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Contextualizing pandemics: Respiratory survivorship before, during, and after the 1918 influenza pandemic in Newfoundland

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Abstract

Background: Research on the 1918 influenza pandemic often focuses exclusively on pandemic years, reducing the potential long-term insights about the pandemic. It is critical to frame the 1918 pandemic within the underlying population dynamics, health, and sociocultural context to understand what factors contributed to pandemic mortality and survivorship, with respect to observed inequality, and consequences of the pandemic.

Materials & Methods: Individual death records and censuses from The Rooms Provincial Archives and Memorial University of Newfoundland Digital Archives for three major causes of death—influenza and pneumonia; tuberculosis; and pooled bronchitis, measles, and whooping cough—were collected for three periods in the early 20th century: pre-pandemic (1909–11), pandemic (March 1918–Janaury 1919), and post-pandemic (1933–1935). We calculated pooled age-standardized mortality rates and changes in pre- to post-pandemic mortality rates by region. We fit Kaplan–Meier and Cox proportional hazards models to each period, controlling for age, cause of death, and region.

Results: Pandemic mortality was higher than that of pre- and post-pandemic periods. Post-pandemic mortality was significantly lower than pre-pandemic mortality in all regions, except Western Newfoundland. Survival was lowest during the pandemic and increased significantly post-pandemic ($p < 0.0001$), with no significant differences among regions during the pandemic ($p = 0.32$). Significant differences in survivorship in 1933–1935 were driven by increasing differences in survivorship for P&I among the regions more than other causes of death.

Discussion: Myopic perspectives of pandemics can obscure our understanding of observed outcomes. Inequalities in respiratory disease mortality are evident in pre- and post-pandemic periods, but these would have been missed in investigations of the pandemic period alone.

KEYWORDS
1918 influenza pandemic, historical demography, social inequalities, survivorship, tuberculosis

1 | INTRODUCTION

Pandemics are typically more severe and geographically extensive than localized outbreaks and tend to be caused by novel pathogens and affect more than one country, continent, or the whole world relatively simultaneously (Dimka et al., 2022). They are regularly occurring phenomena through history, although the definition of a pandemic is not standard across fields (e.g., Doshi, 2011). The 1918 influenza pandemic is often considered a worst-case scenario for an acute respiratory outbreak with estimated death counts ranging from 15–40 million, or even 50–100 million (Crosby, 1989; Johnson & Mueller, 2002; Patterson & Pyle, 1991; Spreeuwenberg et al., 2018). Since the 1918 flu, recent pandemic studies have further demonstrated that emerging pathogens disproportionately affect those who are most affected by ethnic, gender, economic, and structural inequalities with respect to access to health care, socioeconomic status, and other contributing sociocultural factors, and thus are most vulnerable to contracting the disease and its outcomes (e.g., Alwani et al., 2021; Bentley, 2020; Brzezinski, 2021; Garcia et al., 2021; Khunti et al., 2022; Mountantonakis et al., 2021; Rogers et al., 2020).

Much of the existing epidemiological and demographic research on the 1918 flu is focused on the health and mortality experiences within the pandemic years, generally between 1918–1920, compared to some pre-pandemic baseline (e.g., Chowell, Erkoreka, et al., 2014; Chowell, Simonsen, et al., 2014; Curson & McCracken, 2006; Erkoreka, 2010; Mamelund et al., 2016; Palmer et al., 2007; Saglanmak et al., 2011; Viboud et al., 2013). The proximate focus on pandemic years is an effective approach for understanding the immediate mortality impact of the disease, especially to address pressing questions about disease transmission, morbidity, mortality, and case fatality. However, such analyses tend to lack temporal depth and sociocultural context to fully understand the contributing factors to pandemic mortality and lasting consequences.

Pandemic studies can be strengthened by broadening the period of inquiry, specifically in contextualizing the severity of pandemic outcomes with what could be expected during a non-pandemic period. This approach can better frame whether observed inequalities in pandemic outcomes were typical, amplified, or unique, especially when considering competing causes of morbidity and mortality. For example, if we observe large differences in pandemic mortality among ages, genders, or socially constructed races, it is important to know whether these inequalities deviate from those observed in non-pandemic years, as such patterns may be indicative of underlying syndemic interactions between pandemic diseases, other health conditions, and the sociocultural factors contributing to them (Mendenhall & Singer, 2020; Singer et al., 2017; Singer & Clair, 2003). Other anthropologists have studied the 1918 flu in various geographic locations, and these have revealed underlying demographic inequalities with respect to pandemic mortality and morbidity (Dimka, 2015; Dimka et al., 2014; Herring, 1993; Herring & Sattenspiel, 2007; Sawchuk, 2009; Tripp et al., 2018; Wissler, 2021). Here, we offer a study that reconstructs the pandemic patterns of the 1918 flu to two distinctly nonpandemic periods in early 20th century Newfoundland to further contextualize the pandemic experience from an anthropological perspective.

This paper investigates mortality and survivorship of major respiratory diseases, which were leading causes of morbidity and mortality, on the island of Newfoundland during the 1918 flu and two nonpandemic periods (1909–1911 and 1933–1935). Early 20th century Newfoundland was undergoing major demographic and epidemiological transitions (Schmidt & Sattenspiel, 2017), was plagued with persistent malnutrition (Adamson et al., 1945), an excess burden of tuberculosis (TB) with an estimated prevalence of 148 cases per 10,000 individuals (House, 1981; van Doren & Sattenspiel, 2021), and suffered severe 1918 flu mortality (74.5 deaths per 10,000 individuals) (Sattenspiel, 2011). Within anthropological frameworks that consider the integration of biology, culture, and change (biocultural anthropology), as well as the temporal and social context of the population under study, we can better understand the ultimate determinants and impacts of the 1918 flu in Newfoundland. A goal of this research is to provide depth and clarity on the biosocial impacts of pandemics and, consequently, provide insight into present and future pandemic risks.

1.1 | Epidemiological transition & biocultural integration

It is essential to situate a pandemic event within the broader temporal scope and context because the patterns of unequal pandemic outcomes are products of major long-term demographic, epidemiological, and sociocultural dynamics. An understanding of epidemiological transition theory can aid in the interpretation of how populations worldwide experienced the 1918 flu, as well as how those populations responded to the transition within their own cultural and historical context.

The second epidemiological transition, or the "Age of Receding Pandemics," is characterized by a decrease in infectious disease mortality and a proportionate increase in "man-made," degenerative, and chronic disease mortality (Barrett et al., 1998; Harper & Armelagos, 2010; Omran, 1971). This was proposed as an explanation for the rapid decrease in total mortality that was observed in Western nations through the late 19th and early 20th centuries (Davis, 1945; Kirk, 1996; Thompson, 1929). These models were theorized using data almost exclusively from England, Wales, and the United States (Omran, 1971, 1977); therefore, they suffer from considerable Western bias (Barrett et al., 1998) and do not explain the nature of the demographic and epidemiological transitions elsewhere, like the global south (Caselli et al., 2002; Defo, 2014; Mercer, 2018; Santosa et al., 2014; Yadav & Arokiasamy, 2014).

The second epidemiological transition, along with other transitions that accompanied major shifts throughout human history (Harper & Armelagos, 2010), should be studied within a biocultural framework because they were driven by human behavior and substantially influenced human biology. Sawchuk et al. (2013) integrated sociocultural and demographic contexts over 200 years in the Maltese islands to identify points of crisis and stability in mortality, which is a strength of anthropological approaches to long-term population dynamics and health. The development of indoor plumbing, water treatment, and greater accessibility of diverse food sources were some of the drivers in reducing infectious disease mortality and increasing life expectancy; the decline of TB and other acute respiratory diseases may have contributed the most to lowering total mortality after industrialization (McKeown, 1976; Szreter, 1988). Inequalities of central interest to pandemic research, such as those relating to malnutrition, overcrowding, differential socioeconomic status, and risk of exposure to co-circulating pathogens, are determined by a population's transition status (Harper & Armelagos, 2010).

The sociocultural and socioeconomic environment of a population also has strong effects on population biology and health. Thus, it is essential to situate the experience of a pandemic within the local biocultural context as this can provide explanatory power for reconstructing differential mortality and survivorship between and within populations past and present (DeWitte, 2016; DeWitte et al., n.d.; van Doren, 2021, 2022a). Biocultural anthropology provides a framework for understanding how human biological plasticity and culture coevolve and, importantly, how these factors play a role in the coevolution of humans and pathogens (Goodman & Leatherman, 1998; Leatherman & Goodman, 2020; Wiley & Cullin, 2016). In other words, just as humans and pathogens are in a continuous evolutionary relationship, so too are human biology and culture, the product of which is the "local biology" of a population that reflects ambient macrosocial socioeconomic and ecological forces (Lock, 1993, 2017). Critically, modern population health does not exist in isolation, but is rather determined by intergenerational health and social conditions that can be exacerbated over time by persistent or acute stressors (Hoke & McDade, 2015; Lock, 2017).

Certainly, epidemics and pandemics are also influenced by the physical landscape in which they occur and the mobility of the hosts. While outside the scope of this paper, there has been considerable research on infectious disease ecology and how natural (and constructed) ecosystems have symbiotic effects on diseases and epidemics (Baer & Singer, 2016; Ostfeld et al., 2008; Tallman et al., 2022; Townsend, 2011). Island epidemics, for example, are differentially influenced by the natural boundaries of the landscape and the in- and out-migration of the hosts. Historical epidemiology of the 1918 flu in Iceland, for example, indicates that more isolated parts of the island nation were relatively well protected from the pandemic, especially since air travel was easily restricted (Cliff et al., 2009; Dowell & Bresee, 2008). For other islands worldwide, pandemic severity was variable: some Caribbean islands escaped while others, especially low socioeconomic subpopulations, suffered greatly (Killingray, 1994); Japan did not experience any more or less severe consequences than much of mainland Asia (Chandra, 2013); and quarantines proved effective in some Pacific Islands (McLeod et al., 2008). The ability of islands to prevent, or restrict, inward and outward travel helps them escape or delay pandemic consequences, but when livelihoods and economies depend on travel, they can again become exposed to pandemic transmission.

Biocultural approaches to anthropology can be integrated with the demographic and epidemiological transition theories to develop a holistic understanding of human health, demography, and culture, as well as how infectious disease play a critical role in that evolution (DeWitte et al., n.d.; van Doren, 2022a; Inhorn, 1995). When assessing risk of severe pandemic consequences in a population based on their local biology, it is not trivial to also take stock of the ambient social conditions that contribute to contemporaneous comorbid pathogen circulation, health of young people, or life expectancy. Situating the progression of an infectious disease outbreak against the backdrop of demographic and epidemiological shifts can provide important contextual information about the determinants and outcomes of that outbreak. For this study, we take a biocultural approach to reconstruct the mortality and survivorship patterns of populations on the island of Newfoundland during the periods before, during, and after the 1918 flu to understand the social underpinnings of differential pandemic experiences.

1.2 | Study population: Newfoundland in the early 20th century

Newfoundland is a large island in the North Atlantic region of North America and was an independent dominion of the British Empire until Canadian confederation in 1949 (Cadigan, 2009) (Figure 1). Four major regions are distinguished: the Avalon Peninsula, North, South, and West. These regions are aggregations of the 17 official political districts at the time. In the early 20th century, Newfoundland had a population of approximately 250,000 people, with about 40% of the population consolidated in the largest city on the island, St. John's, and the surrounding urbanizing area in the Avalon Peninsula. The rest of the population was scattered around the northern, western, and southern coasts (the North, West, and South regions) in small fishing villages called "outports," which were relatively remote. Of the nearly 1400 distinct localities described in the 1921 census, ∼98% of them had fewer than 1000 people and nearly 36% of them had 50 or fewer people; the West and South had comparably more of these sparsely populated outports than the Avalon and North regions (Colonial Secretary's Office, 1923).

There were also important differences among regions, namely between the three rural regions (North, South, and West) and the Avalon Peninsula. Based early 20th century census data, the Avalon Peninsula had the highest proportion of people who could read and attended school (while most in the rural regions either did not attend or rarely attended beyond age 15), and the proportion of people in the Avalon Peninsula who engaged in fishing labor was far below those of the rural regions (Colonial Secretary's Office, 1903, 1914, 1923; van Doren, 2022b). Additionally, the West had a higher dependency ratio (the number of people under age 15 and over 65 divided by the number of people between 15 and 65) than all other regions, although the North and South had higher dependency ratios than the Avalon Peninsula. Other anthropological research has described social organization of Newfoundland's outports, which are primarily centered around kinship, namely patrilineal and patrilocal fishing economies (Nemec, 1972; Philbrook, 1966).

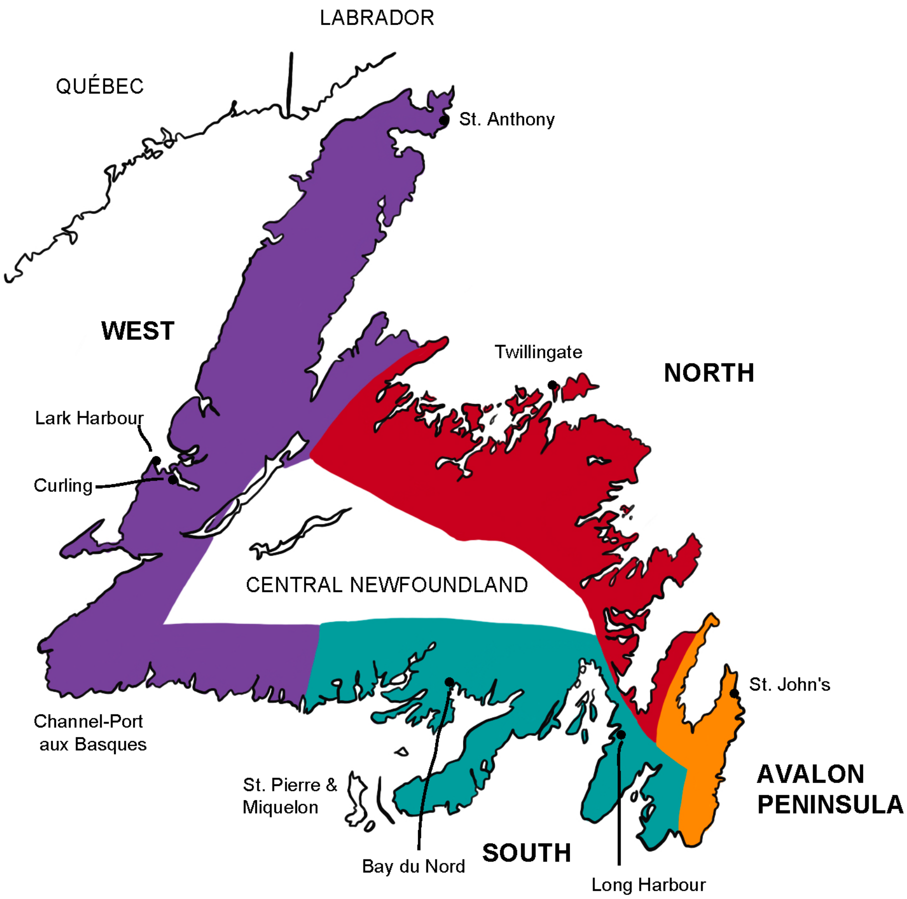

FIGURE 1 A map of the island of Newfoundland with the four research regions in color: Avalon Peninsula = orange, North = red, West = purple, and South = teal.

There were considerable differences in how the rural regions were able to access health care during this time. There was one hospital in St. John's, and the railroad that connected ~100 towns within the Avalon Peninsula and the close districts in the North made it a central location for healthcare access for these localities (Palmer et al., 2007). Since 1892, there was a hospital in St. Anthony called the Grenfell Mission in the northernmost corner of the island in the West (Figure 1), which specialized in care of TB patients (House, 1981). While these are only a few of many potential characteristics of these regions that could be described with census data, they provide some insights into the differences among regions.

The 1918 flu in Newfoundland was severe compared to elsewhere in the Western world. By the end of the pandemic in spring 1920 in Newfoundland, almost 2000 people had died, constituting an estimated mortality rate of 74.5 deaths per 10,000 (Sattenspiel, 2011). This is higher than estimates for other North American and North Atlantic nations, such as 49–58 deaths per 10,000 in England & Wales, 46–54 deaths per 10,000 in Iceland, 47–62 deaths per 10,000 in Canada, and 52–65 deaths per 10,000 in the United States (Johnson & Mueller, 2002; Patterson & Pyle, 1991). However, there was significant variation in pandemic experience across the island. District mortality varied from 28.6 to 109.3 deaths per 10,000 individuals, and the highest mortality occurred in the South (Sattenspiel, 2011).

Like other populations, Newfoundland experienced three waves: (1) an initial wave in summer 1918, which was relatively late compared to the first wave that occurred in the spring elsewhere; (2) a second wave in fall 1918 through winter 1919, during which most of the mortality occurred; and (3) an "echo" wave in 1920 that mostly occurred in St. John's (Palmer et al., 2007; Paskoff & Sattenspiel, 2019; Sattenspiel, 2011). It is not possible to tell when or where the influenza virus first entered the island because the first seven deaths attributed to influenza during the first wave occurred within two weeks in four different districts (Palmer et al., 2007).

Schmidt and Sattenspiel (2017) have shown that only St. John's had begun the second epidemiological transition by 1939. Structural drivers of the transition, such as widespread sanitation procedures, were only available in St. John's; the outports lagged far behind in the development of public health practices (Pitt & Baker, 1984). Government funding in public health also lagged, and until a formal Department of Public Health was established in the 1930s, everywhere outside of St. John's and St. Anthony depended on non-medically trained "handy women" and sporadic physician visits (Lawson & Noseworthy, 2009; Porter, 1985). It is possible that these regional inequalities in public sanitation may have worsened the pre-existing health status of those in rural areas, thereby putting them at greater risk of contracting and suffering from multiple competing health conditions, including flu, and risk of death.

The population also suffered from persistent malnutrition and TB, which even in the early 20th century was known to be a severe and inseparable combination of perpetuating comorbid health conditions

(Adamson et al., 1945; Aykroyd et al., 1949). van Doren and Sattenspiel (2021) highlighted these nutritional deficiencies such as skin lesions, gum swelling, and vitamin C and D deficiencies (Adamson et al., 1945) as central to high TB mortality from 1900–1939, despite the devastating impacts of strong selective effects after the 1918 flu observed elsewhere (Noymer, 2009, 2011). The comorbidity of TB and influenza is well-observed and severe (Walaza et al., 2015, 2020), resulting in observations of selective mortality against those with both diseases and subsequent decline of TB mortality in the decades following the 1918 flu (Noymer, 2009, 2011). Secondary pulmonary infections such as pneumonia, measles, bronchitis, and whooping cough are common—and appear frequently in the Newfoundland death records—and can complicate an influenza infection, especially in young and old people (Kash & Taubenberger, 2015; Rothberg & Haessler, 2010). These comorbid infections can be further complicated by suppression of immune function from chronic or acute malnutrition (Elo & Preston, 1992; Jaganath & Mupere, 2012). We cannot discount the possibility that the mortality and/or survivorship patterns of one or more of these infectious respiratory diseases were impacted by the 1918 flu.

In this paper, we seek to address three research questions about the mortality and survivorship during the 1918 flu in Newfoundland: (1) How did age-based mortality from major causes of respiratory diseases (influenza and pneumonia, all forms of TB, and bronchitis, measles, and whooping cough) change through a pre-, pandemic, and post-pandemic period?; (2) How did survivorship overall and among the four regions change over the three time periods?; and (3) What sociocultural and demographic factors may account for observed differences? Research that situates pandemic events within a broader study period and context requires the passage of enough time to which we can reflect upon population-level changes. This richness of data and context is exactly what makes historical pandemics ideal for studying modern pandemic consequences and heterogeneity in pandemic mortality and survivorship. Ultimately, this paper argues for broader engagement with the decades leading up to and after the 1918 flu to better understand its severity.

2 | MATERIALS & METHODS

2.1 | Data

The primary sources of data used here are individual death records from Newfoundland's Grand Banks (https://ngb.chebucto.org), which were transcribed and made publicly available by volunteers at The Rooms Provincial Archives in St. John's, Newfoundland & Labrador. In addition, data from statistical censuses for the years 1911, 1921, and 1935 were collected from the Digital Archives of Memorial University of Newfoundland.

A database of death records was constructed with three primary disease categories for analysis: (1) pulmonary infections (P&I); (2) tuberculosis (TB); and (3) a binned category of childhood diseases, including bronchitis, measles, and whooping cough ("other"), that occurred in three time periods: (1) pre-pandemic (1909–1911); (2) 1918 pandemic (March 1918–January 1919); and (3) post-pandemic (1933–1935). Bronchitis, measles, and whooping cough were binned into a singular category because these three diseases tended to be age-specific in who they infect and were most likely to result in death (children), and thus, are expected to have distinct age-specific patterns of mortality and survivorship. The sample size used in these analyses was 8265 deaths.

The 1918 pandemic study period captures both the first wave of mortality in the summer and the major second wave, during which most mortality occurred. There was a third wave in spring 1920, but it was comparatively small and mostly occurred only in St. John's (Paskoff & Sattenspiel, 2019), so we focus our analyses on the waves with the largest impact. There are three main reasons why we chose these pre- and post-pandemic time periods. First, we sought to compare mortality and survivorship for three distinct periods. Specifically, for the post-pandemic period, we were most interested in identifying and analyzing trends in mortality and survivorship between distinctly non-pandemic periods in the early 20th century to provide greater contextual and temporal depth, rather than focusing on yearly changes. Second, 1911 and 1935 were census years with known population sizes and structures, eliminating the need to make unnecessary population estimates. Third, the three-year stretches for the nonpandemic periods were chosen to have comparable sample sizes for each cause of death to the pandemic period; these nonpandemic samples would have been very small for all diseases otherwise, and we sought comparisons with more statistical power. A summary of the number and percent contribution of deaths for each region can be found in Table 1.

2.2 | Population calculation & standardization

Since these analyses do not use one-year time periods, population sizes from censuses were scaled to account for the *person-years* lived for each period. The population sizes for 1911 and 1935 were taken directly from their respective censuses. The 1918 population is a linearly interpolated estimate calculated using the 1911 and 1921 censuses. This method assumes population growth is equally distributed over the intercensal period, but there were likely some changes after the pandemic that caused the 1918 interpolation to be slightly overestimated. With around 2000 deaths directly attributed to the pandemic, this may not heavily bias the results of these analyses, but it may cause the mortality rates to be slightly underestimated. Finally, since the pandemic period spans March 1918 through January 1919, we have scaled the estimated 1918 population accordingly.

Crude mortality rates (CDR) per 10,000 individuals for aggregate causes of death were calculated using the following denominator scaling:

$$\mathrm{CDR}_{\text{pre-pandemic}} = \left(\frac{\text{Number of Deaths}_{1909-1911}}{3 \times \text{Population}_{1911}}\right) \times 10{,}000$$

TABLE 1 Descriptive table of the number of deaths for each cause of death and percentage of total deaths contributed by each cause of death in each region of Newfoundland and time period

Region	Time period					
	Pre-pandemic (1909–1911)	(%)	Pandemic (Mar 1918–Jan 1919)	(%)	Post-pandemic (1933–1935)	(%)
Avalon						
P&I	273	(8.3)	435	(19.6)	305	(11.1)
TB	920	(27.9)	274	(12.4)	442	(16.1)
Other[a]	260	(7.9)	118	(5.3)	180	(6.5)
North						
P&I	156	(4.7)	317	(14.3)	298	(10.8)
TB	674	(20.5)	206	(9.3)	498	(18.1)
Other	173	(5.3)	106	(4.8)	112	(4.1)
South						
P&I	69	(2.1)	293	(13.2)	140	(5.1)
TB	376	(11.4)	149	(6.7)	257	(9.3)
Other	77	(2.3)	43	(1.9)	41	(1.5)
West						
P&I	54	(1.6)	177	(8.0)	139	(5.0)
TB	195	(5.9)	76	(3.4)	287	(10.4)
Other	68	(2.1)	23	(1.0)	54	(2.0)
Total	3295		2217		2753	

[a]Bronchitis, measles, and whooping cough are aggregated into "Other".

$$\mathrm{CDR}_{\mathrm{pandemic}} = \left(\frac{\text{Number of Deaths}_{\text{Mar 1918–Jan 1919}}}{\left(\frac{11}{12}\right) \times \text{Population}_{1918}}\right) \times 10{,}000$$

$$\mathrm{CDR}_{\mathrm{post-pandemic}} = \left(\frac{\text{Number of Deaths}_{1933-1935}}{(3) \times \text{Population}_{1935}}\right) \times 10{,}000$$

The calculations for the pre- and post-pandemic periods use the reported census figures and assume that the population size was equal in all 3 years, which is imprecise. While a small limitation, it is unlikely that the population increased or decreased enough in a three-year period to have substantial impacts on denominator size, and therefore the CDR.

To compare mortality rates among the four regions in each period, age-standardized death rates (ASDR) for aggregate respiratory diseases were calculated with direct standardization using the total population of the island as the standard population. The difference between pre- and post-pandemic ASDRs and two-proportion *z*-scores were calculated to assess significant change from the pre- to post-pandemic periods.

2.3 | Survival analyses

We investigated a series of survivorship and hazards calculations to discern if there were changes in survival and mortality risk over the course of early 20th century Newfoundland for the causes of death examined. Survivorship is the probability that an individual will survive to a certain age (time *t*), and this function is dependent on the mortality hazard of preceding ages (Chamberlain, 2006; Wood et al., 1992, 2002). In anthropological demography and paleodemography, non-parametric and semiparametric models of survivorship and hazards analyses are often applied to studies of mortality as an alternative to other demographic models as a way of describing mortality patterns without assuming a prior for the human mortality distribution (Wood et al., 1992, 2002). Two such models, the Cox proportional hazards model (Cox, 1972) and Kaplan–Meier survival analysis (Kaplan & Meier, 1958), are frequently used in historical and paleodemographic analyses of past pandemics (for review of these applications, see DeWitte & Stojanowski, 2015). The Cox model is semiparametric because it allows us to formulate an analysis of survival data where no parametric form of the baseline hazard is specified, but the effects of the covariates are parameterized to alter the baseline hazard function (that for which all covariates are equal to zero) (Cox, 1972). In other words, the model allows for the estimation of the effects of covariables (e.g., time period, region, gender, infectious disease) on the risk of death without specifying the baseline hazard.

These types of similar models are useful for informing us about general trends in historical samples. Kaplan–Meier survival analyses are used to estimate probability that an individual will survive to a specified age, and this is a cumulative function in which the value of the function at a specified age is dependent on the mortality hazard at all preceding ages; thus, points on a survivorship curve are not independent data, a fact that has implications for the statistical comparison of survivorship patterns in different populations (Chamberlain, 2006; Kaplan & Meier, 1958). In sum, these analyses measure the probability of death from an event in a representative population and allow statistical comparisons of these probabilities to probabilities estimated for other populations of interest. Results will reveal whether survival from these diseases during the 1918 flu was different than what would be expected for a nonpandemic period.

Using Kaplan–Meier survival analyses and log-rank tests, we compared survivorship by period for the pooled sample of total respiratory deaths on the island, and then stratified by region for each period. Temporal trends in survivorship, as well as regional differences and cause-specific deaths, were then analyzed. We used Cox proportional hazards models to control for both cause of death and region to investigate the contributions of each variable to the overall trends in survivorship for each period. For all Kaplan–Meier and Cox proportional hazards analyses, significance was interpreted at the $\alpha = 0.05$ level. All statistical analyses were conducted in R using established R packages. R code will be available on the first author's Github page upon publication.

3 | RESULTS

3.1 | Mortality

Results of the standardized age-based pooled respiratory mortality calculations reveal that composite mortality is roughly W-shaped for all time periods (Figure 2). As seen in Table 1, most of the deaths that contributed to these mortality calculations were from TB; van Doren and Sattenspiel (2021) showed that the W-shaped pattern was prominent in TB deaths throughout the early 20th century in Newfoundland, so this observation is not unfounded. Pooled respiratory mortality during the pandemic was higher than pre- and post-pandemic mortality and exhibited a more pronounced peak in ages 20–44, likely due to the contribution of pandemic influenza deaths in this category, as seen in Figure 2 and Table 2. Post-pandemic mortality rates were lower than both pre-pandemic and pandemic mortality rates (Figure 2; Table 2). The Avalon region lost this W-shape and more closely resembled that of the U-shape that is commonly identified for P&I deaths in nonpandemic years (Luk et al., 2001; Taubenberger & Morens, 2006), also a signal that fewer adults in this age class died from TB during this time. Similarly, the curve for the South flattened, and the curve for the North had a less pronounced W-shape, although it was still present. The West is the only region that still had a peak centered around 30–35 years in 1933–1935.

Table 2 shows the total mortality rates for each period, changes in mortality from pre- to post-pandemic periods, and results of the tests for significant differences. Pooled respiratory mortality during the pandemic was highest in the South and had a large decrease in mortality from pre- to post-pandemic periods, but the Avalon had a slightly larger decrease in mortality from its pre- to post-pandemic period. The Avalon, North, and South all had significant decreases in mortality (-20.6 deaths per 10,000, $p < 0.001$; -5.8 deaths per 10,000, $p < 0.01$; and -19.3 deaths per 10,000, $p < 0.001$, respectively). The West was the only region that did not undergo a significant change (-4.3 deaths per 10,000, $p = 0.132$).

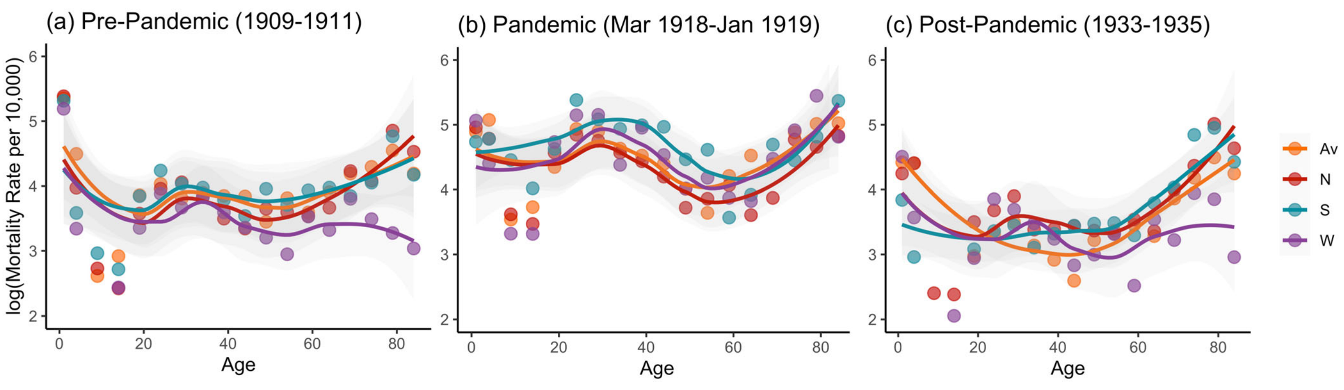

FIGURE 2 Standardized age-based mortality rates per 10,000 individuals (log transformed) for pooled respiratory causes of death for the three time periods.

TABLE 2 Pooled ASDR for each region in each time period, with calculated difference in mortality between pre- and post-pandemic periods and their statistical significance assessed on the $\alpha = 0.05$ level

Region	Pre-pandemic (1909–1911)	Pandemic (Mar 1918–Jan 1919)	Post-pandemic (1933–1935)	ΔPost-pre	χ^2	*p*-value[a]
Avalon	50.1	90.9	29.5	−20.6	182.6	<0.001 ***
North	43.2	81.2	37.4	−5.8	8.5	<0.01 **
South	46.8	114.2	27.5	−19.3	83.1	<0.001 ***
West	32.0	92.7	27.7	−4.3	2.3	0.132

[a]Significance codes: 0.001 "***", 0.01 "**", 0.05 "*"

3.2 | Survival and hazards analyses

Kaplan–Meier and Cox regression analyses for aggregate causes of death in all regions reveal that survivorship curves for the three time periods are significantly different (p < 0.001) (Figure 3, Table 3).

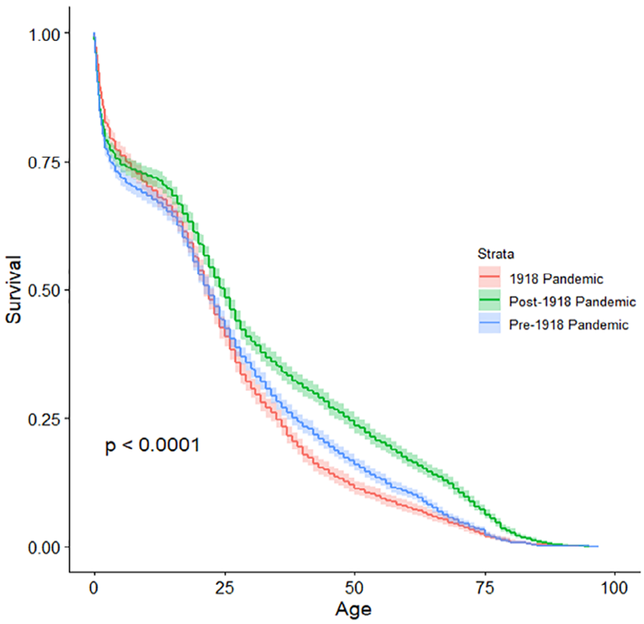

FIGURE 3 Survivorship from pooled causes of death for the three time periods: Pre-pandemic, pandemic, and post-pandemic

Survivorship was significantly lower during the pandemic for pooled respiratory deaths in all regions compared to the pre- and post-pandemic periods (p < 0.001 and $p = 0.04$, respectively).

Regional survivorship analyses for pooled causes of death using the Avalon Peninsula as a baseline revealed that survivorship was relatively equal among Newfoundland's four regions during the 1918 flu, but there was a significant increase in survivorship differences afterwards (Figure 4, Table 4). Pre-pandemic, differences among survivorship curves for the four regions from the pooled respiratory causes were significant ($p = 0.049$), during the pandemic differences were not significant ($p = 0.32$), and post-pandemic differences were significant (p < 0.001) (Figure 4). Pre-pandemic, the West was the only region that had significantly lower survivorship than the other three regions ($p = 0.006$) (Table 4). Post-pandemic, however, the South had significantly higher survivorship than the Avalon and North regions ($p = 0.019$), and the West had significantly lower survivorship (p < 0.001) (Table 4).

For the analyses stratified by cause of death and region, "other" causes of death (bronchitis, measles, and whooping cough) and the Avalon region were the baseline measurements. Controlling for cause of death, clear age-based patterns emerged (Figure 5, Table 5). Specifically, bronchitis, measles, and whooping cough were childhood diseases, and in all time periods, most people who died from one of these three causes died within the first few years of life. In Table 5, the causes of death are highly significant from each other (p < 0.001) across all periods, which can be attributed to the age-specific differences in mortality across diseases (displayed in Figure 5). However, there is variation in mortality hazards based on region as a stratifying

TABLE 3 Results of pooled survivorship analyses by period. Kaplan-Meier results report the mean and median age of survivorship with their estimated standard deviation and 95% confidence intervals, respectively. Cox proportional hazards results report the hazard ratio and significance values using the pandemic period as the standard

	Kaplan–Meier results		Cox proportional hazards results	
Period	Mean age (SE)	Median age (95%)	Exp (β)	p-value
Pandemic	24.4 (0.4)	22 (21–23)	— standard —	
Pre-pandemic	25.5 (0.4)	22 (21–23)	0.756	<0.001 ***
Post-pandemic	30.1 (0.5)	25 (24–26)	0.945	0.04 *

Significance codes: 0.001 "***", 0.01 "**", 0.05 "*"

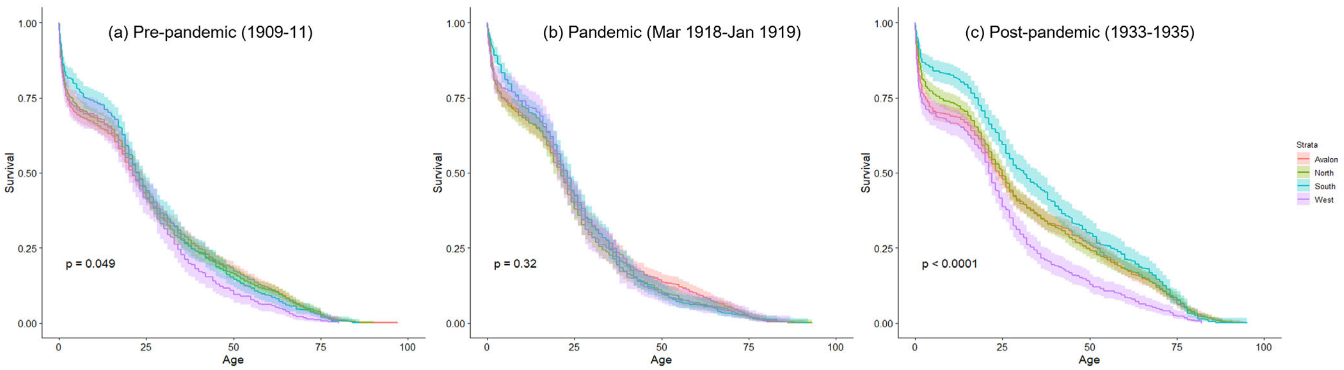

FIGURE 4 Survivorship from pooled causes of death for the three time periods stratified by region of Newfoundland: Avalon, North, South, and West.

TABLE 4 Pooled survivorship calculations (all causes of death) using region as a stratifying variable for the three study periods. Kaplan–Meier results report mean and median age of survivorship with their estimated standard deviations and 95% confidence intervals, respective. Cox proportional hazards results report the hazard ratios and significance values for each of the four regions using the Avalon region as the standard

Period & region	Kaplan–Meier results		Cox proportional hazards results	
Pre-pandemic	**Mean age (SE)**	**Median age (95% CI)**	**Exp (*β*)**	***p*-value**
Avalon	25.6 (0.6)	21 (20–23)	—standard—	
North	25.7 (0.7)	23 (21–24)	1.003	0.947
South	26.4 (0.9)	23 (21–24)	1.008	0.875
West	23.0 (1.1)	21 (19–24)	1.192	0.006**
Pandemic	**Mean age (SE)**	**Median age (95% CI)**	**Exp (*β*)**	***p*-value**
Avalon	25.0 (0.7)	22 (21–23)	—standard—	
North	23.2 (0.8)	21 (19–23)	1.096	0.084
South	24.9 (0.9)	23 (21–24)	1.025	0.665
West	24.0 (1.2)	22 (20–24)	1.083	0.253
Post-pandemic	**Mean age (SE)**	**Median age (95% CI)**	**Exp (*β*)**	***p*-value**
Avalon	30.0 (0.9)	24 (22–26)	—standard—	
North	30.8 (0.8)	25 (23–26)	0.981	0.687
South	35.7 (1.2)	31 (28–36)	0.873	0.019*
West	23.6 (1.0)	21 (20–23)	1.383	<0.0001***

Significance codes: 0.001 “***”, 0.01 “**”, 0.05 “*”

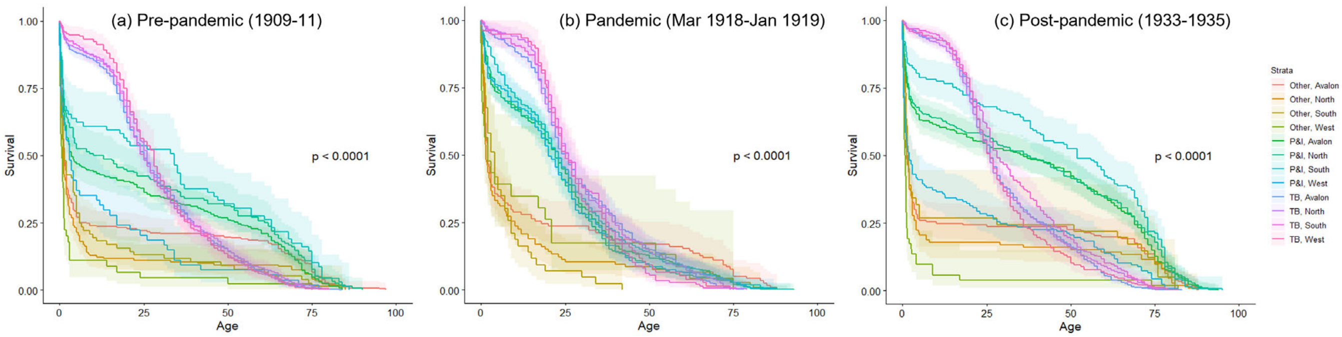

FIGURE 5 Survivorship for the three time periods stratified by region and cause of death: (1) Influenza & pneumonia, (2) tuberculosis, and (3) bronchitis, measles, and whooping cough.

TABLE 5 Results of Cox proportional hazards models using both cause of death and region as stratifying variables for each of the three time periods. Hazard ratios and significance tests are reported using other causes of death and the Avalon region as standards

Variables	Pre-pandemic (1909–1911) Cox proportional hazards results		Pandemic (Mar 1918–Jan 1919) Cox proportional hazards results		Post-pandemic (1933–1935) Cox proportional hazards results	
Fitted values	**Exp (*β*)**	***p*-value**	**Exp (*β*)**	***p*-value**	**Exp (*β*)**	***p*-value**
Cause of Death						
Other	— standard —		— standard —		— standard —	
P&I	0.579	< 0.001 ***	0.617	< 0.001***	0.508	< 0.001 ***
TB	0.603	< 0.001 ***	0.535	< 0.001 ***	0.746	< 0.001 ***
Region						
Avalon	— standard —		— standard —		— standard —	
North	1.040	0.959	0.117	0.037 *	1.024	0.618
South	1.053	0.315	1.068	0.257	0.909	0.106
West	1.259	< 0.001 ***	1.110	0.138	0.1392	< 0.001 ***

Significance codes: 0.001 “***”, 0.01 “**”, 0.05 “*”

variable with the West as highly significant ($p < 0.001$) during the pre- and post-pandemic periods and the North as only marginally significant during the pandemic ($p = 0.037$) (Table 5). In Figure 5, the TB survivorship curves are similar for all three periods, with a decline in probability of survival in ages 25–40. The P&I patterns exhibit the most change. While there are some apparent differences in survivorship among regions in 1909–1911, there are virtually no differences in survival among regions during the pandemic, and the pandemic P&I and TB survivorship curves are very similar.

4 | DISCUSSION

The results presented here paint a complex picture of the mortality and survivorship of the various causes of death during Newfoundland's 1918 flu pandemic compared to non-pandemic periods. Centrally, these results provide longitudinal and contextual understanding for the variation in mortality between periods as a factor of competing causes of death over the age distribution and regional diversity. The age-specific mortality results seem to be driven by the large contribution of TB deaths, as each time period exhibits a distinct W-shaped age-based mortality curve (Figure 2). It has been shown that adults aged 20–44 had the highest TB mortality rates throughout the early 20th century in Newfoundland, even as overall rates were falling (van Doren & Sattenspiel, 2021). TB and P&I are severe comorbid diseases outside of the 1918 flu context (Walaza et al., 2015, 2020), so there was likely selection against individuals with TB and P&I in the pre-pandemic period, albeit on lower levels, due to the clearly present W-shape (Figure 2). During the pandemic, this selection was likely amplified due to the intensity of P&I.

TB was a persistent stressor not only on the health and biology of the population (Adamson et al., 1945; Aykroyd et al., 1949), but also on the government and medical institutions (Mant, 2020). In 1910, a commission appointed to report on public health throughout the island strongly recommended against the necessary expenditure for a general sanitarium and continued to rely on traveling lecture campaigns to educate outport populations on the dangers of TB (PANL, 1911). By 1912, the Association for the Prevention of Consumption had thoroughly conceptualized a system of action to fight TB that went well beyond the government's intentions, which included courses of action via sanitaria, dispensaries, smaller homes for advanced cases, traveling doctors and nurses, and traveling lectures for the most remote outports (PANL, 1912). This inaction made it so the most rural outports continued to depend on infrequent visits from physicians, "handy women," and the sparse cottage hospital system for the majority of the early 20th century, while the Avalon Peninsula continued to take advantage of relatively more accessible medical care.

The unprecedented excess mortality in adults aged 20–44 who were otherwise apparently healthy remains a puzzling characteristic of the 1918 flu (Luk et al., 2001; Taubenberger & Morens, 2006). This pattern has been observed globally (e.g., Andreasen et al., 2008; Erkoreka, 2010; Langford, 2002; Mamelund, 2006, 2011; Saglanmak et al., 2011). Explanations posed for this mortality signature include immunity in elderly age classes through previous exposure to similar influenza viruses (Gagnon et al., 2013; van Wijhe et al., 2018; Wilson et al., 2014), exposure to an antigenically distinct 1889 pandemic virus in individuals born ~1880–1900 leaving them less protected against the novel 1918 pandemic strain (Worobey et al., 2014), an overactive immune response leading to the cytokine storm (Gagnon et al., 2013; Loo & Gale, 2007; Osterholm, 2005), and pregnancy (Gabriel & Arck, 2014).

While any combination of these hypotheses could help explain the unique age-based mortality of the pandemic, future research needs to examine the contribution of TB more closely to the age signature of mortality during the 1918 flu, and more generally, underlying frailty. Noymer (2009, 2011) suggested a passive selection mechanism against individuals of this age who were dually infected with TB and influenza and were more likely to die during the pandemic. In Newfoundland, the W-shapes for the pooled respiratory disease mortality in the pre-pandemic and pandemic periods are nearly identical despite overall higher mortality rates during the pandemic. The W-shaped mortality pattern is present during the pandemic, but it remains unclear if this is due to the unique epidemiology of the 1918 flu or from the contributions of TB. This highlights the need for pandemic researchers to engage with epidemiological patterns of conditions that are directly affected by—and can directly affect—the pandemic pathogen's epidemiology.

The post-pandemic age-based pooled mortality curves also indicate that even in the 1930s, TB was still very present, and only the Avalon Peninsula no longer showed hints of high mortality in ages 20–40. Given the fact that the decline of the contribution of TB to overall mortality was one of the primary drivers of the total decrease in infectious disease mortality during the second epidemiological transition (Holloway et al., 2013; McKeown, 1976; Szreter, 2002) and Schmidt and Sattenspiel's (2017) observation that the second epidemiological transition had only just begun in the Avalon Peninsula (specifically St. John's) but nowhere else on the island yet, this observation is well supported. Further, these results start to show the separation of age-based mortality between the single urbanizing region of the island compared to the rural regions, pointing toward growing inequalities between urban and rural spaces.

The survival analyses provide a clearer picture of this separation, both temporally and geographically. It was not surprising that pooled respiratory survivorship decreased during the pandemic from pre-pandemic levels and then increased to its highest levels during the post-pandemic period (Figure 3). Given the different sociocultural environments of the four regions of the island, specifically the differences between the Avalon region and the rural regions, it was also not surprising that there were differences in survivorship in non-pandemic periods (Figure 4a,c). In general, there was much more wealth in the city of St. John's, and the merchants in charge of the fishing industry operated out of the major city port while they depended on the labor of the small outport fisheries to provide catches (Cadigan, 2009). Further, given the fact that most fresh foods and meats had to be imported to the island, the residents of St. John's could more readily access these foods for a more nutritious diet, while those in the outports had to go without, and in general had to settle for lower quality meats and milk (or none at all) (Adamson et al., 1945; Aykroyd et al., 1949). It was interesting, however, to find no significant differences among regions in respiratory survivorship during the 1918 flu (Figure 4b). If the above-mentioned socioeconomic and nutritional differences were determinants of differential survivorship outside of pandemic years, it is unclear why these differences did not manifest during the pandemic.

The historical record does point toward unequal pandemic experiences. Previous research found that there were inequalities in pandemic experience during the 1918 flu by region and sex and gender (Paskoff & Sattenspiel, 2019; Sattenspiel, 2011). Letters from the archives also show that after the King George V Seaman's Institute in St. John's would become an emergency hospital, everyone who was displaced from the Institute was a woman—mostly from the outports—many of whom could not find accommodations elsewhere because they were already suffering from flu (PANL, 1918a). Further, of the 267 patients that began care within the first 9 weeks of the pandemic, 120 were seamen, fishermen, and outport men, and of the 100 women and children in the patient records, 41 had homes in the outports (PANL, 1918b). This demographic breakdown indicates that over 60% of the patients were from the outports, which, while technically not overrepresented given the urban/rural distribution of Newfoundland's population, is an underestimate of the relative severity of the pandemic in the outports. Primarily, this is because most people in the rural outports were unable to travel to St. John's for treatment, either because of their geographic isolation or because it was simply unfeasible to make the trip given the rapid course of the epidemic flu disease.

The discrepancy between mortality and survivorship raises important points about how researchers understand the impacts of a pandemic event. First, different methods of analysis will yield different insights into pandemic experience. Here, we find there was unequal mortality but equal survivorship from respiratory diseases during the 1918 flu. In other words, the rates at which people died differed, but the probability of dying at any given age was the same. Second, framing the 1918 flu patterns with those of the previous and consecutive decades contextualizes the results of equal survivorship. If we had only investigated the pandemic period for variable survivorship, we would have missed that there were differences in respiratory disease survival in Newfoundland during the 20th century. Further, the results from the Cox proportional hazards analyses suggest that the post-pandemic period had more variation in survivorship than pre-pandemic, indicating increasing differences throughout the early 20th century (Figure 3, Table 4). The increase in survivorship for the aggregated respiratory causes of death indicates that respiratory diseases were gradually moving away from primarily childhood causes of death (bronchitis, measles, whooping cough, and influenza), and more toward adult causes. The general health of a population's young people is an important indicator of overall population health (Elo & Preston, 1992), so increasing survivorship from these infectious diseases may be an important marker of demographic and epidemiological change. This observation invites further research into whether—and how—the 1918 flu played a role in the long-term changes in survival from the end of the pandemic through the following decades.

The above also raises the question: why would inequalities in survival equalize during a major pandemic event? It is possible that the survival analyses capture the ubiquitous nature of the signature age-based mortality profile of the 1918 flu, while the mortality rates better capture social inequalities. The insignificant differences in probability of death from P&I among all the regions of Newfoundland during the pandemic (Figure 5) that are bookended by significant differences in non-pandemic decades helps support the observation that there was something unique about this novel pandemic influenza virus. Indeed, P&I survivorship is the only cause of death studied that manifested marked differences throughout the time periods.

This study has a couple of primary limitations. First, given the data and analyses chosen, we cannot directly discern if the post-pandemic mortality and survivorship are products of the 1918 flu. Pandemic events have demographic, epidemiological, and social consequences, but the 14-year gap between the end of the pandemic period and the beginning of the post-pandemic period makes it difficult to say with any certainty that changes in survivorship in 1933–1935 are direct consequences of the 1918 flu. We re-emphasize, from our discussion on the reasoning for choosing these non-pandemic periods, that the goal of this research was to identify trends in mortality and survivorship between distinctly non-pandemic periods in the early 20th century as a way to provide greater contextual and temporal depth to the 1918 flu pandemic in the region, rather than identify yearly mortality and survivorship changes. We do acknowledge, however, that more detailed investigations of the year-by-year changes in disease epidemiology immediately after the 1918 flu is a worthy avenue for future research to better understand the relationship between pandemics and associated changes in population health.

Second, it is difficult to disentangle the effects of World War I from the 1918 flu. It has been suggested that the novel 1918 flu virus was able to spread around the world specifically because of the war (Oxford et al., 2002). Humphries (2005, 2013) argues that the ways disparate fields of research approach both the war and the pandemic from different angles impedes interdisciplinary crosstalk. As such, World War I did have sociocultural and political impacts in Newfoundland. There is a long history of class conflict and inequalities between the wealthy merchants and the working-class fishermen, which came to a head during the war when the merchants suffered island-wide criticism for taking advantage of fisheries to extract excessive profits during wartime (O'Brien, 2011). The war also holds a storied position in Newfoundland's cultural memory following the tragedy of 324 lives lost at Beaumont-Hamel during the Battle of the Somme in 1916 (Harding, 2006). After 1916, few Newfoundlanders went to Europe, and few wartime deaths appear in the Newfoundland & Labrador death records. The island did undergo compulsory enlistment in summer 1918, but over half the men were turned away due to poor health, stunted growth, or apparent TB disease, and only a few months later the war ended (Sharpe, 1988). The global spread of the pandemic influenza virus was almost certainly driven by movement of troops (Smallman-Raynor & Cliff, 2004), and could have potentially been introduced into Newfoundland via one of the shipping routes connected to the northeast and mid-Atlantic regions of the United States (although the true entry point and origin of the pandemic in Newfoundland is unknown) (Palmer et al., 2007). Despite Humprhies' (2013) apt push for holistic integration of lines of inquiry of the war and the 1918 flu, the research presented in this paper does not explicitly operationalize hypotheses regarding Newfoundland's engagement with World War I.

5 | CONCLUSION

This study investigated the mortality and survivorship of multiple major causes of respiratory death in Newfoundland for pre-pandemic, pandemic, and post-pandemic periods. We identified no significant differences in survivorship among Newfoundland's regions during the pandemic compared to significant differences in non-pandemic periods. These results can be contextualized with the surrounding pre- and post-pandemic periods to show that inequalities in respiratory survivorship did exist in early 20th century Newfoundland, and those deserve further investigation. The discussion of these patterns identified points in the historical record that suggest underlying nutritional concerns and differences between the urbanizing St. John's and the rural outports that could explain the observed pandemic experiences. The backdrop of Newfoundland's in-progress second epidemiological transition is an appropriate context for understanding changes in these respiratory patterns. This contextual information is critical to understanding how Newfoundland experienced the 1918 flu, and more researchers should adopt a broader lens for their pandemic inquiry.

AUTHOR CONTRIBUTIONS

Taylor P. van Doren: Conceptualization (lead); data curation (lead); formal analysis (equal); funding acquisition (lead); investigation (lead); methodology (supporting); project administration (lead); visualization (equal); writing – original draft (lead); writing – review and editing (lead). **Saige Kelmelis:** Formal analysis (equal); investigation (supporting); methodology (equal); software (equal); validation (lead); visualization (equal); writing – review and editing (equal).

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available on the Newfoundland's Grand Banks website at http://ngb.chebucto.org. Any other data is available upon request.

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