Season of Birth and Early Childhood Mortality: A Review of the Debate and a Case Study for the Netherlands, 1812-1912

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PRELUDE

Historically, all components of demography – migration, fertility, nuptiality and mortality – were strongly affected by the seasons of the year. Religious prescriptions, weather conditions, the production cycle in agriculture and other sectors of the economy, the availability of food, all had an effect on the propensity of people to marry, to reproduce, to leave their place of living, and to die. Long-term changes in these active forces may have altered this seasonal patterning, but seasonality is still clearly visible in most demographic indicators. An enormous number of mostly local studies have become available on marriage, birth, and death seasonality. What has been lacking until now is a study in which these different demographic processes are analyzed within a common framework. Theo Engelen's new project 'The Rhythm of Life' is intended to do just that. Theo has, in his long career, worked on a variety of demographic developments and has shown a great sensitivity for the role that economic and cultural forces play in determining the outcome of these developments. He is therefore the right person to offer us a comprehensive framework for the study of the relationship between the passing of the seasons and demographic processes. The four seasons of the year are often used as an allegory of the human life course and we hope for a long harvesting season for Theo.

In the Hippocratic Corpus, the collection of ancient Greek medical works that bears the name of the ´father of medicine´, many references can be found to the marked fluctuations over the course of a year in the incidence of diseases. In the *Aphorisms*, for example, it is said: 'The changes of the seasons are especially liable to beget diseases, as are great changes from heat to cold, or cold to heat in any season. Other changes in the weather have similarly severe effects' (Dong, 2011; Langholf, 1990).

The earliest studies of the seasonal patterning of deaths were clearly inspired by the classical Hippocratic way of thinking, with its emphasis on the importance of the observation of diseases. In the second half of the 18th century, a popularized Enlightenment started to act as an innovative force in European societies. In the medical sciences, fatalism gave way to a belief that pathogenic factors could be prevented or eliminated, and disease was no longer regarded as an individual phenomenon but rather as a collective one, influenced by natural and social causes (Huisman, 1997). This natural process could be understood by studying its effects. By collecting mortality data over as long a period as possible and combining these with meteorological data, and by making cross-regional comparisons, local descriptions of specific diseases could ultimately lead to the formulation of general theories and to universal knowledge.

Nineteenth-century statisticians and medical doctors all over Europe stimulated their national statistical offices to collect data on seasonal patterns in mortality. In particular, the influence of the season on infant mortality was widely studied (Breschi & Livi-Bacci, 1997). Historical demographers and social historians have used these data for a variety of reasons. Seasonal patterns in mortality have been used as proxy information on the role of specific causes of death (Cheney, 1984), as a source of indirect information on how societies coped with changes in the environment (Galloway, 1994), while differences in the effects of the season on mortality by social class were studied to give clues on the conditions – food, shelter, clothing – under which these groups lived (Bengtsson, Campbell, & Lee, 2004). Last but not least, these data might provide us with information on the implications that the moment of conception had for a person's health and his or her likelihood of survival (Doblhammer & Vaupel, 2001; Reher & Sanz Gimeno, 2006).

A common approach to investigating the seasonality of mortality is the examination of monthly fluctuations in the published number of deaths by month of death. A difficulty with this approach in studying infant and child mortality is created by the fact that the monthly number of deaths is influenced by monthly variations in the number of births. Since a high proportion of infant deaths occur within a few weeks of birth, the influence of monthly birth fluctuations on monthly fluctuations in infant and child deaths can be substantial (Knodel, 1988). For some countries in Europe, data have been published for the nineteenth century combining age at death in months with the month of death and by an ingenious procedure these have been used to analyze the month of birth as a risk factor for infant mortality (Breschi & Livi-Bacci, 1994; Breschi & Livi-Bacci, 1986; Vilquin, 1978). It turned out that in the Netherlands (during the period 1860-69) and Belgium, the season of birth had very little influence on the level of mortality in the first year of life (Breschi & Livi-Bacci, 1997).

The above-mentioned data could only *approximate* the month of birth of the deceased and this approximation only made sense for the first six months of birth. Seasonal fluctuations in mortality after that age and even in the second year of life might be present as well. For example, in the second summer of a child's life, it might also be confronted with high risks of infection. Also, a radical change in feeding habits, with weaning sometimes taking place after the first birthday, might be related to heightened seasonal mortality. A more rigorous approach is only possible by using individual-level data with exact dates of birth and dates of death, in combination with information on possible relevant characteristics of the child and his or her family.

A problem with studies in this field is that women who give birth in different seasons might have different characteristics. For example, as marriages have a strong seasonal pattern, and many first-born children are conceived shortly after marriage, there will be strong seasonal pattern of births according to parity. However, the social class, age and marital status of mothers may also vary over the year, with (for example) women from a particular social stratum being more likely to give birth at one season than at another, and these fluctuations might explain the relationship between season of birth and mortality. This selection issue can be dealt with by including maternal characteristics and / or performing a within-mother analysis.

We will analyze here the seasonal patterning of death during the first two years of life by using individual-level data on births and deaths. Seasonal patterns will be studied over a time period of more than a century and for three Dutch provinces with strongly differing levels of infant and child mortality. We have used multivariate proportional hazard models to measure the impact of the season of birth and region, social class, and urban-rural residence on mortality risks of infants and children.

We will start with a summary of recent research on seasonal mortality in (historical) demography. Then we will briefly describe how, from the eighteenth century onwards, the seasonal variation in mortality attracted the interest of Dutch medical men and statisticians. We will present the dataset that we use to study the long-term development and the regional and social variation in seasonal mortality patterning.

STUDYING SEASONAL PATTERNS OF MORTALITY

Historical seasonal patterns of mortality have been studied for a wide variety of reasons. As a discrete topic, it was put on the research agenda by Eric Vilquin (1978). Vilquin estimated for Belgium in the period 1841-1843, on the basis of the number of deaths by month of death and age at death in months, the mortality risk by month of birth and age in months. He observed two excess mortality seasons, the winter and summer that each month-of-birth generation had to go through. For both these excess seasons there was a specific group of ages that was more vulnerable than any other group. Winter excess mortality, for example, was higher among infants aged between five and eleven months, whereas summer mortality affected in particular infants aged between one and five months. Thus, each month-of-birth generation was confronted with a different mortality pattern in its first year of life. Vilquin suggested that selection effects might have played a role: the fact that a particular excess mortality season had only limited effects on a given generation could have been due to the fact that this generation had already undergone excessive mortality a few months earlier during a previous excess mortality season, so that only the most robust members of this generation were still alive.

In the footsteps of Vilquin, Breschi & Livi-Bacci (1986) studied for Italy and various other countries the nineteenth-century seasonal pattern of infant mortality. Infants born in winter had by far the highest death risks, in particular during the first month of life, and this pattern did not change fundamentally until 1956. Not only were these infants exposed to high risks in the first month of life, but they also had to deal with the high summer risks at the age of around six months. Large regional differences in the seasonal pattern were observed, in particular for the first month of life for infants born in the winter. In regions where the winter temperatures were lower, the effects of being born in winter were much stronger than elsewhere. Various factors such as housing, heating methods, and the protection against the cold provided to the infant could have amplified the effect of the winter cold. Interestingly, in the second year of life an upsurge in death risks was observed for children born in June-August. These children were between 12 and 14 months old during this period. A large part of this group had already been weaned and were therefore more vulnerable to intestinal infections (Breschi & Livi-Bacci, 1986). In a later article, Breschi & Livi-Bacci (1997) analyzed mortality data by age at death in months and month of birth for the Netherlands, Russia and Switzerland in the period 1828-1888. In the Netherlands and Belgium, the season of birth had very little influence on mortality in the first year of life. In Italy, Switzerland and Russia, however, the differences between seasons of birth were very large. In the first days and weeks of life, children born in the winter were highly at risk of respiratory infections, a risk that could be reduced by adequate clothing, heating and less exposure to infections. During the warm season children were at risk of contracting infections of the digestive tract, but this risk varied according to the age of the child in summer. The influence of age was partly dependent on the breastfeeding status of the child: whether or not it was breastfed, and the length of the breastfeeding period. This was particularly relevant when the child entered its second summer period. The model found in the Netherlands, with a flat pattern of mortality in the first month of life over the twelve months of birth, pointed to good care of children in winter, even though the Dutch winters were considered harsher than those of Italy. In Russia, a very high peak in the summer was observed, which could be explained by the high agricultural workload; the high participation of females in peak summer activities, often away from home, caused early weaning or irregular breastfeeding of children and a lesser degree of care and protection. For the Netherlands it turned out that the winter-born infants ran higher risks at ages 5-7 months, that is during June, July and August. Children born in the spring ran increased risks in the same months, when they were 3-4 months old. Children born in the summer had slightly increased risks at ages 1-2 months, corresponding with September and October. Children born in the fall were the luckiest ones (Breschi & Livi-Bacci, 1994; 1997).

Knodel used micro-level data from 14 German village populations during the eighteenth and nineteenth centuries to calculate risks of dying between two exact ages in months by month of birth and compared these seasonal risks with the average value over the year. He observed a generally higher mortality risk during late winter and during the late summer months. Over time, there was an increase in the relative summer excess of neonatal and post-neonatal mortality, in particular during the second half of the nineteenth century. He related this to a shift toward less breastfeeding and / or increased supplemental feeding. In regions where breastfeeding was dominant, a summer peak in neonatal and post-neonatal mortality was lacking. In Bavaria, where most infants were not breastfed at all during any season, infant mortality was high throughout the year as the protective effect of breastfeeding was lacking in all seasons. The excess of infant mortality during the late summer and early fall harvesting months was limited to infants in the 1-5 months range. In contrast to the normal pattern of weaning at close to six months of age, during this period infants were weaned considerably earlier. In addition to this, contaminated food was more likely to be fatal among young infants than older ones (Knodel, 1983).

The seasonality of infant deaths can provide clues to the relative importance of various causes of deaths. Huck (1997) showed that during the nineteenth century the seasonal pattern of infant deaths in the UK changed markedly, from a pattern characterized by a winter peak and a summer trough to one with a peak in summer and average levels in winter. Health authorities pointed to the growth of pathogenic microbes and increased numbers of flies facilitating contamination as responsible factors. Huck suggested that the incidence and duration of breastfeeding had fallen during the nineteenth century and that the supplementation of breast milk with cow's milk had become more common. This could have decreased the protection against summer diarrhea and might have been at the heart of the changes in the seasonal mortality pattern of infants.

Reher & Sanz Gimeno (2006), using data for the Spanish city of Aranjuez in the years 1871-1970, showed that children born in late autumn and winter were at a distinct disadvantage whereas those born during late spring and summer were well-positioned for survival over the first five years of life. They observed a strong heterogeneity in the effect of the season on infancy mortality, depending on the child's exact age during different seasons of the year and on the type of infant feeding that was provided. Children in Spain tended to be breastfed almost exclusively during the first couple of months of life and weaning tended to take place after six months. The interplay between the date of entry into a dangerous period of infancy – dangerous because of the weather, teething or changes in feeding – and the age at entry caused a large amount of heterogeneity in mortality in the first year of life. Babies born in the winter and spring had the greatest risk of dying at the age at which they entered the summer season with its high diarrhea risk. Important risks after the first year of life were observed for babies born April-June, who survived their first summer thanks to the protection of their mother's milk but who did not have this protection when they reached their second summer. Infants most affected by intestinal diseases were those born during the winter who reached their first summer when they were being weaned and when teething had begun. For respiratory infections, the younger a child was, the greater the likelihood of death, implying greater risks for those born during the winter months.

Derosas (2009) also tried to explain long-term trends in infant mortality in nineteenth-century Venice by referring to the interplay between a seasonal pattern of mortality, characterized by high neonatal mortality among children born in the winter, and changes in maternal nutrition, in particular during late pregnancy. Maternal malnutrition, measured by prices of wheat and corn during the last three months of pregnancy, was assumed to increase the proportion of underweight children. These children were more exposed to reduced body temperature, because they lost warmth faster and also had less suckling ability; this could have increased their death risks in the first month of life.

In most studies, researchers linked changing seasonal mortality patterns to changes in breastfeeding patterns. Cheney (1984) showed that, in Philadelphia in the years 1865-1920, excess summer mortality in the first year of life decreased from around 1910 and almost disappeared by 1920. The seasonal pattern was associated with diarrheal diseases, sometimes referred to as weaning diarrhea. The shortening of the period of breastfeeding meant earlier weaning, which in turn implied that more and more infants were encountering weaning in the first rather than in the second year of life. Medical doctors advised that a child should be breastfed until after its second summer and never weaned just before or during the summer. A large decline in the summer peak in infant mortality was visible in 1900-1920, due to the improvement of the quality and purity of the milk supply and better informed childcare and feeding practices.

Oris, Derosas, & Breschi (2004) focused in addition to breastfeeding on the role that institutions and policies, housing conditions and food hygiene played in the effect of season on mortality. They compared five nineteenth-century communities in Italy, Sweden and Belgium and showed that the effect of the seasons was different for the various age groups and communities. In the communities in temperate regions, such as those in Belgium and even more so those in Italy, winter had an immediate effect at the beginning of life. Factors contributing to the winter peak for neonatal deaths were the inadequate heating systems of houses and the exposure of children to cold during the baptism ceremony. In Belgium and Sweden the winter effect also remained marked after the first six months. The authors connected this with changes in clothing and the exposure to cold when the babies gradually left the cradle. In the poor rural societies of Belgium and Sweden, children aged six months or older suffered not only during winter, but also during spring. Food supplies were most scarce in this period. Food availability affected not only weaned children but also, indirectly, breastfed children as mothers died at higher rates when food became more expensive, thereby exposing their children to higher death risks as well.

A different strand of research has focused on the association between seasonal variations in early life conditions, such as infectious burdens and nutritional levels, and later adult health status. In a very influential paper, Doblhammer & Vaupel (2001) argued that month of birth may be an indicator for environmental factors linked to the season of birth, and that month of birth was related to remaining life expectancy at age 50. People born in autumn (October – December) in Northern Hemisphere countries lived longer than those born in spring. Seasonal differences in the composition of births might have been at the heart of these mortality differences. Doblhammer & Vaupel (2001) tested (albeit in a rather crude way) whether differences in social composition of births might have been responsible for the observed effect, but did not find such an effect. They suggested that higher birth weights, caused by better nutritional status of the mother during pregnancy, and by seasonal differences in the incidence of infectious diseases of the mother during the third trimester of pregnancy, might have played a role. Mothers who gave birth in autumn and early winter had access to plentiful food throughout most of their pregnancy, whereas women giving birth in spring and early summer experienced longer periods of inadequate nutrition. As nutrition in winter and early spring improved over time, this might explain why the relationship between month of birth and life span has weakened in more recent generations.

The work of Doblhammer & Vaupel inspired other researchers. Ueda et al. (2013) used Swedish longitudinal data between 1991 and 2010 to study the effect of month of birth on mortality above the age of 30. Again, seasonal differences in food supply were mentioned as a relevant factor. At the beginning of the twentieth century, when fruit and vegetables were only widely available in the summer and autumn, mothers of children born in the autumn had a better nutritional status, especially during the third trimester of pregnancy, compared with mothers of spring-born children. Differences in prenatal nutritional levels were also mentioned by Muñoz-Tudurí & García-Moro (2008) to explain the relationship between season of birth and survival within the first three months and between the start of the third month and the end of the first year of life in cohorts born between 1634 and 1870 in a village on the island of Minorca. Summer births had the highest probability of death during the first three months of infancy.

A different perspective, based on life history theory, inspired Lummaa et al. (1998) to test whether humans time their breeding to the months of the highest probability of infant survival probability. Data for two Finnish parishes in the period 1770-1806 showed, however, that births were concentrated at times when the survival probabilities of the children were low. Gagnon (2012) tested whether children growing up in a nutrient-rich prenatal milieu could develop a demanding or hopeful phenotype that becomes accustomed to an abundance of resources over the long term. As an example, he studied individuals born during or after the harvest season. These hopeful phenotypes were disadvantaged when growing up in a harsher environment later in life. By studying conceptions and children under varying conditions of resource availability and disease load in Quebec since the seventeenth century, Gagnon showed that the season of birth acted as a good proxy for the level of nutrition in utero and as a reliable predictor of survival to age 60. A nutrition-rich milieu during the last trimester of pregnancy would lead to a demanding phenotype; whether this led to longer-term survival depended on the environment in which the individual lived later in life. Other researchers also stressed the decisive role of early programming, especially the idea of seasonal programming of the metabolism in the developing fetus. They referred to various environmental factors, climatic and environmental ones such as insolation, food and its nutritional value, as well as intrauterine ones such as levels of vitamins in the blood (Chmielewski & Borysławski, 2016).

As mentioned earlier, recently several authors have suggested that the association between the month of a child's birth and later outcomes such as mortality might reflect inherent differences in personal attributes or family background. Buckles & Hungerman (2013) tested this proposition by using data on births from 1989-2001 and census data for births between 1943 and 1980 in the US. They found that children born in the winter had younger mothers, were less educated and less likely to be married. By introducing a set of family background controls, they could reduce the magnitude of the season of birth effect on outcomes such as lower birth weights and higher prematurity rates. Currie & Schwandt (2013) studied the seasonality of health at birth by comparing siblings conceived by the same mother at different times of the year; in this way, the effects of seasonality were not contaminated by socioeconomic differences between mothers who were selected into different conception months. The authors showed that in births in the period 1994-2010 in three US states there was a clear similarity between the seasonal patterns in gestation length across subgroups. This suggested that external environmental factors affecting society as a whole played an important role. Gestation length was lower for conceptions during the first five months of the year. Influenza infections triggering adverse birth outcomes were considered the factor behind this seasonal pattern in preterm births. In a recent study, Dorélien (2015) studied the relationship between birth month, considered as a proxy for early-life conditions, and child mortality in developing countries. She tested whether a non-random distribution of births within a year was a contributing factor. Accounting for maternal selection did indeed attenuate the relationship between birth month and health, but not in all countries studied.

SEASONAL DEATHS PATTERNS IN THE NETHERLANDS: A HISTORICAL OVERVIEW OF EARLIER RESEARCH

Before the nineteenth century, mortality data in the Netherlands were limited to local death records of ecclesiastical, civil and fiscal natures. In the second half of the 18th century, the group of people interested in this kind of material, namely clergymen and, in particular, medical doctors, constantly expanded (Van der Woude, 1980; Van Nierop, 1919). In 1755, at the request of the medical professor Thomas Schwencke (1693-1767), the municipal council of The Hague established a system of death registration on the basis of the deaths reported to the town clerk's office. These data were compiled by the mayor of The Hague, Johan Pieter Dierquens. He held the view that the lists would 'enable anyone afflicted by any of these diseases (...)

to clearly establish in which month of the year, and at what age in their life, they would be most at risk, and have to take the greatest precautions' (*Verzameling van naauwkeurige lysten, opgemaakt uit oorspronkelyke registers, betreffende de sterfte, geboortens, huwelyken, ouderdommen en ziektens in 's-Gravenhage, in het beloop van XIX jaaren, zedert het jaar 1755. tot 1773. incluis waargenomen : benevens een onderzoek aangaande de luchtstreek en het getal der inwoonderen aldaar*, 1774, p. 33).

Closely connected with the expansion of the Enlightenment into popular channels, reading and scientific societies had developed after 1740. Many of the members of these societies had a medical background. The societies tried to explain the mechanisms of disease and how diseases spread, for example by offering prizes for the best solutions to practical medical problems. In 1770, the Holland Scientific Society (*Hollandsche Maatschappij der Wetenschappen*) offered a prize for the best answer to the question 'What diseases prevalent amongst mankind arise from the natural condition of our fatherland? How can one ward off these diseases, and by what means can they be cured?' (Huisman, 1997, p. 71). In 1779, the Hague physician Iman Jacob van den Bosch (1731-88) founded a society whose aim would be to compile a medical description of the Dutch Republic, the Physics and Medical Correspondence Society of the Dutch Republic (*Natuur- en Geneeskundige Correspondentie Societeit in de Vereenigde Nederlanden*). It attempted to achieve its objective by encouraging doctors and other scientists to compile 'reliable lists of births and deaths for each individual municipality' (Van Nierop, 1919, p. 202-203). The corresponding members were requested to restrict themselves in their medical observations 'to the predominant diseases and epidemics, in addition to the measures and medicaments relating thereto; and at the same time not to forget the location of the place, the differing characteristics of land and water, as well as the difference in the quality of the air' (Van Nierop, 1919, p. 203). The growing interest in the relationship between climatological and geographical factors and health was stimulated further by the systematization of research in meteorology (Van Lieburg & Snelders, 1989). In 1797, a report was published in Amsterdam by the medical board which highlighted the flaws in the existing birth and death registers and suggested ways of improving these. It included models of printed forms which would enable deaths for the municipality as a whole to be recorded in a consistent manner. One of the death forms was intended to compile information 'on the effect of the seasons on the diseases of the deceased persons', and had to provide the number of deaths by month and cause of death (*Verzameling van stukken betrekkelyk de aanstelling eener commissie van geneeskundig toevoorzicht, te Amsterdam. Met Rapporten strekkende als bylaagen*, 1798).

It was only in 1811 that a national system of death registration was introduced, when birth, death and marriage registration, as incorporated in the Code Napoléon, became mandatory under the Imperial Decree of 19 April 1811 (Bulletin des Lois No. 6872). In 1829 the Provincial Medical Supervisory Board of North-Holland announced a competition to devise a death registration system which could meet the requirements of the medical profession. G. C. B. Suringar, professor of anatomy, physiology and surgery, drew up a comprehensive inventory of the requirements that had to be met by the death registration system. A key role was attributed to data enabling death to be related to climatological and geographical factors (Suringar, 1831). Around the same time, Adolphe Quetelet, using monthly numbers of deaths for Amsterdam, Rotterdam and The Hague and for four Belgian cities for an 18-year period, compared the changes in the monthly number of deaths with those of the monthly temperatures. Numbers of deaths were inversely correlated with the average temperatures, with the lowest numbers of deaths and the highest temperatures in the month of July and the highest number of deaths in January. Although Quetelet had no doubt about the importance of temperature, he also referred to the fact that during winter people were more exposed to the risk of death because they had difficulty in acquiring the necessary food, had a lower chance of finding work, and were condemned to a hopeless inactivity, factors that had a negative effect on people's morale and consequently also on their physical fitness (Quetelet, 1827).

From 1840 onwards, data on the number of deaths by sex, age and month of death were published, with a special focus on deaths under the age of two. Later on, these data were published separately for towns and other municipalities. In particular, during periods of extreme heat, medical doctors studied with interest the monthly mortality data for infant deaths. Less attention was paid to excessive infant mortality in the winter period. Based on what doctors observed in their own practices, they blamed the high infant mortality during the summer months to the food supplied to children. During hot weather, milk and bread porridge would undergo 'a slight change, and in this process start to decay… To dilute the milk, or to prepare other foods or drinks, water is used, and if one considers how poor the water is in some places as a consequence of the heat and drought, then one has another reason for the harms that are caused in particular during hot summers by artificial feeding of infants'. In hot summers, the mortality of children of the poor increased more strongly than among children of the well-to-do. 'It is among these families in whose dwellings, sooner than in the houses of the rich, the bad air manifests itself; in which, be it out of ignorance, negligence or frugality, more often bad or badly prepared food is given to the children, or what has been left from an earlier day... Lack of discernment, unfamiliarity with the need for it also leads in these families to a less-than-required care for the complete purity of bottles and other utensils in which the child's food is kept and which is so extremely important, particularly in hot weather. The milk that is bought by those people for whom spending a few more cents is a question of high importance will generally be poorer [in quality] than the one that can be supplied by those who wish to buy good stuff, even if that costs a bit more; and those who buy the bad and often-old milk, very frequently will have more trouble in trying to preserve it from decay' (Pous Koolhaas, 1869, p. 113; see also Wybrants, 1914, p. 104).

In the late nineteenth century, the heights of the summer peaks in infant mortality differed considerably between provinces (Jonkers, 1903). Analysis of the seasonal pattern of infant deaths for provinces and for urban and rural areas revealed that the summer peak in infant mortality had become more pronounced in the period 1895-1905 than it had been in the 1880s. In general, rural municipalities had lower and later summer peaks than urban ones. Zeeland was the province which over the whole period was characterized by the highest summer peaks, whereas in Groningen and Drenthe summer peaks were generally much lower (Saltet & Falkenburg, 1907). Changes over time were visible, however, as during the first decade of the twentieth century excess mortality was now apparent among infants in the countryside; those in the larger towns had taken advantage of the hygienic measures such as good drinking water and controlled milk stations that had been taken there in the recent past (Heynsius van den Berg, 1912, p. 914).

As infant and child mortality lost its role as the determining factor of the length of life, and most of the factors held responsible for the seasonal variation in mortality in this age group (food shortages, contaminated water and food, deficient heating and clothing, baptism ceremonies) became less relevant, medical doctors and statisticians lost interest in the topic. Recent historical studies, however, have taken up the topic again. Hoogerhuis (2003), for example, studied the seasonal pattern of infant mortality in a group of communities in the province of Zeeland in the period 1811-1900. Month of death was the starting point of his analysis.

Index values of the mortality risks of infants aged 1-5 months were in the period July-October 40-50 per cent higher than average; for infants aged 6-11 months this was 15-30 per cent. Short periods of breastfeeding and sudden weaning during the harvest season were responsible for the excess summer mortality. During the 1880s and 1890s, excess mortality in the 1-5 months age group even increased, a phenomenon that was related to the increased demand for female labor in agriculture after the agrarian depression of the 1870s. The likelihood of excess deaths in months 6-11 and at 1-2 years decreased after 1860.

This overview of Dutch and international studies has made it clear that the long nineteenth century was a crucial period for the study of seasonal mortality. In the Netherlands, strong seasonal effects were observed, but they differed as to region and between urban and rural residence. Contemporaries suggested that there were social class differences in seasonal mortality and changes over time. There were conflicting findings regarding the ages at which excess mortality was strongest. One problem is that almost all historical studies published so far made use only of data on numbers of deaths by month of death. In addition to this, seasonal differences in the characteristics of the mothers giving birth were not taken into account. In this paper, we will study the season-mortality relationship by focusing on the month of birth of the child and accounting for maternal characteristics. We use fixed-effects Cox proportional hazard models to shed new light on the effects that seasons had on mortality in the past. The present study encompasses data for three provinces, differing in their microclimatological environment. The dataset covers a very long time period, making it possible to study trends over time in the season-mortality relationship.

DATA AND HISTORICAL CONTEXT

Nationwide compulsory birth and death registration according to the rules of the Napoleonic Code was introduced in the Netherlands in 1811. From the 1990s onwards, volunteers and staff of Dutch archives began to enter these records into databases. These databases cover the period from the introduction of the vital registration system up to the varying dates at which these data are no longer in the public domain.[1] In 2009, a project called LINKS was launched, which aimed at the reconstruction of all nineteenth- and early twentieth-century families in the Netherlands on the basis of these separate regional databases (Mandemakers, 2009).[2] The data that will be used here are the result of the LINKS project. They cover the provinces of Zeeland, Groningen and Drenthe, for which data entry has been completed and for which occupational information from certificates has been systematically entered (Mandemakers & Laan, 2017).

The province of Zeeland was for a long time a rural area with sea-clay grain farming. In the second half of the nineteenth century, agricultural modernization eroded the position of small farmers and farm laborers; industrialization took place after 1900 (Priester, 1998; Wintle, 1985). Groningen can be roughly divided into a northern area of clay soils where agriculture was highly commercialized, like in Zeeland, and a southern area of sand and peat. The peat districts became zones of important industrial development in the second half of the nineteenth century. In connection with the cultivation of potatoes, factories were established for making spirits, straw paper, etc. In Drenthe, peat-digging was conducted on a regular system of fen colonization. Sheep and cattle were reared and forest cultivated on the sand grounds. The poor agricultural soil did not always yield enough to provide the farmers with a decent living. In all three provinces, there were few urban centers of any importance and population density was low.

The database for each province consists of three basic tables with births, marriages and deaths. Death records are complete for the period 1811-1963, marriage records for 1812-1938, and birth records cover the period 1811-1913. The starting point for the construction of the database was a standardization of all first and last names. After standardization, birth and death certificates were linked on the basis of the names of the child, of his or her mother and father, or based on the names of child and mother. In the next step, births and deaths were linked to the marriage certificate of the child. This provided supplementary information for linking birth and death certificates, as the marriage certificates supplied the names of the parents of the bride and groom, information that was sometimes not available on the death certificate of the child, as well as the names of the parents of the child's partner, which could enable a connection to be made to a death certificate containing the partner's name. Next, the information on brides and grooms was linked to the marriage certificates of their parents. Information thus became available on date of birth, sex, place of birth, date of marriage of the individual, date of marriage of the individual's parents, and date of death of the individual. The death file also contained information on children recorded as being in a lifeless state (mostly stillbirths) but we excluded this group from the analysis. For children for whom no death certificate was available, for instance because they were still alive in 1963, the date of last observation was determined on the basis of the date of their marriage. In cases where neither a death record nor a marriage record were available, we assumed that a person had at least survived until the age of two. In our analyses we have tested whether this assumption could have affected our results.

The exact age at death was unknown for about 46 per cent of the children (Zeeland, 46 per cent; Groningen, 45 per cent; Drenthe, 49 per cent). For about 44 per cent of these censored deaths we have information on the marriage date. For between 24 and 27 per cent of the individuals we censor their observed length of life at age two. This includes individuals who remain single for their whole life and individuals who died outside their province.

Given the different observation windows for birth, death and marriage records, not all births could be linked to the marriage information of the parents, as some parents were married before 1811. The nature of our data does not allow us to find out a couple's exact number of children in all cases. For each couple we only know the children who were born in the specific province in the period for which birth and death records were available. The number of children used in the analysis will therefore underestimate the actual number of children produced. However, by comparing our data with available statistics from other sources on births and infant mortality (Oomens, 1989; Ekamper & Van Poppel, 2008), we are confident that our data offer a more or less correct estimate of the fertility and mortality levels of our provinces.

Table 1 shows that we possessed information on almost 1,695,000 live-born children. Almost 67 per cent of the study group belonged to the working classes, 13.9 per cent to the middle class and only 1.6 per cent to the elite.[3] Infant mortality was between 9 and 19 per cent and early childhood (under-two) mortality between 12 and 23 per cent, which is again in the range of values found in published statistics. Zeeland was characterized by very high infant mortality, in many parts even higher than 30 per cent. Infant mortality rates were very low (below 10 per cent) in the western part of Groningen and in Drenthe.

The sex ratio of live births was 1.05 male to female births. Unfortunately, the age of the mother at birth is only available for Zeeland, and only for mothers that could be linked to marriage records. The highest percentage of mothers in Zeeland was in the age group 25-29 years (22%). A rough approximation for the life phase when mothers gave birth which is available for all provinces is the timing of births relative to the time of marriage, but of course this is available only for those parents who were indeed married. Only 5 per cent of children were born less than a year after the date of marriage or before marriage. For around 4 per cent of all births the father is unknown. As expected, a minority of the children born in the selected, mainly rural, provinces was born in an urban environment[4]: 22 per cent in Zeeland, 25 per cent in Groningen, and 10 per cent in Drenthe.

METHODS

Recently, seasonal mortality patterns have been studied by using survival methods as data often contain (right-)censored observations. Another advantage of survival methods is that they take the whole life history into account. Survival methods modeling the hazard rate (the mortality rate) are particularly suitable for dealing with censoring, because the hazard rate is invariant to censoring (Kleinbaum & Klein, 2005). Hazard rates models are therefore perfect tools to deal with the observational problems that we encounter for that part of the study population for which we have no information on a child's date of death but only on his or her date of marriage (provided that this marriage was performed in the province of birth). When the date of marriage was not given we censored these observations at age two.[5]

A common way of accommodating the presence of observed characteristics is to specify a proportional hazards model in which the hazard rate is the product of a baseline hazard (also called duration dependence, in our case age dependence) common to all individuals and a covariate effect (Cox, 1972). In this model, a change in a covariate, say the age of the mother at birth, shifts the hazard proportionally. We tested three different specifications of Cox proportional hazards models to study the seasonal birth month patterns of early childhood (under-two) mortality: (1) a baseline model accounting for birth month only; (2) an extended model accounting for available additional individual and family characteristics as presented in Table 1 (model 1 plus sex, years since marriage, father known or unknown, social class, urban or rural residence, and period of birth); (3) a fixed-effects model stratifying by mother's identity (Rabe-Hesketh & Skrondal, 2012) to control for unobserved characteristics associated with having the same mother, excluding model 2 control variables that were

Table 1. Descriptive statistics of the dataset on births covering the Dutch provinces of Drenthe, Groningen, and Zeeland for the period 1812-1912

Province		Drenthe	Groningen	Zeeland
Number of live births		329,849	687,668	661,009
Mortality	Infant mortality	8.9	10.7	19.0
	Mortality under age 2	12.3	13.8	22.5
Month of birth	January	8.8	9.1	9.0
	February	8.5	8.8	8.6
	March	9.3	9.4	9.3
	April	8.5	8.5	8.2
	May	8.2	7.9	7.6
	June	7.3	7.1	7.0
	July	7.6	7.3	7.4
	August	8.1	8.1	8.5
	September	8.6	8.6	8.9
	October	8.7	8.5	8.8
	November	8.0	8.1	8.2
	December	8.5	8.5	8.5
Sex of child	Male	51.4	51.3	51.2
Mother's age	< 20			0.9
	20 – 24			12.4
	25 – 29			22.0
	30 – 34			20.2
	35 – 39			14.4
	40 +			6.6
	Unknown	100.0	100.0	23.5
Years since marriage	< 1	5.1	5.1	4.4
	1 – 2	17.8	18.9	17.2
	3 – 5	17.6	18.6	17.4
	6 – 9	16.3	17.0	16.5
	10 +	20.5	20.1	20.6
	Unknown	22.7	20.3	23.9
Father unknown		2.7	4.3	4.5
Social class	Unskilled workers	42.6	40.5	49.3
	Semi-skilled workers	5.6	10.1	10.0
	Skilled workers	11.3	14.9	12.1
	Farmers	24.8	11.8	6.3
	Middle class	12.2	18.2	10.2
	Elite	1.4	2.0	1.2
	Unknown	2.0	2.5	11.0
Urban place of birth		10.0	24.8	24.1
Period of birth	1812-1836	13.5	18.3	21.2
	1837-1861	19.3	21.7	24.0
	1862-1886	27.7	28.3	27.4
	1887-1912	39.5	31.8	27.3

Source: links dataset 2017

fixed for mothers over time (Dorélien, 2015).[6] To test whether birth month patterns varied over social classes, we also ran models for each social class separately. All models were run for each province separately. We tested the significance of birth month effects by running joint significance tests on all models.

Additionally, we analyzed the monthly hazard rate patterns of infant and early childhood mortality by month of birth over the first 24 months of life by running Cox proportional hazards models for each combination of month of birth and month of life, controlling for additional individual and family characteristics per province. We again ran the models for social classes separately.[7] The adequacy of the proportional hazards assumption was confirmed by examining plots of Schoenfeld residuals (Schoenfeld, 1980). To visually analyze changes in hazard rate patterns over time and monthly birth cohorts, we used a heat map approach (Wilkinson & Friendly, 2009).

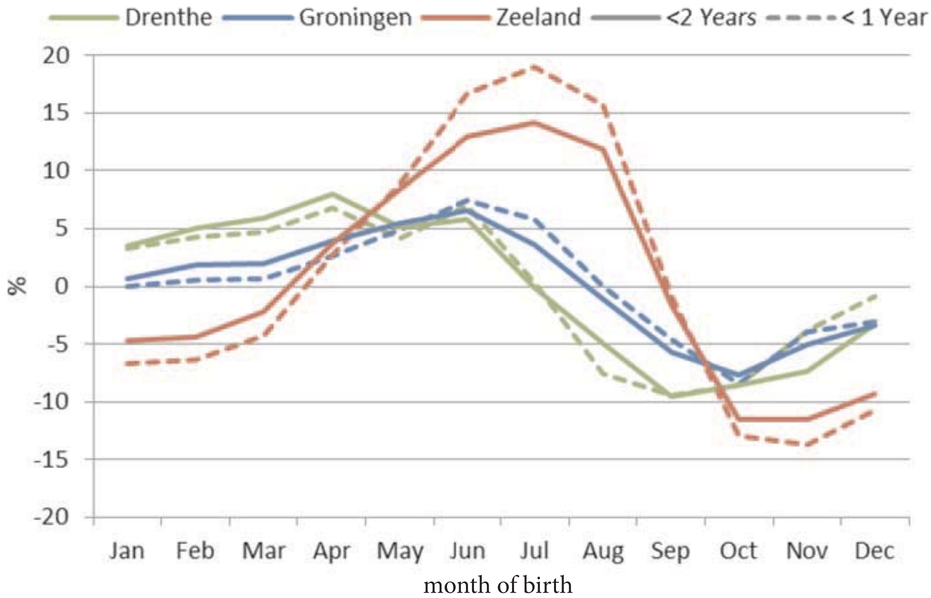
RESULTS

DESCRIPTIVE INDICATORS

The overall under-two childhood mortality rates by birth cohort over the period 1812-1912 varied from relatively low in Drenthe (12.3%) and Groningen (13.8%) to relatively high in Zeeland (22.5%). Decomposing early childhood mortality by month of birth reveals clear seasonal patterns, although the patterns show remarkable differences between the provinces (Figure 1). Early childhood mortality in Zeeland shows a strong peak in the summer and lows in autumn. Compared to the overall average mortality, rates are 14 per cent higher in July and almost 12 per cent lower in October and November. Seasonal patterns in Drenthe and Groningen are clearly less strong. The Groningen data show a less pronounced summer high and autumn low. Moreover, the summer peak is earlier than in Zeeland. The highs and lows in the seasonal pattern of Drenthe are even earlier than in Groningen. With no clear peak in the summer, mortality rates in Drenthe are the highest in April and lowest in September. If we look at infant mortality only, the seasonal patterns are quite similar, but slightly more pronounced.

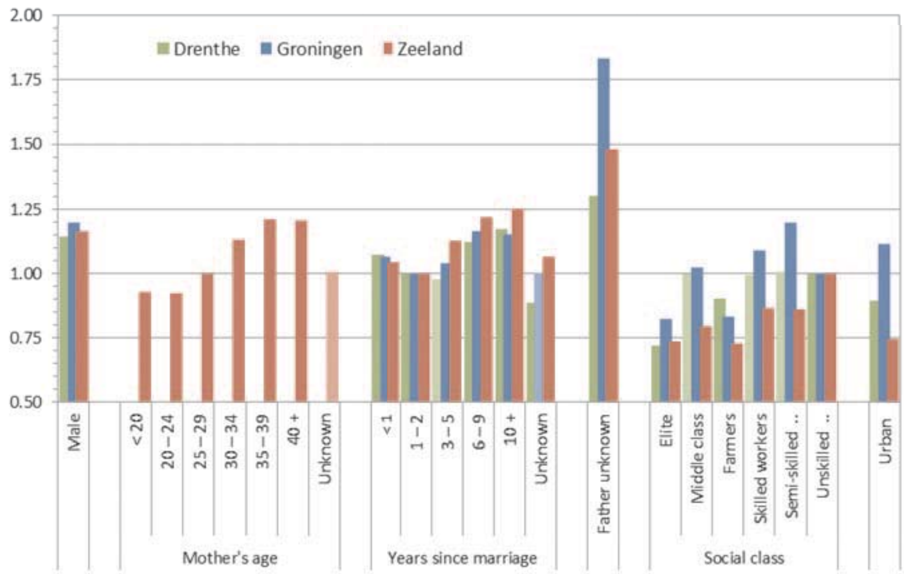
Looking at other characteristics of the infants and their families, we observe early childhood mortality differences in line with other studies (Fig-

Figure 1. Early childhood and infant mortality by month of birth and province (deviation from average provincial hazard rates), the Netherlands, 1812-1912



ure 2). Early childhood mortality rates are 14 to 20 per cent higher for boys than for girls. Children born from older mothers show higher risks than those born from younger mothers (data available for Zeeland only). We do not find higher risks for the youngest mothers. However, since the age of the mother was only known for married mothers, this might be caused by the missing age data for unmarried (and more likely younger) mothers. We see a similar pattern for the timing of births since marriage, although children born before marriage or within one year of the marriage show higher risks than the reference category. Children born from unknown fathers face much higher risks than the other children, which could also very well be linked to younger mothers. With respect to social class, children from the elite and from farmers have lower risks than children from the working class. Differences between children born in rural or urban environments are quite variable. Urban mortality rates are higher in Groningen, but lower in Drenthe and Zeeland. However, all provinces are predominantly rural with relatively small cities, except for the city of Groningen by far the largest city of the whole dataset. Children born in smaller cities apparently face lower risks than children born in rural areas, and even much lower than those born in a large city.

Figure 2. Early childhood (under-2) mortality by characteristics and province (hazard ratios), the Netherlands, 1812-1912*



* non-adjusted for other characteristics; light color bars are non-significant (p<0.05).

COX PROPORTIONAL HAZARDS MODELS

To test whether the descriptive results of the previous section on early childhood mortality persist, Table 2 presents the results of three different Cox proportional hazards models as specified in the methods section. The results of model 1, the baseline model, reflect the results presented in Figure 1 and serve as the reference model. The results of model 2 show to what extent the baseline model results persist when accounting for the additional individual and family characteristics presented in Figure 2, In general the birth month patterns remain similar to the baseline model and are even slightly more pronounced, particularly for the summer months in Zeeland. As for all additional individual and family characteristics in the joint model, the patterns of the hazard ratios are similar to the baseline models and remained statistically significant. Boys remain more vulnerable than girls; the longer the period in years since marriage (~ the older the mother[8]), the higher the risk compared to those born 1-2 years after marriage (again except for children born before or within one year of marriage); children with unknown fathers remain more vulnerable; children from the highest social class and from farmers are again less vulnerable than (unskilled) laborers; and children born in the city of Groningen still are more at risk than children born in rural areas. After controlling for maternal selection (model 3), the birth month effects remained jointly significant in all provinces. In Zeeland, the seasonal pattern remained more or less similar, but the summer peak strongly increased. In Groningen, the autumn low remained, but the hazard ratios for birth months February to June leveled with the July summer peak. In Drenthe, the overall pattern remained rather similar except for slightly lower hazard ratios for birth months June and July.

To test whether birth month patterns varied over social classes, we ran all models for each social class (and province) separately. In general, social class specific birth month patterns were in line with the overall provincial patterns (see appendix Table 1). However, there were a few exceptions. Middle-class children in Drenthe showed higher under-two mortality risks for those born in the winter months, but hardly any increase for those born in the summer months. Children of farmers in Groningen showed higher risks than the other social classes in Groningen when born in the summer months, and the mortality peak was earlier (May-June) for children from unskilled workers. Almost all birth month patterns were significant according to the joint significance tests. However, in Drenthe and Groningen, the patterns for the elite were in line with the general pattern but not significant due to the small numbers. In Zeeland, all social classes followed similar patterns, with the skilled workers showing the lowest summer peak.

Years since marriage						
< 1	1.126 ***	1.249 ***	1.098 ***	1.180 ***	1.042 **	1.064 ***
1 – 2	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
3 – 5	0.981	1.019	1.044 ***	1.045 ***	1.127 ***	1.088 ***
6 – 9	1.123 ***	1.212 ***	1.163 ***	1.194 ***	1.220 ***	1.190 ***
10 +	1.157 ***	1.367 ***	1.150 ***	1.271 ***	1.267 ***	1.271 ***
Unknown	0.905 ***	1.000 ***	0.815 ***	1.000 ***	1.187 ***	1.000 ***
Father is unknown	1.268 ***		2.018 ***		2.512 ***	
Social class						
Unskilled workers	(ref)		(ref)		(ref)	
Semi-skilled workers	1.077 **		1.146 ***		0.873 ***	
Skilled workers	1.029		1.090 ***		0.976 **	
Farmers	0.923 ***		0.841 ***		0.768 ***	
Middle class	1.042 *		1.027 **		0.870 ***	
Elite	0.781 ***		0.854 ***		0.795 ***	
Unknown	1.257 ***		1.301 ***		0.366 ***	
Urban place of birth	0.883 ***	0.260 ***	1.050 ***	0.295 ***	0.723 ***	0.269 ***
Period of birth						
1812-1836	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
1837-1861	1.397 ***	1.143 *	1.207 ***	1.060	1.061 ***	1.040
1862-1886	1.558 ***	1.217 **	1.308 ***	1.055	0.916 ***	1.014
1887-1912	1.363 ***	1.292 **	0.996	1.072	0.600 ***	0.943

Notes: *** p<0.001, ** p<0.01, * p<0.05

Model 1: baseline model; Model 2: additionally controlled for individual and family characteristics and period; Model 3: controlled for (same mother) fixed-effects.

Table 2. Cox proportional hazards model hazard ratios (hr) for early childhood mortality (< 2 years) by control variables, by province, the Netherlands, 1812-1912

	Drenthe			Groningen			Zeeland		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
	HR	HR	HR	HR	HR	HR	HR	HR	HR
Month of birth									
January	1.144 ***	1.150 ***	1.182 ***	1.100 ***	1.099 ***	1.116 ***	1.084 ***	1.071 ***	1.092 ***
February	1.162 ***	1.174 ***	1.204 ***	1.113 ***	1.117 ***	1.163 ***	1.086 ***	1.080 ***	1.124 ***
March	1.171 ***	1.178 ***	1.186 ***	1.114 ***	1.123 ***	1.183 ***	1.110 ***	1.106 ***	1.143 ***
April	1.192 ***	1.193 ***	1.211 ***	1.136 ***	1.147 ***	1.178 ***	1.184 ***	1.193 ***	1.243 ***
May	1.159 ***	1.154 ***	1.150 ***	1.154 ***	1.160 ***	1.179 ***	1.250 ***	1.275 ***	1.332 ***
June	1.168 ***	1.163 ***	1.139 ***	1.168 ***	1.177 ***	1.189 ***	1.322 ***	1.358 ***	1.407 ***
July	1.098 ***	1.091 **	1.050	1.136 ***	1.144 ***	1.172 ***	1.351 ***	1.393 ***	1.466 ***
August	1.040	1.038	1.032	1.078 ***	1.081 ***	1.088 ***	1.326 ***	1.344 ***	1.410 ***
September	0.988	0.989	0.986	1.024	1.026	1.057 **	1.134 ***	1.139 ***	1.157 ***
October	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)	(ref)
November	1.017	1.017	1.003	1.034 *	1.030	1.035	0.997	0.992	0.991
December	1.065 *	1.066 *	1.079 *	1.052 **	1.048 **	1.066 **	1.026	1.019	1.019
Male child		1.145 ***	1.157 ***		1.199 ***	1.208 ***		1.154 ***	1.190 ***

MONTHLY PATTERNS OVER TIME

To obtain a better understanding of the patterns of early childhood mortality over time, we analyzed the monthly hazard rate patterns in the first two years of life by month of birth. Figures 3 to 5 show early childhood mortality rates by consecutive months of birth from January to December over the first 24 months of life. Over the whole period, monthly mortality rates are much higher for Zeeland than for Drenthe and Groningen. However, the monthly variation over the period shows some remarkable variation between Zeeland and the other provinces. Infant mortality in the first month of life (the dots in the graphs) shows seasonal patterns with the highest risks for those born in the summer and winter. In Groningen and Zeeland, mortality risks among those born in the summer are higher than among those born in the winter, but in Drenthe mortality risks in the winter are higher than in the summer. Although mortality risks are roughly declining as children get older, cohort mortality rates do not show a continuous decline over time. In particular, in the first summer after birth, mortality rates stop declining or even increase again. In Drenthe, mortality rates for children born in the months January to April stop declining after three months (or for those born in March slightly increase in July) and start declining again from July-August. In Groningen, the pattern is quite similar except for children born in April who face a clear mortality increase in July. This summer effect, however, is much stronger in Zeeland where mortality rates for children born from February to June strongly increase in August and are even higher for those born in May and June than in their month of birth. The summer effect thus appears to be particularly strong in Zeeland compared to the other provinces, not only for children born in the (late) summer months, but also for children born a couple of months before summer. Although mortality rates in general decline again after the summer mortality peak, this again is not a continuous decline. However, this cannot be easily read from Figures 3 to 5.

Figure 3. Average monthly hazard rates by month of birth for the first 24 months of life, province of Drenthe, the Netherlands, 1812-1912

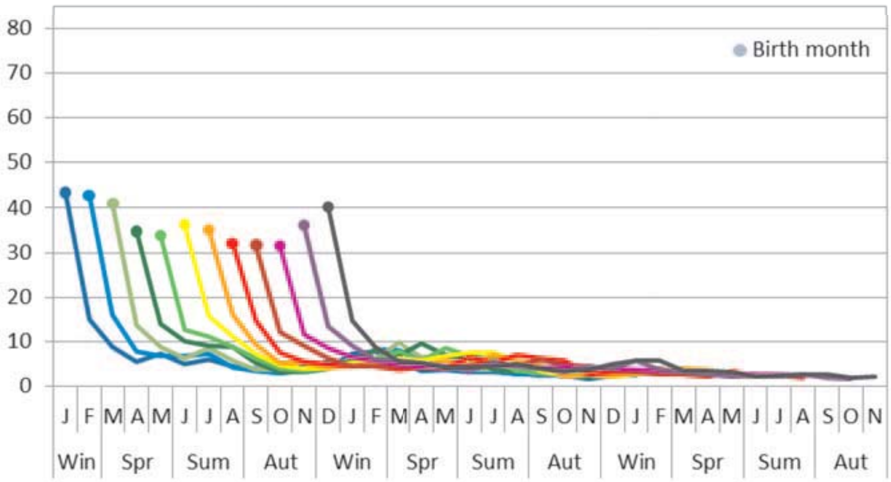


Figure 4. Average monthly hazard rates by month of birth for the first 24 months of life, province of Groningen, the Netherlands, 1812-1912

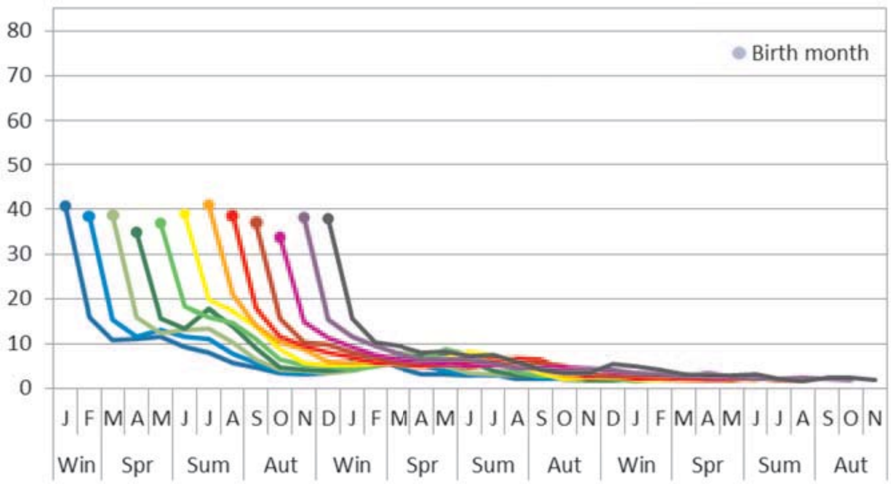
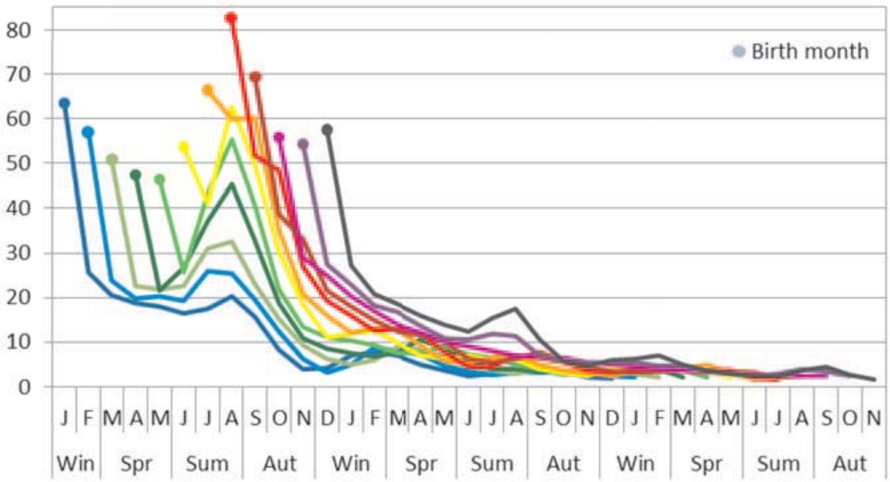


Figure 5. Average monthly hazard rates by month of birth for the first 24 months of life, province of Zeeland, the Netherlands, 1812-1912



By presenting the data from Figures 3 to 5 in a different way, we obtain a better view of the mortality patterns after the summer peak. Figures 6 to 8 show the same data in heat maps. The heat maps show the monthly mortality rates displayed in a two-dimensional table by month of birth and calendar month. The heat map table cells are color-graded, ranging from high (red) via medium (yellow) to low (green) mortality rates, enabling us to detect clustering patterns over cohorts and time. The heat maps again show the summer mortality peaks, particularly in Zeeland, but also reveal a cohort mortality increase clustering in the diagonal of higher mortality rates 12 to 13 months after birth. The early childhood mortality by birth month cohort thus is affected by cohort effects for month of birth and 12 to 13 months after birth, as well as by period effects for summer months.

We observe similar patterns for separate social classes (not shown). Mortality differences in the first month of life show similar birth month patterns for children born from workers, farmers and the middle class. However, the most striking differences between these social classes are that the mortality risks in the first summer after birth are much lower for children from farmers (around 40%) and slightly lower for middle-class children (around 13%) than for working class children, especially in Groningen and Zeeland. Differences between social classes in Drenthe are much smaller. According to the joint significance tests, birth month patterns were in general significant in all of the first 15 months.

Figure 6. Heat map of average monthly hazard rates by month of birth for the first 24 months of life, province of Drenthe, the Netherlands, 1812-1912

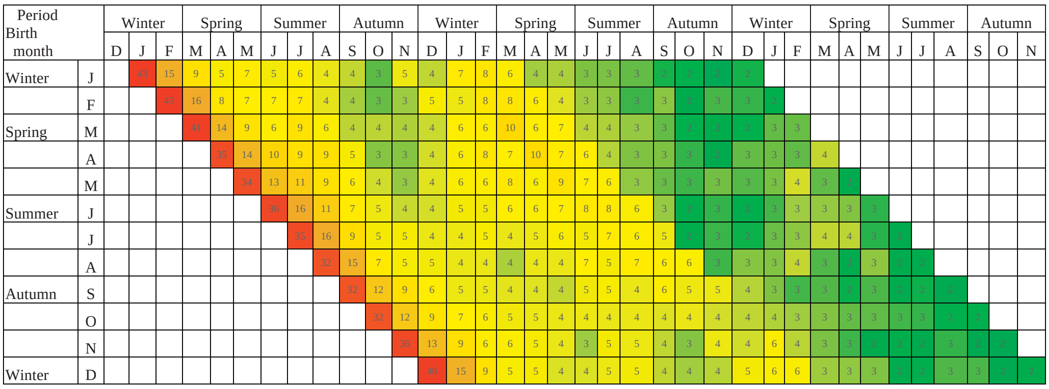


Figure 7. Heat map of average monthly hazard rates by month of birth for the first 24 months of life, province of Groningen, the Netherlands, 1812-1912

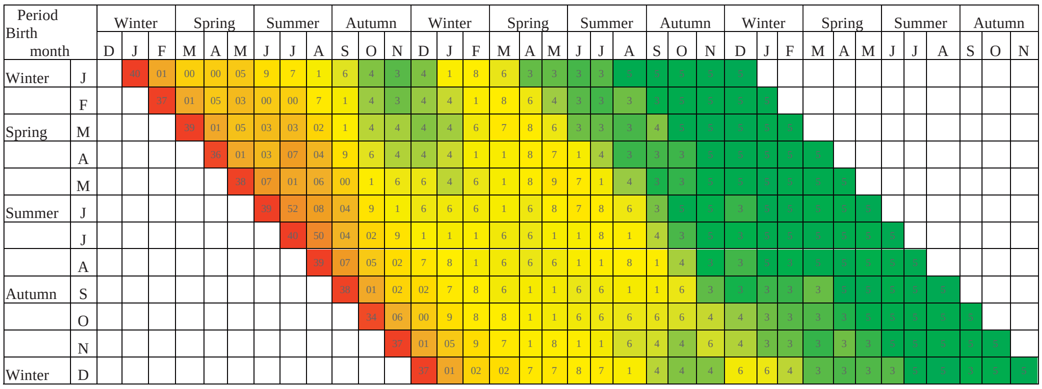
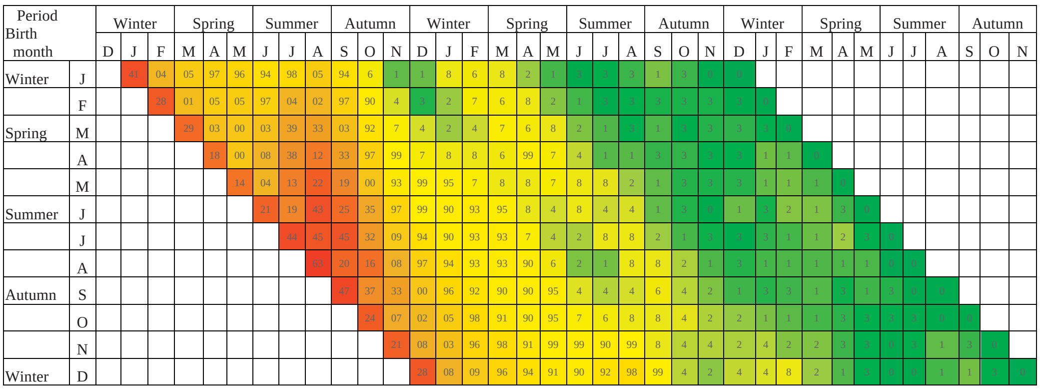


Figure 8. Heat map of average monthly hazard rates by month of birth for the first 24 months of life, province of Zeeland, the Netherlands, 1812-1912



Compared to most earlier research on the historical patterns of seasonal infant and childhood mortality, in which fluctuations in the published number of deaths by month of death were studied, this study took a different approach. We simultaneously analyzed individual-level data on month of birth and month of death. Another step forward was that we included in our analysis personal and family attributes such as social class, urban-regional background and time to make sure that the association between the month of a child's birth and his or her death does not reflect inherent differences in the backgrounds of the mothers giving birth. We studied a long period of time and applied multilevel hazard models on the seasonal patterning of death during the first two years of life.

In all provinces, we observed significant birth month effects on infant and childhood mortality. These effects remained when we controlled for a variety of background characteristics such as the social class of the family, urban or regional residence, province, and period of birth. Another important finding is that there were very marked differences in the strength of the seasonal effects between the three studied regions. This finding is in line with the studies on Italy by Breschi et al. (1986; 1997) and on Germany by Knodel (1983). The fact that even in a small country such as the Netherlands, with only tiny differences in weather conditions, such large differences in seasonal patterns were observed makes it clear that social, economic and ecological conditions and cultural practices are more relevant than temperature. At the same time it makes clear that national-level analyses of seasonal mortality patterns do not make much sense. A third, provisional conclusion is that mortality differences in the first month of life do not differ between social classes. However, the mortality risks in the first summer after birth are much lower for children from farmers and slightly lower for middle-class children than for working-class children. This might be explained by their better access to different kinds of food and perhaps also by different weaning patterns. Until now, we have not seen any other study which included information on the specific seasonal patterns of the various social classes, although many studies implicitly referred to the greater workload of mothers performing agricultural work. It remains to be seen whether social class differences remain absent or present themselves when a more detailed classification is used, in which agricultural workers are distinguished from those working outside agriculture. A fourth element, again in line with earlier studies such as those by Breschi et al. (1986) is that in the Netherlands the cold winter months do not show increased mortality risks for children.

In our study, Zeeland stands out as a province with much stronger seasonal effects. Mortality in the first month of birth in Zeeland showed a strong peak for children born in the summer and low values for those born in the autumn. Seasonal patterns in Drenthe and Groningen were much weaker. In Groningen, the summer high was less pronounced, and in Drenthe and Groningen the summer mortality rates were earlier than in Zeeland. In general, the introduction of the family characteristics caused an increase in the effect of month of birth in the summer in Zeeland whereas elsewhere the patterns remained similar. In Zeeland, children born in the months January to May all faced high risks in their first month of birth and these risks again reached high values as soon as these children reached the summer period. The children of workers were even more vulnerable than those of farmers. Children born in the summer faced extremely high risks in the first month of birth, but did not show increased risks when they entered their second summer period. For children born in the autumn, first-month risks were comparable with those of children born in the winter, but the increase in risks when this group reached the summer was lower. Winter effects were very small, in particular in Groningen, and were slightly greater in Zeeland.

Contemporary Dutch medical doctors had pointed to the fact that infants ran a strongly increased risk of dying during the harvest period when mothers worked on the land and a premature move from breastfeeding to artificial feeding took place (Helderman, 1875). In the nineteenth century, a large number of women in Zeeland were involved in fieldwork, in particular between April and September-October. Labor-intensive crops like wheat, peas, beans and colza, common madder and flax were dependent on the labor of women (Priester, 1998; Van Cruyningen, 2000) and this frequently led to a shortening of the length of the breast-feeding period. In Groningen as well, intensification of agriculture in the last quarter of the nineteenth century led to an increased demand for female labor during the period from April to October (Paping, 1995), but this did not have effects of the same order as in Zeeland. This might be related to differences in the frequency and duration of breastfeeding. Few data have been published by contemporaries on the practice and duration of breastfeeding (Hofstee, 1983; Hoogerhuis, 2003). For Groningen no data are available at all whereas for Drenthe it was argued that infants were breastfed by the mother for a period of one year or more. However, supplementary food was given to the child after only a few weeks. For Zeeland, information for various parts of the province was available from the 1860s and 1870s. In the city of Goes, only one in four children was breastfed, while in several other parts of the province breastfeeding was almost absent; in particular, artificial feeding predominated in the countryside. It is highly probable that the very high peak in mortality in the summer might be explained by the high participation of females in peak summer activities, often away from home, causing early weaning or irregular breastfeeding of children and a lesser degree of care and protection. Many of those classified as workers in Zeeland in effect were working in agriculture. An additional factor is the difference in the sanitary situation of the provinces. The situation in Zeeland was generally worse than in Groningen and Drenthe, due to the gradual salinization and the high water table in Zeeland. This rendered the restricted volume of fresh running and well water undrinkable, and provided an ideal environment for the larvae of the malaria-carrying mosquito, thereby making malaria virtually endemic in this part of the Netherlands until about 1870 (Hoogerhuis, 2003). Where breastfeeding was absent or irregular and artificial feeding was practiced, the salinization and the high level of environmental contamination of the water strongly increased the risk of diarrhea, the most significant cause of death among infants. In this way, it was the interaction between low incidence of breast-feeding and the atrocious condition of the drinking water and sanitation that led to high summer mortality in Zeeland, not only for children born in the summer but also for those born a few months before summer.

A question that remains to be answered is whether the seasonal effects have changed over time as sanitary and environmental conditions, and hygienic knowledge and practices, improved and the female labor force participation decreased. Has the gradual elimination of the differences in ecological environment and socioeconomic setting between regions led to a decreasing impact of the season on child survival? Another issue to take into account is the climatic variation over time and within and between meteorological seasons. Do extremely hot summers or cold winters lead to an increasing impact on seasonal child mortality?

Furthermore, there is an urgent need to extend this kind of study to provinces with a more varied population, with larger urban communities, a more numerous middle class and elite, and with a more limited number of women involved in work.

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1. Death records enter the public domain only after 50 years, marriage records after 75 and birth records after 100 years.
2. *LINKS* is hosted by the International Institute of Social History (IISG). Other participating institutes include the Historisch Centrum Overijssel (HCO), Tresoar, and the Leiden Institute of Advanced Computer Science (LIACS), the Netherlands Interdisciplinary Demographic Institute (NIDI), the Meertens Institute and the Virtual Knowledge Studio (VKS).
3. This social class categorization is based on the HISCO coding scheme (*Historical International Standard Classification of Occupations*) (Van Leeuwen, Maas & Miles, 2002). These historical occupational titles were classified according to the SOCPO social class scheme proposed by Van de Putte & Miles (2005). SOCPO (Social Power) is defined as the potential to influence one's "life chances" through control of scarce resources, and is based on economic and cultural resources. Economic power is based on factors such as self-employment, skill and authority (command). Sources of cultural power were "non-manual versus manual occupations" and nobility and prestige titles.
4. We classified all municipalities with a population size of at least 5,000 inhabitants and a population density of at least 350 inhabitants per km2 in the year 1850 as urban: the city of Groningen (population size 33,500, population density 1,300 km2), Meppel (6,500; 590) in Drenthe, and Goes (5,300; 750), Middelburg (15,800; 1,100), Vlissingen (9,800; 1,200), and Zierikzee (7,000; 360) in Zeeland.
5. To test for potential biases we repeated all analyses excluding all artificially censored observations. Results (not shown) were similar to the analyses including the censored data.
6. We excluded father known or unknown and social class. Both variables are not fixed by definition, but appeared to be (close to) fixed for mothers in our dataset.
7. Due to too limited numbers of observations we left out the elite.
8. Model 2 results for Zeeland including age of the mother instead of years since marriage (not shown) are similar to the results presented in Figure 2.

Appendix – Table 1. Cox proportional hazards model hazard ratios (hr) for early childhood mortality (< 2 years) by month of birth, per social class and province, the Netherlands, 1812-1912

Province Birth month	Unskilled workers	Semi-skilled workers	Skilled workers	Farmers	Middle class	Elite
Drenthe	HR	HR	HR	HR	HR	HR
January	1.2039 ***	1.1040	1.0901	1.1113 **	1.1278 *	1.1547
February	1.1907 ***	1.3045 ***	1.2189 ***	1.0867 *	1.1861 **	1.1682
March	1.2853 ***	1.4024 ***	1.0550	1.0682	1.0925	1.2449
April	1.2769 ***	1.3213 ***	1.1099	1.1688 ***	1.0372	1.3157
May	1.2026 ***	1.2051 *	1.1732 **	1.1433 ***	1.0524	1.3538
June	1.2196 ***	1.2377 **	1.1340	1.1400 **	1.0520	1.4010
July	1.1133 ***	1.1395	1.1609 **	1.0424	1.0363	1.1876
August	1.0510	1.1993 *	1.0903	1.0056	0.9683	1.2822
September	1.0386	1.0002	1.0209	0.8813 **	0.9438	0.9155
October	(ref.)	(ref.)	(ref.)	(ref.)	(ref.)	(ref.)
November	0.9991	1.1155	1.1885 **	0.9783	0.9334	1.1418
December	1.0193	1.1366	1.1902 **	1.0389	1.1199 *	1.1208
Groningen						
January	1.1148 ***	1.0635	1.0785 *	1.0897 *	1.1142 ***	1.0168
February	1.1285 ***	1.1497 ***	1.1337 ***	1.1521 ***	1.0646 *	1.2047
March	1.1590 ***	1.0859 *	1.1228 ***	1.1056 **	1.1139 ***	1.0558
April	1.1810 ***	1.1711 ***	1.1183 ***	1.0719	1.1288 ***	1.1843
May	1.2463 ***	1.1012 **	1.1479 ***	1.1295 **	1.0854 **	1.0650
June	1.2220 ***	1.0992 *	1.1989 ***	1.2252 ***	1.0947 **	1.1983
July	1.1543 ***	1.1674 ***	1.0892 **	1.2435 ***	1.1363 ***	1.0637
August	1.0629 **	1.1234 **	1.1113 **	1.0552	1.0781 **	1.0851
September	1.0341	1.0794	1.0170	1.0212	0.9872	0.9744
October	(ref.)	(ref.)	(ref.)	(ref.)	(ref.)	(ref.)
November	1.0021	1.0371	1.0637	0.9829	1.0692 *	0.9581
December	1.0665 **	1.0268	0.9984	1.0230	1.0297	1.1407
Zeeland						
January	1.0838 ***	1.0502	0.9806	1.0766	1.0918 **	1.3810 **
February	1.0945 ***	1.0413	1.0019	1.0874	1.1733 ***	1.1937
March	1.1368 ***	1.0771 *	0.9742	1.1052 *	1.1274 ***	1.1508
April	1.2172 ***	1.2183 ***	1.1072 ***	1.1285 **	1.2161 ***	1.2738 *
May	1.3160 ***	1.2741 ***	1.1686 ***	1.2961 ***	1.2730 ***	1.2958 *
June	1.4170 ***	1.2762 ***	1.2230 ***	1.3457 ***	1.3792 ***	1.3934 **
July	1.4446 ***	1.3810 ***	1.2808 ***	1.3966 ***	1.2915 ***	1.5758 ***
August	1.3794 ***	1.3241 ***	1.1907 ***	1.4575 ***	1.3450 ***	1.5083 ***
September	1.1489 ***	1.1314 ***	1.0391	1.3455 ***	1.1073 **	1.3088 **
October	(ref.)	(ref.)	(ref.)	(ref.)	(ref.)	(ref.)
November	0.9807	0.9818	0.9365 *	1.0636	1.0064	1.4995 ***
December	1.0232	1.0058	0.9697	1.0346	1.0714	1.1101

Notes: *** p<0.001, ** p<0.01, * p<0.05
Results from full models per province and social class including individual and family controls