What was Killing Babies in 19th-Century Europe? Categorising Their Deaths Using ICD10h

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To cite this article: Reid, A., & Janssens, A. (2025). What was Killing Babies in 19th-Century Europe? Categorising Their Deaths Using ICD10h. *Historical Life Course Studies, 15*, 266–280. https://doi.org/10.51964/hlcs23751

HISTORICAL LIFE COURSE STUDIES

What was Killing Babies?
European Comparative Research on Infant Mortality
Using Individual Level Causes of Death

VOLUME 15, SPECIAL ISSUE 6

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HISTORICAL LIFE COURSE STUDIES
VOLUME 15 (2025), 266–280, published 9-10-2025

What was Killing Babies in 19th-Century Europe?

Categorising Their Deaths Using ICD10h

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ABSTRACT

This paper draws together the results from a set of complementary analyses of the causes of infant mortality in eight European port cities in the late 19th century. The deaths were all coded according to ICD10h, with granular codes and a bespoke categorisation for infant deaths. The paper assesses and improves the categorisation of the causes of infant death by considering age and seasonal patterns. We find that while there were similarities in the levels and trends of infant mortality there were also important differences which are ripe for investigation by further research. Cause of death patterns were dominated by a transfer from vague to more specific terms over time, but the vague terms used tended to differ by location, and in the speed of their disappearance. Seasonality analysis suggested that most commonly used vague terms, including convulsions and weakness, probably reflected a variety of different underlying causes and should not be combined with more distinct and coherent categories such as airborne disease or food and water-borne diseases. Although teething is commonly treated as a proxy for diarrhoea, this does not appear to have been universally the case. We illustrate how comparative exercises such as this can further understanding of particular historic terms and their use in different settings, and can produce improved cause of death categorisations. Even the improved categorisation produced here, however, does not free the researcher from the need to consider changes in medical provision, knowledge and terminology within a sensitive and historically informed interpretation.

Keywords: Infant mortality, Neonatal mortality, Post-neonatal mortality, Seasonality, 19th Century, Causes of death

e-ISSN: 2352-6343
DOI article: https://doi.org/10.51964/hlcs23751

1 INTRODUCTION

This special issue is not quite like most special issues. This special issue is devoted to a single topic from historical demography, that is infant mortality in European history. However, that is not what makes this collection of papers different. All authors contributing to this special issue are not only asking exactly the same research questions, but they are also using similar data and are applying exactly the same methodological and analytical routines. Hence, this collection of papers can be regarded as a unique exercise in comparative history.[1] This special character is connected to this issue's origin in the SHiP network. The SHiP network brings together a large number of researchers who all have, or are in the process of creating, datasets which contain individual level causes of death for urban areas in the 19th century (Janssens, 2021). It so happened, during the initial years of the project, that these locations were port towns or port cities. Port cities offer an interesting context to study historical mortality because their high rates of population turnover and often rapid population growth meant they acted as transmission hubs and in some way pre-figure the highly mobile societies of today. Their role as potential gateways of disease is also particularly interesting and the availability of individual level cause of death data allows a unique insight into this aspect. In more recent years the network decided to also incorporate other types of towns and cities for which individual level causes of death are available, in order to increase the scale of comparative work that this allows. This collection, however, focuses on eight port towns and cities from different parts of the European continent, namely Amsterdam (the Netherlands), Copenhagen (Denmark), Hermoupolis (Greece), Ipswich (UK), Rostock (Germany), Sundsvall (Sweden), Trondheim (Norway) and Palma (Spain) (Garrett & Reid, 2022; Janssens & Riswick, 2023; Ludvigsen et al., 2023; Maltesdotter & Edvinsson, 2025; Mühlichen & Cilek, 2024; Pujadas-Mora, 2024; Raftakis, 2022; Sommerseth, 2023). The selection of these locations was determined by the availability of the data.

The aim of this special issue is two-fold. Firstly, we want to determine and compare the dominant cause of death patterns for infants in different European port towns over the late 19th and early 20th centuries — basically to examine how similar or different the levels of mortality and cause of death structures were in the different places. Secondly, we want to test the use of the ICD10h coding system for historical causes of death that was developed by some of the founding members of the SHiP network (Reid et al., forthcoming). The further development of this international historical coding scheme, the ICD10h, for individual cause of death data is one of the main aims of the SHiP network. This special issue has been a first step in testing a prototype of this coding scheme in the actual research practice of the study of infant mortality. For this aim the group of authors decided on a preliminary categorisation to group the coded individual causes. We ask whether the coding allows different causes to be identified, whether the categories work well in grouping similar causes, and whether historic symptomatic causes like teething and convulsions are likely to represent a single underlying cause across the different countries. We know that mortality in the first month or so of life is subject to rather different influences than mortality later in the first year, so comparisons of cause-specific mortality rates for neonatal and post-neonatal mortality can help answer these questions. Different types of causes also tend to exhibit different seasonal patterns, so seasonality in particular causes can also shed light on these issues.

In order to allow such comparisons contributors were given a rather strict set of guidelines, specifying exactly what to include in each category and how to calculate rates and produce graphs. The categorisation was loosely based on previous analyses of infant mortality, and separating out particular vague causes (weakness, convulsions, and teething) for which we wanted to investigate the nature and international comparability in more detail. Comparisons of causes of death over time and between places can be fraught with difficulty. Temporal and spatial variations in terminology, medical knowledge, medical provision around the time of death, certification practices and other issues make it hard to interpret differences. Using individual causes of death offers unprecedented opportunities to overcome issues of changing nosologies, and permits deeper insights in historical epidemiological and mortality change over time and between places. However it also adds complexity. In this introduction we will first discuss what we already know of the history of infant mortality in Europe. Next we outline previous approaches to historical cause of death data and strategies to code and classify these types of data. Following an overview of the ICD10h coding scheme and a justification of the categorisation scheme, we discuss the substantive results of the eight studies across the European continent. We conclude with a discussion and evaluation of the coding and the categorisation scheme that was used, and the lessons for future research that these studies provide us with.

1 There have been a number of special issues or collections on infant mortality but each contribution within these tends to offer a different type of analysis or focus (Corsini & Viazzo, 1993; Pozzi & Barona, 2012) so direct comparisons are rare.

2 WHAT WE KNOW ABOUT INFANT MORTALITY IN EUROPE

Research on infant mortality has dominated historical studies of mortality (Reid, 2021, p. S163) — perhaps because high levels of mortality permit the use of relatively small datasets, and the fact that population counts are not required as denominators because the number of births is more appropriate. Another reason is that in many places it remained high after mortality at older ages had started to decline, and sometimes after fertility had started to fall too, and therefore became the focus of a considerable amount of attention from the contemporary public health machinery in the early 20th century (Pozzi & Fariñas, 2016). However it has also been used as an important indicator of the social and economic development of a population (Masuy-Stroobant, 1997). The latter two reasons mean that identifying the underlying societal influences on infant mortality is of particular interest.

One approach to identifying the influences on infant mortality examines the individual correlates of infant death, commonly characteristics pertaining to the child (e.g. sex), mother (e.g. age), father (e.g. occupation or social status), household (e.g. size of house or facilities), and area (e.g. urban/rural). Such studies rely on rich individual-level data sets which include this information for infants who survive as well as those who die (Dribe et al., 2020; Oris et al., 2023; Reid et al., 2023). This sort of data can offer hints about the mechanisms leading to infant deaths but require assumptions that, for example, the better off might have lower infant mortality because they have higher quality of sanitation or better knowledge of disease prevention. Information on cause of death of the infants can help to clarify these pathways as certain causes of death have distinct transmission pathways (for example food and water borne diseases are likely to be affected by sanitation, water supply and hygiene, whereas air-borne diseases are more likely to be affected by overcrowding). Datasets which offer information about both a range of individual correlates and cause of death offer a sort of gold standard, but such datasets are relatively rare (Jaadla & Puur, 2016; Reid, 2001, 2002; Reid & Garrett, 2012). In the absence of cause of death data some studies have exploited the relationship between age at death and broad cause of death groups (deaths which occur in the first month or neonatal period are dominated by endogenous causes related to the pre-birth environment including the health of the mother, while those in the post-neonatal period are more likely to be caused by exogenous causes such as infections), but the relationship between the proxies and the recorded causes are rarely examined. However, there is an increasing number of datasets which contain individual level causes of death, which can be combined with numbers of births to test the relationships between these proxies and the recorded causes of death and which can provide new levels of insight into the patterns of, and influences on, mortality in the 19th century.

Infant mortality has been much examined across Europe, but there have been relatively few comparative studies. Masuy-Stroobant (1997) analysed infant mortality in 27 European countries from 1900 to 1990, finding that although infant mortality was falling over this time period there were five groups of countries with remarkably similar levels and trajectories of mortality. Other evidence suggests that these patterns were continuations of those in the 19th century (Pozzi & Fariñas, 2016). Examination of small area variation across Europe for 1910 has indicated although the broad regional pattern is confirmed, national borders were rarely relevant for understanding variation in infant mortality rates and many countries exhibited strong sub-national variation (Klüsener et al., 2014). Even in such a small country as the Netherlands we see high levels of variation between regions and even between individual communities (Janssens & Pelzer, 2014; van den Boomen, 2021). This means that an examination of specific case studies where more is known about the specific contexts might be more illuminating than national aggregates.

3 APPROACHES TO HISTORIC CAUSES OF DEATH

Working with causes of death is challenging, even today, when the complexity of conditions contributing to a death, together with the different actors and their experience, make filling out a death certificate and allocating cause of death codes and categories a challenging process (O'Malley et al., 2005). This can affect national mortality statistics (McGivern et al., 2017) and arguably presents an even greater challenge when working with historic causes of death where rapid advances in medical knowledge and fashion and changes in medical attendance and death certification produce considerable variation in the way that causes of death are expressed, understood and grouped over time and between places (Alter & Carmichael, 1996, 1997, 1999; Anderton & Leonard, 2004; Hardy, 1994; Kintner, 1986; Kunitz, 1999; Risse, 1997; Williams, 1996).

Historic causes of death come in two forms which present different but related challenges (Janssens & Devos, 2022). The first form is published statistics of causes of death which have already been grouped into a nosology or classification. The first official international nosology was developed in the 1850s by William Farr and Jacob Marc d'Espine for the International Statistical Congress (Hirsch et al., 2016). This was followed by Jacques Bertillon's classification and the adoption of the first ICD in 1900 (which then stood for the International list of Causes of Death). The ICD system was gradually adopted by different countries, and remains in use today — in its 11th incarnation (ICD11). These different incarnations — the regular updating of the system — were necessary to keep up with the development of scientific knowledge and improved understanding of the aetiology of disease and the connections between different conditions. Each version of the ICD was therefore more detailed than the last, and certain diseases and causes of death were frequently switched from one category to another. It is the last feature of which poses the main challenge associated with working with published data on cause of death. Most approaches have involved grouping up the lower level categories for which statistics are reported to achieve a small number of higher level groups which remain consistent over time (Kintner, 1986; Meslé & Vallin, 1996; Preston et al., 1972; Wolleswinkel-van den Bosch et al., 1996), or using statistical time series methods to smooth data series (Janssen & Kunst, 2004; Rey et al., 2011; van der Stegen et al., 2014). A further approach, bridge-coding, according to which the same set of deaths is coded to time-adjacent nosologies, is used to gauge the effect of changes (Anderson & Rosenberg, 2003), but this is considered to be only useful for assessing a particular change and not for producing a comparable time series over a long time frame (Rey et al., 2011).

The second form in which historic causes of death appear is records listing individual level causes. This type of source material to a large extent avoids many of the problems inherent in creating comparable and consistent long-term cause of death series — i.e. those which stem from the need to reconcile different nosologies over time. This is because for any given dataset, the same categorisation can be applied to all deaths and a bespoke classification can be designed which best reflects the historical context and knowledge. It is generally accepted that modern classifications such as the high level categories of ICD10 or ICD11 are inappropriate for use with historic datasets as the vagueness and symptomatic nature of many historic causes leads to an overly large number of causes being placed in the 'ill-defined' category (Kintner, 1986). Instead, researchers have generally chosen to use a version of a published historical classification. This reflects contemporary understandings of disease causation and groupings, and also enables comparisons with published data. For example Bernabeu-Mestre et al. (2003) developed a system variously referred to by others as the BeRaSaRo-system or the CMM – Modified Causes of Death Classification (Revuelta-Eugercios et al., 2022; Sáinz-Otero et al., 2020). Arguing that the ICD classifications, primarily relying on placing diseases within their "seat" in the body were not very useful for the analysis of influences on mortality, they took inspiration from Thomas McKeown's classification with its distinction between diseases with different transmission mechanisms, but it was also harmonised with ICD2, as was the classification used by Bailey et al. (2023).[2] This classification was designed primarily for use with infants and children, and others working with this age group (and indeed with older ages) have also used their own bespoke systems but only describe these briefly or as part of a more substantive piece of analysis, rendering it more difficult for others to replicate (Bengtsson & Lindström, 2000; Jaadla & Puur, 2016; Reid, 2001, 2002; Reid & Garrett, 2012; van Poppel et al., 2002). Recently Sáinz-Otero et al. (2020) have developed a historic classification for use with individual level COD certificates for Spain (CCHM – the Classification of Causes of Historical Mortality) based on ICD4 and designed for use over the second half of the 19th and the first half of the 20th centuries.

While the publication of these standardised systems, with instructions for their application, are very welcome advances, they also have some disadvantages. One of these is the problem of applying a single classification to long time periods. Changes in the understanding of diseases, and differences in terminology and specificity, pose real problems for applying a single classification system over many years. The historic classification systems, because they rely on coding straight to a relatively small number of categories, lack flexibility. Each embeds an assumption about where each cause of death belongs and although the classifications can reflect interesting questions about the influences on disease (in the way that the Bernabeu-Mestre and McKeown schemes focus on infectious disease and

2 The McKeown classification itself was constructed using the building-blocks of the nosologies used by the Registrars General of England and Wales, which distinguished a set of diseases with contagious or infectious transmission, and non-infectious diseases according the "seat" of the body. Interestingly the Registrars General of Scotland took a more strictly anatomical approach leading to a lack of statistical comparability within the British Isles (Crowther, 2006; Hardy, 1994).

the different forms of disease transmission), declines in infectious disease over time lead to dwindling relevance of such categorisations in more recent decades (Janssens & Devos, 2022). Revuelta-Eugercios et al. (2022) argued that the best way to deal with this is dual classification — to code each death to more than one scheme, in a similar fashion to bridge-coding approaches. However, this can be extraordinarily time-consuming particularly as historic causes of death can be messy and complex: it may require researchers to code to a historical international scheme as well as to a number of different official schemes for different time periods covered by the data.

A further disadvantage is that most of the classifications code straight to one of a relatively small number of categories (for example the Preston et al. (1972) classification has only 12 categories). While this is a desirable quality for an overall classification over long periods of times, it also means that it is impossible to use such systems to study interesting questions about how terminology changed and the balance of the more individual causes within a larger grouping developed over time.

Here we use a relatively new (although long in gestation) scheme which addresses these issues by taking a two-stage approach to the coding and categorisation of historic causes of death, the ICD10h. The next section introduces the ICD10h and the categorisation for the study of 19th century infant mortality.

4 DESCRIPTION OF CODING SCHEME ICD10h AND INFANT CATEGORIES

ICD10h was first developed for the automatic coding of individual level causes of death for Scotland from 1855 to 1973, and adopted by the SHiP+ network in 2018 (Janssens, 2021; Reid, Garrett, Hiltunen Maltesdotter, & Murkens, 2024; Reid at al., forthcoming). Both of these uses require a flexible system which could be used across a long time period and deal with reported causes from very different historical contexts. So, bearing in mind the considerations outlined in the previous section, a system was designed which allocated each cause of death string to a particular code, and which could provide a number of different categorisations. In essence this is analogous to the multi-classification system proposed by Revuelta-Eugercios et al. (2022), but the initial stage of allocating to a code makes it easier to apply new categorisations as they are developed.

The system is called ICD10h because it is an extension of ICD10 for historic time periods. This does not mean that it unthinkingly applies ICD10 to historic causes, but that it uses the basic structure and codes of ICD10 as a starting point. The scheme has been introduced elsewhere (Janssens, 2021; Reid at al., forthcoming) and is described in more detail in the scheme documentation (Reid, Garrett, Hiltunen Maltesdotter, & Murkens, 2024), so here we outline only the general principles:

- ICD10h takes the 4-digit ICD10 codes (e.g. A00.9 for 'cholera, unspecified') as a starting point and transforms these to ICD10h by adding two further zeros (e.g. to A00.900).
- Where there is an exact match, a string is assigned to one of these existing codes, irrespective of whether the string means something different at particular points in time (these issues are dealt with at the categorisation stage).
- Additional codes are introduced for historic or archaic terms within existing chapters or where a changed meaning over time is suspected. These new codes are identified using the additional digits. For example 'apoplexy' is commonly interpreted as 'stroke' and therefore given a code (I64.001) which is essentially a variant of the normal code for 'stroke' (I64.000).

These codes can then be built up into different categorisations, for example to match existing nosologies, for specific age-groups, for particular time periods, or for international comparisons. Because we use ICD10 as a basis, the scheme builds in the ability to code directly to ICD10, but we stress that this is unlikely to be a satisfactory classification for historic terms. Instead, the scheme aims to provide a series of different categorisations which can, for example, unite vague terms assigned to codes under 'signs and symptoms of the respiratory system' with the more specific diseases of the respiratory system in Chapter X. So far[3] two categorisations have been introduced: HistCat — a general historical categorisation which was originally designed for use with the Scottish published nosologies over a long time frame

3 More categorisations are in the process of being produced which are specific to different age groups, or which reproduce existing widely used high level classifications.

(Reid et al., 2015, 2016) and the categorisation used here, InfantCat — for the specific analysis of infant mortality (Reid, Garrett, Hiltunen Maltesdotter, & Janssens, 2024). It is hoped that these two classifications work well for the late 19th century and for a variety of different countries, but one of the purposes of the papers in this special issue is to test the infant classification and propose improvements.

The rest of this section describes and explains the InfantCat, the categorisation of infant deaths used by the papers in this special issue. InfantCat groups causes into the following broad categories:

- Air-borne diseases
- Water- and food-borne diseases
- External causes
- Congenital-birth disorders
- Weakness
- Convulsions
- Teething
- Other infectious
- Other non-infectious
- Ill-defined causes
- Unknown
- Blank

As in many other classifications, because we are interested in the influences on infant mortality and modes of transmission can help identify those, we separate groups of causes according to their most likely modes of transmission. The first group listed above is airborne diseases, comprising the common infectious diseases such as measles, scarlet fever, mumps, rubella, whooping cough, diphtheria and chickenpox. We also include smallpox, and meningitis irrespective of causal agent, infections of the ear and upper respiratory tract such as laryngitis and tonsillitis as well as influenza, pneumonia (however caused), bronchitis and various signs and symptoms associated with the respiratory system (cough, pleurisy and inflammation of the lungs). These may be of bacterial or viral origin and spread by various means (including different particles and droplets), but in general are likely to be contracted by exposure to others with the disease and therefore affected by overcrowding. It is, of course, possible that some conditions included here were not caused by infection transmitted by air-borne means (for example aseptic meningitis), but this is where 'meningitis, unspecified' is placed and in the 19th century many unspecified cases will have been bacterial in origin (and therefore likely transmitted by air). We expect air-borne disease to have a slight winter peak, due to the higher likelihood of people being inside with windows and doors closed, aiding the transmission of such infections.

Water and food-borne diseases include cholera, typhoid, food poisoning, enteritis, gastritis, dysentery and colitis irrespective of whether they are coded to ICD10 chapter I (indicating infectious diseases) or chapter XI (diseases of the digestive system) because these causes were generally used symptomatically in the 19th century and those reporting the death are unlikely to have known whether or not they were infectious in origin. Tuberculosis of the intestines was also placed in this category, as this was commonly attributed to milk from infected cattle. The same caveat applies that some cases of diarrhoea will not have been infectious in origin, but it is impossible to separate them out. We expect water- and food-borne diseases to be concentrated among post-neonatal infants (as breast-feeding reduced exposure to the pathogens transmitting such conditions) and in the summer and early autumn when the effect of hot summers caused a speeding up of the lifecycle of the housefly (the main vector of diarrhoeal disease to human food and drink), and consequently an increase in the housefly population and the risk of transmission of pathogens between different sources (Brownlee & Young, 1922; Morgan, 2002).

We include two groups we suspect might signify endogenous causes and which we expect to be particularly prominent in neonatal mortality. The congenital and birth disorders category includes conditions which specifically mention 'congenital', 'from birth', or carry an implication to that effect (with the exception of convulsions of the newborn). This covers deaths which specified complication of labour, prematurity and immaturity, birth injury, birth asphyxia, atelectasis, foetal blood loss, neonatal jaundice, congenital debility/asthenia/atrophy etc, congenital hydrocephalus, spina bifida, and congenital malformations of various sorts. Many such causes will have been affected by the health and net nutritional status of the mother during pregnancy, but the quality of care during delivery will also be implicated in some deaths. It is important to note that this category includes 'weakness from birth' and certain related terms used in English for neonatal causes. Our second endogenous group separates out 'weakness' without specification that it is from birth. This is done because 'weakness' was also used as a cause of death for older people,

including older infants and children who can develop weakness or wasting for example as a result of improper feeding or illness (Reid, 2002). Some authors even combine atrophy with diarrhoeal disease in a category (de Looper et al., 2019; Lewis, 1979). We wanted to see whether there were differences in the usage of 'weakness'/'atrophy'/'debility' etc according to whether or not they were specified as congenital or neonatal in origin. This group includes asthenia, debility, weakness, prostration, exhaustion, cachexia, inanition, wasting, atrophy and the Swedish causes 'tvinsot' and 'tärande sjukdom' (the latter literally translated as 'consuming disease') from the ICD10 signs and symptoms chapter, as well as 'marasmus' and 'atrepsia' (a specifically Spanish cause) which are both coded to ICD10 chapter IV (nutritional deficiencies).

Two individual causes which are particularly problematic and where there is an absence of consensus in the literature about their meaning in this period are also separated out into their own groups: teething and convulsions. We wanted to see whether there were systematic patterns in these conditions in terms of seasonality, time trends, and age at death over the first year of life. If there were patterns, we were interested in whether a consistent interpretation over time and space was possible.

The first of these causes is teething (including dentition). Although teething was not considered an acceptable cause by the medical establishment of the 19th century, it was still common enough to merit a category in various national nosologies. For example a new nosology introduced in England and Wales in 1902 included a category for teething, although this was identified as one of a set of "certain unofficial terms which are still in common use but which are objectionable either as being the names of symptoms merely or as being otherwise indefinite . . . it is hoped that medical practitioners will use them only when accurate information is wanting" (Anon, 1902, p. 1341). Many contemporary and modern observers take the view that deaths from teething were most likely from diarrhoea, the confusion arising because teething children tend to put things in their mouth to ease the irritation of the erupting teeth, and at the age that teeth often come through children are generally newly mobile with access to items which are less than ideally clean (de Looper et al., 2019; Lewis, 1979; Rendle-Short, 1955; Sawchuk et al., 1985). However it has also been suggested that teething could really signify deaths from scurvy, mercury poisoning (from treatments for syphilis), or sudden-infant death (Gibbons & Hebdon, 1991; Rendle-Short, 1955). We hoped that comparison of the seasonality of teething and of food- and water-borne disease would shed light on whether or not it is reasonable to include deaths due to teething in the latter category.

The other particular cause singled out is convulsions, which includes convulsions of newborn infants, together with any other convulsions, seizures and fits from the signs and symptoms chapter. In the previous literature convulsions or cramps are often interpreted as a symptom of diarrhoea (Kintner, 1986) and some researchers have therefore combined convulsions with diarrhoeal disease at least for the analysis of post-neonatal mortality (de Looper et al., 2019; Jaadla & Puur, 2016; Lewis, 1979; Murkens et al., 2023), or with other infectious diseases (van den Boomen, 2021). Other studies group them with specified non-infectious diseases (Molitoris, 2017) or omit them from the analysis altogether (van Poppel et al., 2002). Based on the similarity of factors influencing mortality from convulsions and diarrhoeal disease, Reid (2001, 2002) argued that in early 20th century Derbyshire convulsions was unlikely to have been used as a proxy for diarrhoea in the post-neonatal period but might have been for neonates. Using a medical history approach rather than a historical demographic one, Radtke (2002) explicitly rejected the suggestion that convulsions (specifically the German word 'gichteren') was used as a proxy for diarrhoeal disease in the German case, and Rüttiman and Loesch (2012) suggest that the same term in German-speaking Switzerland might signify epilepsy or tetanus. Again, an examination of the age patterns and seasonality of convulsions might help to shed some light on this problematic cause.

Finally we include a number of other groups that we expect to account for relatively few deaths. 'External causes' includes deaths attributed to injuries, accidents and violence, including deaths attributed to 'overlaying'. 'Other infectious diseases' includes vector-borne diseases, sexually transmitted infections and those with other transmission modes (such as plague, typhus, polio, tetanus, blood poisoning and septicaemia, erysipelas, syphilis). These tend to form small proportions of infant deaths and are less likely to be affected by overcrowding, water supply or sanitation. 'Other non-infectious diseases' includes all other deaths which have been given a specific cause. 'Ill-defined causes' have been given a cause but this is symptomatic or unintelligible. 'Unknown' are specifically stated to be unknown and 'Blank' are empty responses. Although we could combine the last two or three groups we kept them separate in this exploratory exercise, in order to see whether there were big differences or changes over time in the balance between them, as this could indicate changes in the extent or quality of medical attendance which might have ramifications for the interpretation of those deaths which had been given causes.

5 INFANT MORTALITY IN THE DIFFERENT STUDY LOCATIONS

Most of the infant mortality series exhibit signs of the decline in mortality which formed part of the demographic transition, the major exception being Rostock, while the IMR decline in Hermoupolis started rather later than in other places. Rostock exhibited a significant increase in IMR in the 1840s and 1850s, which was concentrated in the post-neonatal period. The reasons for this are not very clear but it is worth noting that the dataset does not cover the whole city. Before the transition there was little uniformity in mortality rates, with Palma, Trondheim and Ipswich exhibiting relatively low mortality compared to the other places.

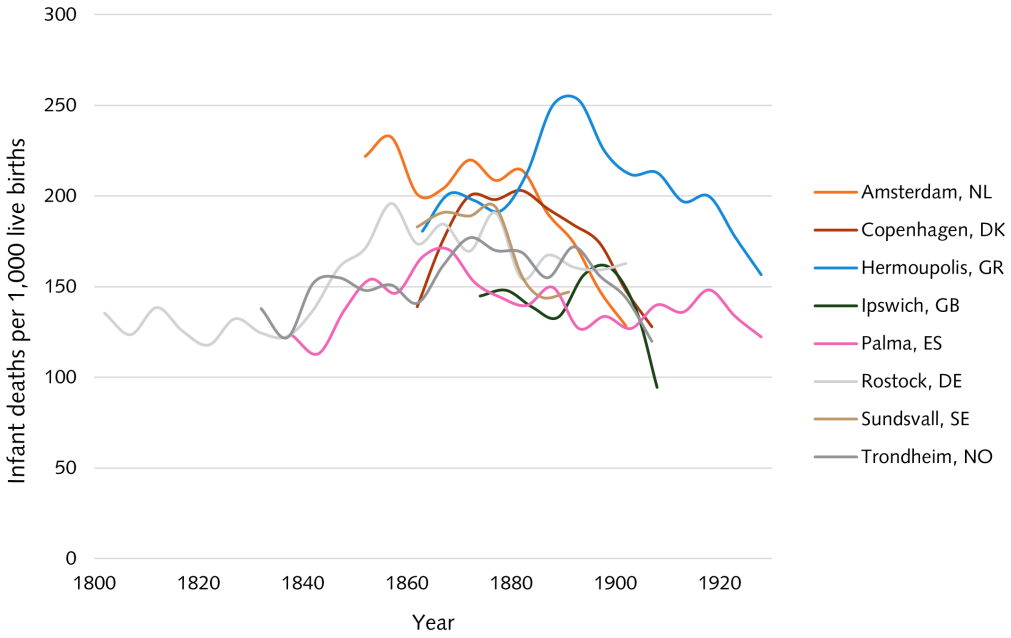
Ipswich demonstrates a major mortality peak in the 1890s. This was common to the majority of British cities and has been attributed to the effects of a series of long, hot summers in urban areas where advances in sanitation and water supply failed to keep up with rapid population increases, manifesting in outbreaks of epidemic diarrhoea. The cause of death patterns in Ipswich confirm that the food and water-borne diseases were particularly prevalent in this decade. It is particularly interesting that these weather conditions did not have similar effects in other parts of Europe, particularly Amsterdam, which is geographically very close. It is possible that differences in sanitation and environmental cleanliness, or in child-care practices such as infant feeding and weaning, made British cities more vulnerable to hot summers. But this would be puzzling given the relatively low level of infant mortality in Britain before the peak of the 1890s, which went hand-in-hand with relatively low levels of food and water-borne diseases in Ipswich. Better knowledge of local sanitary provision and childcare is needed to get to the bottom of this conundrum.

The population of the town or city appears to have little effect on IMR at this geographical scale: although the largest places (Copenhagen and Amsterdam) had the highest mortality in the 1860s and 1870s, the smallest places (Sundsvall and Hermoupolis) had the next highest. There is also no clear pattern according to area in Europe: with Mediterranean cities having the highest and lowest rates.

In general, fluctuations in mortality were concentrated in the post-neonatal period, and in most places that age group also had stronger reductions in mortality than the first month of life. In terms of causes of death, there were expected similarities between the places: congenital and birth disorders were common in the neonatal period, while post-neonatal mortality tended to have more airborne and food and water-borne diseases. However, there were strong differences between the places in the balance between vague and more precise causes (Ipswich having particularly few vague causes) and in the type of vague cause used. In the neonatal period convulsions and not known were particularly popular in some places (Trondheim and Sundsvall respectively), with a transfer towards congenital and birth disorders over time. In the post-neonatal period, convulsions, weakness, ill-defined, and not known declined as water and food-borne diseases and airborne diseases increased. The fact that vague causes declined as more precise causes increased suggests that these changes are more likely to reflect better diagnosis than real changes in the prevalence of particular diseases. In the light of this it would be inadvisable to read much into variations in causal patterns of either neonatal or post-neonatal mortality, either between places or over time (except perhaps when an increase in a particular causal group was associated with an increase in overall infant mortality, such as during the 1890s in Ipswich).

Reassuringly, the airborne disease and food and water-borne disease groups exhibited consistent seasonality across locations in both the neonatal and post-neonatal periods (where numbers allowed), with a winter peak for airborne and a summer peak for water and food-borne diseases. We hoped that seasonal patterns in the vague causes might also help identify consistent interpretations, but these groups were far less consistent in terms of seasonality. Teething, convulsions and weakness will be discussed in the next section, but even congenital and birth disorders, which in the last paragraph we interpreted as more precise, exhibited winter peaks in Hermoupolis, Ipswich and Palma, but a summer peak in Amsterdam, suggesting that the balance of causes it contained may have been different in different places.

Figure 1 *Trends in infant mortality in the eight study locations*



Source: Papers in this special issue.

6 EVALUATING THE CATEGORISATION OF INFANT DEATHS

In this section we reflect on the categorisation of infant deaths. We designed this categorisation to permit examination of several ambiguous causes of infant mortality as well as grouping into categories large enough for meaningful analysis. Our contributors helpfully reflected on the internal consistency of the larger categories as well as considering whether the age and seasonality patterns of the more ambiguous causes inform where they should be grouped. We reflect on the implications and suggest a refined grouping to use.

First, however, it is useful to revisit the aim of categorisation and issues of comparability over time in the special circumstances of infant mortality. Most categorisations aim to group those terms representing the same real underlying cause to enable assessments of variation and change in these. Historic infant mortality, however, is dominated by vague and symptomatic causes such as convulsions and weakness. As the discussion below indicates, it is likely that these terms represent a variety of actual conditions. Grouping up to prevent shifts in terminology over time from influencing patterns is therefore likely to place such a high proportion of deaths into a single category as to make the categorisation uninformative. Changes in the remaining "definable" categories are also likely to be affected. An alternative is to retain some of the particular terms which were commonly used in the historic record as separate groups, and to recognise that patterns will be affected by shifts between categories as well as by changes in the real balance between causes. Which terms deserve their own grouping will depend on the numeric volume of the causes concerned as well as their internal consistency.

Teething: The literature has often assumed that teething should be interpreted as diarrhoea, and while this might be the case in some historical eras and places (such as Palma), it had rather different seasonality in other places, such as Ipswich. In view of the small numbers we suggest, therefore, that teething is grouped with ill-defined causes in a general infant categorisation. However, it would be worth users of the coding and categorisation scheme considering whether teething was a significant cause in their specific setting.

Convulsions: Convulsions and equivalent terms such as spasm and cramp were used very variably across the cities in our comparison. The term was virtually never used to describe infant deaths in Sundsvall and was rare in Hermopoulis, but formed a particularly large group in mid-19th century Trondheim and Rostock, with large declines over time. Again, there is little evidence that it should

be universally interpreted as indicating diarrhoeal diseases, with either little seasonality (Rostock) or patterns that suggest it was often a complication of infectious diseases such as whooping cough (Amsterdam and Trondheim). Convulsions was clearly a symptomatic description, could represent a variety of underlying causes, and was replaced over time by more specific descriptors in different categories. However, because it was so large in many settings we decided to retain a convulsions category. The decline in this category over time is likely to be balanced by an increase in categories such as food and water-borne diseases, airborne diseases, or congenital and birth disorders as the underlying causes of the convulsions became better recognised by those reporting the deaths.

Weakness: This was a more contentious grouping. Our separation of 'weakness/atrophy' from 'weakness/atrophy from birth' originated in the fact that most people coding large volumes of individual level historic deaths first create a list of unique cause of death strings which is generally far shorter than the list of deaths, then assigning a code to each unique string. Codes are therefore assigned without knowledge of the age and gender of the deceased. It is therefore possible for 'weakness from birth' to be assigned to a cause in the perinatal group. However 'weakness' without any other qualifier was often also used for people who died in old age, and the more general grouping associated with ICD10h, Histcat, therefore included a separate 'weakness' or 'debility' group.[4] While we could have assumed that whenever weakness was used for infant deaths it related to those dying shortly after birth, we wanted to see if different terms were used for those dying later in infancy, and if the seasonality differed: this might suggest different underlying causes compared to those involved in 'weakness from birth'. Comparisons of the different study settings revealed that although in some places the seasonality of weakness (as opposed to weakness from birth) exhibited summer peaks (Ipswich, Greece, Copenhagen) comparability was hampered by the fact that 'weakness from birth' was included in the more general 'congenital and birth disorders' which also encompassed congenital abnormalities and birth injury which we would not expect to show a summer peak. Overall there was little evidence to support keeping 'weakness' separate from 'weakness from birth', and many contributors advised combining these groups. In Copenhagen and Ipswich, it appears that atrophy was used more for older infants than younger and this might indicate a difference in the character and perhaps also the causes of the ensuing weakness and death (in Ipswich neonates were more likely to die from congenital debility which gave way, over time, to prematurity). More research is needed on the way that these terms varied over time in the different settings to inform how we should understand and interpret them, and we recommend that, for the time being, a single congenital and birth category remains (with weakness included). We rename this 'Perinatal and weakness' to better reflect the fact that these are causes which might have their roots before or during birth (while recognising that weakness or similar might arise after that period as a result of something like improper feeding).

The airborne diseases category included bronchitis, pneumonia and broncho-pneumonia as well as the common infectious diseases. This was partly because the common infectious diseases form a relatively small proportion of infant deaths (for example in Derbyshire, UK in the early 20th century it formed around 10% of infant deaths) although it was much more prominent for child mortality. Combining with bronchitis and pneumonia made sense due to the mode of transmission and the fact that many deaths from common infectious diseases culminated with bronchitis or pneumonia, so the joint categorisation mitigates issues with correct attribution of multiple causes. However several of our contributors recommended separating out these two categories, and we agree that this would be a good idea, particularly for post-neonatal mortality where infectious diseases are more prominent (in Derbyshire infectious diseases formed 16%, and bronchitis and pneumonia formed 30% of post-neonatal mortality (Reid, 2002)). However it would be sensible to combine them for analyses of neonatal mortality (in early 20th century Derbyshire together they accounted for only 6% of neonatal mortality (Reid, 2001)).

The water and food-borne category was the only other grouping that accounted for a sizeable proportion of deaths. This seemed to work well, although one contributor (Rostock) suggested that some conditions placed in the non-infectious diseases (such as stomach disorder) could be placed in the food-water born category. We have reviewed such conditions, but the 2024 version of ICD10h better separates infectious from non-infectious conditions, and we felt there was not enough evidence to add non-infective conditions to the food and water born category.

4 The general documentation now recommends that users use age to redistribute these causes to the perinatal group for those under 1 year, to old age for those aged 70 or over, and to ill-defined for those in between (Reid, Garrett, Hiltunen Maltesdotter, & Murkens, 2024, p. 10, 33)

The other categories which contained reasonably well-defined causes of death accounted for very small proportions of deaths in most places. Therefore, despite calls from the contribution from Palma for a separate vector-borne diseases category, this does not seem useful for a pan-European comparison. The 'other infectious', 'other non-infectious' and 'external causes' categories accounted for extremely small proportions of deaths and keeping them separate did not add any insights. The new categorisation therefore combines them into a single 'Other' category for simplicity.

Finally we turn to the 'ill-defined', 'unknown' and 'blank' categories. We kept these separate because we felt that the three categories might represent different circumstances: instances where a cause was written down but was simply too vague or difficult to read, those which were stated to be unknown by the doctor or person reporting the death, and those where no cause was offered, which could reflect problems with registration. The different categories had different balances in different places, and some people recommended combining them with 'other'. However, we feel it is important to keep one category for 'ill-defined' causes and another for those cases where no information on cause of death was given, because any changes in these are likely to represent changes in registration practices and medical knowledge more than evolving epidemiology.

The resulting revised categorisation of infant deaths, Infantcat2024, comprises the following categories:[5]

- Common infectious diseases*
- Broncho-pneumonia (including bronchitis and pneumonia)*
- Food-water borne
- Perinatal and weakness (combines 'congenital and birth disorders' and 'weakness' categories)
- Convulsions
- Ill-defined (combines 'ill-defined', 'stated to be unknown' and 'teething')
- Other (includes all causes from previous 'other', 'other infectious', and 'external' categories, and a few from 'airborne')
- No cause given

* to be combined in the analysis of neonatal mortality

7 CONCLUSIONS

The coding and classification of historic causes of death is never easy, and infant deaths are particularly difficult to work with due to the large proportion attributed to symptomatic causes such as weakness or convulsions or where the cause was given as 'not known'. The revised categorisation we devised embeds a recognition that much of the change in the causes of death profile of infant mortality over the late 19th century is in fact change in the terms used to describe the cause of death. This is likely to reflect changes in the person reporting the death, patterns of medical attendance, the development of medical knowledge, and fashion and preference relating to particular conditions. Our classification has made a conscious choice to leave some vague causes intact which we know will bleed into other, better defined, causal groups over time, and it is important to recognise this "reallocation" in the interpretation of results. There will always be compromises between the best classification for one setting as opposed to another; between maintaining consistency of a particular group over time and showing differences; between capturing real changes in the distribution of different conditions and capturing information about how terms were used over time. It is probably impossible to create any classification which avoids all issues of "reallocation" and really allows comparisons of like with like when applied to comparisons over time and space. Therefore interpretations should always balance the likelihood of real changes in the prevalence or risks of disease with changes in recording practices. In other words, even with the best coding and classification possible, there is still the onus of sensitive and historically informed interpretation on the part of both researcher and reader.

Changing medical provision, knowledge and terminology make it difficult to construct a classification which will be useful over time. This difficulty is amplified when also trying to compare between places as differences between countries are compounded by language and translation issues. Using comparative

5 A full mapping of the ICD10h codes onto both InfantCat and InfantCat2024 is provided in (Reid, Garrett, Hiltunen Maltesdotter, & Janssens, 2024).

exercises such as the one undertaken by this collection of papers can greatly help the understanding of the way that vague causes gradually were replaced by more specific terms, and can identify whether or not there are consistencies in the interpretation of different terms. This process is an important part of constructing a useful categorisation, and has been made possible by the two-step process of first allocating granular codes and then forming categorisations which can be easily tweaked without the need to revisit the underlying codes. Testing and evaluating categorisations in different circumstances, and gaining feedback from users, is an important part of the development. This collaborative process has pros and cons — it can add to the understanding of the way that causes are recorded and provide deeper insight into the results, but it also means that classifications will not be fixed in stone. Careful version control and translations between versions going forward are essential.

ACKNOWLEDGEMENTS

We would like to acknowledge the network funding that enabled the comparative work:

SHIP (Studying the History of Health in Port Cities) and SHIP+ (NWO grant number 236-53-010), PI: Angélique Janssens), and particularly the authors who contributed the comparative studies. We also thank the following universities which all contributed in kind to the meetings of the network: University of Cambridge, University of Copenhagen, Autonomous University of Barcelona, Ghent University, Heinrich Heine University Düsseldorf, The Arctic University of Norway.

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