic years was seen in the 25-34 year age category, in which the number of deaths were 30.18 times greater than 1910 baseline influenza and pneumonia deaths (Table 5.1). The smallest difference (4.50 times greater than baseline deaths) was noted in the 65 years and over age category followed by the 0-4 year age category (5.11), as the majority of deaths during a typical influenza epidemic tend to occur in the youngest and oldest individuals.

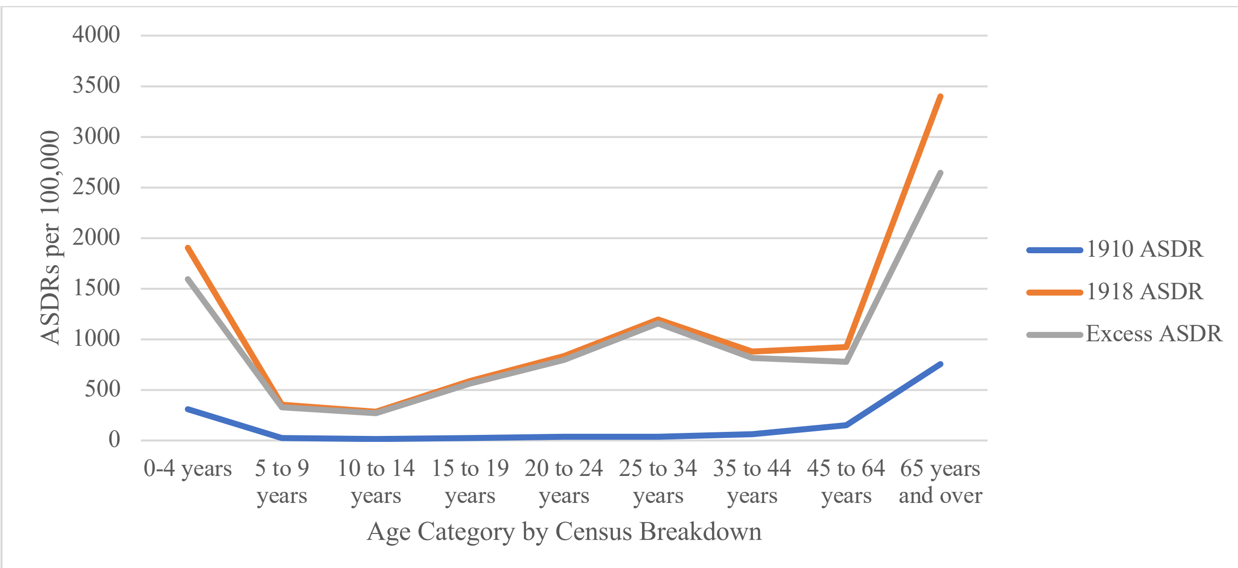


Figure 5.3. Comparison of 1910 baseline ASDRs, 1918-1920 ASDRs, and excess ASDRs for the 1918 influenza pandemic.

Table 5.1. Comparison of 1910 ASDRs, 1918 ASDRs, and number of times higher than baseline per age category for the state of Missouri.

Age Category	1910 ASDR	1918 ASDR	Number of Times Higher than Baseline
0-4 years	311.23	1902.90	6.11
5 to 9 years	25.43	352.42	13.86
10 to 14 years	14.50	284.09	19.60
15 to 19 years	26.04	587.90	22.57
20 to 24 years	36.59	834.04	22.79
25 to 34 years	39.56	1194.01	30.18
35 to 44 years	61.82	876.74	14.18
45 to 64 years	149.06	925.27	6.21
65 years and over	754.73	3399.60	4.50

Minimal variation of the excess age specific mortality curve shape for the 1918 influenza pandemic can be seen between urban, semi-urban, and rural counties (Figure 5.4). Rural counties had the lowest average excess mortality rates in all age categories, while urban counties had the highest. Semi-urban counties averages fell in-between those of rural and urban counties with the exception of the 10-14 year age category, which was marginally greater than the urban average.

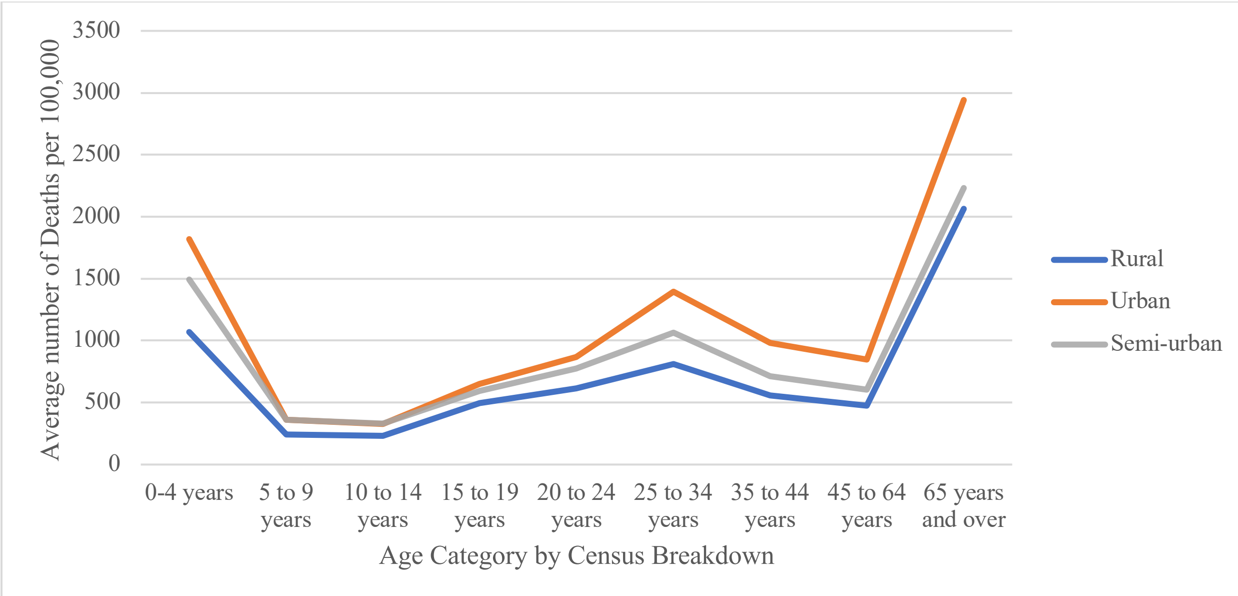


Figure 5.4. Comparison of average excess ASDRs in rural, urban, and semi-urban counties in Missouri 1918-1920.

A Comparison of Mining Districts

While 26.32% of counties within Missouri had a higher echo wave compared to the main wave during the pandemic, 10 out of the 12 (83.33%) representative mining counties in this study experienced a larger echo wave. Only Morgan county, located in the Central District, and St. Francois, located in the Old Lead Belt, experienced larger main waves. Overall, these counties did not share many demographic characteristics beyond both designated as rural. While this finding does show a potential correlation, it is not prominent as 7 out of the 10 (70%) counties that experienced a larger echo wave were designated rural as well.

The Tri-State District and Old Lead Belt clearly experienced bi-modal first waves with the first peak occurring in early October 1918 for the Tri-State District and in late October for the Old Lead Belt (Figure 5.5). The second peak occurred in the beginning of December for both districts. The Central District experienced one mortality peak within the main wave, occurring in mid- and early December. Less variation in timing and spread of the echo wave occurred, as all districts experienced an echo wave in early February 1920. This reduced variation may have occurred due to the disease already being in circulation within all districts.

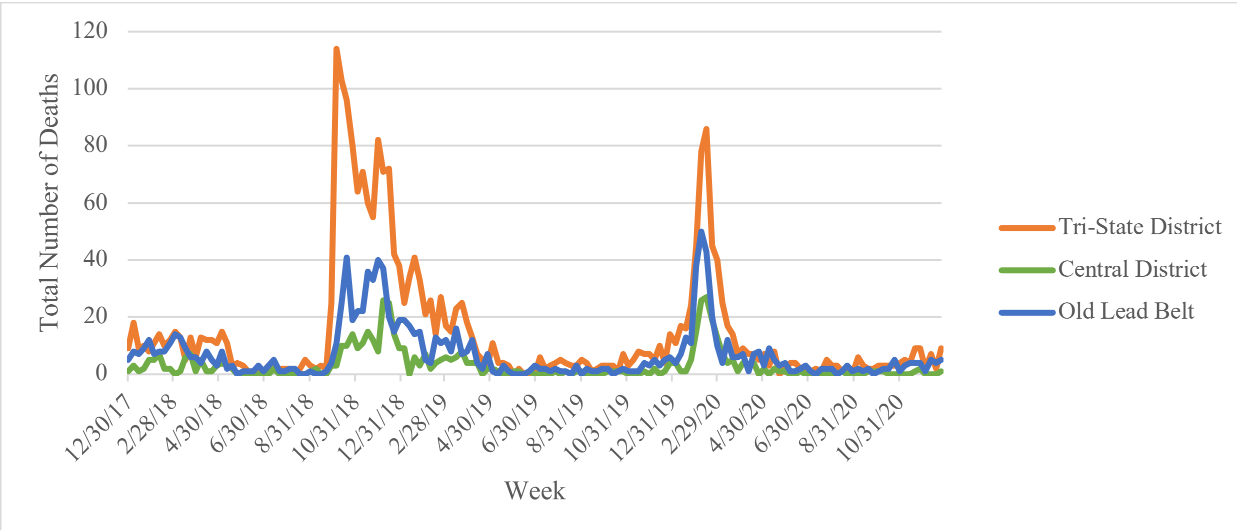


Figure 5.5. Weekly number of total deaths in mining districts.

The Tri-State District experienced the most deaths throughout the pandemic, followed by the Old Lead Belt then the Central District (Figure 5.5). This is expected, as this is the descending order of total population and population density for the mining districts. Once standardized (Figure 5.6), it is clear that the Tri-State District experienced the pandemic very differently compared to the Central District and Old Lead Belt in October 1918 with an increased number of 55.01 deaths per 100,000. Only slight variation is visible throughout the rest of the pandemic and within the echo wave, with deaths per 100,000 ranging from 37.64 - 47.75 in early February 1920. This is striking, as each of these districts are unique in terms of demographic characteristics that could affect disease transmission and severity.

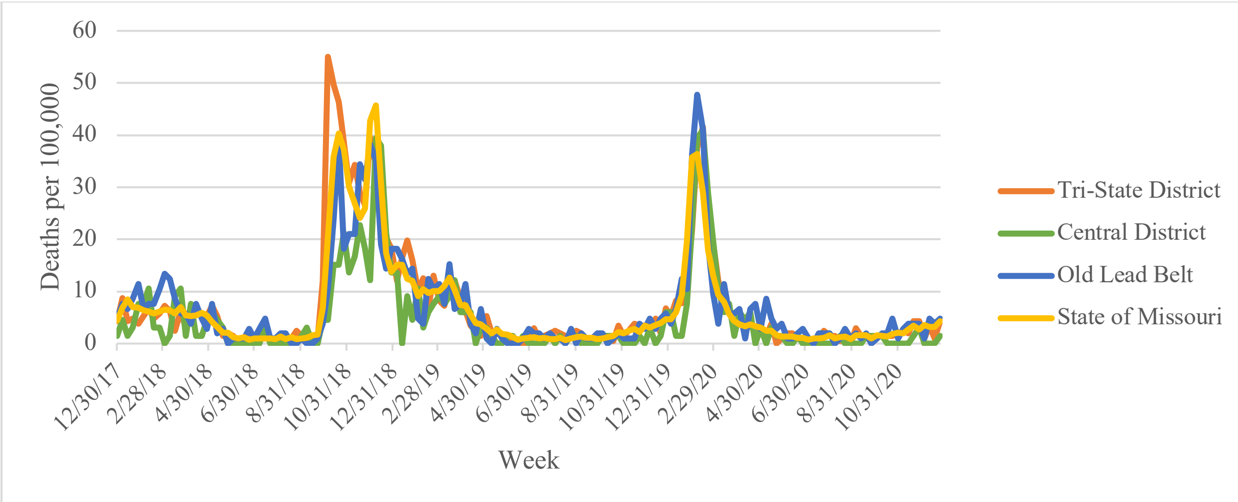


Figure 5.6. Standardized deaths per 100,000 for mining districts and the state of Missouri.

Variation in the age distribution of deaths occurred between mining districts (Figure 5.7). The most noticeable variation is seen within the 0-4 years group with the Central District (15.88%) experiencing approximately half the proportion of deaths observed in the Old Lead Belt (29.06%). The Tri-State district was slightly higher than the Central District with 18.74%. The 25-34 year age category had significant variation as well, with the Old Lead Belt (15.36%) having a much lower proportion of deaths compared to the Tri-State (22.57%) and Central Districts (20.17%). All representative counties in the Old Lead Belt are rural, which may explain this phenomenon as urban areas tend to have higher proportions of working-aged adults. All other age categories experienced less variation ranging from 1.33% (10-14 years) to 5.12% (15-19 years). The three age categories that had the highest proportion of deaths in all three mining districts were 0-4 years, 25-34 years, and 65 years and older. This follows the W-shaped age-specific mortality curve unique to this pandemic as described in Chapter 3.

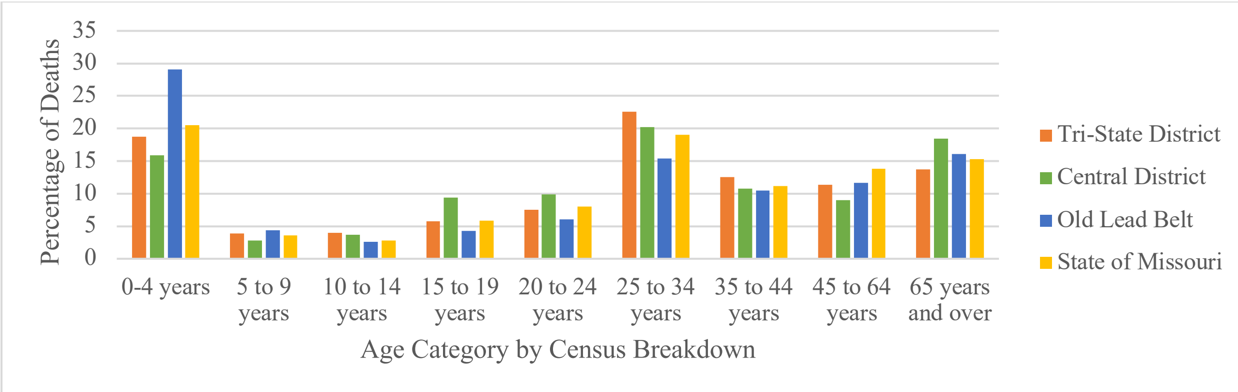


Figure 5.7. Age specific mortality percentages in mining districts and the state of Missouri.

As expected, the 1910 baseline ASDRs for all mining districts followed the typical U-shape mortality curve for influenza epidemics with highest mortality occurring in young children (0-4 years) and older individuals (65 years and older) (Figure 5.8). Overall, minor variation can be seen between the 1910 ASDRs with the exception of the 65 years and older age category for the Central District (393.33) which was significantly lower than the Tri-State District (655.90) and Old Lead Belt (885.22). The 1918 ASDRs followed a W-shaped age-specific mortality curve with three peaks at the 0-4 year, 25-34 year, and 65 year and older age categories (Figure 5.9).

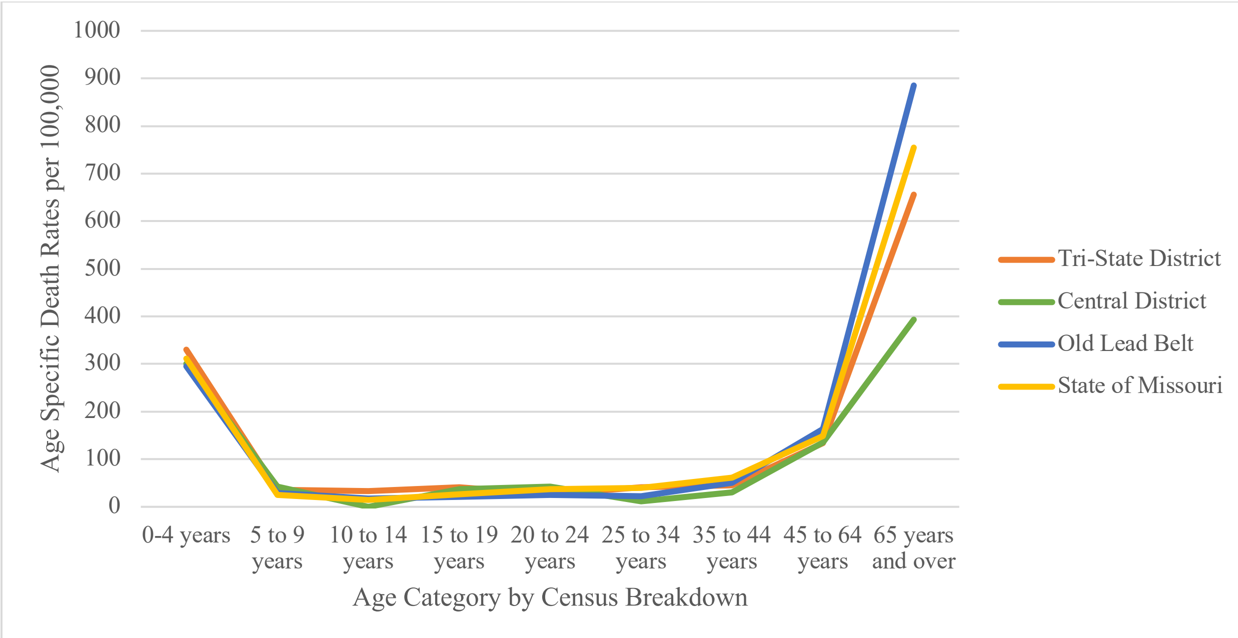


Figure 5.8. 1910 baseline ASDRs for mining districts and the state of Missouri.

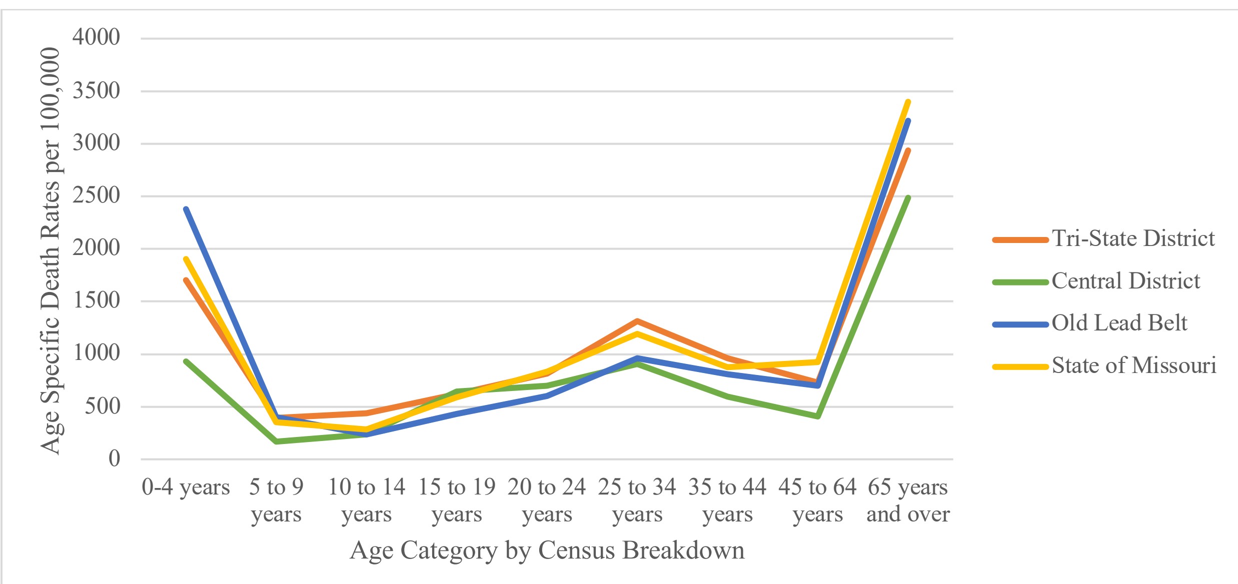


Figure 5.9. 1918 ASDRs for mining districts and the state of Missouri.

Excess ASDRs (Figure 5.10) indicate that the Old Lead Belt experienced the largest impact of the 1918 influenza pandemic within the 0-4 year (2086.29) and 65 year and older age categories (2334.17), although all districts were below the state average for the oldest age group. Overall, the Central District experienced the least amount of excess ASDRs in all age categories with the exception of 15-19 years (605.63) and 25-34 years (898.17). The largest difference in age category by district is seen in 0-4 years, as the Tri-State (1374.84) and Old Lead Belt (2086.29) experienced excess ASDRs more than double than the Central District (628.46). The Tri-State District had the highest excess ASDR for the 25-34 year age category (1271.35).

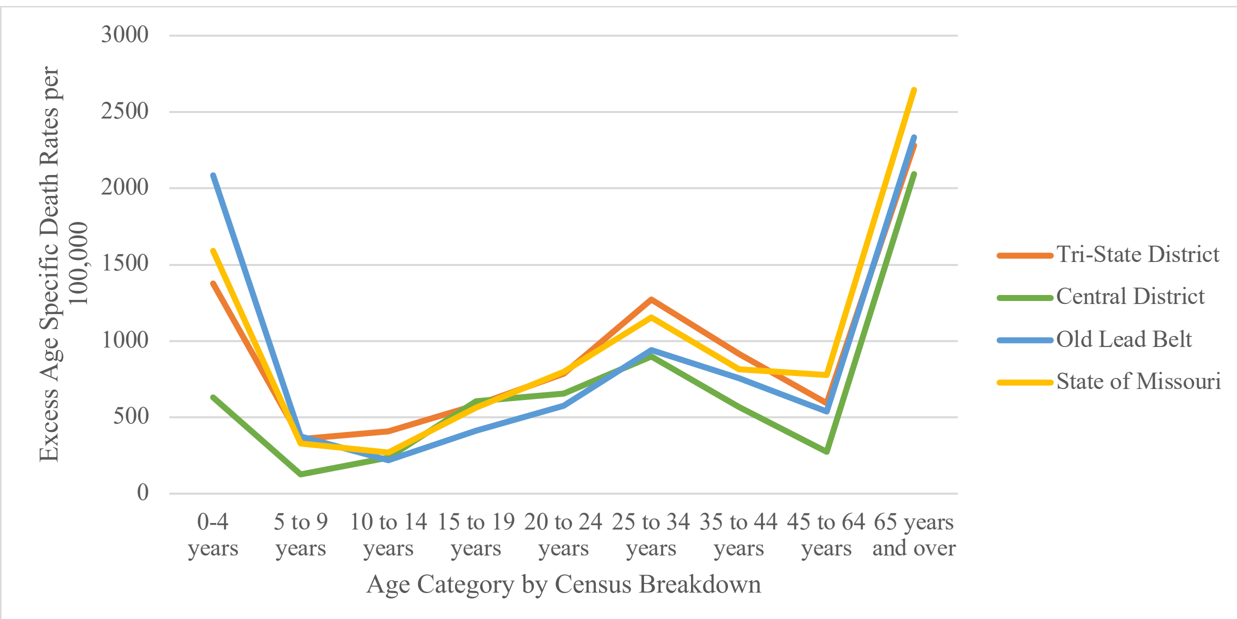


Figure 5.10. Excess ASDRs for mining districts and the state of Missouri.

Comparison to the State of Missouri

Overall, the timing of the pandemic experienced by the mining districts was very similar to that experienced by the entire state of Missouri (Figures 5.6). The main wave began in

September 1918 and ended in approximately late April 1919. Once standardized, the Tri-State District's first peak (55.01) within the main wave was much larger than the state of Missouri (40.29), indicating that the Tri-State District experienced heavier disease burden. Overall, the Central District had less deaths per 100,000 compared to the entire state with the exception of the echo wave which all mining districts experienced a higher peak. The Old Lead Belt experienced the amount and timing of standardized deaths most similarly to the state of Missouri, deviating slightly by experiencing more deaths within the echo wave (47.75) compared to the state (36.41).

Overall, little variation between the age distribution of deaths of the mining districts and entire state was seen, with the largest difference occurring in the 0-4 years age category with the Old Lead Belt (29.06%) experiencing a higher proportion of deaths compared to the state (20.52%) (Figure 5.7). Little variation in 1910 ASDRs was found between the mining districts and state, with the exception of 65 years and older age category (Figure 5.8). The Old Lead Belt experienced a higher 1910 ASDR (885.21) compared to the state (754.73), while the Central District's ASDR (393.33) was approximately half of the state.

The 1918 ASDR data for the mining districts followed the same shape of the state (Figure 5.9). Overall, the Central District's 1918 ASDRs differed the most from the state in a beneficial manner as the vast majority of ASDRs were well below the state data, particularly in the 0-4 years and 65 years and older age categories. All mining districts experienced smaller ASDRs for the 65 years and older age category compared to the state. Interestingly, the Old Lead Belt experienced a much higher 1918 ASDR in the 0-4 years age category (2382.04) compared to the state (1902.90); as stated previously, this is not surprising as the Old Lead Belt had the least access to healthcare of all districts and younger individuals have weakened immune systems.

Excess ASDRs for the 1918 influenza pandemic (Figure 5.10) follow the same pattern as the 1918 ASDR data (Figure 5.9).

CHAPTER 6: SYNOPSIS AND FUTURE IMPLICATIONS

This project investigated the impact of mining operations in Missouri on influenza transmission and severity during the 1918 influenza pandemic. Missouri is a place of interest as it one of several locations that experienced the pandemic differently in regards to number and timing of mortality waves. The state of Missouri provides the opportunity to analyze how rural communities experienced the pandemic, a task that is often unfulfilled due to limitations working with historical data. Each of the 114 counties and St. Louis City is comprised of its own unique demographic characteristics that influence disease transmission and severity. In order to uncover more geographic variation in disease impact and occupational risk, this study examined the impact of the 1918 influenza pandemic within three mining districts, using four representative counties for each district, and the entire state of Missouri.

It is clear and unsurprising that urban areas within Missouri experienced more deaths compared to rural areas. This effect is somewhat seen when comparing mortality within the mining districts. The Tri-State District had the largest number of deaths with two of four counties categorized as urban, while the Old Lead Belt had the second highest number of deaths with all counties considered to be rural. The Central District had the lowest number of deaths of all mining districts with one of four counties categorized as urban; however, the total percentage of rural inhabitants in the Old Lead Belt (20.83%) is higher than that of the Central District (13.50%). While this may indicate that factors beyond urban/rural distinction influenced disease spread within these communities, urban areas intrinsically have higher population densities, which leads to more person to person contact and more opportunities for droplet diseases such as influenza to spread. (Tarwater & Martin, 2001). The largest difference between the baseline year and pandemic years was seen in the 25-34 year age category in all analyses. This is not surprising, as all influenza epidemics prior to the 1918 pandemic produced a U-shaped age-specific mortality curve with individuals 25-34 years old experiencing little to no excess mortality.

Standardized deaths per 100,000 indicate several points in time in which the Tri-State District and Old Lead Belt experienced increased disease burden compared to the state of Missouri (Figure 5.6). This is clearly seen in first peak of the wave within the Tri-State District, which occurred approximately one month earlier than the entire state. This is not surprising, as a theory proposed by Barry (2004) regarding the exact origin of the pandemic suggests that initial 1918 influenza cases began in Camp Funston located in Kansas – one of the states that consists of Tri-State District mining operations (Barry, 2004). Infected soldiers from this military base then spread the disease by traveling to fight in World War 1; the disease continued to spread as soldiers traveled home when the war ended. Out of the five cities in Missouri that had over 25,000 inhabitants, Springfield, located in Greene County, experienced the earliest first main wave of the pandemic (Orbann et al., in preparation). As one of the first regions in Missouri to experience the pandemic, communities within the Tri-State District may not have been as prepared to combat influenza compared to other districts that were provided more notice about the circulating disease.

The Old Lead Belt experienced a much more severe echo wave compared to the state. This may have been influenced by the region's close proximity to St. Louis City allowing for increased human interaction with travelers, low inhabitant to physician ratio indicating less access to healthcare, and low literacy rate indicating potentially low health literacy within the community. The Central District experienced a slightly more severe echo wave compared to the state; however, it had lower levels of severity throughout the main wave and the majority of the pandemic. This may have been caused by a superspreading event(s), a large gathering of individuals which results in a significant spreading of disease, as individuals living in the Central District became comfortable with consistently low mortality rates and began loosening their disease prevention strategies.

The Tri-State District experienced higher excess mortality compared to the state in the 10-14 year and 25-34 year age categories (Figure 5.10). The prior may have been caused by a disease outbreak occurring within a school or another location where children aged 10-14 years gather. This may represent overall impoverishment as well, as schoolchildren across the state during this time had high rates of various ailments, including anemia and nutritional issues, which can impact immune function (Knight, 1920; Collins, 1922). The latter excess mortality was most likely caused by an increased prevalence of individuals 25-34 years living in the Tri-State District due to more employment opportunities located in urban areas, particularly in mining operations which facilitate disease transmission by requiring workers to be close proximity with each other for extended periods of time. The Old Lead Belt experienced much higher excess mortality compared to the state in the 0-4 year age category, likely because the Old Lead Belt had the least access to healthcare of all districts and this age group in general has weaker immune systems. Overall, the Central District experienced lower levels of excess mortality in all age categories. This may be due to the fact that the Central District has the least population density, highest rurality levels, and least amount of mining operations of all mining districts, allowing inhabitants the ability to social distance and reduce opportunities to contract/transmit disease. The Central District also had the highest ratio of population density to number of physicians per 100,000 of all mining districts, likely resulting in better health outcomes.

The primary hypothesis of this project, that these three mining regions experienced a greater impact in terms of mortality compared to the state average during the 1918 influenza pandemic, was proved to be partially supported as not all mining districts experienced a greater impact in terms of mortality compared to the state during the 1918 influenza pandemic. Statistical analysis showed that the Tri-State District and Old Lead Belt experienced higher mortality several times throughout the pandemic while the Central District experienced less mortality overall. The secondary hypothesis, that the Tri-State District experienced the greatest disease impact while the Central District experienced the least based on the average rurality and population density of the counties comprised in each mining region, was supported, as the Tri-State District experienced the greatest impact out of the three mining districts and the Central District experienced the least.

Although mining operations in Missouri have significantly decreased since 1918, this study provides insights for potential new work expanding on the goal to uncover geographical variation in regard to occupational risk during historical pandemics; more particularly, in rural areas that are often disregarded due to data collection limitations. The value of this research is becoming more recognized as the current COVID-19 pandemic continues, as much can be learned about the way a disease acts within populations in terms of timing and levels of severity. These insights can then be applied to current and future disease prevention and control efforts. Additionally, this study highlights the value of applying anthropological concepts onto biological phenomena in order to gain a deeper understanding of how human interaction, influenced by specific occupational presence, may influence the health of a community.

APPENDIX A – DEMOGRAPHIC VARIABLES

The follow table lists all the demographic data for each representative county, followed by the average values within each mining region (with the exception of using summed values for total population, area, and number of farms). Values for the entire state of Missouri are provided as well.

Table A.1. Demographic data for each representative county, mining region, and state of Missouri

County or Mining District	Total Population	Urban vs. Rural	Population in Urban Areas (%)	Population in Rural Areas (%)	Area (sq. miles)	Population density (sq. miles)	Literacy rate	Area of farmland (sq. miles)
Greene	63831	Urban	55.10	44.90	667	95.70	96.10	602.05
Jasper	89673	Urban	64.60	35.40	635	141.20	97.40	506.56
Lawrence	26583	Rural	15.60	84.40	609	43.70	94.70	556.78
Newton	27136	Rural	13.50	86.50	622	43.60	93.50	475.77
Tri-State District	207223	--	37.20	62.80	2533	81.05	95.43	535.29
Cole	21957	Urban	54.00	46.00	380	56.40	94.10	349.67
Miller	16717	Rural	0.00	100.00	593	28.20	93.60	508.37
Moniteau	14375	Rural	0.00	100.00	410	35.10	95.40	393.57
Morgan	12863	Rural	0.00	100.00	614	20.90	93.90	437.23
Central District	65912	--	13.50	86.50	1997	35.15	94.25	422.21
Franklin	29830	Rural	12.30	87.70	879	33.90	94.30	745.09
Jefferson	27878	Rural	26.10	73.90	681	40.90	92.30	555.11
Madison	11273	Rural	23.30	76.70	499	22.60	90.40	200.76
St. Francois	35738	Rural	21.60	78.40	458	78.00	86.50	285.89
Old Lead Belt	104719	--	20.83	79.18	2517	43.85	90.88	446.71
State of Missouri	3293335	Rural	42.50	57.50	68727	47.90	94.70	54048.83

County or Mining District	Number of farms	Average value of all property per farm ($)	Estimation of Rurality (%)	Number of Physicians per 100,000	White Inhabitant (%)	Black Inhabitant (%)	Other Inhabitant (%)
Greene	4434	5660	90.26	175.46	95.87	4.11	0.02
Jasper	3117	7500	79.77	136.05	98.45	1.53	0.03
Lawrence	3278	5729	91.43	112.85	99.65	0.34	0.00
Newton	3215	4599	76.49	84.76	97.88	1.99	0.13
Tri-State District	3511	5872	84.49	127.28	97.96	1.99	0.04
Cole	1610	6338	92.02	109.30	90.18	9.82	0.00
Miller	2341	3566	85.73	83.75	99.35	0.57	0.08
Moniteau	2052	6827	95.99	118.26	96.49	3.50	0.01
Morgan	2027	5402	71.21	108.84	96.81	3.19	0.00
Central District	2007.5	5533.25	86.24	105.04	95.71	4.27	0.02
Franklin	3781	5438	84.77	113.98	95.42	4.58	0.00
Jefferson	2720	5319	81.51	71.74	94.39	5.61	0.00
Madison	1168	3278	40.23	115.32	97.52	2.48	0.00
St. Francois	1243	5568	62.42	92.34	98.44	1.56	0.01
Old Lead Belt	2228	4900.75	67.23	98.34	96.44	3.56	0.00
State of Missouri	277244	7405	78.64	173.74	95.19	4.78	0.03

APPENDIX B –MORTALITY DATA

The following tables provide mortality data used for this project. Table B.1 provides the weekly number of influenza-associated deaths for each representative mining county, each mining district, and the state of Missouri. Table B.2 provides the 1910 age distribution of deaths for each representative mining county, each mining district, and the state of Missouri. Table B.3 provides the 19-18-1920 age distribution of deaths for each representative mining county, each mining district, and the state of Missouri.

Table B.1. Weekly number of influenza-associated deaths for each representative mining county, each mining district, and the state of Missouri

Week	Greene	Jasper	Lawrence	Newton	Tri-State District Total	Cole	Miller	Moniteau	Morgan	Central District Total
12/30/17	2	4	0	3	9	1	0	0	0	1
1/6/18	7	9	1	1	18	0	3	0	0	3
1/13/18	1	7	0	1	9	0	1	0	0	1
1/20/18	3	5	1	1	10	1	0	0	1	2
1/27/18	0	5	1	2	8	3	1	0	1	5
2/3/18	4	5	0	2	11	4	1	0	0	5
2/10/18	5	8	1	0	14	3	3	0	1	7
2/17/18	3	3	0	4	10	0	2	0	0	2
2/24/18	1	8	2	1	12	0	1	0	1	2
3/3/18	6	5	1	3	15	0	0	0	0	0
3/10/18	2	6	2	3	13	1	0	0	0	1
3/17/18	5	0	0	0	5	3	2	0	1	6
3/24/18	2	7	3	1	13	4	1	0	2	7
3/31/18	0	2	1	3	6	1	0	0	0	1
4/7/18	2	7	2	2	13	1	3	0	1	5
4/14/18	3	9	0	0	12	0	0	0	1	1
4/21/18	2	10	0	0	12	1	0	0	0	1
4/28/18	4	6	1	0	11	2	0	0	1	3
5/5/18	7	6	1	1	15	1	1	0	2	4
5/12/18	4	6	1	0	11	1	2	0	0	3
5/19/18	0	3	0	0	3	1	1	0	0	2
5/26/18	2	2	0	0	4	0	0	0	0	0

6/2/18	1	1	1	0	3	0	0	0	0	0
6/9/18	0	1	0	0	1	0	0	0	0	0
6/16/18	0	0	0	0	0	0	0	0	0	0
6/23/18	1	1	0	0	2	0	0	0	0	0
6/30/18	0	1	0	0	1	0	0	0	0	0
7/7/18	1	2	0	0	3	0	0	0	0	0
7/14/18	2	0	0	0	2	1	0	0	1	2
7/21/18	2	0	0	0	2	0	0	0	0	0
7/28/18	0	1	0	1	2	0	0	0	0	0
8/4/18	1	1	0	0	2	0	0	0	0	0
8/11/18	1	0	0	0	1	0	0	0	0	0
8/18/18	0	2	0	0	2	0	0	0	0	0
8/25/18	3	2	0	0	5	0	0	0	0	0
9/1/18	1	2	0	0	3	0	1	0	0	1
9/8/18	0	2	0	0	2	0	1	0	1	2
9/15/18	0	3	0	0	3	0	0	0	0	0
9/22/18	0	2	0	0	2	0	0	0	0	0
9/29/18	17	5	1	2	25	1	2	0	0	3
10/6/18	89	15	6	4	114	1	1	1	0	3
10/13/18	66	19	11	7	103	4	0	6	0	10
10/20/18	33	46	6	11	96	3	4	3	0	10
10/27/18	24	42	4	10	80	5	4	3	2	14
11/3/18	7	42	6	9	64	2	3	1	3	9
11/10/18	15	36	8	12	71	2	3	1	5	11
11/17/18	12	32	5	11	60	7	0	3	5	15
11/24/18	15	29	0	11	55	11	0	0	1	12
12/1/18	24	45	2	11	82	6	0	0	2	8
12/8/18	15	41	10	5	71	15	4	4	3	26

12/15/18	20	39	7	6	72	20	2	1	2	25
12/22/18	13	21	6	2	42	7	4	0	3	14
12/29/18	9	19	7	3	38	3	3	2	1	9
1/5/19	7	10	7	1	25	3	4	0	2	9
1/12/19	13	13	4	4	34	0	0	0	0	0
1/19/19	13	15	6	7	41	4	1	0	1	6
1/26/19	11	11	10	1	33	1	0	1	1	3
2/2/19	2	14	3	2	21	7	0	0	0	7
2/9/19	3	13	6	4	26	1	0	0	1	2
2/16/19	4	9	1	0	14	0	1	2	1	4
2/23/19	6	18	0	3	27	0	2	1	2	5
3/2/19	5	10	0	2	17	4	1	0	1	6
3/9/19	5	9	1	0	15	2	2	0	1	5
3/16/19	5	15	2	1	23	2	1	0	3	6
3/23/19	6	14	3	2	25	2	2	0	4	8
3/30/19	5	8	3	2	18	2	1	0	1	4
4/6/19	4	6	2	1	13	0	0	1	3	4
4/13/19	2	4	1	0	7	2	1	1	0	4
4/20/19	3	1	0	1	5	0	0	0	0	0
4/27/19	1	0	0	2	3	1	0	0	1	2
5/4/19	5	4	0	2	11	0	1	1	0	2
5/11/19	2	2	0	0	4	1	0	0	0	1
5/18/19	0	3	0	1	4	0	0	0	0	0
5/25/19	3	0	0	0	3	0	0	0	0	0
6/1/19	0	0	0	0	0	0	0	0	1	1
6/8/19	0	2	0	0	2	1	0	0	0	1
6/15/19	0	0	0	0	0	0	0	0	0	0
6/22/19	0	0	0	0	0	0	1	0	0	1

6/29/19	0	0	0	0	0	0	0	0	0	0
7/6/19	3	3	0	0	6	0	0	0	0	0
7/13/19	1	1	0	0	2	0	0	0	0	0
7/20/19	1	2	0	0	3	0	0	0	0	0
7/27/19	2	0	0	2	4	1	0	0	0	1
8/3/19	1	3	0	1	5	0	0	0	0	0
8/10/19	1	3	0	0	4	0	0	1	0	1
8/17/19	2	0	1	0	3	0	0	0	0	0
8/24/19	1	1	0	1	3	0	1	0	0	1
8/31/19	2	3	0	0	5	0	1	0	0	1
9/7/19	2	2	0	0	4	0	0	0	0	0
9/14/19	0	1	0	0	1	0	0	0	0	0
9/21/19	2	0	0	0	2	0	0	0	0	0
9/28/19	1	2	0	0	3	0	0	0	0	0
10/5/19	1	1	0	1	3	0	0	0	1	1
10/12/19	1	1	0	1	3	1	0	0	0	1
10/19/19	0	1	0	0	1	1	0	0	0	1
10/26/19	3	1	2	1	7	0	0	0	1	1
11/2/19	1	1	1	0	3	0	0	0	0	0
11/9/19	2	2	0	1	5	0	0	0	0	0
11/16/19	3	3	0	2	8	0	0	0	0	0
11/23/19	2	4	1	0	7	1	0	0	0	1
11/30/19	2	3	1	1	7	0	0	0	0	0
12/7/19	2	3	0	0	5	0	0	0	2	2
12/14/19	2	6	0	2	10	0	0	0	0	0
12/21/19	1	1	0	2	4	1	0	0	0	1
12/28/19	3	8	2	1	14	2	0	0	2	4
1/4/20	6	5	0	0	11	1	1	1	1	4

1/11/20	9	6	2	0	17	1	0	0	0	1
1/18/20	1	8	3	4	16	0	0	0	1	1
1/25/20	9	8	4	3	24	1	2	1	1	5
2/1/20	22	16	3	4	45	6	4	2	3	15
2/8/20	30	30	7	11	78	8	6	4	8	26
2/15/20	33	30	5	18	86	9	7	5	6	27
2/22/20	13	16	7	9	45	7	1	7	4	19
2/29/20	18	10	6	6	40	4	1	4	4	13
3/7/20	15	4	3	3	25	4	3	0	0	7
3/14/20	7	7	2	1	17	0	3	1	0	4
3/21/20	6	2	3	3	14	1	2	0	2	5
3/28/20	1	4	1	1	7	1	0	0	0	1
4/4/20	3	3	1	2	9	1	1	0	2	4
4/11/20	4	1	2	0	7	1	1	0	1	3
4/18/20	3	4	0	0	7	3	0	0	1	4
4/25/20	2	3	0	0	5	0	0	0	0	0
5/2/20	3	2	1	1	7	1	0	0	1	2
5/9/20	1	1	0	1	3	0	0	0	0	0
5/16/20	2	5	1	0	8	2	0	0	0	2
5/23/20	0	0	0	0	0	1	0	0	0	1
5/30/20	0	1	1	0	2	1	0	0	0	1
6/6/20	3	0	0	1	4	0	0	0	0	0
6/13/20	0	1	2	1	4	0	0	0	0	0
6/20/20	0	1	1	0	2	0	0	1	0	1
6/27/20	0	0	1	0	1	0	0	0	0	0
7/4/20	1	0	0	0	1	0	0	0	0	0
7/11/20	1	1	0	0	2	0	0	0	0	0
7/18/20	1	0	0	0	1	0	0	0	0	0

7/25/20	1	2	0	2	5	0	0	0	0	0
8/1/20	2	0	1	0	3	0	0	0	0	0
8/8/20	2	0	0	1	3	0	0	0	0	0
8/15/20	0	1	0	0	1	0	0	0	1	1
8/22/20	1	0	0	0	1	0	0	0	0	0
8/29/20	0	0	0	0	0	0	0	0	0	0
9/5/20	1	5	0	0	6	0	0	0	0	0
9/12/20	0	3	0	0	3	0	0	0	0	0
9/19/20	0	2	0	0	2	1	0	0	0	1
9/26/20	0	2	0	0	2	1	0	0	0	1
10/3/20	0	3	0	0	3	1	0	0	0	1
10/10/20	1	1	0	1	3	0	0	1	0	1
10/17/20	2	1	0	0	3	0	0	0	0	0
10/24/20	1	1	0	1	3	0	0	0	0	0
10/31/20	1	3	0	0	4	0	0	0	0	0
11/7/20	3	2	0	0	5	0	0	0	0	0
11/14/20	2	1	0	1	4	0	0	0	0	0
11/21/20	4	3	0	2	9	0	0	0	1	1
11/28/20	2	3	2	2	9	1	0	0	1	2
12/5/20	1	1	0	0	2	0	0	0	0	0
12/12/20	4	1	0	2	7	0	0	0	0	0
12/19/20	0	2	0	0	2	0	0	0	0	0
12/26/20	6	3	0	0	9	0	0	0	1	1

Table B.1. Weekly number of influenza-associated deaths for each representative mining county, each mining district, and the state of Missouri (continued)

Week	Franklin	Jefferson	Madison	St. Francois	Old Lead Belt Total	State of Missouri
12/30/17	1	1	0	3	5	147
1/6/18	4	1	1	2	8	226
1/13/18	0	3	1	3	7	279
1/20/18	5	0	1	3	9	229
1/27/18	2	4	3	3	12	226
2/3/18	2	1	2	2	7	212
2/10/18	2	3	0	3	8	202
2/17/18	3	0	0	5	8	189
2/24/18	2	2	2	5	11	203
3/3/18	5	2	2	5	14	216
3/10/18	3	2	3	5	13	211
3/17/18	0	1	3	5	9	192
3/24/18	1	3	0	2	6	231
3/31/18	3	0	1	2	6	176
4/7/18	0	1	1	2	4	173
4/14/18	1	0	1	6	8	179
4/21/18	1	0	1	3	5	194
4/28/18	1	0	0	2	3	177
5/5/18	1	3	1	3	8	136
5/12/18	1	0	0	1	2	104
5/19/18	0	2	0	1	3	70
5/26/18	0	0	0	0	0	68
6/2/18	0	0	1	0	1	42

6/9/18	1	0	0	0	1	33
6/16/18	0	0	0	1	1	42
6/23/18	0	1	0	2	3	24
6/30/18	0	0	0	1	1	31
7/7/18	0	0	1	2	3	33
7/14/18	1	1	0	3	5	34
7/21/18	0	1	0	0	1	31
7/28/18	0	1	0	0	1	28
8/4/18	1	0	0	1	2	45
8/11/18	0	0	0	2	2	30
8/18/18	0	0	0	0	0	42
8/25/18	0	0	0	0	0	29
9/1/18	0	1	0	0	1	31
9/8/18	0	0	0	0	0	37
9/15/18	0	0	0	0	0	52
9/22/18	1	0	0	0	1	55
9/29/18	2	1	0	1	4	222
10/6/18	5	4	0	2	11	672
10/13/18	4	17	2	2	25	1182
10/20/18	3	31	2	5	41	1327
10/27/18	1	11	2	5	19	1226
11/3/18	4	8	4	6	22	992
11/10/18	4	4	6	8	22	885
11/17/18	10	10	7	9	36	794
11/24/18	13	9	3	8	33	856
12/1/18	8	11	2	19	40	1408
12/8/18	2	11	2	22	37	1505
12/15/18	1	9	1	9	20	1010

12/22/18	4	4	1	6	15	569
12/29/18	7	7	0	5	19	455
1/5/19	4	9	2	4	19	497
1/12/19	1	11	1	4	17	498
1/19/19	4	1	1	8	14	407
1/26/19	2	6	2	5	15	397
2/2/19	2	2	0	1	5	300
2/9/19	0	3	0	1	4	343
2/16/19	4	1	2	6	13	319
2/23/19	3	5	0	3	11	330
3/2/19	4	2	2	4	12	332
3/9/19	1	3	2	2	8	366
3/16/19	6	5	0	5	16	416
3/23/19	3	2	1	1	7	338
3/30/19	3	1	2	2	8	244
4/6/19	2	4	1	5	12	241
4/13/19	0	2	0	2	4	182
4/20/19	0	2	0	0	2	128
4/27/19	2	1	1	3	7	123
5/4/19	1	0	0	0	1	91
5/11/19	0	0	0	0	0	66
5/18/19	0	0	0	3	3	88
5/25/19	0	0	0	1	1	60
6/1/19	0	0	0	0	0	57
6/8/19	0	0	0	0	0	41
6/15/19	0	0	0	0	0	26
6/22/19	1	0	0	0	1	31
6/29/19	0	0	1	2	3	36

7/6/19	0	0	1	1	2	42
7/13/19	0	0	0	2	2	31
7/20/19	0	0	0	1	1	36
7/27/19	1	0	0	1	2	30
8/3/19	0	0	0	1	1	28
8/10/19	1	0	0	0	1	38
8/17/19	0	0	0	0	0	22
8/24/19	0	0	0	3	3	33
8/31/19	0	0	0	0	0	40
9/7/19	0	0	0	2	2	45
9/14/19	0	1	0	0	1	37
9/21/19	0	0	0	1	1	37
9/28/19	0	0	0	2	2	28
10/5/19	0	0	0	2	2	32
10/12/19	0	0	0	0	0	39
10/19/19	0	0	0	1	1	47
10/26/19	0	0	0	2	2	73
11/2/19	0	0	0	1	1	65
11/9/19	0	1	0	0	1	79
11/16/19	0	1	0	0	1	95
11/23/19	0	1	2	1	4	71
11/30/19	0	1	1	1	3	112
12/7/19	0	2	0	3	5	101
12/14/19	0	2	1	0	3	116
12/21/19	2	1	1	1	5	130
12/28/19	2	0	0	4	6	155
1/4/20	1	2	0	1	4	154
1/11/20	3	2	0	2	7	199

1/18/20	2	7	1	3	13	306
1/25/20	2	4	2	3	11	649
2/1/20	6	6	2	24	38	1178
2/8/20	2	12	5	31	50	1199
2/15/20	7	14	3	19	43	954
2/22/20	3	5	1	11	20	592
2/29/20	2	2	2	4	10	431
3/7/20	1	1	0	2	4	309
3/14/20	3	4	1	4	12	262
3/21/20	3	0	2	1	6	186
3/28/20	1	2	0	3	6	140
4/4/20	2	2	0	3	7	121
4/11/20	0	0	0	1	1	110
4/18/20	0	2	1	4	7	120
4/25/20	2	0	1	5	8	110
5/2/20	1	0	1	1	3	101
5/9/20	2	1	0	6	9	81
5/16/20	2	1	0	2	5	79
5/23/20	0	0	0	3	3	51
5/30/20	2	0	0	2	4	45
6/6/20	0	0	1	0	1	46
6/13/20	0	0	0	1	1	45
6/20/20	0	1	0	1	2	36
6/27/20	0	2	0	1	3	37
7/4/20	0	1	0	0	1	23
7/11/20	0	0	0	0	0	31
7/18/20	1	0	0	1	2	34
7/25/20	0	0	0	2	2	38

8/1/20	0	1	0	1	2	51
8/8/20	0	0	0	0	0	33
8/15/20	0	0	0	1	1	39
8/22/20	0	0	0	3	3	43
8/29/20	1	0	0	0	1	30
9/5/20	0	0	0	2	2	52
9/12/20	0	0	0	1	1	54
9/19/20	1	1	0	0	2	51
9/26/20	0	0	0	0	0	32
10/3/20	0	0	0	1	1	52
10/10/20	0	0	0	2	2	49
10/17/20	0	0	1	1	2	45
10/24/20	0	0	0	5	5	60
10/31/20	0	0	0	1	1	70
11/7/20	2	1	0	0	3	66
11/14/20	0	1	1	2	4	89
11/21/20	0	1	0	3	4	113
11/28/20	2	0	1	1	4	87
12/5/20	0	0	0	1	1	118
12/12/20	0	2	0	3	5	105
12/19/20	2	0	0	2	4	104
12/26/20	1	4	0	0	5	140

Table B.2. 1910 age distribution of deaths for each representative mining county, each mining district, and the state of Missouri

Age Category	Greene	Jasper	Lawrence	Newton	Tri-State District Total	Cole	Miller	Moniteau	Morgan	Central District Total
0-4 years	28	34	3	14	79	7	10	2	5	24
5-9 years	0	1	2	2	5	0	2	0	1	3
10-14 years	3	1	1	1	6	0	0	0	0	0
15-19 years	2	2	2	1	7	2	1	0	0	3
20-24 years	0	2	2	0	4	2	0	1	0	3
25-34 years	6	5	3	0	14	0	1	0	0	1
35-44 years	4	5	1	2	12	0	1	0	1	2
45-64 years	14	16	2	9	41	10	2	0	3	15
65 years and over	34	14	10	6	64	7	7	1	0	15

Table B.2. 1910 age distribution of deaths for each representative mining county, each mining district, and the state of Missouri (continued)

Age Category	Franklin	Jefferson	Madison	St. Francois	Old Lead Belt Total	State of Missouri
0-4 years	7	13	2	18	40	1122
5 to 9 years	0	2	0	2	4	86
10 to 14 years	0	2	0	0	2	47
15 to 19 years	0	0	1	0	1	87
20 to 24 years	0	1	0	2	3	117
25 to 34 years	2	1	0	1	4	211
35 to 44 years	0	2	2	0	4	264
45 to 64 years	2	2	6	11	21	743
65 years and over	17	15	5	10	47	1134

Table B.3. 1918-1920 age distribution of deaths for each representative mining county, each mining district, and the state of Missouri

Age Category	Greene	Jasper	Lawrence	Newton	Tri-State District Total	Cole	Miller	Moniteau	Morgan	Central District Total
0-4 years	136	190	41	45	412	29	21	6	18	74
5-9 years	27	38	8	13	86	6	4	1	2	13
10-14 years	24	37	10	16	87	6	6	2	3	17
15-19 years	47	46	15	19	127	18	5	12	9	44
20-24 years	63	64	13	25	165	25	8	6	7	46
25-34 years	188	228	38	42	496	46	18	15	15	94
35-44 years	103	118	20	34	275	26	4	9	11	50
45-64 years	91	112	24	22	249	19	10	5	8	42
65 years and over	97	129	38	37	301	34	21	4	27	86

Table B.3. 1918-1920 age distribution of deaths for each representative mining county, each mining district, and the state of Missouri (continued)

Age Category	Franklin	Jefferson	Madison	St. Francois	Old Lead Belt Total	State of Missouri
0-4 years	54	82	30	133	299	6860
5 to 9 years	10	19	5	11	45	1192
10 to 14 years	5	10	2	10	27	921
15 to 19 years	10	17	6	11	44	1964
20 to 24 years	13	21	4	24	62	2667
25 to 34 years	22	65	12	59	158	6368
35 to 44 years	12	33	10	53	108	3744
45 to 64 years	25	33	7	55	120	4612
65 years and over	49	43	23	51	166	5108

REFERENCES:

Andreasen, V., Viboud, C., & Simonsen, L. (2008). Epidemiologic characterization of the 1918 influenza pandemic summer wave in Copenhagen: implications for pandemic control strategies. *Journal of Infectious Diseases, 197*(2), 270–278. https://doi.org/10.1086/524065

Ansart, S., Pelat, C., Boelle, P.-Y., Carrat, F., Flahault, A., & Valleron, A. J. (2009). Mortality burden of the 1918-1919 influenza pandemic in Europe. *Influenza and Other Respiratory Viruses*, *3*(3), 99–106. https://doi.org/10.1111/j.1750-2659.2009.00080.x

Association of American Railroads. (2021, July 16). *Chronology of America's Freight Railroads*. Retrieved August 03, 2021, from https://www.aar.org/chronology-of-americas-freight-railroads/#!

Barry, J.M. (2004). The site of origin of the 1918 influenza pandemic and its public health implications. *Journal of Translational Medicine, 2*(3), 1-4.

Bedford, T., Riley, S., Barr, I. G., Broor, S., Chadha, M., Cox, N. J., Daniels, R.S., Gunasekaran, C. P., Hurt, A. C., Kelso, A., Klimov, A., Lewis, N. S., Li, X., McCauley, J. W., Suchard, M. A., Tashiro, M., Wang, D., Xu, X., Lemey, P., & Russell, C. A. (2015). Global circulation patterns of seasonal influenza viruses vary with antigenic drift. *Nature, 523*(7559), 217-220. doi:10.1038/nature14460

Bhat, Y. R. (2020). Influenza B infections in children: A Review. *World Journal of Clinical Pediatrics*, *9*(3), 44–52. https://doi.org/10.5409/wjcp.v9.i3.44

Bodewes, R., Morick, D., de Mutsert, G., Osinga, N., Bestebroer, T., van der Vliet, S., Smits, S. L., Kuiken, T., Rimmelzwaan, G. F., Fouchier, R. A. M., & Osterhaus, A. D. M. E.

(2013). Recurring influenza B virus infections in seals. *Emerging Infectious Diseases*, *19*(3), 511–512. https://doi.org/10.3201/eid1903.120965

Bouvier, N. M., & Palese, P. (2008). The biology of influenza viruses. *Vaccine, 26(4)*, D49-D53. doi:10.1016/j.vaccine.2008.07.039

Brobst, D. A. & Wagner, R. J., (1967). Nonmetallic Mineral Resources. In W. C. Hayes (Ed.), *Mineral and Water Resources of Missouri* (2nd ed. v. 48, pp. 99-106). U.S. Government Printing Office: Washington.

Bureau of Mines. (1918). *Mining and Mine Inspection of the State of Missouri* (32nd ed.). The Hugh Stephens Company Printers.

Byerly, C. R. (2010). The US military and the influenza pandemic of 1918–1919. *Public Health Reports, 125*(3 suppl), 81-91.

Centers for Disease Control and Prevention [CDC]. (2021, April 6). *1970s - 1980s CLPPP timeline*. Centers for Disease Control and Prevention. Retrieved March 28, 2022, from https://www.cdc.gov/nceh/lead/about/1980s.html

Centers for Disease Control and Prevention [CDC]. (2022, March 24). *Influenza (Flu).* Retrieved March 28, 2022, from https://www.cdc.gov/flu/index.htm

Collins, S. D. (1922). The relation of physical defects to sickness. A study of absence from school on account of sickness among 3,786 children in four localities in Missouri during the School Session 1920-21. *Public Health Reports (1896-1970), 37*(36), 2183–2193. https://doi.org/10.2307/4576499

Costa, D. L. (Ed.). (2007). *Health and labor force participation over the life cycle: evidence from the past.* University of Chicago Press.

Crawford, D.H. (2018). *Viruses: A Very Short Introduction* (2nd ed.). New York:

Oxford University Press Inc.

Crosby, A.W. (2003). *America's Forgotten Pandemic: The Influenza of 1918* (2nd ed.).

Dignam, T., Kaufmann, R. B., LeStourgeon, L., & Brown, M. J. (2019). Control of lead sources in the United States, 1970-2017: Public health progress and current challenges to eliminating lead exposure. *Journal of Public Health Management and Practice, 25*(1). https://doi.org/10.1097/phh.0000000000000889 Feehan, J., & Apostolopoulos, V. (2021). Is COVID-19 the worst pandemic? *Maturitas*, *149*, 56–58. https://doi.org/10.1016/j.maturitas.2021.02.001

Gagnon, A., Miller, M. S., Hallman, S. A., Bourbeau, R., Herring, D. A., Earn, D. J., & Madrenas, J. (2013). Age-specific mortality during the 1918 influenza pandemic: unravelling the mystery of high young adult mortality. *PloS One, 8*(8), e69586.

Girard, M. P., Cherian, T., Pervikov, Y., & Kieny, M. P. (2005). A review of vaccine research and development: Human acute respiratory infections. *Vaccine, 23*(50), 5708-5724. doi:10.1016/j.vaccine.2005.07.046

Hadler, J. L., Yousey-Hindes, K., Pérez, A., Anderson, E. J., Bargsten, M., Bohm, S. R., Hill, M., Hogan, B., Laidler, M., Lindegren, M. L., Lung, K. L., Mermel, E., Miller, L., Morin, C., Parker, E., Zansky, S. M., & Chaves, S. S. (2016). Influenza-related hospitalizations and poverty levels — United States, 2010–2012. *Morbidity and Mortality Weekly Report, 65*(05), 101-105.

Hobday, R. A., & Cason, J. W. (2009). The open-air treatment of pandemic influenza. *American Journal of Public Health*, *99*. https://doi.org/10.2105/ajph.2008.134627

Hoffman, B. L. (2011). Influenza activity in Saint Joseph, Missouri 1910-1923: Evidence for an early wave of the 1918 pandemic. *PLoS Currents*. https://doi.org/10.1371/currents.rrn1287

Huffman, O. V. (1910). Miners' consumption. *The Journal of the American Medical Association, 55*(22), 1891. https://doi.org/10.1001/jama.1910.04330220035012

Institute of Medicine (US) Committee on Employment-Based Health Benefits. (1993). *Employment and health benefits: A connection at risk.* (M. J. Field & H. T. Shapiro, Eds.). National Academy Press.

Institute of Medicine & National Research Council. (2009). *Sustaining global surveillance and response to emerging Zoonotic Diseases*. National Academies Press.

Interstate Historical Society. (1917). *The Ozark Region, Its History and Its People* (Vol. 1).

Johnson, N. (2006). *Britain and the 1918-19 Influenza Pandemic: A Dark Epilogue*. Routledge.

Johnson, N. P. A. S., & Mueller, J. (2002). Updating the accounts: Global mortality of the 1918 1920 "Spanish" influenza pandemic. *Bulletin of the History of Medicine, 76*, 105–115.

Jones, K. E., Patel, N. G., Levy, M. A., Storeygard, A., Balk, D., Gittleman, J. L., & Daszak, P. (2008). Global trends in emerging infectious diseases. *Nature*, *451*(7181), 990–993. https://doi.org/10.1038/nature06536

Kalnins, I. (2006). The Spanish Influenza of 1918 in St. Louis, Missouri. *Public Health Nursing*, *23*(5), 479–483. https://doi.org/10.1111/j.1525-1446.2006.00586.x

Keeling, A. W. (2010). "Alert to the necessities of the emergency": US nursing during the 1918 influenza pandemic. *Public Health Reports, 125*(3_suppl), 105-112.

Kenah, E., Chao, D. L., Matrajt, L., Halloran, M. E., & Longini, I. M. (2011). The global transmission and control of influenza. *PLoS One, 6*(5). doi:10.1371/journal.pone.0019515

Kiilsgaard, T. H., Hayes, W. C., & Heyl, A.V. (1967). Lead and Zinc. In W. C. Hayes (Ed.), *Mineral and Water Resources of Missouri* (2nd ed. v. 48, pp. 41-63). U.S. Government Printing Office: Washington.

Knight, C. P. (1920). Progress report on field investigations in child hygiene in the State of Missouri to June 30, 1920. *Public Health Reports (1896-1970), 35*(53), 3141-3162. https://doi.org/10.2307/4575842

Lanza, A. J., & Higgins, E. (1915). *Pulmonary disease among miners in the Joplin District, Missouri, and its relation to rock dust in the mines; a preliminary report.* Washington: Government Printing Office.

Maggini, S., Pierre, A., & Calder, P. (2018). Immune function and micronutrient requirements change over the life course. *Nutrients*, *10*(10), 1531. https://doi.org/10.3390/nu10101531

Mamelund, S. E., & Dimka, J. (2019). Tuberculosis as a Risk Factor for 1918 Influenza Pandemic Outcomes. *Tropical Medicine and Infectious Disease, 4*(2), 74. https://doi.org/10.3390/tropicalmed4020074

Manuguerra, J. C., & Hannoun, C. (1992). Natural infection of dogs by influenza C virus. *Research in Virology*, *143*, 199–204. https://doi.org/10.1016/s0923-2516(06)80104-4

McKinsey, D. S., McKinsey, J. P., & Enriquez, M. (2018). Part I: The 1918 Influenza in Missouri: Centennial Remembrance of the Crisis. *Missouri Medicine, 115*(3), 183–188.

Missouri Department of Health & Senior Services. (2021). *Bureau of Vital Records.* Retrieved August 09, 2021, from https://health.mo.gov/data/vitalrecords/

Missouri Department of Natural Resources. (2021, May 18). *History of Lead Mining in Missouri by County or District - PUB2979*. Retrieved October 22, 2021, from https://dnr.mo.gov/print/document-search/pub2979

Missouri Secretary of State. (2021). *Soldiers' Records: War of 1812 - World War I*. Retrieved August 13, 2021, from https://www.sos.mo.gov/archives/soldiers/ww1history

Missouri Secretary of State. (2022). *Missouri Vital Records*. Missouri State Seal. Retrieved March 11, 2022, from https://www.sos.mo.gov/archives/resources/bdrecords

Moore, M., Gould, P., & Keary, B. S. (2003). Global urbanization and impact on health. *International Journal of Hygiene and Environmental Health*, *206*(4-5), 269–278. https://doi.org/10.1078/1438-4639-00223

Morens, D. M., Taubenberger, J. K., & Fauci, A. S. (2008). Predominant role of bacterial pneumonia as a cause of death in pandemic influenza: implications for pandemic influenza preparedness. *Journal of Infectious Diseases, 198*(7), 962-970.

Mougel, N. (2011). World war I casualties. *Reperes Centre Européen Robert Schuman*, 4, 1-13.

Mugel, D. N. (2017). *Geology and Mining History of the Southeast Missouri Barite District and the Valles Mines, Washington, Jefferson, and St. Francois counties, Missouri. Scientific Investigations Report*. https://doi.org/10.3133/sir20165173

Muley, D., Shahin, M., Dias, C., & Abdullah, M. (2020). Role of transport during outbreak of infectious diseases: Evidence from the past. *Sustainability*, *12*(18), 7367. https://doi.org/10.3390/su12187367

Myers, K. P., Olsen, C. W., Setterquist, S. F., Capuano, A. W., Donham, K. J., Thacker, E. L., Merchant, J. A., Gray, G. C. (2006). Are swine workers in the United States at increased risk of infection with zoonotic influenza virus? *Clinical Infectious Diseases, 42*(1), 14-20. doi:10.1086/498977

Noymer A. (2009). Testing the influenza-tuberculosis selective mortality hypothesis with Union Army data. *Social Science & Medicine (1982), 68*(9), 1599–1608. https://doi.org/10.1016/j.socscimed.2009.02.021

Orbann, C. (2022). *The 1918 influenza pandemic in Missouri: patterns in spread across rural and urban locations.* Manuscript in preparation.

Palmer, C. T., Sattenspiel, L., & Cassidy, C. (2007). Boats, Trains, and Immunity: The Spread of the Spanish Flu on the Island of Newfoundland. *Newfoundland and Labrador Studies*, *22*(2), 474–504.

Park, J. R. (2005). *Missouri Mining Heritage Guide*. Stonerose Publishing Co.

Peiris, J. S., Cowling, B. J., Wu, J. T., Feng, L., Guan, Y., Yu, H., & Leung, G. M. (2016). Interventions to reduce zoonotic and pandemic risks from avian influenza in Asia. *The Lancet Infectious Diseases, 16*(2), 252-258. doi:10.1016/s1473-3099(15)00502-2

Phimister I. R. (1973). The "Spanish" influenza pandemic of 1918 and its impact on the Southern Rhodesian mining industry. *The Central African Journal of Medicine, 19*(7), 143–148.

Polk's Medical Register and Directory of the United States and Canada - 1917. (1917). Detroit, MI: R.L. Polk.

Reid, A.H., & Taubenberger, J.K. (2003). The origin of the 1918 pandemic influenza virus: a continuing enigma. *Journal of General Virology, 84*, 2285-2292.

Reperant, L. A., Kuiken, T., & Osterhaus, A. D. (2012). Adaptive pathways of zoonotic influenza viruses: from exposure to establishment in humans. *Vaccine, 30*(30), 4419-4434. doi:10.1016/j.vaccine.2012.04.049

Rice, G. W., & Palmer, E. (1993). Pandemic influenza in Japan, 1918-19: mortality patterns and official responses. *Journal of Japanese Studies, 19*(2), 389-420.

Robinson, K. R. (1990). The role of nursing in the influenza epidemic of 1918-1919. *Nursing Forum, 25*(2), 19–26. https://doi.org/10.1111/j.1744-6198.1990.tb00845.x

Sattenspiel, L. (2011). Regional patterns of mortality during the 1918 influenza pandemic in Newfoundland. *Vaccine*, *29S*, B33–B37.

Sattenspiel, L. (2022). *A Comparison of Socioeconomic and Demographic Factors influencing the 1918 influenza and COVID 19 pandemics in Missouri counties*. Manuscript in preparation.

Shanks, G. D., & Brundage, J. F. (2012). Pathogenic responses among young adults during the 1918 influenza pandemic. *Emerging Infectious Diseases, 18*(2), 201.

Short, K. R., Kedzierska, K., & van de Sandt, C. E. (2018). Back to the future: lessons learned from the 1918 influenza pandemic. *Frontiers in Cellular and Infection Microbiology, 8*. doi.org/10.3389/fcimb.2018.00343

Smith, K. B., Humphreys, J. S., & Wilson, M. G. (2008). Addressing the health disadvantage of rural populations: How does epidemiological evidence inform rural health policies and research? *Australian Journal of Rural Health*, *16*(2), 56–66. https://doi.org/10.1111/j.1440-1584.2008.00953.x

Starko, K. M. (2009). Salicylates and pandemic influenza mortality, 1918–1919 pharmacology, pathology, and historic evidence. *Clinical Infectious Diseases, 49*(9), 1405-1410.

Starr, E. B. (1920). Excessive mortality from influenza-pneumonia among bituminous coal miners of Ohio in 1918. *American Journal of Public Health, 10*(4), 348–351. https://doi.org/10.2105/ajph.10.4.348

Tamerius, J., Nelson, M. I., Zhou, S. Z., Viboud, C., Miller, M. A., & Alonso, W. J. (2011). Global influenza seasonality: reconciling patterns across temperate and tropical regions. *Environmental Health Perspectives, 119*(4), 439-445. doi:10.1289/ehp.1002383

Tarwater, P. M., & Martin, C. F. (2001). Effects of population density on the spread of disease. *Complexity, 6*(6), 29-36. doi:10.1002/cplx.10003

Taubenberger, J. K., & Morens, D. M. (2006). 1918 influenza: The mother of all pandemics. *Review of Biomedicine*, *17*, 69–79.

Taubenberger, J.K., Reid, A.H., & Fanning, T.G. (2000). The 1918 influenza virus: a killer comes into view. *Virology*, *274*, 241-245.

Taubenberger, J.K., Reid, A.H., & Fanning, T.G. (2005). Capturing a killer flu virus. *Scientific American, 292*, 62-71.

Tian, H., Zhou, S., Dong, L., Van Boeckel, T. P., Cui, Y., Newman, S. H., Takekawa, J. Y., Prosser, D. J., Xiao, X., Wu, Y., Cazelles, B., Huang, S., Yang, R., Grenfell, B. T., & Xu, B. (2014). Avian influenza H5N1 viral and bird migration networks in Asia. *Proceedings of the National Academy of Sciences, 112*(1), 172–177. https://doi.org/10.1073/pnas.1405216112

Tognotti, E. (2003). Scientific triumphalism and learning from facts: bacteriology and the 'Spanish flu' challenge of 1918. *Social History of Medicine, 16*(1), 97-110.

Treanor, J. (2004). Influenza vaccine—outmaneuvering antigenic shift and drift. *The New England Journal of Medicine*, *350* (3), 218-220.

U.S. Census Bureau. (1914). *1910 Census: Volume 4. Population, Occupation Statistics*. Retrieved from https://www.census.gov/library/publications/1914/dec/vol-4-occupations.html

U.S. Census Bureau. (1913a). *1910 Census: Volume 1. Population, General Report and Analysis*. Retrieved from https://www.census.gov/library/publications/1913/dec/vol-1-population.html

U.S. Census Bureau. (1913b). *Thirteenth Census of the United States Taken in the Year 1910 – Statistics for Missouri*. Retrieved from https://www2.census.gov/library/publications/decennial/1910/abstract/supplement-mo.pdf

U.S. Environmental Protection Agency [EPA]. (2022). *Learn about Lead*. EPA. Retrieved March 28, 2022, from https://www.epa.gov/lead/learn-about-lead#:~:text=Adults%20exposed%20to%20lead%20can,in%20both%20men%20and%20women).

van Seventer, J. M., & Hochberg, N. S. (2017). Principles of infectious diseases: Transmission, diagnosis, prevention, and control. *International Encyclopedia of Public Health*, 22–39. https://doi.org/10.1016/b978-0-12-803678-5.00516-6

World Health Organization [WHO]. (2018a). *Influenza (avian and other zoonotic)*. World Health Organization. Retrieved September 22, 2021, from https://www.who.int/news-room/fact-sheets/detail/influenza-(avian-and-other-zoonotic).

World Health Organization [WHO]. (2018b, November 6*). Seasonal influenza*. Retrieved September 22, 2021, from https://www.who.int/ith/diseases/influenza_seasonal/en/

Yang, W., Petkova, E., & Shaman, J. (2013). The 1918 influenza pandemic in New York City: Age-specific timing, mortality, and transmission dynamics. *Influenza and Other Respiratory Viruses*, *8*(2), 177–188. https://doi.org/10.1111/irv.12217

Yuanji (Kuo Yuanchi), G., Fengen, J., Ping, W., Min, W., & Jiming (Chu Chinming), Z. (1983). Isolation of influenza C virus from pigs and experimental infection of pigs with influenza C virus. *Journal of General Virology*, *64*(1), 177–182. https://doi.org/10.1099/0022-1317-64-1-177

Zhang, H., Porter, E., Lohman, M., Lu, N., Peddireddi, L., Hanzlicek, G., Marthaler, D., Liu, X., & Bai, J. (2018). Influenza C virus in cattle with respiratory disease, United States, 2016–2018. *Emerging Infectious Diseases*, *24*(10), 1926–1929. https://doi.org/10.3201/eid2410.180589