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ORIGINAL RESEARCH ARTICLE

Sex- and age-based differences in mortality during the 1918 influenza pandemic on the island of Newfoundland

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Abstract

Objectives: Our aim was to understand sex- and age-based differences in mortality during the 1918 influenza pandemic on the island of Newfoundland. The pandemic's impact on different age groups has been the focus of other research, but sex-based differences in mortality are rarely considered. Aspects of social organization, labor patterns, and social behaviors that contribute to mortality between males and females at all ages are used to explain observed mortality patterns.

Methods: Recorded pneumonia and influenza deaths on the island (n = 1871) were used to calculate cause-specific death rates and to evaluate differences in sex-based mortality. Mortality levels in 17 districts and four regions (Avalon, North, South, and West) were compared using standardized mortality ratios (SMRs). A logistic regression model was fit to determine in which regions sex-based mortality could be predicted using age and region as interactive predictors.

Results: Differences in sex-based mortality varied across regions; they were not significant for the aggregate population. SMRs were also variable, with no significant sex-based differences. Sex-based differences were highly variable within regions. Results from a logistic regression analysis suggest that females in the South region may have experienced a higher probability of death than other island residents.

Conclusions: Mortality analysis for aggregate populations homogenizes important epidemiologic patterns. Men and women did not experience the 1918 influenza pandemic in the same way, and by analyzing data at the regional and district geographic levels, patterns emerge that can be explained by the economies and social organization of the people who lived there.

1 | INTRODUCTION

Mortality patterns of the 1918 influenza pandemic have been studied extensively in populations all over the world. This pandemic is currently estimated to have taken around 50–100 million lives, 3%–4% of the world's population (Humphries, 2013; Johnson & Mueller, 2002). Mortality during the pandemic, although highly variable across populations and dependent on population characteristics, was substantially higher than the typical baseline flu mortality observed in 1915–1917, firmly cementing the 1918 pandemic mortality in the territory of unprecedented excess (Dull & Dowdle, 1980; Murray, Lopez, Chin, Feehan, & Hill, 2006)

Influenza is a disease that affects populations in different ways depending on demographic and social characteristics such as age distributions, labor and mobility patterns, and socioeconomic development (Grantz, Rane, Salje, Glass, Schachterle, & Cummings, 2016; Mamelund, 2006; Mamelund, 2011; Nishiura & Chowell, 2008; Rutter, Mytton, Mak, & Donaldson, 2012). Because of this, the observed case fatality rate is merely a global average and obscures a great deal of heterogeneity. Johnson and Mueller (2002) reported estimated national mortality rates for nearly

70 countries and regions throughout the world, the lowest of which include Argentina at 12 per 10 000 individuals, the Philippines at 17 per 10 000, and Russia/USSR at 24 per 10 000. On the highest end, Johnson and Mueller (2002) reported a rate of 549 per 10 000 in Fiji, 2361 per 10 000 in Western Samoa, and a staggering 4450 per 10 000 in Cameroon. Nations are comprised of subpopulations, however, and even national average mortality rates tend to homogenize the epidemic patterns of subpopulations.

The Dominion of Newfoundland and Labrador was one of the places in which the pandemic was highly heterogeneous, reflecting variability in socioeconomic status, access to healthcare, and social systems throughout the region. The estimated average mortality over the course of the pandemic on the island of Newfoundland was 74.5 deaths per 10 000 individuals, but individual district mortality varied from approximately 28.6 to 109.3 deaths per 10 000 individuals (Sattenspiel, 2011).

The worldwide pandemic is generally thought to have begun around March or April of 1918 and peaked in the early fall; many locations experienced an echo wave in the spring of 1919 (Crosby, 1989; Johnson & Mueller, 2002; Taubenberger & Morens, 2006). The pandemic in Newfoundland, however, was delayed compared to many places across the globe, most likely a product of its relative isolation as an island. The first wave of the flu in Newfoundland primarily hit the island in June and July of 1918; the deadly second wave did not peak until late October 1918. The echo wave, or the third wave, did not occur until the spring of 1920 (Palmer, Sattenspiel, & Cassidy, 2007; Sattenspiel, 2011).

Despite the fact that the 1918 influenza pandemic is one of the most studied events in historical epidemiology, there are very few studies that address sex differences in mortality directly. Sattenspiel (2011) highlights geographic heterogeneity in flu mortality in Newfoundland during the pandemic, but also suggests that the mortality data and analyses described in the article were not sufficient to be able to distinguish among the various hypotheses proposed to explain this heterogeneity. In this article, we examine in detail sex- and age-based differences in mortality in an attempt to identify different behavioral patterns of the individuals in these spaces that could contribute to the observed heterogeneity.

Sex-based differences in mortality are difficult to address, especially for an infectious disease such as influenza. Influenza's pervasive nature, characteristics of which include a high attack rate, short latent and infectious periods (<1 week total), and low mortality, make it difficult to track even for general epidemiologic purposes (Frost, 1919; Saglanmak, Andreasen, Simonsen, Mølbak, Miller, & Viboud, 2011; Sattenspiel & Slonim, 2012; Shope, 1957). Influenza's ability to move quickly through highly variable geographic areas makes it clear that all are susceptible; the difficulty lies in discerning levels of susceptibility. Average baseline flu mortality is 0.05%–0.1% of cases, therefore the mortality data represent an extremely small fraction of all who fall ill during any given year. Analyses of mortality data can potentially reveal inherent biological susceptibility to a highly transmissible disease such as influenza, but the increased risk for pregnant women is one of the only well-described links to biological susceptibility to influenza (Gabriel & Arck, 2014; Garenne, 2015; Palmer et al., 2007). Twentieth-century data for diseases in the United States such as chronic nephritis, tuberculosis, heart disease, influenza and pneumonia, diabetes, and cancer consistently exhibit higher male mortality, and this mixture of both chronic and infectious diseases may have led to the generalized assumption that males are more prone to succumbing to these conditions (Battles, 2016; Gage, 1994; Garenne, 2015; Lock & Kaufert, 2001; Noymer & Garenne, 2003). Further, influenza mortality in general can be difficult to identify if the individual is also infected with well-known comorbidities such as pneumonia and/or tuberculosis. The uncertainty in levels of sex-based differences in influenza mortality, especially for the early twentieth century, stems from the general underreporting of influenza mortality in the death records, human error in reporting of causes of death because of comorbidities, and the ambiguity of generalized differential susceptibility to chronic and infectious diseases.

Reasons for the differential mortality for socially transmitted diseases such as flu will likely be behavioral in nature, based on differential patterns of human interactions of males as opposed to females in their labor, migration, and day-to-day activities. It is well known that in early twentieth-century Newfoundland, considerable sex differences in these behaviors occurred and varied regionally depending upon the individuals' locations on the island. In the urban center of the island, the city of St. John's, the labor opportunities for men and women were diverse; men worked in fisheries in addition to management positions and factories, and they performed industrial labor, but women also enjoyed diverse opportunities in teaching, nursing, and secretarial positions either outside of, or in addition to, homemaking. The remaining population, scattered along the coasts of the island, was much more limited in labor opportunities, with both men and women spending the majority of their time working and maintaining the fisheries (Davis, 1986; Dimka, 2015; Forestell, 1989; Porter, 1985). We posit that these critical differences in socioeconomic development, social organization, and specific behaviors of males and females in these spaces contribute more to the proliferation of influenza than any inherent biological mechanism.

The three central questions addressed in this article are: (1) what are the individual patterns of male and female influenza and pneumonia (hereafter P&I) mortality within the designated districts and regions; (2) what are the sex- and age-based differences in mortality within and among the designated regions; and (3) what factors contribute to these differences in mortality, specifically in terms of socioeconomic status, access to healthcare, social organization, and mobility? By addressing these questions, we hope to expose demographic, socioeconomic, and behavioral patterns that can help explain the heterogeneity observed in previous studies. This research takes an important step in the epidemiological literature by acknowledging that epidemic patterns of males and females are not the same; the sexes should be analyzed as separate subpopulations to illuminate critical epidemiological phenomena that would otherwise be homogenized.

2 | STUDY CONTEXT AND POPULATION

Newfoundland and Labrador, an independent Dominion in the British Empire during the time of the 1918 influenza pandemic, was a preindustrial society with a population of approximately 250 000 people. Neither modern communication nor transportation such as trains or automobiles were in widespread use; therefore, there were very high levels of geographic isolation and local social autonomy. A railroad and a few roads connected the more "urban" centers of the Avalon Peninsula (the H-shaped peninsula in the southeasternmost part of the island) to the western regions of the island (Figure 1), but there remained a large number of northern, southern, and western coastal communities accessible only by boat, some of which are still inaccessible by road (Palmer et al., 2007; Philbrook, 1966; Schmidt & Sattenspiel, 2017). Economies of the locally autonomous communities were centered around local resources and core institutions of kinship, primarily in the form of patrilineal, patrilocal fishing industries. This was especially true for people living in the outports (the Newfoundland word for outlying communities) of the island (Nemec, 1972; Philbrook, 1966; Porter, 1985).

At the time of the 1918 influenza pandemic, the Dominion had not yet undergone either the demographic or the epidemiological transitions that characteristically occurred in other Western European and North American countries during the late nineteenth and very early twentieth centuries. The term "demographic transition" relates to a pattern in which populations experienced first a decrease in mortality, followed later by a decrease in fertility, resulting in an overall rapid population increase. The epidemiologic transition, first described by Omran (1971), focuses on the mortality component of the demographic transition in Western Europe and North America. Special emphasis in this model is placed on reasons for the decline in mortality, which is characterized by a decrease in mortality from infectious diseases such as influenza, pneumonia, bronchitis, tuberculosis, and other childhood illnesses, and a corresponding increase in the proportionate mortality due to chronic illnesses such as cardiovascular diseases, respiratory failure, and cancer.

These classic models of the demographic and epidemiologic transitions are not mutually exclusive, and they are most characteristic of modern, industrialized societies in which there is low fertility, low infant mortality, and a longer life expectancy. The types of transitions observed in modern, industrialized societies have also been observed in other worldwide populations, but the temporal pattern they have followed is often significantly different (Agyei-Menash & deGraft Aikins, 2010; Amuna & Zotor, 2008; Caldwell, 1976; Defo, 2014; Lesthaeghe, 2010; Teitelbaum, 1975; Waters, 2006). Newfoundland does not fit the classic demographic and epidemiologic transition models; life expectancy in the early twentieth century ranged from 30 to 40 until 1940, infant mortality in St. John's ranged from 140 to 200 deaths per 1000 live births from 1900 to 1930, and the highest proportionate mortality was from communicable diseases compared to noncommunicable diseases and injuries (Schmidt & Sattenspiel, 2017).

Throughout the first half of the twentieth century, Newfoundland exhibited preliminary to moderate signs of the demographic and epidemiological transitions in the capital city, St. John's, which had increasing availability of healthcare and a strong commitment to raising awareness on health issues. Outside of St. John's and neighboring districts, both transitions were even more delayed (Orbann, Dimka, Miller, & Sattenspiel, 2014; Sattenspiel & Mamelund, 2013; Schmidt & Sattenspiel, 2017). General health of the population throughout the Dominion was poor, however, especially in the outports. Very few doctors were available for the small populations in the districts outside the Avalon Peninsula, and in communities where there were no doctors at all there were "handy women" who were trained by nurses and operated from nursing stations (Porter, 1985). Based on data in the Newfoundland and Labrador vital records, infant mortality was 139.3 deaths per 1000 live births for the years 1910–1919, the highest found in the Western world at the time (Schmidt & Sattenspiel, 2017). The island's low average life expectancy was undoubtedly driven downwards by the high infant mortality rate, but the struggling economy of Newfoundland during and after the First World War likely also contributed (Cadigan, 2009). Island-wide, there were some attempts to improve health infrastructure in the early twentieth century, but poor transportation throughout the island and low population density impeded the progress of costly health reforms (Baker & Pitt, 1984; Cadigan, 2009; Sattenspiel, 2011).

The island was also overwhelmed by infectious diseases, especially tuberculosis, in the early twentieth century. Tuberculosis was the leading cause of death in Newfoundland throughout the first half of the twentieth century, and remained a public health issue well into the 1970s (House, 1981). Further, infection with tuberculosis can increase the susceptibility of an individual to other infections, primarily P&I diseases, and was likely a factor in pandemic spread

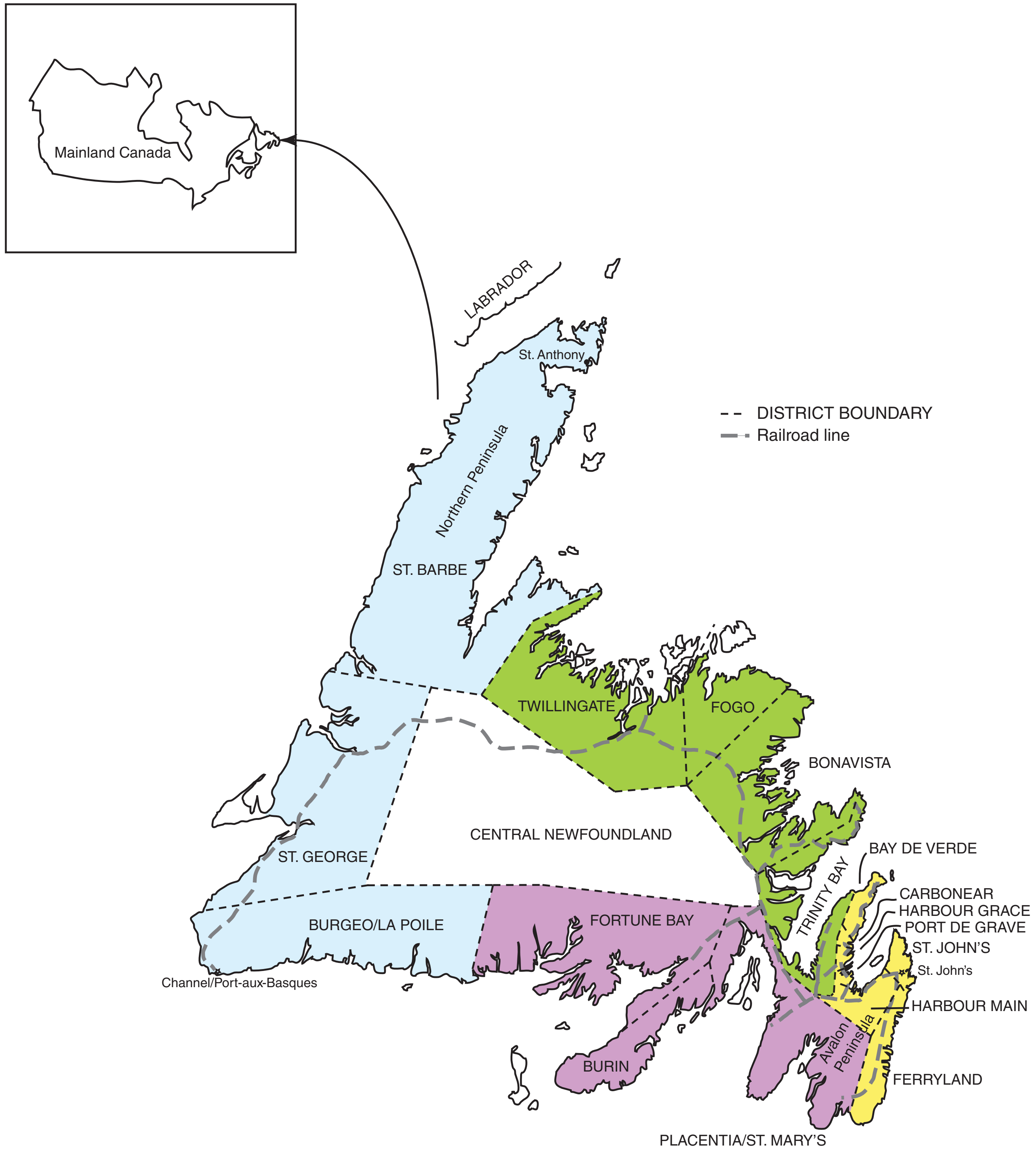

FIGURE 1 Map of the island of Newfoundland with all districts labeled and railroad lines (dark gray dashed lines) throughout the island in the early 20th century. The colors represent the four study regions: yellow = Avalon Peninsula; green = North; blue = West; purple = South. The inset shows Newfoundland's location in relation to the rest of Canada

(Chowell, Bettencourt, Johnson, Alonso, & Viboud, 2008; Oei & Nishiura, 2012). Because of this, the topic of tuberculosis is an important one in the discussion of overall health on the island of Newfoundland. The prevalence of tuberculosis in Newfoundland was high even before the twentieth century, and did not begin to decline until the mid- to late twentieth century (House, 1981; Schmidt & Sattenspiel, 2017), therefore it is likely that tuberculosis played an important role in P&I mortality during the 1918 pandemic. The implications of P&I and tuberculosis comorbidity on the sex- and age-based mortality will be discussed below.

Social life and labor activities differed greatly between rural and urban spaces in Newfoundland and Labrador, as well as between men and women within each region.

St. John's, located on the northeastern arm of the Avalon Peninsula, was the capital of the Dominion, with a population of over 51 000 (about 20% of the entire population) during 1918–1920. The main economic staple was the fishing industry, but, as the primary urban center of Newfoundland, St. John's had diverse and gendered labor opportunities for men and women that were not available in the outports. Men in St. John's were managers of ports, teachers, merchants, and medical professionals. They also performed industrial labor, such as mining and working the railroad. The fisheries were still the backbone of the economy in St. John's, as fishing and seal hunting excursions departed from the ports there, but the city's ports were also critical for long-range shipping of goods to Labrador, Québec, Nova Scotia, and northeastern cities of the United States such as Boston and New York. Because of the relative isolation of the island and these long shipping routes, male mobility was high, and there were periods of time, typically on the scale of months, during which men would travel away from Newfoundland. This long-range and frequent mobility is important to consider when it comes to the location of the males and the frequency of contact among individuals during pandemic times (Dimka, 2015; Forestell, 1989).

Opportunities for work for women were distinct from male labor and highly diverse in St. John's. Women were frequently employed full-time in factories until marriage (commonly in their early 20s), although some middle-class women sought employment as teachers, nurses, or office clerks. Even after marriage, women (as well as older children) often earned supplementary income for their families, usually out of necessity because of the economic difficulties of the First World War. This work could be in the form of sewing, cleaning, or performing other domestic tasks for neighboring families, in addition to working in factories, tailoring, and clerking. Women also took on the sole responsibility for domestic tasks within their own households, and did most of the child rearing. These domestic tasks were complicated further by the fact that advances in household technology had not reached Newfoundland in full force during the early twentieth century, and few homes had running water and indoor plumbing. Thus, women were in charge of maintaining the household without the aid of modern technology (Forestell, 1989). Given all of the responsibilities and activities of women in St. John's, it has often been argued that women are too often overlooked as equal, possibly majority, contributors to their households during this time period (Davis, 1986; Dimka, 2015; Porter, 1985).

In the outports of Newfoundland, male activities were limited almost exclusively to working in the fisheries during the summer, no matter where they were located along the coast (North, West, or South). Knowledge was passed down through the male lines, and young boys began learning the ins and outs of the fisheries at a very young age. During the spring months, May and June, men would sometimes fish for over half of every day, but would always return home to their outport and typically were not absent for extended periods (Dimka, 2015). During the summer, ships of men, sometimes with their whole families, would migrate to Labrador for the fishing season; during the early twentieth century, as many as 1400 ships per year would travel from Newfoundland to the Labrador fisheries (Staveley, 1977). Hunting seal was a major wintertime activity. After several months of preparation for the seal hunts, men would leave their ports in February and hunt for five to six, and sometimes as many as fifteen, weeks. When it was not seal hunting or fishing season, men typically found work in carpentry, mining, lumbering, teaching, or medical work (Dimka, 2015; Nemec, 1972; Queen & Habenstein, 1974). The variation in labor activities for men on the island and in Labrador meant that men were highly mobile throughout the year. The presence or absence of males, and the time period in which these different activities occurred, could significantly change the composition of the population in some of the smaller districts, thus affecting male and female morbidity and mortality during pandemic years.

Women were also highly active in the fisheries of the outports, and their labor has been estimated to have contributed nearly half of the income for each family (Porter, 1985). Women were in charge of carrying the fish from the wharves, and cleaning and preparing fish for sale and consumption. Further, in the fall, women and children harvested and preserved fruits and vegetables to be eaten during the winter. Aside from assisting in the fisheries, women worked throughout the year on domestic tasks without opportunities to travel. They made clothing, took care of the children, and prepared meals. Women were also far more social than men, who primarily only interacted with their immediate family members. Women commonly visited friends, especially in the winter, and were the first ones to offer help to individuals who were ill, even if they were not related through kinship. They were also involved in community activities through church groups and service organizations (Davis, 1986; Dimka, 2015; Feltham, 1986).

3 | MATERIALS AND METHODS

In the early twentieth century, there were 17 distinct districts on the island of Newfoundland, plus Labrador (which had approximately 4000 residents). These districts were given three-letter abbreviations to simplify analyses, and the 17 districts from the island of Newfoundland were grouped into four different regions (Figure 1, Table 1). These groupings are consistent with Sattenspiel's (2011) classifications. The primary focus of this study is on the island of Newfoundland because of insufficient data for deaths in Labrador. Labrador did fall victim to the 1918 pandemic; in fact, its communities, particularly in the northern regions, experienced some of the highest mortality in the world (Mamelund,

TABLE 1 Summary of regions, districts (abbreviations), standardized male and female population counts, and male to female population ratios

District (Abbrev.)	1918–1920 population[a]			
	Total	M	F	M/F[b]
Avalon				
St. John's (STJ)	51 127	24 433	26 694	0.92
Harbour Grace (HRG)	11 546	5748	5798	0.99
Bay de Verde (BDV)	10 573	5393	5181	1.04
Harbour Main (HRM)	9303	4781	4522	1.06
Port de Grave (PDG)	6631	3351	3280	1.02
Ferryland (FYL)	5972	3103	2869	1.08
Carbonear (CRB)	4885	2455	2430	1.01
North				
Twillingate (TWI)	25 921	13 638	12 285	1.11
Bonavista (BVA)	24 462	12 755	11 707	1.09
Trinity Bay (TRI)	23 093	12 033	11 060	1.09
Fogo (FGO)	8960	4710	4250	1.11
South				
Placentia/St. Mary's (PSM)	16 397	8533	7864	1.09
Burin (BUR)	12 386	6304	6082	1.04
Fortune Bay (FNB)	11 013	5700	5313	1.07
West				
St. George (STG)	13 216	6903	6313	1.09
St. Barbe (STB)	11 836	6235	5601	1.11
Burgeo/La Poile (BLP)	8482	4377	4105	1.07
Island	255 803	130 452	125 351	1.04

[a] These population figures are aggregate population counts for each district on the island; male and female age distributions for each district and the island as a whole used to calculate sex ratios can be found in the Supporting Information.
[b] "M" = males, "F" = females. M/F is the male/female population ratio.

Sattenspiel, & Dimka, 2013; Palmer et al., 2007; Sattenspiel, 2011; Sattenspiel & Mamelund, 2013). Unfortunately, the quality and quantity of death records in Labrador is insufficient—deaths were consistently underreported not only for P&I, but from all causes (Palmer et al., 2007).

By the time the 1918 flu had run its course in Newfoundland and Labrador in 1920, nearly 2000 individuals had died. Death records of these individuals were collected at the Newfoundland and Labrador Provincial Archives ("The Rooms"). Data from a total of 1885 individuals whose recorded cause of death was a form of flu and/or pneumonia were included in these analyses. These death records include individual-level information such as name, age, sex, date of death, cause of death, place of birth, place of death, place of internment, and occasionally information on occupation. We cannot assume these death records are complete, however, as it is known that underreporting of deaths was common in all regions touched by the pandemic, especially in locations where health surveillance and services were either difficult to provide or nonexistent (Johnson & Mueller, 2002; Mamelund et al., 2013; Sattenspiel & Mamelund, 2013). Because of this, even though it is reasonable to assume deaths counts across the island are underestimates of the true number of deaths, due to its relative geographic isolation, recorded P&I deaths in the South may be even further underestimated. Ultimately, it is impossible to know the full extent of this underrepresentation without accurate measures of morbidity.

Within the death records, an "attendant physician" was recorded, and most records do list a specific person in this column; however, it is unknown what proportion of those listed were actually physicians, or were nurses, clergy, or family members. Thus, there is some uncertainty in the accuracy of reported cause of death. Nonetheless, even though the Dominion was relatively underdeveloped, it was a twentieth-century North American member of the British Commonwealth with the level of government standards expected from Commonwealth members, and it is reasonable to assume that these data have similar accuracy to those reported for other North American and Western European countries at the time.

Causes of death were not distinguished between flu and pneumonia for two reasons: (1) these two infections are not mutually exclusive and are frequently comorbid; therefore, during autopsy it is difficult to tell which one was the true cause of death, and (2) combining flu and pneumonia deaths is consistent with the World Health Organizations' (2008) *International Classification of Diseases* (ICD) of flu and pneumonia (P&I). All flu deaths include recordings such as "influenza," "Spanish flu," "epidemic flu," and "La Grippe." Pneumonia deaths include all variations, such as "bronchopneumonia" and "pleural pneumonia."

Death dates were collected from the death records for all individuals with deaths attributed to all forms of P&I, and these deaths were aggregated into monthly categories by sex from January 1918 through December 1920. Two death progressions were generated, one showing the monthly mortality rates (per 100 000) by district, the other monthly mortality rates (per 100 000) by sex as the pandemic progressed over the three-year period.

Age-specific census data from 1911 to 1921 were linearly interpolated to estimate yearly age-specific populations for all districts in the Dominion from 1909 to 1923. It was assumed that the age distribution for each district did not change during inter-census years because there is no information that might suggest the true age distributions for those years. The 1911 age distribution was used for the years 1909–1915, and the 1921 age distribution was used for 1916–1923. The estimated age-specific population sizes for the pandemic years (1918–1920) were used to calculate male to female population ratios for each age class (Table 1, sex- and age-specific population ratios available in Supporting Information Table S1).

Using the interpolated population figures and P&I death data collected for 1918–1920, male and female deaths were aggregated into age classes (<1, 1–4, 5–9, etc., increasing by five until 80+). Total populations of each age class were calculated as the average of the total yearly populations of

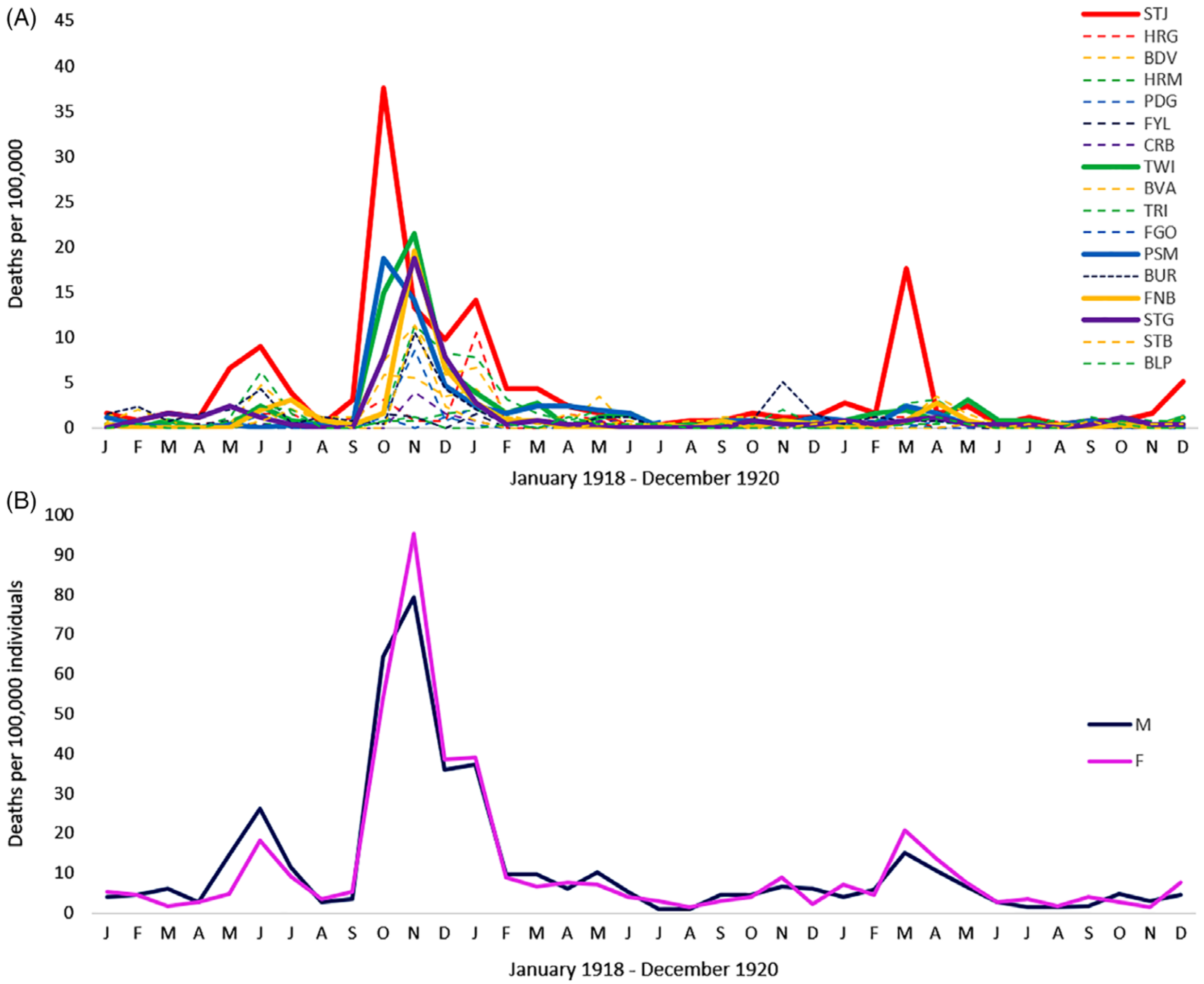

FIGURE 2 Monthly mortality rates (deaths per 100 000) during each month of the pandemic, January 1918–December 1920. A, Mortality rate in each of the 17 island districts; B, mortality rate by sex. See Supporting Information Figure S1 for the regional breakdown of the monthly mortality curves in A

1918–1920 from the linear interpolations. Fourteen individuals were removed from the original 1885 observed deaths for these analyses because of lack of age data recorded with their deaths ($n = 1871$).

Cause-specific death rates (CSDR) per 10 000 individuals were calculated for both males and females for each age class within each of the 17 districts. To ensure comparability between and among districts on the island, the expected number of deaths were first calculated for each district using the St. John's age structure as the standard population. St. John's was chosen as the standard population for two reasons: (1) the population in this district accounted for nearly 20% of the total population of the island in the early twentieth century, which increases the reliability of population estimates at this time, and (2) it was the first and only urban center and has displayed good population stability over a long period of time, something that cannot be guaranteed in any of the sparsely populated districts.

To compare standardized sex-based mortality rates, the female rate was subtracted from the male rate in order to avoid dividing by zero, which would occur for districts with small populations and no recorded female deaths in some age classes. For these comparisons, positive CSDR values indicate a lower than expected female mortality rate, whereas negative values indicate a higher than expected female mortality rate. This method is consistent with that of Noymer and Garenne's (2003) study performed on male and female mortality rates to determine the long-term impacts on the population from the 1918 influenza pandemic in the United States. Observed mortality levels in the rural districts were compared to the urban district, St. John's, using standardized mortality ratios (SMRs) for all districts. SMRs represent percentage of P&I deaths that could be expected in the remaining 16 districts if they were to have the same age structure as St. John's. The differences between male and female CSDRs were plotted both by district and all age classes. It is well-observed globally that young adults (20–40) were disproportionately affected during the pandemic relative to baseline flu mortality rates, so differences in male and female mortality were also plotted for ages 15–44 for each region.

Finally, a logistic regression model was fit to the data using the age and region variables to predict the probability of male death in any of the four regions for any age. In this analysis, a value of 1.00 indicates a 100% chance of a male death, a value of 0.50 indicates a 50% chance of a male death, and 0.00 indicates a 0% chance of a male death. A logistic regression analysis supplements the descriptive statistics because the model can predict the probability of mortality patterns revealed by the sex-based mortality rates and SMRs previously calculated. Every datum used to fit the model represents a single individual in the death records; therefore, a decrease in probability of a male death represents an increase in probability of female death. The coefficients estimated by the logistic model were used to calculate the probabilities of male death in each of the four regions for ages 1, 20, 40, 60, and 80 to discern any regional or age patterns in sex-based mortality.

4 | RESULTS

Graphs of monthly P&I mortality rates were generated using death dates by district and by sex (Figure 2; see Supporting Information Figure S1 for a regional breakdown of these monthly mortality curves). These graphs exhibit some important characteristics about the progression of the disease throughout the island. In particular, like other locations, Newfoundland experienced three distinct waves of the pandemic: wave I peaked in June 1918, wave II peaked at the end of October 1918, and wave III did not peak until March 1920. Three important characteristics should be noted for the curve broken down by district (Figure 2A): (1) all three waves were delayed compared to the global averages, (2) wave II led to recorded deaths in all districts, whereas some districts escaped the first wave, but only St. John's experienced a significant third echo wave in 1920 (a few others reported small death rates at this time), and (3) the highest death rates were observed in St. John's; regional breakdown of these monthly mortality curves are available in the Supporting Information (Table S2). It is well known that the three waves in Newfoundland were delayed by several weeks compared to the global averages (Palmer et al., 2007; Sattenspiel, 2011), and it is not surprising that the largest number of deaths were recorded for the district in which both population counts and population density were highest. Despite this, all districts on the island of Newfoundland experienced P&I deaths during the pandemic.

A comparison of monthly P&I mortality for males and females (Figure 2B) indicates few sex differences for the entirety of the pandemic, although differences can be observed at the peaks of each wave. Males have higher mortality during the first wave, but females surpass males at the peak of waves II and III. A very similar pattern in which males outpaced females in their morbidity only for wave I has also been observed for 1918 flu data in Maryland (urban and rural regions) and Bergen, Norway (Mamelund, Haneberg, & Mjaaland, 2016). Mamelund et al. (2016) analyzed both morbidity and mortality data and found that age-specific patterns of both were generally similar. Thus, although their sex difference during wave I was observed for morbidity data, whereas ours was for mortality data, a similar analysis of their mortality data would likely have led to the same male excess.

As seen in Table 1, population ratios by district show there is only a slight bias toward a male majority (for age- and sex-specific population counts for each district, see Supporting Information, Table S1). Island-wide, males outnumber females by a mere 5000, a small difference for a total population of over 250 000. This relative equality of the male and female populations for the years of study (1918–1920) is important to consider when analyzing their differences. As seen in Table 2, however, the total mortality

TABLE 2 Sex-based mortality rates, differences in sex-based mortality, and sex-based SMRs for each district for pandemic years (1918–1920)

District (Abbrev.)	Mortality rate[a]			SMR[b]	
	M[c]	F	M–F[d]	M	F
Avalon					
St. John's (STJ)	88.4	63.7	24.7	–	–
Harbour Grace (HRG)	76.0	60.2	15.8	2.5	2.7
Bay de Verde (BDV)	90.8	90.8	0.0	2.1	1.7
Harbour Main (HRM)	29.9	66.9	−37.0	6.0	2.5
Port de grave (PDG)	54.6	52.3	2.2	3.4	3.5
Ferryland (FYL)	32.3	29.1	3.2	5.4	6.5
Carbonear (CRB)	75.8	86.3	−10.5	2.4	1.9
North					
Twillingate (TWI)	72.1	69.1	3.0	2.5	2.3
Bonavista (BVA)	58.3	68.7	−10.3	3.0	2.3
Trinity Bay (TRI)	58.6	74.1	−15.5	3.1	2.2
Fogo (FGO)	68.7	47.1	21.6	2.7	3.6
South					
Placentia/St. Mary's (PSM)	88.9	112.4	−23.6	2.0	1.5
Burin (BUR)	82.1	117.8	−35.7	2.2	1.4
Fortune Bay (FNB)	98.2	121.0	−22.9	1.8	1.3
West					
St. George (STG)	101.7	117.3	−15.7	1.8	1.4
St. Barbe (STB)	43.5	62.0	−18.5	4.0	2.6
Burgeo/La Poile (BLP)	49.2	29.9	19.4	3.6	5.5
Island	71.1	77.1	−6.1	–	–

[a] Number of P&I (pneumonia and influenza) deaths per 10 000 individuals in each district.
[b] The standardized mortality ratio (SMR) using St. John's as the standard population for the island; population standardized by both age and sex.
[c] These mortality rates represent the mortality rate (per 10 000) for males and females in each district as a whole; see Supporting Information for age- and sex-specific mortality rates and SMRs within each district.
[d] M–F is the subtraction of the female mortality rate from the male mortality rate (deaths per 10 000). This comparison was used to avoid dividing by zero.

FIGURE 3 Average age-specific death rates for males (dark blue) and females (pink) from January 1918 to December 1920 including 95% confidence intervals. These age-specific mortality curves are the characteristic W-shaped curve observed worldwide, in which infants and elderly died at high rates, but young adults also died at unexpectedly high rates. For age- and sex-specific mortality rates, see Supporting Information

rates for males and females for the entire population vary slightly, with values of 71.1 and 77.1 deaths per 10 000, respectively. These values result in 6.1 per 10 000 more female deaths than expected throughout the three-year pandemic island-wide (for age- and sex-based mortality rates by district, see Supporting Information, Table S2).

Standardized age-specific mortality rates are shown in Figure 3. This curve shows that infants died at the highest rates, as expected for seasonal flu mortality, but it also shows that there was a spike in young adult (ages 15–44) mortality. The elderly died at high rates as well; reasons for the relatively low mortality rates for both males and females 80+ are not clear, but the observed rates likely were influenced by the small number of individuals of this age in general across the island. These results, particularly for young adults, are consistent with the age-specific mortality patterns observed worldwide, but have yet to be fully explained (Morens & Fauci, 2007; Shanks & Brundage, 2012; Taubenberger & Morens, 2006).

The SMRs calculated for the sexes in each district are also reported in Table 2. These ratios represent the percentage of individuals expected to die compared to the district's observed mortality if they were to have the same age structure as St. John's district. Ferryland exhibited both high male and female SMR (5.4 and 6.5, respectively), whereas the other districts were more varied between ratios. Twillingate (M = 2.5, F = 2.3) and Harbour Grace (M = 2.4, F = 2.6) were the only two districts that exhibited comparable ratios between males and females. Burgeo/LaPoile (M = 3.6, F = 5.5) and Harbour Main (M = 6.0, F = 2.5) exhibited the largest difference in male and female SMRs. Female SMRs were higher in only five districts (Harbour Grace, Port de Grave, Ferryland, Fogo, and Burgeo/La Poile).

The differences between male and female death rates are variable within districts. In the Avalon Peninsula, females in two districts, Harbour Main, and Carbonear, died at higher rates than expected (−37.0 and −10.5 deaths per 10 000, respectively), whereas males died at higher rates in St. John's, Harbour Grace, Port de Grave, and Ferryland (24.7, 15.8, 2.2, and 3.2 deaths per 10 000, respectively). The clear outliers in the Avalon Peninsula are the male-biased mortality rate in St. John's and the female-biased mortality rates in Harbour Main and Carbonear. In reference to the results for the patterns found in SMRs, there may be significant impact of comparative population size on the higher than expected death rates for females in Harbour Main and Carbonear. Another explanation that must be considered is absence of males in these districts for one of several reasons, possibly including seasonal labor migrations, travel to St. John's hospitals for treatment, or presence in Europe fighting in the First World War. The Harbour Main death records indicate that 33 individuals were recorded as "killed in action" in France for the years 1915–1918, as opposed to only three individuals in Carbonear (Newfoundland Grand Banks, http://ngb.chebucto.org). These data, however, cannot reveal the extent of Newfoundland's presence in the war; therefore, this question must await further research.

The only region that exhibited consistent differences in male and female death rates was the South, where females died at substantially higher than expected rates in all districts (−23.6, −35.7, and −22.9 deaths per 10 000 in Placentia/St. Mary's, Burin, and Fortune Bay, respectively). Figure 4 shows the highly variable differences in male and female cause-specific death rates (CSDR) by district (Figure 4A) and age class (Figure 4B).

The differences in young adult male and female mortality (15 to 44) within each district are reported in Figure 5A–D. Figure 5 shows the differences in male and female mortality for each region as a whole grouped by age classes, 15–19 through 40–44, for each of the four regions. The data for age classes by district (Figure 5A–D) exhibit similar trends to those seen in Figure 4A: the Avalon, North, and West are variable

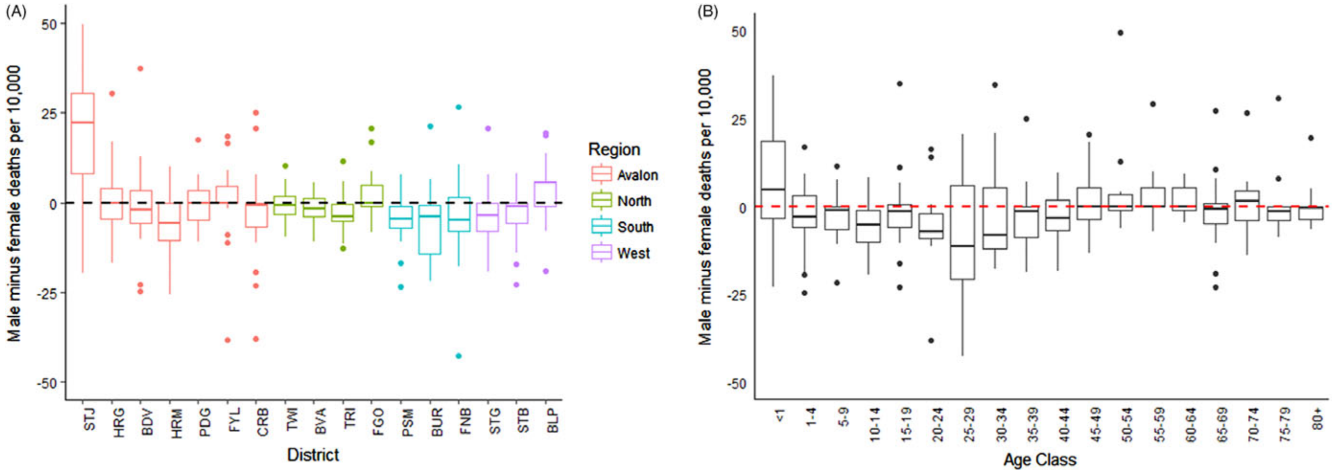

FIGURE 4 Difference in cause-specific death rates (CSDR) by geographic region, and age class (male CSDR–female CSDR). A, CSDRs by district and region; B, CSDRs by age-class

with no discernable patterns, whereas the females in the South exhibit consistently greater mortality than expected. The most interesting results emerge when sex-based differences in mortality are plotted by age class in Figure 6A–D: the Avalon, North, and West regions again display no clear bias toward either male or female mortality, but the females in the South

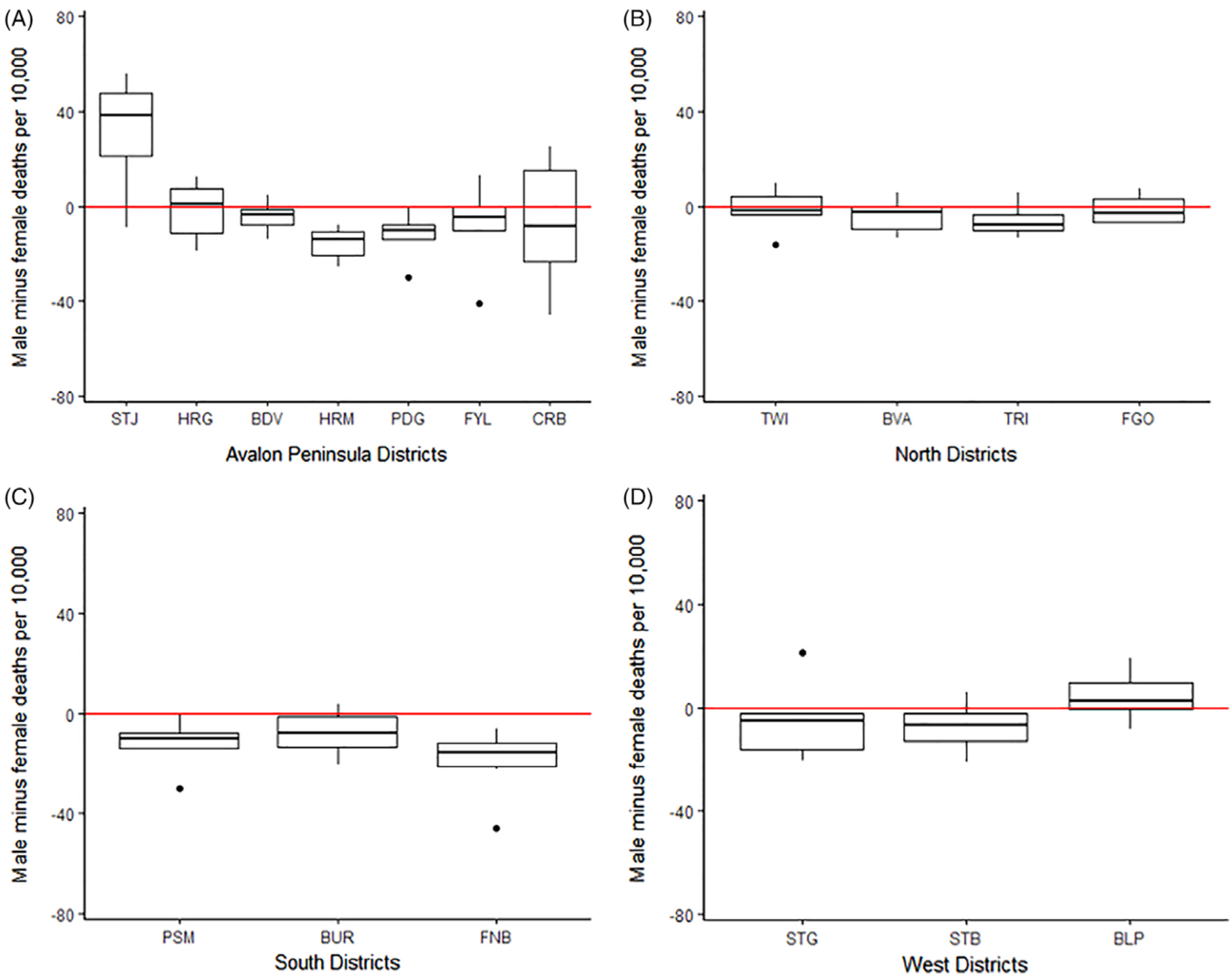

FIGURE 5 Differences in CSDR (male–female) by district (ages 15–19 through 40–44 only): A, Avalon Peninsula; B, North; C, South; and D, West

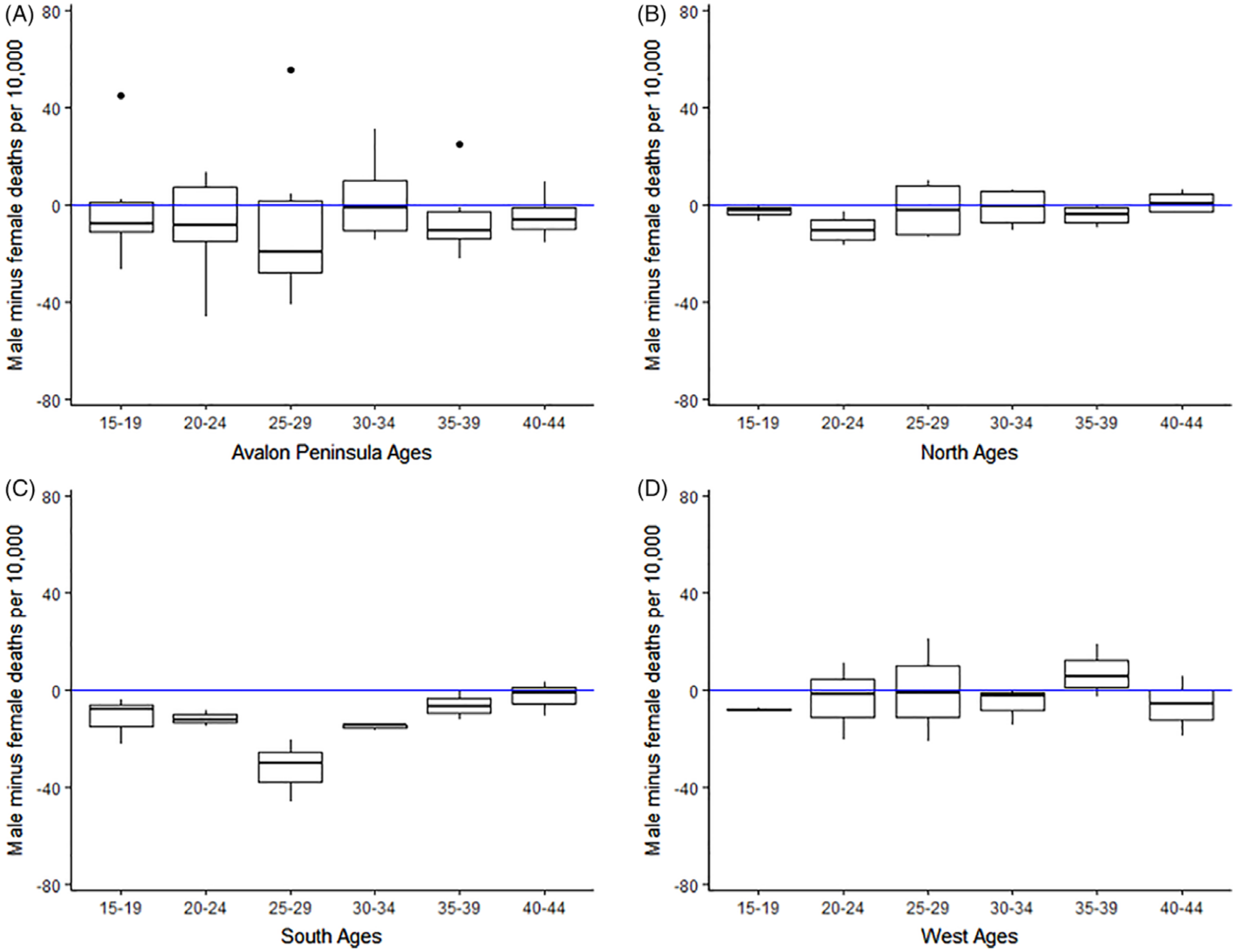

FIGURE 6 Differences in CSDR (male–female) by age class (15–19 through 40–44 only) in the four designated regions: A, Avalon Peninsula; B, North; C, South; and D, West

exhibit higher mortality than males for the given age classes, especially for ages 25–29 and 30–34. Possible reasons for this result are discussed below.

A logistic regression model was fit using age and region as interactive variables in order to determine the probability of male death in each region; a value of 1 on the y-axis indicates 100% chance of a male death for a specific age in one of the four regions, whereas a value of 0 on the y-axis indicates a 0% chance of male death, that is, a female death. The Avalon Peninsula region was used as the reference category for this analysis. The results of the logistic regression (Table 3) show that there are no significant predictors for male death in the model. Age ($z = 0.115$, $P = .908$) and region ($z = -0.200, -0.697, -0.703$; $P = .842, .486, .482$) individually are also insignificant in predicting sex-based mortality. However, the near-significance of the interaction between age and the Southern region ($\beta = -0.0098$, $z = -1.629$, $P = .103$), especially in combination with the clear lack of significance for other regions (Age*North: $z = -0.302$, $P = .763$; Age*West: $z = 0.130$, $P = .897$), suggests that there may be a tendency toward sex-based differences in mortality in this region.

The plot of the logistic regression (Figure 7) shows the probability of male death and exhibits a downward spike through the young adult and elderly age classes, suggesting a lower probability of male death and thus a higher

TABLE 3 Results of logistic regression using age and region as interactive variables to predict male or female death within each region. While no variable is highly significant, the age*south variable is the only variable approaching significance, indicating a trend toward sex-based differences in mortality for certain ages in the Southern region

Variable	Coefficient (β)	95% CI (range)	Std. error	z value	P-value
Intercept	0.1031	−0.0137, 0.2199	0.1168	0.882	.378
Age	0.0004	−0.0030, 0.0038	0.0034	0.115	.908
Region					
North	−0.0358	−0.2152, 0.1436	0.1794	−0.200	.842
South	−0.1390	−0.3383, 0.0603	0.1993	−0.697	.486
West	−0.1628	−0.3942, 0.0686	0.2314	−0.703	.482
Age*region					
North	−0.0016	−0.0069, 0.0037	0.0053	−0.302	.763
South	−0.0098	−0.0166, −0.003	0.0060	−1.629	.103
West	0.0009	−0.0059, 0.0077	0.0068	0.130	.897

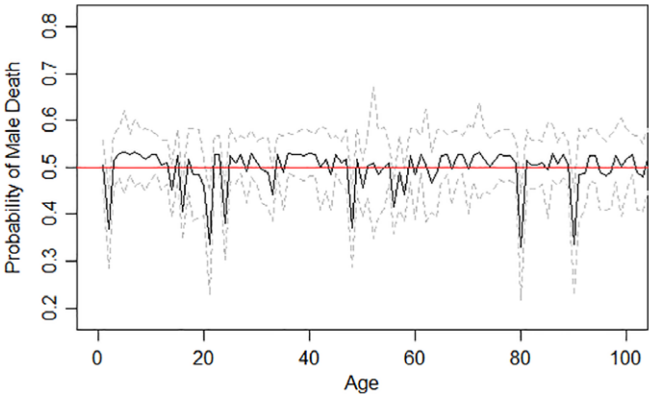

FIGURE 7 Plot of results of logistic regression predictions to determine probability of male death using age and region as predictor variables, with 95% confidence intervals. The horizontal line indicates a 50% chance of male death

probability of female death for these ages. Figure 7 shows that there are clear age ranges in which the probability of either male or female death is relatively equal (eg, ages 60–80), but there are also clear ranges through which the probability of male death trends downward.

The logistic function was used to calculate the probability of male death for ages 1, 20, 40, 60, and 80 (Table 4). These results show that, despite the fact that the model indicated no significant predictor variables, there is a clear downwards trend in the probability of male death in the South for ages 40, 60, and 80. For age 40 in particular, there is only a 39.8% chance that a death of this age will be male, compared to a 53.0%, 50.5%, and 49.8% chance in the Avalon, North, and West, respectively. The downward trends in the elderly age classes may in fact be due to the relatively small number of P&I deaths that occurred, either male or female, therefore any trends observed in those age classes may be the product of chance.

5 | DISCUSSION

The temporal pattern of deaths over the course of the pandemic on the island of Newfoundland matches the general pandemic progression described around the world. Figure 2 shows the pandemic progression by district (Figure 2A) and sex (Figure 2B), and both clearly exhibit the three waves that characterized the 1918 influenza pandemic. St. John's had the highest proportion of deaths for the entirety of the pandemic, especially for waves II and III. Further, both men and women in the district of St. John's were very mobile socially and economically, which are population characteristics that may have increased the potential of coming into contact with an infected individual by chance. As discussed previously, both men and women in the capital city enjoyed diverse labor opportunities apart from the standard fishery and domestic labor that characterized the rest of the outport cities and towns on the island. This observation suggests that the nonrandom pandemic mortality observed could depend on these different socioeconomic and behavioral patterns.

TABLE 4 The probability of male death in every region for the given ages calculated using the logistic function. Out of the four regions, there is a clear decrease in probability of male death in the Southern region, particularly for ages 40, 60, and 80

Age	Avalon	North	South	West
1	0.526	0.517	0.489	0.485
20	0.528	0.511	0.444	0.492
40	0.530	0.505	0.398	0.498
60	0.532	0.499	0.354	0.504
80	0.534	0.493	0.312	0.511

Figure 2A shows very clearly that there were few, if any, districts that escaped affliction. Wave I appears to be driven by deaths in St. John's, Trinity, and Bonavista, all districts with major port cities on the island. Wave II hit every district, with the highest death counts observed in St. John's and every other district recording deaths in every month during the fall of 1918. This is likely due to the trans-island railroad that was used to transport materials and individuals daily. This railroad connected all the districts within the Avalon Peninsula to each other and to the major districts in the northern and western regions of the island (Palmer et al., 2007; Schmidt & Sattenspiel, 2017). Finally, St. John's had the highest number of recorded deaths during wave III in the spring of 1920, but the other districts recorded relatively few deaths during this time. This is most likely because St. John's was the primary shipping port of the island, which allowed the flu to be reintroduced onto the island from one of the other major North American port cities. Further, since its population was much larger than the other districts, there was potentially a larger pool of susceptible individuals who could become infected, resulting in higher overall mortality rates by the summer of 1920.

Even though railroads connected approximately 100 towns throughout Newfoundland, boat travel was the more frequent means of transportation for most residents and involved travel to and from ports on the island, out to sea for fishing and sealing, and to and from the coast of Labrador during fishing season, with some trips lasting weeks to months (Palmer et al., 2007). It is likely that in the late spring of 1918, influenza found its way onto the island through the port of St. John's and spread there first. Whether the entry was via a ship returning from the First World War in Europe with the Newfoundland Regiment and/or the Royal Navy, or from one of the other major associated ports (eg, Boston, New York City, Nova Scotia, and Québec), remains a question with no clear answer. Indeed, reported deaths appear in earnest in St. John's first, with an increase in recorded deaths beginning in May 1918, and the first wave peaking in June 1918 (Figure 2A).

The graphs for males and females seen in Figure 2B seem very similar at first, but, during the first wave, men experienced higher mortality than women, whereas for the second two waves the pattern is flipped. This is not a trivial result, and it has been observed in studies of morbidity in Maryland and Bergen, Norway, two locations very distant from Newfoundland (Mamelund et al., 2016). It is important to make the distinction between morbidity and mortality because they reflect different biological characteristics, especially for diseases such as influenza. Influenza epidemics are always characterized by high morbidity and low mortality; this includes the 1918 pandemic (Dull & Dowdle, 1980; Johnson & Mueller, 2002; Palmer et al., 2007). The morbidity data collected for Maryland and Bergen only account for the individuals who were deemed ill during the pandemic, but, even for high mortality influenza epidemics, the individuals who die are only a small fraction of those who become ill. As the pandemic appears to have entered the island through St. John's via the military or general shipping, men were most likely the ones who brought the pandemic to the island and were the first to be infected at higher rates. If mortality patterns in Newfoundland generally reflect morbidity patterns, as was observed in Mamelund et al.'s (2016) data, we can assume that more males than females fell ill during the first wave and recovered after their illness, leaving fewer susceptible males in the population to be infected and die in later waves. As a result, during the second and third waves, more females fell ill and subsequently died, accounting for the observed higher mortality.

As seen in Table 2, and supported by Figures 3–5, the mortality rates for males and females separated by district and age class reveal interesting and important information about the specific epidemiology of each region that would otherwise be homogenized. When specific districts are considered, Harbour Main, in the Avalon Peninsula, is observed to have a strong bias toward female mortality with a male to female difference of 37.0 deaths per 10 000. The only district to exhibit equal observed male and female mortality is Bay de Verde; other districts that come close to equal sex-based mortality are Port de Grave (a difference of 2.2 deaths per 10 000), Ferryland (a difference of 3.2 deaths per 10 000), and Twillingate (a difference of 3.0 deaths per 10 000). The Southern region, comprised of the districts Placentia/St. Mary's, Burin, and Fortune Bay, is the clear outlier for female-biased mortality at the regional level (Table 2, Figures 4C and 5C).

The South is the only region for which there is a trend toward predicting sex-based mortality, though the results are not statistically significant (Table 3). The probabilities of male death reported in Table 4, however, help support the hypothesis that there was indeed a lower probability of male death, thus higher probability of female death, in the South for the age classes tested. By conventional standards, these results are not significant, but they are very suggestive when placed in context with the results from other regions, which are markedly nonsignificant. Identifying whether or not the mortality in any one region was different from the others requires a more balanced understanding of regional differences in health, and this analysis only succeeds in capturing a small piece of this complicated issue. Important factors contributing to regional health differences that may also impact sex-based differences include nutritional deficiencies in regions where natural resources are limited, regional prevalence of tuberculosis and other comorbid infections, and accessibility of health workers in geographically isolated communities.

It is possible that the higher than expected female mortality in the Southern region of the island was due to the increased risk for pregnant women. Pregnancy is biologically difficult on the female body, and it is well known that the introduction of the influenza virus during gestation can cause an excessive immune response, leaving both mother and baby more exposed to outside infection than they were before introduction of the virus (Gabriel & Arck, 2014). This relationship may be critical, as medical resources were relatively scarce in the South, and the geographic isolation of the region did not lend itself to easy travel to the medical centers in St. John's. As seen in Figure 5C, the highest female mortality in the South was observed for the prime childbearing years, and Figure 7 exhibits the higher probability of female mortality for the same age ranges. In the early twentieth century, boat travel was the most efficient way to access the southern coast of the island because there were few, if any, roads to southern towns (Palmer et al., 2007). This relative isolation compared to that between the Avalon Peninsula and the Northern districts, for example, may have inhibited women from accessing the medical care needed during pregnancy and childbirth. Without specific fertility and maternal mortality data to quantify the risk of infection and death for women on the island in relation to the 1918 pandemic, however, we must simply acknowledge that significant risk existed and probably played an important role in female pandemic mortality.

Another likely explanation for the trend toward higher female P&I mortality in the South involves the well-known comorbidity of influenza and tuberculosis. Tuberculosis was highly prevalent in Newfoundland during this time period (House, 1981; Schmidt & Sattenspiel, 2017), and it has been repeatedly observed that infection with tuberculosis increases the risk of mortality from P&I (Mamelund, 2011; Noymer & Garenne, 2003; Oei & Nishiura, 2012; Walaza, Cohen, Nanoo, Cohen, McAnerney, von Mollendorf, Moyes, & Tempia, 2015). Preliminary observations of yearly vital records suggest that although tuberculosis had the highest mortality rates of any respiratory disease, year to year mortality rates did not vary significantly, and there was no clear significant excess during the 1918–1920 pandemic period. Further exploration of tuberculosis mortality rates with individual death records for 1918–1920, however, reveal that within the South, women had higher tuberculosis mortality than men (124.1 deaths per 10 000 vs 92.5 deaths per 10 000). Further, women in the South had the highest mortality of all regions; outside of this region, sex-based mortality ranged from a low of 62.8 deaths per 10 000 (men in the West) to a high of 98.7 deaths per 10 000 (women in the North). Although this analysis is preliminary, given the knowledge that high tuberculosis prevalence can influence P&I mortality, these figures may suggest that female tuberculosis mortality in the South can help explain the differences in observed P&I mortality in this region.

Economy and social organization of the subpopulations of the island can help to explain the patterns of sex- and age-based mortality that have been homogenized by island-wide analysis. Unlike the city of St. John's where both sexes enjoyed diverse and clearly gendered labor opportunities, in the outports those opportunities were severely limited, although the sexual division of labor in these areas was probably at least as strong as in St. John's. Labor for males and females was primarily centered around the fisheries. Family organization consisted of nuclear families and close contacts of the immediate family, whereas relationships with distant kin were more similar to those with nonkin (Dimka, 2015). In the ethnographic literature on the fisheries and social structure of the Newfoundland outports, discussions center almost exclusively on the men's labor and contributions to the household. This focus severely diminishes the recognition of economic and political contributions of the women in the outports, which were extensive (Porter, 1985). Women were responsible for nearly half of the income of the family, performing the landside tasks of fisheries such as gathering, carrying, and preparing the catch, and performing all domestic tasks within the home (Dimka, 2015; Porter, 1985). Women maintained important social contacts even with nonkin throughout the villages, presenting far more opportunities for infection with an easily transmissible respiratory infection such as influenza. They also commonly took on the responsibility of caring for their neighbors when they were ill, even if they were nonkin, which put them in the direct line of potential infection (Porter, 1985).

In the context of susceptibility to pandemic flu, these gendered social activities seem to have placed females in a more vulnerable position in that the probability of coming into contact with an infected individual simply by chance increased with their total number of contacts in the community. Males working exclusively with their other male kin suggests they were not coming into contact with as many different individuals as their female kin, and their interaction with children, who are notorious infectious disease transmitters, was much lower. By highlighting the labor and social activities of males and females in the outports, it is clear that there are distinctions. In the face of the pandemic, these differences in social activities may have been the prime driver in transmission of the pathogen throughout the communities. Larger numbers of connections among women of different families may have increased the transmission probability of flu simply by chance, whereas the men were primarily only coming into contact with a small number of related individuals. The mortality patterns observed clearly suggest a strong social component to the differences in the effect of flu on men and women.

The observation that the chances of coming into contact with susceptible individuals increases with the total number of contacts is especially applicable to the densely populated Avalon Peninsula. As seen in Figures 4A and 5A, the differences between male and female flu deaths were variable depending on the district. There were districts within the Avalon Peninsula that experienced substantial sex differences in mortality, such as in Harbour Main (37.0 deaths per 10 000), and some of the highest SMRs were calculated for the Avalon Peninsula districts of Ferryland (M = 5.4, F = 6.5) and Harbour Main (M = 6.0, F = 2.5). Diverse labor opportunities and social behaviors in the dense population of St. John's ultimately resulted in a larger number of social interactions for both sexes. St. John's did not have the highest mortality rates for males and females independently (Bay de Verde was highest, with 90.8 P&I deaths per 10 000 for both males and females), but the capital did have the highest male-biased mortality rate in the Avalon Peninsula. Based on previous discussion about the relationship between influenza morbidity and mortality patterns, this result seems to indicate that men were consistently infected at higher rates than females. This may be due, again, to the consistent contact with the major Canadian mainland and United States port cities and the constant interaction of men infected with influenza.

Finally, individuals' ages must also be considered a critical variable in Newfoundland's flu pandemic patterns because the people performing most of the labor, domestic tasks, and social interactions were the young adults. Further, in the outport districts in the North, South, and West, female flu mortality was slightly higher than expected compared to males, a phenomenon that could most likely be explained by the fact that the women who died at unprecedentedly higher rates (especially in the Southern districts) were of childbearing age. Discussed previously, the high prevalence and mortality rates of tuberculosis across the island, specifically in the South, also likely played a role in the observed P&I mortality patterns. Relative isolation of the regions outside of the Avalon Peninsula likely contributed to the sex-based differences in mortality observed in the study. These features are not mutually exclusive; in terms of Newfoundland specifically, the organization of families is critically linked to the economy of that family and to the population to which they belong.

Despite the fact that the 1918 influenza pandemic is characterized by high morbidity and relatively low mortality compared to many human infectious diseases (eg, smallpox, Ebola, or plague), it was not an indiscriminate killer.

Aggregate mortality patterns can obscure important region-specific patterns; pandemic mortality in Newfoundland can be more accurately described by considering the sex- and age-based mortality patterns on a geographic scale below the island level. Sex-based mortality differed depending on the specific economy of the region, but also because of the greater relative risk during pregnancy in the more isolated regions of the island. Age-based mortality was closely linked to these factors; the age classes with the highest observed mortality were those most active in the gendered labor and social activities of all regions, and the highest female mortality occurred in women of childbearing age. The island-level data and consequent epidemiologic patterns homogenized these mortality trends of the different regions of the island. For this reason, biological, behavioral, and socioeconomic factors must be assessed for subpopulations in order to explain the epidemiologic patterns of the 1918 pandemic in more detail.

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AUTHOR CONTRIBUTIONS

TP and LS designed the study. LS obtained most of the death data and archival materials at the Newfoundland and Labrador Provincial Archives. TP analyzed the data and drafted all parts of the manuscript. LS provided input into the interpretation of the results and the overall structure of the manuscript, and provided editorial support and critical comments.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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