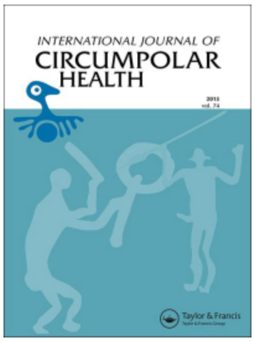

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Age-specific mortality and the role of living remotely: The 1918-20 influenza pandemic in Kautokeino and Karasjok, Norway

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ABSTRACT
The 1918–20 pandemic influenza killed 50–100 million people worldwide, but mortality varied by ethnicity and geography. In Norway, areas dominated by Sámi experienced 3–5 times higher mortality than the country's average. We here use data from burial registers and censuses to calculate all-cause excess mortality by age and wave in two remote Sámi areas of Norway 1918–20. We hypothesise that geographic isolation, less prior exposure to seasonal influenza, and thus less immunity led to higher Indigenous mortality and a different age distribution of mortality (higher mortality for all) than was typical for this pandemic in non-isolated majority populations (higher young adult mortality & sparing of the elderly). Our results show that in the fall of 1918 (Karasjok), winter of 1919 (Kautokeino), and winter of 1920 (Karasjok), young adults had the highest excess mortality, followed by also high excess mortality among the elderly and children. Children did not exhibit excess mortality in the second wave in Karasjok in 1920. It was not the young adults alone who produced the excess mortality in Kautokeino and Karasjok. We conclude that geographic isolation caused higher mortality among the elderly in the first and second waves, and among children in the first wave.

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Introduction

The H1N1 influenza pandemic of 1918–20 killed between 50 and 100 million people or 2.5–5.0% of the global population [1]. While mortality was less than 1% in non-Indigenous populations in countries with well-developed communication systems and in larger cities in North America, Europe, and Oceania, it was, on average, 3–8 times higher among Indigenous peoples within the same countries [2]. For example, areas with extremely high mortality include Labrador and Alaska, where 27% and 8% of the population, died. However, Alaska and Labrador experienced even higher death tolls locally. Brevig Mission in Alaska had 90% mortality, and Okak in Labrador had 79% mortality [3]. In some remoter areas of northern Scandinavia, primarily inhabited by Sámi, there were also high death tolls (10% mortality in Enare, Finland, 3% in Arjeplog, Sweden, and 2.2% in Karasjok, Norway) [4]. Common for all these populations are that they lived relatively remotely, i.e. with less frequent contact to and from these areas, compared to other places in Norway or Scandinavia.We still know little as to why remotely living Indigenous communities had higher age-specific mortality *levels* than their non-Indigenous counterparts and whether there were ethnic differences in the *age patterns* of death.

In a study using multivariate analysis and medical districts as data units (N = 351), it was documented that the Sámi people in Norway had higher mortality levels even after controlling for summer wave exposure (or not) that could protect against later assaults, persons per room, economic sectors, per capita wealth, share of the population receiving public support due to poverty and whether living inland or by the coast [4]: Because this paper controlled for some possible factors influencing higher mortality *levels* among the remotely living Sámi, such as variation in exposure and susceptibility *during* the pandemic, the paper concluded that relative geographic isolation leading to less pre-pandemic exposure to influenza and lower levels of immunity could explain the higher mortality among the Sámi population. This study used aggregated data, and could not disentangle the age-specific mortality *patterns* by ethnic groups and district. Hence, the role of isolation on age-specific mortality patterns in remotely living Sámi remained elusive.

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Later research has shown that in Norway and other well-connected majority populations in Scandinavia, North America, and Oceania, excess mortality was driven by young adults aged 20–40, with peak mortality at age 28 and lower-than-expected mortality among those older than 60 to 70 years of age [2]: The sparing of the elderly in these locations partly explains the relatively low overall mortality rates below 1% observed in these places. In remote Brevig Mission, Alaska, on the other hand, where 90% died, only a handful of children between 5 and 14 years survived, all younger siblings as well as parents and the elderly died [3].

Our study seeks to investigate explicitly whether the people living in the Norwegian parishes of Karasjok and Kautokeino, who were predominately of Sámi origin, exhibited a different *age pattern* in excess mortality during the 1918–20 influenza pandemic compared to findings from non-isolated and well-connected areas with majority populations. Little sparing and excess mortality among the elderly in the two isolated areas of Norway in 1918–20, could lend support to the theory of lower immunity in the population in those older than 28 years of age because of the low incidence of influenza before 1918, in particular less exposure to putative H1-like viruses circulating before the 1889–90 influenza pandemic. We hypothesis that relative isolation and less previous exposure to seasonal influenza has resulted in both a higher general mortality level and a different age distribution of mortality than that typical of the 1918–20 pandemic in non-isolated majority populations [2].

This paper contributes to the international literature on the epidemiology of the 1918–20 influenza pandemic by merging two strands of the literature. First, it studies the role of the sparing of the elderly in the overall excess mortality by studying *individual-level* mortality data by age and time in two relatively remote inland areas of Northern Norway between 1918 and 1920. Second, it contributes to the literature on why remotely living Indigenous peoples in the Arctic and elsewhere were so severely impacted by the 1918–20 influenza pandemic, but also why some but not all Indigenous peoples were hard hit by later pandemics such as the influenza pandemic of 2009–10 and the COVID-19 pandemic [2, 5–11].

Materials and methods

Study context

The traditional area of the Sámi people is called Sápmi. At the time of the 1918–20 influenza pandemic, about two-thirds (20,000) of all Sámi lived in northern Norway. The remaining one-third lived in northern Sweden (7,100), northern Finland (1,600), or in northwestern Russia (1,800). Most of the Sámi in Norway traditionally lived in the northernmost counties of Nordland, Troms, and Finnmark.

The Finnmark county was Norway's largest county (48,018 km^2) but has historically been the smallest population in Norway (39,126 in 1910). At the time of the pandemic, the inland parishes of Karasjok (5,261 km^2) and Kautokeino (8,690 km^2) were among the geographically largest in the country, but each had a population of only around 1,000 individuals. While the overall population density for Norway in 1910 was 7.3 persons per km^2, in Finnmark county and Karasjok and Kautokeino parishes, respectively, only 0.8, 0.2, and 0.1 persons occupied each km^2. Although Finnmark, Kautokeino and Karasjok was sparsely inhabited, the people in these areas tended to live close together in villages. The population density does however indicate the great distances between the villages in Finnmark. Most of the population in Finnmark, including the Sámi, lived along the coast and in rural areas, and their primary way of travel between towns was by boat. The improvement of the infrastructure was not a priority because of the large distances between settlements and the low population density The first roads connecting the coast to the inland were not built until around the time of the second world war.

The main economic base of the Norwegian Sámi included fishing (55%), agriculture (27%), and reindeer keeping (7%). However, most of the Sámi in Kautokeino and Karasjok were pastoral mountain Sámi, living a nomadic life with reindeer herding as their main way of living. These Sámi would move with the herds from the coast in summer to the inland in winter. According to the 1910 census, 94.1% of the population in Kautokeino and 95.8% in Karasjok spoke Sámi daily. This illustrates the high percentage of Sámi people that lived in the two study areas. Our study settings still are considered core areas for the Sámi population in Norway.

Historical death and census records

The data for this study was obtained from two sources. First, we use data from the burial registers for the parishes of Kautokeino and Karasjok (1907–1923). Total population and age-specific population size are derived from the censuses for the years 1900, 1910, and 1920 (carried out 1st of December each of those 3 years). Second, medical reports and prior literature provide qualitative insight into the course of the pandemic and give supporting information to the burial registers.

The church records were kept by the priests and provide, among other things, an overview of the sacred events of baptism, confirmation, marriage and burial. The church's funeral records contain, among other things, the date of birth, date of death, and cause of death at the individual level. The sources have been digitised by the National Archives of Norway and transcribed at The Norwegian Historical Data Centre (NHDC) at the Arctic University of Norway. Variables of interest have been standardised and in cases of incomplete or ambiguous registration, the transcription has been checked against the original source. Individuals without an age were not included when the age specific mortality was analysed. Individuals that were listed more than once were also checked with the original source.

Age at death was calculated as the difference between the date of birth and the date of death. For each all-cause death record, we compiled month of death and age group. Because only around 2,000 individuals lived in the two areas altogether, there were relatively few deaths overall. To create robust age-specific excess mortality categories, we used three broad categories in our analyses: 0–19 years, 20–49 years, and 50 years above. These categories also separated those in non-isolated communities affected the most (children and young adults) from those who were hypothesised to have lower-than-expected mortality (the elderly).

The geometric mean method has been used to estimate the total population at risk and age-specific population size in the intercensal years of 1901–10 and 1911–21. The method assumes a theoretical stable population growth or decline between the censuses. This method does not, however capture yearly or seasonal fluctuation in the population.

The Kautokeino and Karasjok populations declined between the censuses of 1910 and 1920, which could be explained by the high mortality from the 1918–20 pandemic. Based on the data from the two censuses, the population in Karasjok fell from 1013 to 993 individuals, and in Kautokeino the population dropped from 1024 to 979 individuals.

The population decline between 1910 and 1920 contrasts the overall trend in the first half of the 20th century as both Karasjok and Kautokeino experienced increased population numbers before and after the pandemic.

Statistical analysis

To quantify the mortality pattern associated with the 1918–1920 influenza pandemic among the Sámi population in Karasjok and Kautokeino, we estimated all-cause excess mortality rates per 10,000 population across three age groups by computing the mortality rate above a seasonal baseline of expected mortality rates in the absence of influenza activity, as done in previous studies [12–15].

To define the pandemic, we first determined the most likely period of pandemic influenza activity from the time series of monthly all-cause death rates in each of the parishes separately. Then these months associated with the influenza activity were excluded for further modelling the baseline non-influenza mortality rate. The baseline mortality level was estimated by fitting cyclical Serfling regression models to all-cause deaths for the total population in non-influenza months. Once a monthly baseline and its 95% confidence interval (CI) were obtained, periods of pandemic influenza circulation were defined as the months in 1918–1920 where the observed total all-cause mortality rate was greater than the upper 95% CI of the baseline. We estimated the age-specific excess mortality rate for the same pandemic period. This was done separately for each parish.

We defined the excess mortality rate as the difference between the observed and model-adjusted baseline mortality rates for each month constituting a pandemic wave. Negative excess mortality estimates were replaced by zero in our analyses. We summed the excess death rates across the pandemic waves from 1918–1920 to get the overall pandemic excess mortality for the total population and the age groups in line with previous studies [12–15].

Results

Diffusion of the pandemic

The first sporadic cases of the 1918–20 influenza in Norway were reported in army camps in early April 1918. More than three months later, in mid-June, the first pandemic wave started in the capital of Kristiania (renamed Oslo in 1924), situated in the country's southeastern part. In the summer of 1918, influenza diffused rapidly along the west coast with people travelling by coastal steamers towards northern Norway. The transmission route along the fjords went typically with local boats, while the major railways and communication networks played the pivotal role between the largest cities and centres of industry and commerce [16].

The coastal steamers going between Bergen on the Southwest coast and Hammerfest in Finnmark and between the city of Trondheim in Mid-Norway and

Kirkenes in Finnmark took six days. The first cases of the 1918 flu were registered in the coastal areas of Finnmark less than two weeks after it had reached Kristiania and Bergen [16]. Although the 1918 flu spread quickly to the coast of Finnmark, it took a while to spread inland. Our studies of the burial registers indicate that the illness did not spread to Karasjok before early October 1918 and as late as January 1919 to Kautokeino. The first influenza death recorded in the burial registers for Karasjok was registered on the 31st of August 1918. This person was, however, buried in Honningsvåg, close to the North Cape on the coast. This falls in line with the first outbreaks in Finnmark recorded in earlier research [16]. The person was most likely a person with a summer residence near Honningsvåg and therefore was infected near the coast. Relative to Southern Norway and urban and coastal areas across the country, there was no summer wave exposure and a 3 to 6 months delayed disease onset in Karasjok and Kautokeino.

Parish-level monthly time-series of excess mortality 1910-21

Two peak outbreaks associated with the pandemic occurred in Karasjok, the first in October-November 1918 (215 deaths per 10,000 observed in October) and the second in February 1920 (observed number of deaths of 165 per 10,000) (Figure 1). Four of the six months from August 1918 to January 1919, including the first outbreak period, exhibited significant excess mortality. The accumulated excess mortality in these six months was 289 per 10,000 population.

Three of the seven months from October 1919 to April 1920, including the second outbreak period in Karasjok, also exhibited significant excess mortality. The total excess mortality during these seven months was 129 per 10,000 population. The accumulated excess mortality covering both periods is 418 per 10,000 population.

Kautokeino parish had just one major peak outbreak, in January 1919, with an observed death rate of 244 deaths per 10,000 (Figure 2). However, a significantly higher mortality rate than predicted occurred in five of the eight months from August 1918 to March 1919. The total excess mortality from August 1918 to March 1919 in Kautokeino parish was 279 per 10,000 population.

Excess mortality was also apparent in the winter of 1915, 1916, and 1917, both in Karasjok and in Kautokeino, but the level of excess mortality was more than three times higher during the peak outbreaks associated with the 1918–20 pandemic compared to the peak outbreaks of these pre-pandemic excess mortality periods.

Excess mortality by age groups 1918-20

Figure 3 shows excess mortality by three age groups (0–19, 20–49 and 50+) for wave 1 (August 1918-January 1919) and wave 2 (October 1919-April 1920) in Karasjok and for wave 1 (August 1918-March 1919) in Kautokeino.

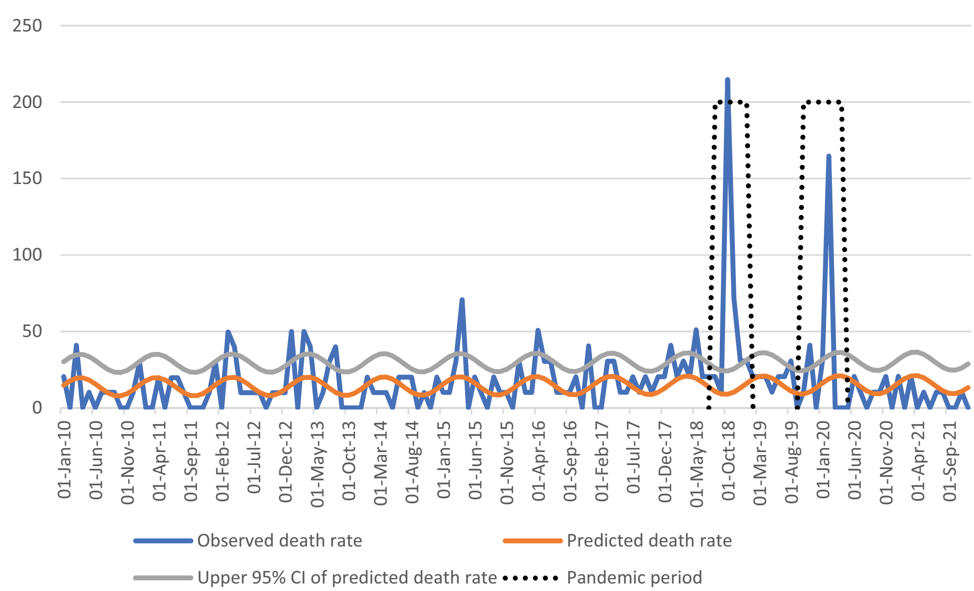

Figure 1. Time series of monthly mortality rates per 10,000 population (Y-axis), Karasjok, 1910–1921 (X-axis).

Source: Norwegian Historical Data Centre, UiT the Arctic University of Norway, Historical Population Register of Norway, [Church books, Kautokeino and Karasjok 1907–1923], [Population censuses 1900, 1910 and 1920]. Original sources at the National Archive of Norway.

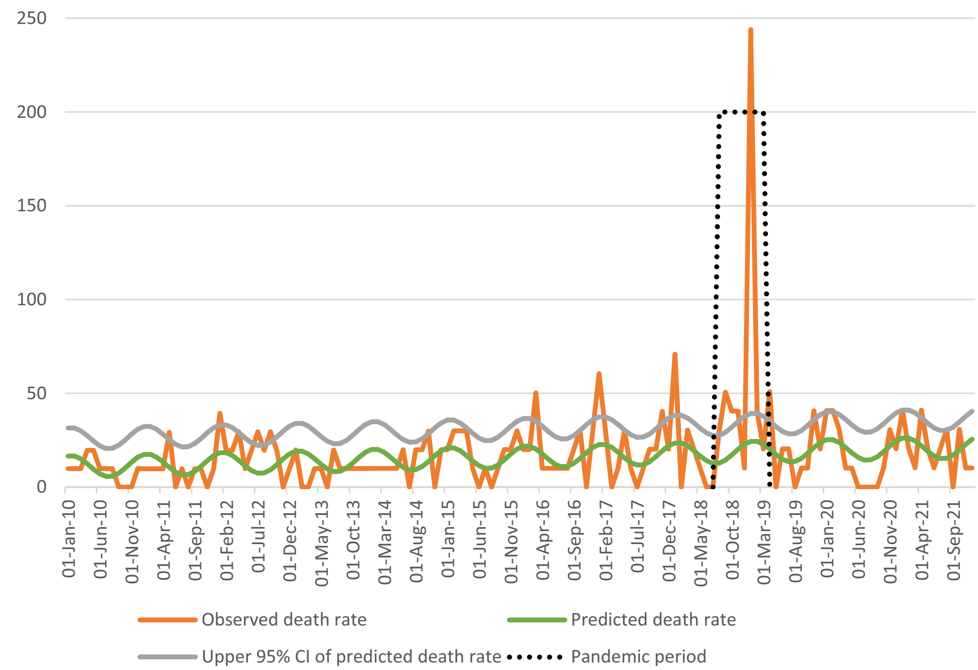

Figure 2. Timeseries of monthly mortality rates per 10,000 population (Y-axis), Kautokeino 1910–1921 (X-axis).
Source: see Figure 1.

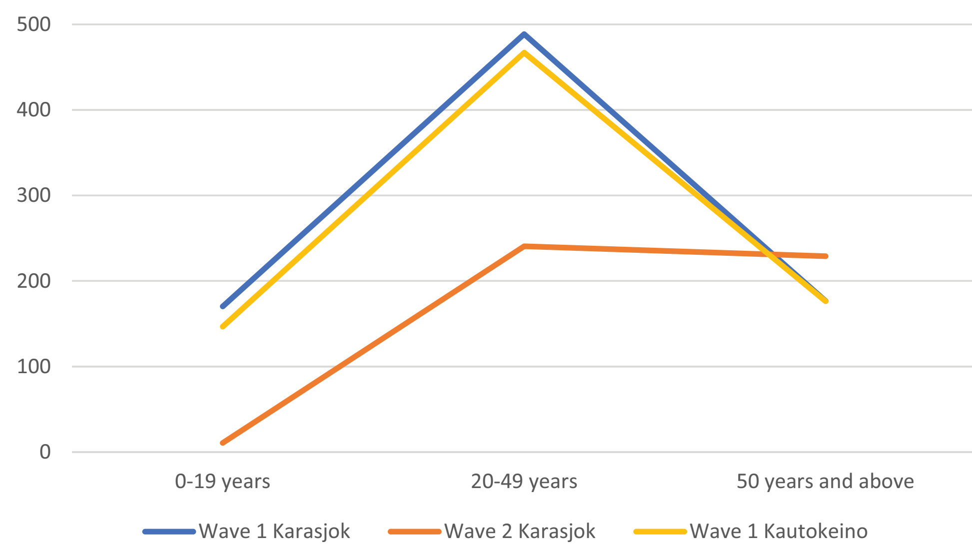

Figure 3. Excess mortality per 10,000 population (Y-axis) by age in Karasjok for wave 1 (August 1918-January 1919) and wave 2 (October 1919-April 1920) and Kautokeino for wave 1 (August 1918-March 1919).
Source: see Figure 1.

The levels and patterns of excess mortality by age were identical in the two areas during the first wave. Although all three age groups had excess mortality in both areas compared with non-pandemic periods, it was significantly higher in the 20–49 age group compared with both the 0–19 and the 50+ age groups (the 95% CI for the young adults were not overlapping with the younger and older age groups; not shown).

In the second wave in Karasjok (October 1919-April 1920), all age groups had significant excess mortality compared to non-pandemic years. The excess mortality of the 20–49 age category and the 50 + category was similar, but both groups had significantly higher mortality than the 0–19 age category (the 95% CI for the young adults and the elderly were not overlapping with the younger age group; not shown).

The excess mortality for the 0–19 and the 20–49 age categories was significantly lower in the second than in the first wave in Karasjok (the 95% CI for the two age groups in the two periods were not overlapping; not shown). However, mortality among the 50+ age category was higher in the second wave than in the first, but not significantly so, as 95% CI were overlapping (results not shown).

Discussion

In this paper, we have for the first time studied the timing of the 1918–20 influenza pandemic and the associated age-specific mortality patterns in two relatively remote areas of Finnmark, Norway, using detailed individual-level burial records from parish registers coupled with census data to estimate excess mortality. The monthly time series and age distribution of excess mortality have been examined based on a hypothesis that relative isolation and less previous exposure to seasonal influenza has resulted in both a higher general mortality level and a different age distribution of mortality than that typical of the 1918–20 pandemic in non-isolated majority populations [2].

Diffusion of the pandemic

Our analyses show for the isolated parishes of Karasjok and Kautokeino that three distinctive periods with excess mortality occurred, a pattern similar to that observed in outbreaks of the 1918–20 influenza pandemic in other parts of Norway and internationally [4]. These were 1) a first wave in Karasjok with a peak in October 1918, referred to as the second wave or the fall wave in the literature, 2) a first wave in Kautokeino with a peak in January 1919, referred to as the third wave or the winter wave in the literature, and finally, 3) a second wave in Karasjok with a peak in February 1920, referred to as the fourth wave or the "echo" wave in the literature. The distinct outbreak of the pandemic in Karasjok in 1920 has not been documented earlier, although an increasing number of recent international studies have noted this fourth wave of the pandemic [14,17,18].

Kautokeino or Karasjok had outbreaks within the timeframe of the three last waves described in Norway and internationally but did not experience the wave in the spring or summer of 1918 that was prominent in Scandinavian cities and the Eastern seaboard of the USA [19, 20]. One-tenth of Norway escaped the summer wave in 1918, and these were usually rural areas without larger cities/towns and major communication routes and networks such as Karasjok and Kautokeino [16].

There was a lack of a spring/summer wave in 1918 in both Karasjok and Kautokeino. Additionally, there was a much-delayed disease onset in both areas relative to the capital city in south-eastern Norway. Finally, there was a distinct and severe 1920 wave in Karasjok. These three characteristics suggest that 1) the geographic remoteness of these large parishes, 2) their low number of inhabitants (1,000 in each) and relatively low population densities, and 3) the lack of permanent communication routes, may explain why the spread did not happen as quickly over land in these vast parishes compared to relatively more urban areas in southern Norway.

The delay in the disease outbreaks in the two remote study areas may also be associated with the Sámi nomadic lifestyle. A majority of the people in Karasjok and Kautokeino were Sámi who engaged in pastoralism centred around reindeer herding. They moved between their inland mountain-winter lands of Kautokeino and Karasjok (October-April) and their summer-forest-coastal grazing lands (May–September) and had little interaction with outsiders. This likely resulted in less exposure to the 1918 spring/summer influenza pandemic wave, and past annual influenza epidemics [4]. Because of the lack of roads during the study period, we can assume that the accessibility of and the number of people that travelled to and from Kautokeino and Karasjok varied throughout the year. Given the climate and environment in the parishes, the travel distance and time to travel would be shorter in the winter using reindeers and sleds or horses and sleds. It is likely that the number of people travelling to and from the settlements and communities was higher in the winter months compared to the summer months. Although the pandemic first arrived along the coast of Finnmark in the summer when the pastoral Sámi were at their coastal summer pasture, this was the time of the year with less travel. In rural areas in Southern Norway the disease did not spread to the general population during the summer of 1918; most cases occurred among tourists coming from the larger cities, those travelling by train or coastal steamers, in areas close to the railway stations, towns and harbours and among businessmen and tourists staying at hotels [16]. Perhaps this also explains why few Sámi got the disease in the summer, although the disease was prevalent among passengers on the coastal steamers and in the harbours along the coast and the fjords. However, when the pastoral mountain Sámi returned to their home places for the winter, they probably also brought with them the disease in the fall of 1918 in Karasjok and the winter of 1919 in Kautokeino. In addition, the medical practitioner in Karasjok described the housing conditions as cramped during the winter season. Some Sámi families in Karasjok built houses in the proximity of the church site and marketplace for their winter settlement, and it was common practice to lodge the numerous individuals who did not have a house during the winter season. The Kautokeino Sámi lived more traditionally in tents and turf huts year-round. It was not common to build more permanent housing before the middle of the 20th century in Kautokeino [21]. To hinder diffusion of the disease from Alta (at the coast) to Kautokeino, the fall market in Alta was cancelled [16]. The cancellation, however, apparently came too late as several participants from Kautokeino brought the disease home, as suggested by the small outbreak in October 1918 (see Figure 2). When the nomad winter school in Kautokeino opened in early January 1919, several Sámi schoolchildren and their parents got infected for the first time [4].

There are two potential explanations for the later pandemic peak in Kautokeino compared to Karasjok. First, Karasjok is closer to the coast than Kautokeino. Its main link to the coast would have been via Porsanger, a distance of 70 km, while Kautokeino mainly communicated with the coast through Alta in the east of Finnmark, a distance of 135 km. Second, both parishes had a low population density at the time of the pandemic, but Kautokeino's density (0.1 persons per km^2) was lower than Karasjok's (0.2 persons per km^2). The low population density combined with the nomadic way of life of the Finnmark residents suggests that the frequency of interpersonal contact was relatively low. This may have allowed Karasjok to escape the spring/summer wave and delay the peak of its first wave (the fall 1918 wave) by 3 months compared to other parts of Norway. Kautokeino, with an even smaller population density also missed the spring/summer wave, had only a small fall wave and experienced a 6-month delay before the large wave and peak pandemic outbreak in the spring of 1919.

Excess mortality over time

The accumulated excess mortality in the first Karasjok outbreak that extended from August 1918 to January 1919, was 289 per 10,000. The accumulated excess mortality in the concurrent Kautokeino outbreak, from August 1918 to March 1919, was similar in size to the Karasjok outbreak at 279 per 10,000 population (95% CI were overlapping; not shown). The accumulated excess mortality in the second Karasjok outbreak from October 1919 to April 1920 was 129 deaths per 10,000 population, significantly lower than in the first outbreak in this parish (the 95% CI were not overlapping; not shown). The accumulated excess mortality in Karasjok covering both periods was 418 per 10,000 population.

The 2.89% all-cause excess mortality in Karasjok for August 1918 to January 1919 documented here is a little higher than a prior estimate of 2.23% [4,16]. This prior estimate was specifically for Influenza-Pneumonia mortality in this parish for the calendar year of 1918 and did not include all causes or controls for baseline mortality. Thus, the difference between the two estimates is due to 1) increases in deaths from other causes besides influenza and pneumonia, 2) studying the exact outbreak months rather than calendar years and 3) controlling for baseline mortality. An assessment of which conditions were responsible for these additional increases in excess mortality will have to await further research. As noted above, the second outbreak in Karasjok from October 1919 to April 1920 was neither identified nor studied in prior research.

Kautokeino (Aug 1918- March 1919) and Karasjok (Aug 1918-Jan 1919) both experienced excess all-cause mortality that was five times higher than the average of 0.56% in Norway (Sep 1918 to May 1919) [22], and these results also concur with prior research [4]. Although a mortality of around 3% in these areas is the highest recorded in any area of Norway, this mortality is on par with the global mortality of 2.5–5% and mortality in the Sámi dominated area of Arjeplog, Sweden. It is also higher than the mortality observed among Inuits in Greenland [23], where 1.6% of the population died of influenza related deaths in 1919, similar to the pre-pandemic year of 1916 (1.4%). The Indigenous Sámi mortality toll was much lower than among Indigenous people elsewhere in the Arctic, however [2].

Excess mortality by age

As discussed above, the pastoral Sámi lived and moved short distances within their inland-winter-grazing land during the high season for influenza epidemics (October–April). In addition, they were relatively isolated in open spaces and often in tents far away from other people and navigable roads [4]. The lack of a summer wave and a delayed disease spread during the 1918–20 influenza pandemic suggests that Karasjok and Kautokeino were areas with less exposure to seasonal influenza and influenza pandemics in the past, giving people living here less immunity to fight the 1918–20 influenza strain. Those older than 28 years of age in 1918, the ones born before the "Russian flu" pandemic of 1889, would also have been less exposed to H1-like viruses circulating before 1889 (the Russian flu strain replaced the H1 viruses) and less exposed to the putative H3N8 pandemic strain in 1889. Because of this, adults over age 28 in Finnmark may have been more susceptible to the 1918 pandemic influenza strain than would people of the same age in other parts of Norway.

Our results show that in the fall of 1918 (Karasjok), winter of 1919 (Kautokeino) and winter of 1920 (Karasjok), the young adults (20–49 years) had the highest excess mortality, followed by also high excess mortality among elderly above the age of 50 and those under 19 years of age. During Karasjok's second wave in 1920, individuals under 19 years of age did not have excess mortality compared with non-pandemic years.

During the main first outbreaks in 1918 in Kautokeino and Karasjok, and also in Greenland [14], excess mortality occurred in all age groups during the pandemic, contrasting with the observed pattern for the average (majority) population of Norway. Most regions in Norway exhibited the well-known pandemic signature pattern of excess mortality being highest among young adults and very low excess mortality for 50- and 60-year-olds. In addition, in many places, including the US, Asia and Europe, age groups older than 70 years old had mortality levels that were actually lower than expected [3, 13, 24–27]. In contrast to this, there was no mortality sparing among Mexican seniors 65 years and older in the two large Mexican cities, Mexico City and Toluca, highlighting potential spatial differences in pre-existing immunity to the 1918 virus and less exposure to prior influenza even in large cities [28].

The excess mortality rates in Karasjok and Kautokeino form a mixture of what can be expected in an urban community with less than 1% mortality and what is observed in more isolated communities found, for example, in Brevig, Alaska [2], where mortality was over 90%. This is a somewhat expected result. Although the innermost areas of Finnmark were relatively remote and located on the outskirts of Norway and Europe, other places in the Arctic such as the territory of Alaska, were even more remote, sparsely populated and with a harsher climate. Geographically, Alaska (1,481,350 km^2) was 31 times larger than the county of Finnmark (48,018 km^2), but the population size did not differ much (in 1910, 64,356 in Alaska vs. 39,126 in Finnmark), meaning that population density was only 0.04 per km^2 in Alaska compared with 0.8 per km^2 in Finnmark. Population densities varied throughout Alaska but also in Finnmark (with down to 0.1–0.2 persons in our study areas). Much of Alaska is icebound over winter while the coast of Finnmark is ice free due to the Gulf Stream, and it was even more remote and with fewer people per km^2. This possibly reduced contacts between Alaska and the outside world and also the chance of importing an infectious disease such as influenza.

The excess mortality for the 0–19 and the 20–49 age categories was significantly lower in the second (October 1919-April 1920) than in the first wave (August 1918-January 1919) in Karasjok. However, mortality among the 50+ age category was higher in the second wave than in the first, but not significantly so. The lower mortality among those under 50 years of age in the second compared to the first wave in Karasjok may be a consequence of exposure to the first wave, which may have provided some immunity to protect individuals and families in the next assault [20]. "Harvesting effects" is another potential explanation, the tendency that a higher share of those with poorer health die when first exposed, leaving a healthier population to be exposed for later outbreaks. Given the remoteness of the Finnmark parishes and the low population densities in the region, it may also be the case that only some individuals and families were exposed during the first wave in Karasjok, leaving other individuals and families susceptible to infection in the second wave. These individuals would also be at risk for severe outcomes similar to those observed in the prior wave because they had not yet been exposed to the virus. Either way, it is interesting to observe that those older than 50 had excess mortality at the same high level in both waves. Could it be due to poorer immune systems and/or lower morbidity among the elderly than the young adults?

The low mortality among the Sámi in Scandinavia, relative to Indigenous people in the North American part of the Arctic [3, 29, 30] is not well understood. What are the major factors responsible for this difference? Why were the Sámi also spared from extremely high young adult mortality? Finally, the Inuit on Greenland are not culturally related to the Scandinavian Sámi. However, it is a striking finding that the relatively low mortality of the Indigenous on Greenland (1.6%) and in Karasjok and Kautokeino in Norway (2.8–2.9%) as well as the relative Indigenous and non-Indigenous mortality differences in Denmark and Norway are similar in magnitude (5 times greater), while at the same time 1/3 of the Labrador Inuit died [2, 3]. We hypothesise that the equal and relatively low mortality rates in the Indigenous in the Sámi and in Greenland provide indirect evidence for a high degree of historical contact and greater amounts of genetic diversity than in other Arctic and remote populations, but perhaps also cultural and political admixture between Norway, Denmark and Greenland [2].

Results from studies of historical pandemics are important in themselves but can also cast light on differences in pandemic outcomes by Indigenous status under current or future pandemic outbreaks and point to potential mechanisms for these differences. Our work provides another example of the more severe impact of pandemic diseases on Indigenous populations of the world, and it also points out that the reasons for the serious impact include both factors broadly common to Indigenous people, such as remoteness of the population and access to resources, and factors that are specific to the affected regions. Our results also highlight the important conclusion that the pandemic experience of Indigenous peoples, such as age-specific patterns of mortality, may vary in fundamental ways from that observed in the urban populations more commonly studied, stressing the need to collect more and better disease data and to carefully assess potential differences in COVID-19 pandemic outcomes by Indigenous status [6, 10] if we are to better understand and predict future pandemic impacts. Both historical studies such as this one and more recent studies on, for example, the 2009 H1N1 influenza and the COVID-19 pandemics, clearly illustrate the importance of analysing high-quality individual-level data disaggregated by region, ethnicity, and age to illuminate issues of diffusion and levels and patterns of excess mortality over time and age.

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