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1. Introduction

1 The study of spatial differences in mortality has a long tradition in Belgium. As early as 1826, the renowned Belgian government official and statistician Adolphe Quetelet noted '*la prodigieuse différence*' between city and countryside [Quetelet, 1826]. The urban health penalties were confirmed by later in-depth studies on nineteenth and early-twentieth century Wallonia, the southern part of Belgium [Eggerickx, Debuisson, 1990; Eggerickx, 2001; Neven, 2000; Oris, 1998]. Whereas many historical studies in Belgium and beyond have focused on the urban-rural mortality gap, few studies for the nineteenth and early twentieth century have examined other spatial levels.[1]

2 Notable exceptions for Belgium are the study of Grimmeau *et al.* [2010] at the provincial level and our recent studies at the urban level [Devos and Van Rossem, 2015; Van Rossem *et al.*, 2017]. During the nineteenth century, there was a marked health divide between the

Flemish and Walloon provinces. Average life expectancy at birth was much lower in Flanders, the northern part of the country, than in Wallonia [Grimmeau *et al.*, 2010]. According to the literature, the low life expectancy in Flanders was strongly related to high infant mortality caused by bad feeding practices (i.e. early weaning) and low-quality drinking water from slow-flowing rivers and stagnant waters. The regional variability and determinants of infant mortality have been studied in detail by Masuy-Stroobant [1983] and Debuisson [2001]. However, because the summary measure of life expectancy is extremely sensitive to infant and child mortality, mortality in some areas of Flanders could potentially have been lower at other ages. Our research has already demonstrated spatial variation in age-specific mortality across Belgian cities. High death rates for infants and children did not necessarily occur in the same towns and cities where high death rates for adolescents, adults and the elderly were noted. Whereas the highest levels of mortality for infants and children were consistently observed in Flemish towns and cities, above the age of 10, the ranking of Flemish and Walloon cities was mixed. In other words, high death rates for adolescents, adults and the elderly were observed in Flemish as well as Walloon towns and cities [Van Rossem *et al.*, 2017]. Grimmeau *et al.* [2010] also noted that around the turn of the twentieth century (1880-1920) there was another geographical demarcation for the adult age groups besides the Flemish-Walloon divide. According to their analyses, mortality at adult ages was higher in the strongly urbanised and industrialised provinces of Liège, Limburg, Brabant, Antwerp and Hainaut than in other Belgian provinces.

3 In this article, we provide more insight into the spatial mortality differences within Belgium at the beginning of the twentieth century. Grimmeau *et al.* [2010] indicated that the provincial level possibly masked interesting patterns at the district level. We therefore present maps detailing age-, sex- and disease-specific mortality in 1910 for the 41 Belgian districts, according to indirectly standardised mortality rates that reflect their deviation from the national average. According to Grimmeau *et al.* [2010], this period largely marks the end of lower life expectancy in Flanders. After the 1920s, the spatial clustering gradually blurred. From the 1980s onwards, the pattern actually reversed and life expectancy was clearly lower in Wallonia than in Flanders. This reversal started in the late nineteenth century among the elderly and is usually attributed to the more negative lifestyle habits in Wallonia, such as the preference for unhealthy foods that can lead to modern degenerative and cardiovascular diseases. On the other hand, the young were extremely vulnerable to infectious diseases. The reversal in their mortality pattern was related to sanitation measures, such as the installation of water distribution networks that resulted in the consumption of healthier water in Flanders [Grimmeau *et al.*, 2010].

4 The maps in this article clarify how the health disadvantages were spatially distributed during this transition, according to age group. The advantage of using district data is threefold [see also Debuisson, 2001]: (1) There is a larger social and economic homogeneity in districts than in provinces. (2) In contrast to the small municipalities, the level of (disease-specific) death for most districts is large enough to derive meaningful statistical results. (3) The collection and digitization of mortality data for the 41 Belgian districts is a task that can be completed within a reasonable amount of time. In the period under study, Belgium consisted of more than 2,600 municipalities, so it would have taken months to digitize all the municipal data on population and mortality.

5 We used death rates to avoid the disadvantages of the life expectancy measure. The mortality data were derived from *Le Mouvement de la Population et de l'Etat Civil*,[2] the

register of vital events, while we used the population census of 1910 for data on population size and structure.[3] We distinguish six different age groups: infants (<1 year old), young children (1-6 years old), older children (7-14 years old), adolescents (15-20 years old), young adults (21-49 years old) and elderly adults (50+ years old). Men and women are studied separately because they face different genetic and biological risks. Women have two X chromosomes and X-linked immunoregulatory genes appear to give them more resistance to infectious diseases [Waldron, 1983]. Moreover, in contrast to men, women faced many risks related to childbearing. Besides biological differences, the different work and living circumstances of men and women are also important factors.

6 Furthermore, our mortality research on early twentieth-century Belgium is original in that it includes disease-specific mortality data. Belgian mortality data at the aggregate level are available from 1886 onwards, but 1910 is the first year for which the aggregated age-specific cause-of-death data in *Le Mouvement* are based on individual data registered according to the new detailed international nomenclature introduced in 1903.[4] The cause-of-death data are extremely useful because most diseases are strongly linked to specific determinants. According to Reid and van den Boomen [2015, p. 310], '*by using epidemiological insights into the origin and course of the diseases and conditions that eventually caused death, the complex context determining mortality levels can be, to a certain extent, unveiled*.' The disease-specific results presented here are based on a classification with 16 different disease categories. Most of them, such as airborne infectious diseases and enteritis, are spread via distinct transmission routes that are strongly related to specific environmental and socioeconomic conditions.

7 In recent decades, the use of geographical methods has greatly enriched this kind of research. The growing understanding that spatial analysis is an excellent means for gaining insight into regional and local health inequalities has resulted in historical mortality atlases in several European countries. For instance, the *Atlas of Victorian Mortality* by Woods and Shelton, which covers England and Wales from the 1860s to the 1890s, show reconstructions of the disease-specific mortality rates of infants, young children, adults and the elderly by district [Woods and Shelton, 1997]. They noted important geographical variations, depending on whether the district was rural or urban. Spatial differences clearly varied by age, sex and cause of death. Goubert, furthermore, presented in his *Atlas de la Révolution Française* the disease distributions across France between 1780 and 1820 [Goubert *et al.*, 1993]. Considering the epidemic nature of the many infectious diseases prevailing at the time, such as smallpox and measles, there was a clear geographical clustering. For other types of diseases, such as skin and bone diseases, this clustering was less obvious. Two more recent spatial comparisons have targeted infant mortality. First, Edvinsson and colleagues, who examined Nordic countries between 1780 and 1930, stressed the importance of local mortality regimes and revealed that regional differences crossed national borders [Edvinsson *et al.,* 2008]. On a larger European scale, Klüesener *et al.* [2014] confirmed regional variations around 1910 and claimed that national borders are usually irrelevant for understanding spatial variations in infant mortality. Large internal differences were observed in large countries such as the German and Russian Empires, as well as in smaller countries such as the Netherlands, Belgium and Switzerland.

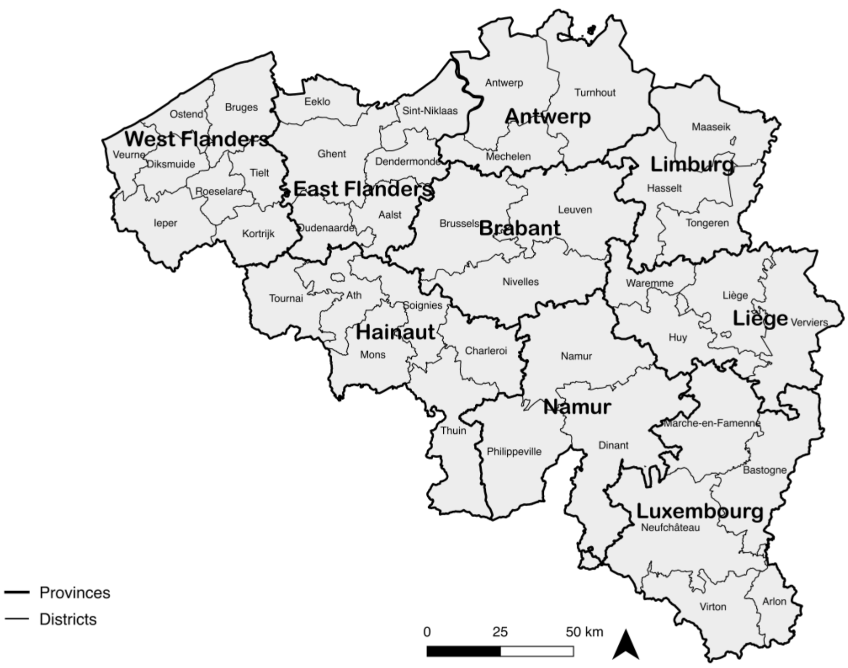
8 Besides contributing to these discussions on historical spatial mortality differences in Europe, this article answers three important questions regarding the early twentieth-century Flemish-Walloon divide in mortality: (1) Did every age group experience higher

mortality risks in the Flemish than in the Walloon districts? (2) Were there important differences in the spatial mortality patterns of men and women? (3) Which diseases were responsible for the largest differences in mortality in the Belgian districts? These questions are handled separately in sections 4, 5 and 6. Before addressing these research questions, in section 2 we briefly discuss the socioeconomic background of the Flemish and Walloon districts. In section 3, the data and methods used to create the maps are explained. Finally, section 7 concludes with a discussion of the spatial disparities in Belgium at the beginning of the twentieth century. The absence of a clear geographical clustering of high and low death rates after early childhood is particularly notable.

2. The Belgian context

9 At the beginning of the twentieth century, the Belgian territory was divided into 9 provinces and 41 districts. This division is presented in figure 1. The Flemish districts are situated in the northern part of the country and consist of the districts of the provinces of West Flanders, East Flanders, Antwerp and Limburg, together with the Brabant districts Brussels and Leuven. The southern or Walloon districts are the districts of the provinces of Hainaut, Namur, Liège and Luxembourg, together with the Brabant district Nijvel.

The districts and provinces of Belgium, 1910



Source: Map constructed by author

10 Around 1910, the socioeconomic differences between the Belgian provinces and districts were essentially the result of an extensive industrialisation process that started in the early nineteenth century. Belgium was, in fact, the second country to experience the industrial revolution after the pioneer Great Britain [Hobsbawm, 1995]. It industrialised rapidly in the nineteenth century, following a long artisanal tradition in textiles and metallurgy. Belgium's industrialisation was largely based on coal, iron and textiles.

However, Flanders and Wallonia followed different paths to industrialisation. In Wallonia, the industrial revolution began earlier and on a much larger scale, resulting in the region remaining the economic backbone of the country until the 1930s [De Brabander, 1983; Vandermotten, 1997]. Industrialisation in Wallonia centred on the provinces of Liège in the east and Hainaut in the west [Vandermotten, 1985].

11 Mechanisation in Belgium, however, started in textile production. It was instigated around 1807 by William Cockerill, an English engineer who introduced technological innovations for the spinning and carding of wool to local entrepreneurs in the Walloon town of Verviers. Following the subsequent boom in wool production, Cockerill and his son John quickly entered other industries in the area, producing industrial machinery and iron around Liège with great success. They introduced the first coke-blast furnace and built the first steam locomotive and railway on the Belgian mainland. By the 1840s, Cockerill was the world's largest manufacturer of steel [Van der Herten *et al.*, 1995].

12 The western pole of the Walloon industry was situated in Hainaut, which flourished due to the presence of rich coal mines and iron ore in the areas around Mons, Charleroi and the Sambre-Meuse river valley. Transportation was facilitated by the construction of a network of canals such as the Brussels-Charleroi canal in 1832, and the development of an extensive railway network across the country, funded by new financial institutions and large national holdings. Thriving steel and machine-building industries, alongside the export of transport equipment generated much wealth in the area. After 1870, Hainaut lost its industrial primacy to the more diversified economy of Liège, where modern chemical industries and the newly mechanised glass and zinc industries were expanding [Mérenne-Schoumaker, Vandermotten, 1992].

13 The main industrial centre in Flanders was situated in Ghent. The city's cotton factories had provided employment to many women and children since the late 1820s [Verhaegen, 1961]. On the other hand, the domestic linen industry was widespread throughout the Flemish countryside. In inland Flanders, many families cultivated their small farm during the summer and engaged in linen weaving and spinning at home during the winter. In Flanders, the ties between the textile industry and agriculture had been extremely close since early modern times, as linen manufacturing was dependent on locally produced flax. This combination proved very resistant to change during the second quarter of the nineteenth century, when the rural linen industry collapsed in the face of British mechanised cotton [Vandenbroeke, 1984]. Together with successive cereal crop failures in the late 1840s, this led to the impoverishment of broad sections of the rural population in the provinces of East Flanders and West Flanders. Economic modernisation was also largely absent in the agricultural provinces of Limburg, Namur and Luxembourg [Deneckere *et al.*, 2009; Leboutte *et al.*, 1998]. After 1875, massive imports of cheap cereals from abroad caused a severe crisis among the farmers and many were forced to convert to dairy farming [Segers, 2003]. Although there was no exodus from the Flemish countryside during the second half of the nineteenth century, these rural crises were instrumental in the migration of a cheap labour force to the cities and to the more prosperous provinces of Antwerp, Brabant and industrial Wallonia. Towards the end of the century, however, the Flemish population preferred seasonal employment or to commute to their place of new employment. The success of commuting in Belgium was the result of the development of a dense railway network and the availability of cheap railway passes [Deprez, Vandenbroeke, 1989; Pollet, 1998].

14 The provinces of Antwerp and Brabant had an intermediate position with regard to economic development. Commercial and transport-related industries were of particular importance here. The city of Antwerp and its surrounding area underwent a rapid transformation as its harbour developed into an international port, which also benefitted from good railway and waterway connections with the industrial areas of Wallonia, western Germany and northern Germany. By the late nineteenth century, the location of industry was no longer tied to coal. It favoured central Belgium, which offered better qualified labour, particularly along the Antwerp-Brussels corridor and extending somewhat to Charleroi, creating an important axis of economic power. In the Brussels district, there was substantial metal production and major machinery and chemical industries. Likewise, expanding luxury industries such as paper, printing and food processing, together with tertiary activities stimulated employment. The city of Brussels had been established as the capital city in 1831, so administrative and financial activities were also clearly important. As a result, by the early twentieth century Brussels was the most important economic district [De Beule, 1994; Leboutte *et al.*, 1998; Lefebvre, Buyst, 2007].

15 This distinct pattern of industrialisation in the Belgian provinces and districts is largely reflected in their population growth. During the nineteenth century, there was negative relative population growth in the provinces of West Flanders, East Flanders, Limburg, Namur and Luxembourg. On the other hand, the industrial activities in Hainaut and Liège and the important commercial and administrative activities in Antwerp and Brabant attracted many migrants, as mentioned above. Most of the population growth took place in large cities, but there was also a sharp increase in communes of between 10,000 and 50,000 inhabitants [Devos, Van Rossem, 2015]. This was related to the growing importance of suburbs, industrial basins (such as around Mons and Charleroi) and regional service centres [Deprez, Vandenbroeke, 1989].

16 Besides the demographic differences, the industrial development also led to a clear-cut divide in relative GDP per capita. Analyses of the 1896 censuses by Erik Buyst [2009] clearly demonstrate low levels of GDP per capita in 'poor Flanders' compared to the more prosperous Wallonia. The Flemish provinces of West Flanders, East Flanders, Antwerp and Limburg had a GDP per capita well below the Belgian average: in the peripheral regions of West Flanders and Limburg it was even more than 30% lower. The highest levels (more than 15% higher) were found in Liège and Hainaut, while moderate levels prevailed in Namur, Brabant and Luxembourg.

3. Data and method

17 The maps presented in this article are based on age-, sex- and disease-specific death rates of the 41 districts of Belgium, which reflect the number of deaths per 1,000 people in 1910. We show the results for six age groups for men and for women: infants (<1 year old), young children (1-6 years old), older children (7-14 years old), adolescents (15-20 years old), young adults (21-49 years old) and elderly adults (50+ years old). These groups are based on the presentation of the disease-specific mortality rates in *Le Mouvement de la Population et de l'Etat Civil*, the register of vital events. Our original contribution here is the presentation of the spatial variation in the most important causes of death by age group. To highlight the geographical patterns, we calculated the indirectly standardised mortality rate (SMR), compared to the Belgian sex- and age-specific average, for the

general and disease-specific mortality of each district by sex and age group.[5] Based on the confidence intervals around this SMR [method of Breslow and Day, 1987], we distinguish five groups: much lower than the average, lower than the average, not significantly different from the average, higher than the average, and much higher than the average. The distinction between the two groups with significantly lower or higher SMRs is based on the average SMR of all districts with a significantly lower or higher SMR. In the case of lower SMRs than the Belgian average, those below the average of the deviant districts are designated as much lower; for the SMRs higher than the Belgian average, those above the average of the deviant districts are designated as much higher. The districts with lower SMRs are coloured dark and light green, the non-significantly different districts are coloured grey, and those with higher SMRs are coloured light and dark red (see figures 2 to 7).

18 The collection of data on population numbers and mortality needed for the construction of the death rates was facilitated by the digitisation of nineteenth-century municipal mortality and population statistics in the HISSTER database.[6] The population size was derived from the population census for the year 1910.[7] This census offers detailed age- and sex-specific figures on the residents in the provinces, districts and municipalities with 10,000 inhabitants or more. The mortality data were derived from *Le Mouvement de la Population et de l'Etat Civil*.[8] From 1886 onwards, *Le Mouvement* includes tables with the number of de facto deaths according to sex, age and residence. This information was derived from municipal population registers and vital registration, which the municipal government had to summarise annually on pre-printed forms. For general mortality, we used data for three years centred around the census year: 1909, 1910 and 1911. The disease-specific information by sex, on the other hand, was based on data for 1910, as only the registers at census years provide an age-specific classification of cause-of-death mortality. The data are based on the municipal registers of causes of death, which Belgian municipalities have been obliged to keep since 1851. A uniform cause-of-death nomenclature for the completion of these registers was introduced in Belgium as early as 1867. Changes in the classification scheme in 1874 and 1903 profoundly facilitated the cause-of-death registration [Bracke, 2008; Velle, 1985]. We clustered the causes of death into 16 categories, mainly based on the broad categories distinguished in *Le Mouvement* and their transmission route. As a result, we categorised airborne, waterborne and other infectious diseases, cancer, cardiovascular diseases, congenital weakness, maternal mortality, neurological diseases and urogenital diseases. Because of their historical importance, pulmonary tuberculosis and enteritis are given their own categories and not included the categories of respiratory diseases [see also Reid *et al.*, 2015] and intestinal diseases, respectively. Furthermore, we divided the external causes of death into the categories of violent deaths and accidents, and we established a general category for 'other causes of death'. The classification matrix is presented in table A1 in the appendix.

19 The population and mortality numbers can be considered to be fairly reliable. Since the end of the nineteenth century, Belgium has had a well-developed public administration, with clear guidelines for counting and processing demographic data, and thorough supervision by the central government [Preneel, 2010; Vrielinck, 2013]. Internationally, however, historical demographers and medical historians have debated the quality of historical cause-of-death statistics [for an overview see Van Rossem *et al.*, forthcoming]. The main problems noted relate to (1) the limited medical knowledge of civil administrators, (2) the statement of false causes of death, as in the case of socially loaded

diseases such as pulmonary tuberculosis, (3) the nomenclature changing over time, and (4) misclassification of causes of death during the transfer of information from individual death certificates to larger categories at an aggregated level. Consequently, the results of the disease-specific mortality figures have to be interpreted very carefully.

4. Spatial variation in age-specific mortality

20 The first question we address is whether every age group experienced higher mortality risks in the Flemish districts than in the Walloon districts. The findings reveal that death rates in Flanders were consistently higher than in Wallonia only for infants and young children under the age of 7, as shown in figures 2 to 4. In the districts of West Flanders and East Flanders, in particular, the death rates were significantly higher than the Belgian average. Hence, the maps for infants and young children essentially reveal a difference between the high-mortality area in the northwest of Belgium and the rest of the country. Specifically, the rates for male infants, female infants and male young children were highest in the coastal Ostend district, with levels of 332.04, 282.91 and 18.62 per 1,000 (the Belgian averages were 175.02, 144.28 and 12.62), respectively. For female young children, the highest level was noted in Thielt (18.34 compared to an average of 11.96). In the Walloon districts, only very low to moderate death rates were observed. The lowest rates for male (98.56) and female infants (69.97) and female young children (6.69) were noted in Philippeville, the lowest rate for male young children in Bastogne (6.96). Previous studies have explained the high infant mortality levels in Flanders through the impact of breastfeeding habits (i.e. early weaning) and environmental factors such as water quality. In Flanders, the water added to bread soup and potato porridge was usually extracted from artesian wells and of low quality. In contrast, domestic water in Wallonia usually came from fast-flowing rivers [Backs, 2003; Cornut, 1999; Debuisson, 2001; Lesthaeghe, 1987; Masuy-Stroobant, 1983].

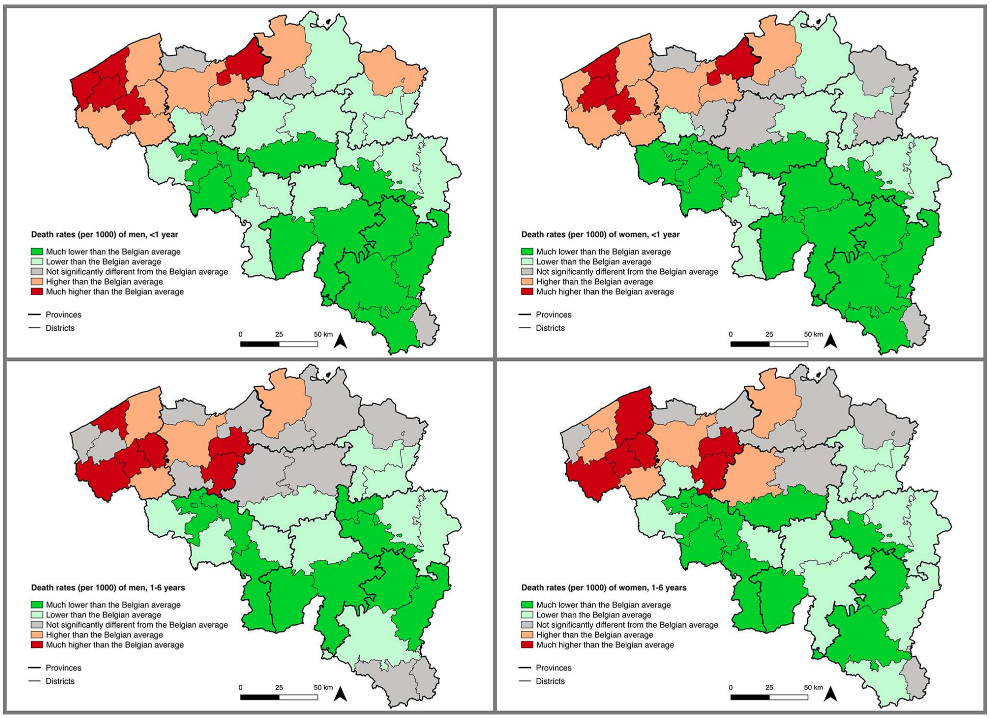
21 For the older children (7-14 years old), we observe no Flemish-Walloon divide in mortality (see figures 3 and 4). Because the number of deaths was relatively low between the ages of 7 and 20, only a small number of districts differed significantly from the Belgian average. Nevertheless, just as for adults, districts with high and low death rates were observed in the northern as well as in the southern part of the country. The ranking clearly differed by age. There were, moreover, large mortality differences among neighbouring districts and among those belonging to the same provinces. This underpins the importance of choosing a suitable spatial level of analysis [see also Edvinsson *et al.*, 2008]. The death rates of young adult men, shown in figure 4, were for instance very low in two districts of the province of Luxembourg: Bastogne and Virton (5.03 and 5.12 per 1,000, respectively), compared to the average (6.52), while a high rate was noted in Arlon (7.70). Unlike the case for infants and young children, it is not yet clear which specific determinants were responsible for these spatial differences at older ages.

22 In sum, not every age group in Flanders experienced consistently worse health than in Wallonia. At a time when mortality risks at young ages were still very high, life expectancy figures can be misleading and cannot be used to understand the mortality experiences of every population.

5. Spatial variation in sex-specific mortality

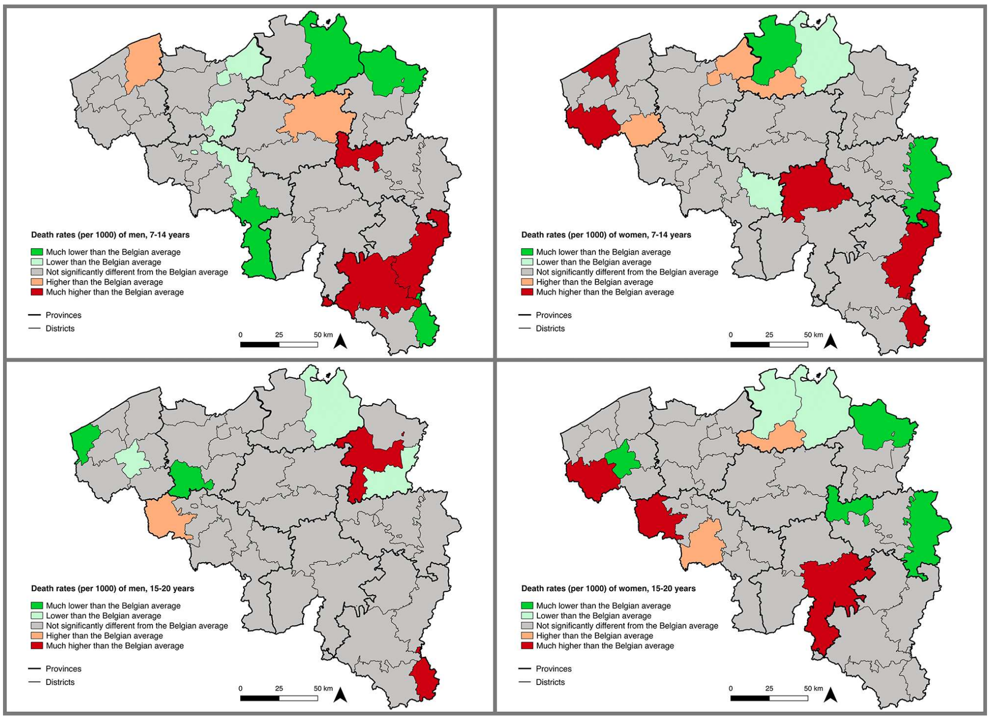
23 In addition to spatial differences in age-specific mortality, the maps also show differences by sex in the ranking according to the deviation from the national average. Figure 2 demonstrates that there were no important spatial differences by sex among infants and young children. In general, districts with significantly higher death rates for boys compared to the Belgian average also displayed significantly higher death rates for girls and there is a similar pattern for low death rates. From the age of 7 onwards, however, we notice important differences in the colouring of districts according to the male or female SMRs (see figures 3 and 4). Male older children in Sint-Niklaas experienced, for instance, lower mortality rates than the Belgian average (1.68 per 1,000 compared to an average of 2.24), while female children between the ages of 7 and 14 in the same district experienced significantly higher death rates than the average (2.80 compared to an average of 2.31). Conversely, male young adults experienced significantly higher death rates than the national average in Antwerp (6.80 compared to an average of 6.52), while female young adults in this district fared better (5.12 compared to an average of 5.92), as shown in figure 4. Numerous other examples of such sex-specific differences can be noted when comparing the maps of older children, adolescents, and adults. In line with the explanation for the observed sex-specific mortality differences in Victorian England and Wales [Woods, Shelton, 1997], we assume that the variation at these ages was related to the increasing importance of sex-specific determinants of health and mortality during the life course. For example, there were large differences in Belgium between men and women with regard to their employment activities and associated health impact [e.g. Devos, 2000; Eggerickx, Tabutin, 1994; Van Rossem *et al.*, 2017]. In the next section we assess whether the differences in general mortality were also reflected in disease-specific mortality. For now, we can deliver a positive answer to our second question: from the age of 7 onwards, the spatial pattern of high and low general mortality was highly different for men and women.

General death rates (per 1,000) of male and female infants (<1 year old) and young children (1-6 years old) by age and district compared to the national average, 1910



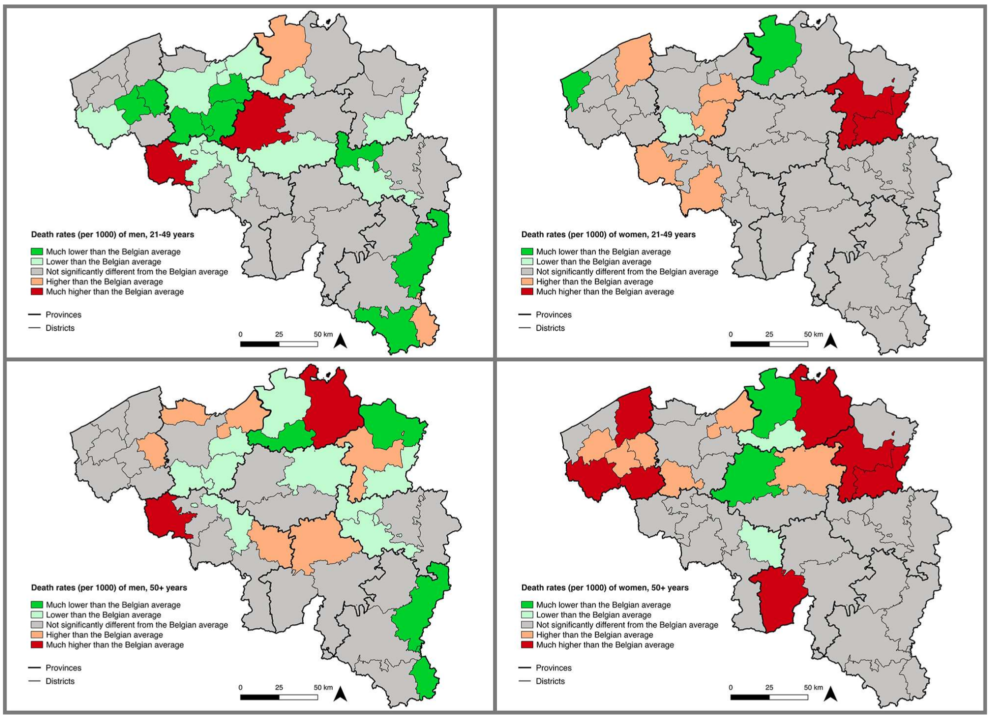
Source: the population census of 1910 and annual data for 1909, 1910 and 1911 from *Le Mouvement.*

General death rates (per 1,000) of male and female older children (7-14 years old) and adolescents (15-20 years old) by age and district compared to the national average, 1910



Source: the population census of 1910 and annual data for 1909, 1910 and 1911 from *Le Mouvement.*

General death rates (per 1,000) of male and female young adults (21-49 years old) and elderly adults (50+ years old) by age and district compared to the national average, 1910



Source: the population census of 1910 and annual data for 1909, 1910 and 1911 from *Le Mouvement.*

6. Spatial variation in disease-specific mortality

24 Figures 5 to 7 display the disparities in disease-specific mortality of male and female infants, children, adolescents and adults. We present the results for the most important cause of death for each age group. They largely correspond to the most important age-specific causes of death of the English and Welsh population at the end of the nineteenth century [see Woods, Shelton, 1997]. The results tell us whether there were differences according to region and sex, compared to the national average.

25 The most important cause of death for infants was enteritis or diarrhoeal diseases, while for young children it was airborne infectious diseases (see figure 5). Digestive diseases and airborne infectious diseases are strongly related to malnourishment [Masuy-Stroobant, 1983; Rabb, Rotberg, 1985]. Airborne infectious diseases, moreover, spread rapidly in crowded areas due to droplet infection [Kiple, 1993]. In Victorian England and Wales, these diseases were particularly prevalent in urban districts [Woods, Shelton, 1997]. In Belgium, the infant death rates due to enteritis were especially high in the districts of East Flanders and West Flanders, which partly explains the high general mortality there. This is generally attributed to the bad feeding habits of infants (see section 4). Significantly higher rates than the Belgian average also occurred in the Antwerp and Brussels districts, which contained the two largest Belgian cities at the time. Districts with high child death rates due to airborne infectious diseases were also common in West Flanders and East Flanders. Moreover, we noted significantly higher rates in Maaseik, for boys in the Walloon districts of Namur, and for girls in Arlon. Thus, the Flemish-Walloon divide does not entirely hold for this specific cause of death. In

general, at these young ages we do not observe large differences in the spatial mortality patterns of boys and girls.

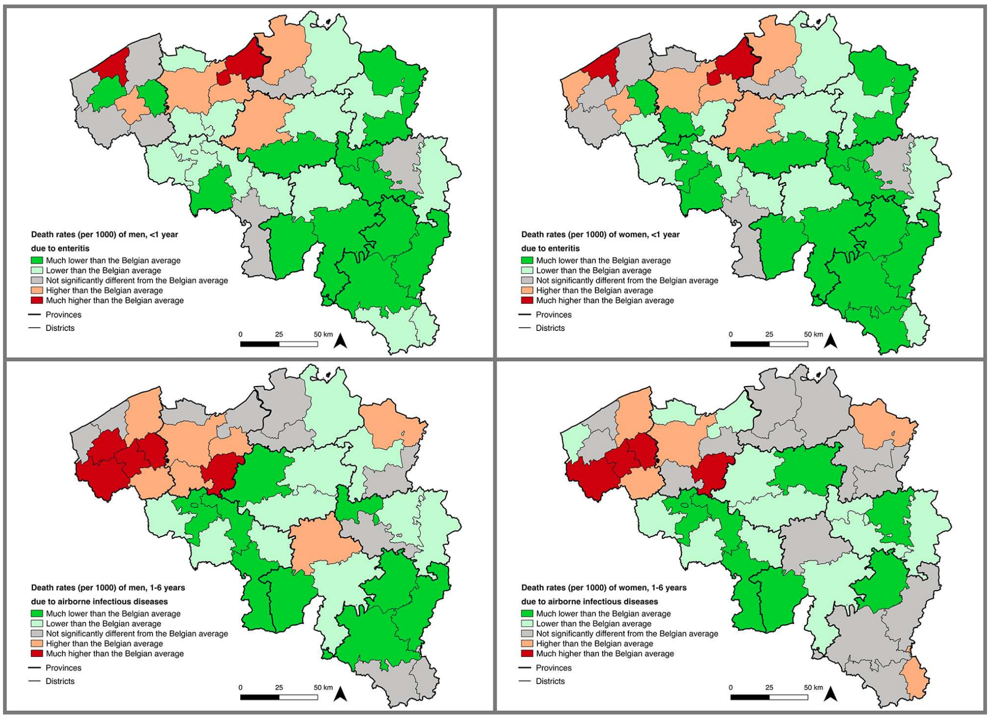
26 In 1910, neurological diseases, i.e. mainly simple meningitis and tuberculosis of the meninges, were the most important cause of death for older children (7-14 years old) in Belgium. Both diseases are usually spread by droplet infection, so unhygienic and crowded living conditions are an important risk factor for their development [Kiple, 1993]. High death rates for this disease were found in both parts of the country (see figure 6). Moreover, not every district with a significantly different SMR for boys also displayed such a deviation for girls. Remarkably, in Ostend we noted for instance a much higher death rate for girls compared to the national average (0.89 per 1,000 compared to the Belgian average of 0.36), while the rate for boys was equal to 0.00 (compared to an average of 0.31).

27 Pulmonary tuberculosis explains an important part of the mortality of adolescent and young adult men and women (see figures 6 and 7). The development of the disease is strongly related to dusty living and working conditions in badly ventilated and illuminated houses and workplaces, as well as to an inadequate diet [Kiple, 1993]. The spatial patterns displayed in figures 6 and 7 demonstrate the high death rates from this disease in Walloon as well as Flemish districts. The largest deviations from the Belgian average for women were mainly found in Walloon districts. The clustering of significantly high death rates for young adult women in the neighbouring districts of Namur, Philippeville, Dinant, Marche-en-Famenne and Neufchâteau is striking, especially because of the extremely low rates in the adjoining districts Bastogne and Thuin. The maps furthermore illuminate important differences between men and women according to the districts. While young adult men in Brussels experienced, for instance, very high death rates due to pulmonary tuberculosis (2.22 per 1,000 compared to an average of 1.42), women in this district had a moderate death rate that was not significantly different (1.20 compared to an average of 1.24). Conversely, the death rate in Marche-en-Famenne was very high for young adult women (2.17) but moderate for men (1.21). These differences by sex underpin the assumption that the development of this disease was to a significant degree related to working conditions [see also Devos, 2000; Van Rossem *et al.*, forthcoming].

28 In old age, respiratory diseases were the most prevalent cause of death for men, and cardiovascular diseases for women (see figure 7). Like airborne infectious diseases, respiratory diseases are strongly related to malnourishment and overcrowding (see supra). Cardiovascular diseases mainly affect the elderly, which is why they are frequently placed under the general heading of 'degenerative diseases'. The development of such diseases can be caused by unhealthy lifestyle factors such as tobacco smoking, an unhealthy diet and stress, as well as air pollution [Lee *et al.,* 2014; WHO, 2017]. High death rates from these diseases for the elderly were clearly found in both parts of the country. Analyses (not shown here) further clarify that the mortality of men and women did not run in parallel: the districts that were unfavourable to men were not identical to those that were disadvantageous to women, and vice versa.

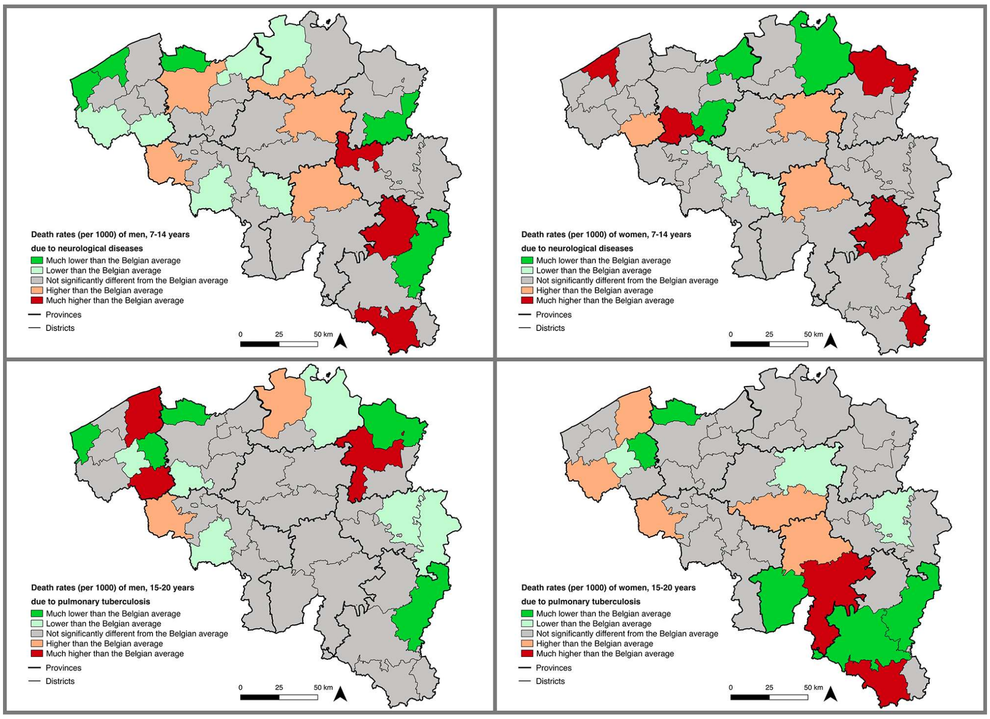
29 In sum, this overview demonstrates that for most ages, districts with high death rates from the most prevalent cause of death were found in both parts of the country. Moreover, there was no apparent specific geographical pattern except for infants in Flanders, who consistently had the highest disease-specific death rates. For adolescents and adults, there were important differences in the classification of the districts by sex.

Death rates (per 1,000) of male and female infants (<1 year old) due to enteritis and of male and female young children (1-6 years old) due to airborne infectious diseases by district of Belgium compared to the national average, 1910



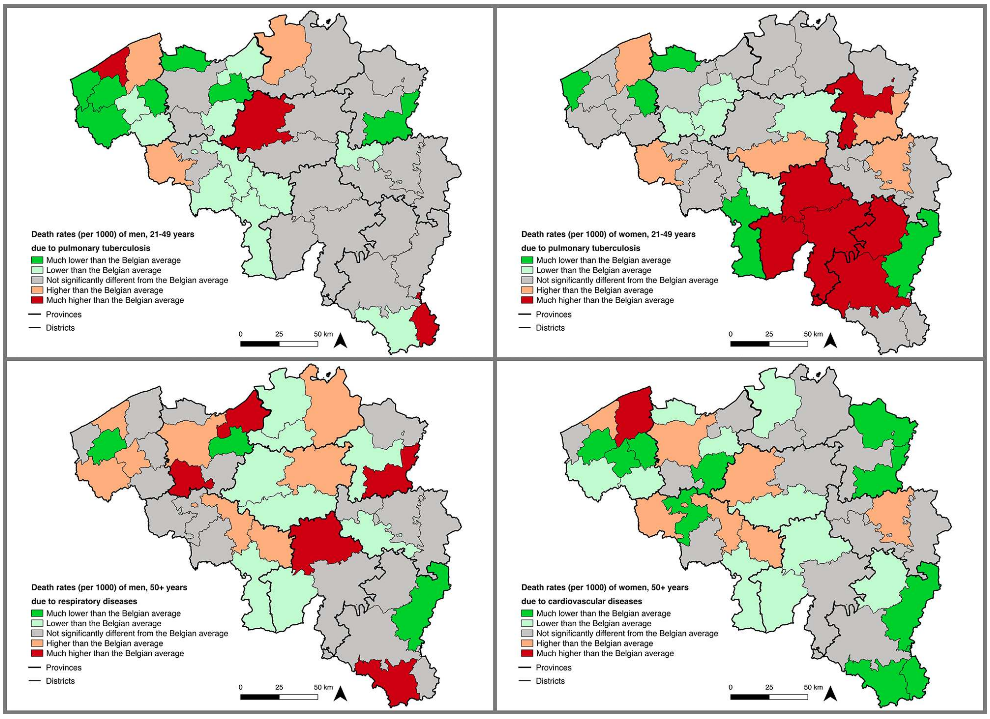
Source: the population census of 1910 and annual data for 1909, 1910 and 1911 from *Le Mouvement.*

Death rates (per 1,000) of male and female older children (7-14 years old) due to neurological diseases and of adolescents (15-20 years old) due to pulmonary tuberculosis by district of Belgium compared to the national average, 1910



Source: the population census of 1910 and annual data for 1909, 1910 and 1911 from *Le Mouvement.*

Death rates (per 1,000) of male and female young adults (21-49 years old) due to pulmonary tuberculosis, of male elderly adults (50+ years) due to respiratory diseases and of female elderly adults due to cardiovascular diseases by district of Belgium compared to the national average, 1910



Source: the population census of 1910 and annual data for 1909, 1910 and 1911 from *Le Mouvement.*

Conclusions

30 The spatial analysis of mortality in this article clearly demonstrates that geographical differences in Belgium at the beginning of the twentieth century cannot be simplified according to the Flemish-Walloon divide. The only clear distinction that existed was for infants and children below the age of 7, with considerably higher mortality in Flanders than in Wallonia. Infants and children experienced a particularly large penalty in West Flanders and East Flanders, i.e. the northwest part of Belgium. Because of the sensitivity of the life expectancy measure to mortality at young ages, these outcomes explain the low life expectancies at birth in Flanders at the beginning of the twentieth century. However, for older children, adolescents, and young and elderly adults, low and high mortality were observed in Flemish as well as in Walloon districts. For many age groups, large differences in mortality were also noted among districts belonging to the same province. Hence, the district level seems more suitable for studying spatial mortality than the provincial level. Furthermore, the ranking of the districts varied considerably according to age: for men as well as women, high death rates of infants, children, adolescents, and adults per se did not appear in the same districts. These results are in line with findings for Victorian England and Wales, for which Woods and Shelton [1997, p. 142] concluded that there were '*sharp and important differences between localities in terms of the level of mortality*' and '*that the age component is especially important*'. Moreover, from adolescence onwards, we observed important differences in the ranking of the Belgian districts for

sex-specific mortality, a feature which was also stressed for Victorian England and Wales [Woods, Shelton, 1997].

31 Besides general mortality, we also examined spatial variation in disease-specific mortality. Again, important similarities with the experiences of the English and Welsh populations could be noted [see Woods, Shelton, 1997]. The high infant mortality in Flanders was mainly explained by high levels of enteritis, while airborne infectious diseases were the most important cause of death for young children. For infants, a divide between Flemish and Walloon districts was visible, but it began to disappear from childhood onwards. Neurological diseases were the most important cause of death for older children, while for adolescents and young adults it was pulmonary tuberculosis. Respiratory diseases were important killers of elderly men, while cardiovascular diseases explained the largest proportion of deaths in elderly women. Besides a lack of geographical clustering, we also noted that the spatial variation of most diseases, especially of pulmonary tuberculosis, differed between men and women at adolescent and adult ages. This suggests the increasing importance of sex-specific mortality determinants over the life course. Future studies should study the determinants of these patterns in more detail.

32 To conclude, our study clearly demonstrates that at the start of the twentieth century, the mortality ranking of the Belgian districts varied considerably according to age, sex and disease. For infants and children, a clear divide in general mortality between the Flemish and Walloon districts could be distinguished. However, for the group of young children there was no divide for specific causes of death and after age 7 geographical clustering disappeared for both general and disease-specific mortality. Hence, we can formulate the following answers to the three questions posed in the introduction: 1) After the age of 7, there were high death rates in Flemish as well as Walloon districts; 2) After the age of 7, there were important differences in the spatial ranking of the general and disease-specific mortality of men and women; 3) The diseases mainly responsible for high mortality were enteritis for infants, airborne infectious diseases for young children and neurological diseases for older children, pulmonary tuberculosis for adolescents and adults, and respiratory and cardiovascular diseases for the elderly.

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APPENDIXES

Table A1. Classification of the different causes of death into comprehensive categories

Comprehensive category	**Diseases**	**Description of the causes of death in *Le Mouvement* (1910)**
Accidents	Accidents	Accidents

Airborne infectious diseases	Diphtheria and croup Influenza Measles Scarlet fever Smallpox Whooping cough	Diphtérie et croup Grippe Rougeole Scarlatine Variole Coqueluche
Cancer	Cancer	Cancer et autres tumeurs malignes
Cardiovascular diseases	Organic diseases of the heart	Maladies organiques du Cœur
Congenital weakness	Congenital weakness	Décès par défaut de viabilité
Enteritis	Diarrhoeal diseases and enteritis (younger than 2 years old)	Diarrhée et entérite (au-dessous de 2 ans)
Intestinal diseases	Alcoholism, acute or chronic Cirrhosis of the liver Diseases of the stomach (cancer excluded) Hernia, intestinal obstruction	Alcoolisme aigue ou chronique Cirrhose du foie Affections de l'estomac (cancer excepté) Hernies, obstructions intestinales
Maternal mortality	Puerperal septicaemia Other puerperal accidents of pregnancy and childbirth	Septicémie puerpérale Autres accidents puerpéraux de la grossesse et de l'accouchement
Neurological diseases	Congestion, haemorrhage and softening of the brain Simple meningitis Tuberculosis of the meninges	Congestion hémorragie et ramollissement du cerveau Méningite simple Tuberculose des méninges
Other causes of mortality	Old age Sudden death Unreported and unknown causes Other unspecified diseases and causes of death	Vieillesse (débilité sénile) Mort subite Causes de décès non spécifiées ou mal définies Autres causes de décès
Other infectious diseases	Intermittent fever Tuberculosis of other organs Other infectious diseases	Fièvre intermittente et cachexie palustre Autres tuberculoses Autres affections épidémiques
Pulmonary tuberculosis	Tuberculosis of the lungs	Tuberculose des poumons

Respiratory diseases	Bronchitis Pneumonia	Bronchite aigue & Bronchite chronique Broncho-pneumonie & Pneumonie
Urogenital diseases	Nephritis and Bright's disease Noncancerous tumours and other diseases of the female genital organs	Néphrite aigue et maladie de Bright Tumeurs non cancéreuses et autres maladies des organes génitaux de la femme
Violence	Homicides Suicides Suspicious cases	Homicides Suicides Cas douteux
Waterborne infectious diseases	Cholera Typhoid fever	Choléra Asiatique & Choléra nostras Fièvre typhoïde (typhus abdominal)

NOTES

1. For the late twentieth and early twenty-first century, on the other hand, we are rather well informed about age-, sex- and disease-specific mortality variations across Belgium [See inter alia Decroly, Grimmeau, 1991; Grimmeau *et al.*, 2012; Levêque *et al.*, 1999; Poulain *et al.*, 1984; Renard *et al.*, 2014; 2015].

2. Statistique de la Belgique, 1909-1910-1911, *Statistique du mouvement de la population et de l'état civil en Belgique*. Bruxelles, Ministère de l'intérieur et de l'instruction publique.

3. Statistique de la Belgique, 1910, *Population: Recensement général du 31 décembre 1910.* Bruxelles, Ministère de l'intérieur et de l'instruction publique.

4. This classification is based on the nomenclature agreed upon during the international conference on the revision of the nosological nomenclatures organised in Paris in 1900 [Velle, 1985].

5. The indirectly standardised mortality rate (SMR) indicates how much higher the observed death rate is in a certain district compared to what it would have been if the sex- and age-specific death rate of Belgium had applied. A SMR higher than 100 reflects a higher number of deaths than expected, an SMR below 100 reflects a lower number of deaths than expected.

6. HISSTER. A database of Belgian mortality statistics for the 19th and 20th centuries available at the local and regional level, Ghent University, Quetelet Center, supervised by Isabelle Devos.

7. Statistique de la Belgique, 1910, *Population: Recensement général du 31 décembre 1910.* Bruxelles, Ministère de l'intérieur et de l'instruction publique.

8. Statistique de la Belgique, 1909-1910-1911, *Statistique du mouvement de la population et de l'état civil en Belgique*. Bruxelles, Ministère de l'intérieur et de l'Instruction Publique.

ABSTRACTS

At the beginning of the twentieth century, life expectancy at birth was much lower in Flanders, the northern part of Belgium, than in Wallonia, the southern part of the country. In the literature, this excess mortality is mainly attributed to high levels of infant mortality caused by bad feeding practices and low-quality drinking water. The regional variability of mortality risks at other ages during this period has received less attention. In this article, we reconstruct age-, sex- and disease-specific death rates for the 41 districts of Belgium around the year 1910. To show the mortality variations, we construct maps according to indirect standardised mortality rates that reflect the deviation from the national average. Our spatial analysis shows that there was a clear-cut Flemish-Walloon divide in general mortality only for infants and children under the age of 7. For older children, adolescents, and young and elderly adults, low and high mortality were observed in both regions. For disease-specific mortality, moreover, a geographical pattern was only visible for infants, who consistently had the highest death rates in Flanders. Hence, the spatial disparities in general and disease-specific mortality cannot be simplified according to a Flemish-Walloon divide. Furthermore, we noted large differences among districts belonging to the same province, and in the ranking of the districts by age. In other words, high mortality levels of infants, children, adolescents and adults did not per se appear in the same districts. From adolescent ages onwards, there were also large differences in the ranking of districts by sex-specific mortality. This strongly suggests the importance of sex-specific determinants of health and mortality at these ages.

Au début du XX^e^ siècle, l'espérance de vie à la naissance était plus faible en Flandre, la partie nord de la Belgique, qu'en Wallonie, la partie sud du pays. Des études précédentes ont attribué cette surmortalité principalement à des taux élevés de mortalité infantile, provoqués par de mauvaises pratiques d'alimentation et par une eau insalubre. La variation régionale des risques de mortalité à d'autres âges pendant cette période a reçu moins d'attention. Dans cet article, nous reconstituons les taux de mortalité des 41 arrondissements belges vers 1910 par âge, sexe et causes de décès. Nous produisons des cartes selon les taux de mortalité standardisé indirect, représentant l'écart par rapport à la moyenne nationale respective. Notre analyse spatiale montre qu'il n'y a eu seulement pour les nourrissons et les enfants de moins de 7 ans, un clivage net de mortalité totale entre la Flandre et la Wallonie. Pour les enfants plus âgés, les adolescents, les jeunes adultes et les adultes plus âgés, une mortalité faible et élevée a été observée dans les deux régions. En outre, pour la mortalité par maladie, une répartition géographique n'était visible que pour les nourrissons, qui affichaient systématiquement les taux de mortalité les plus élevés en Flandre. Nous concluons que les disparités spatiales de mortalité totale et de mortalité par cause de décès ne peuvent être simplifiées en une clivage entre la Flandre et la Wallonie. De plus, il y avait même de grandes différences entre les arrondissements d'une même province et la position relative des arrondissements variait considérablement en fonction de l'âge. En d'autres termes, les taux de mortalité élevés des nourrissons, des enfants, des adolescents et des adultes n'apparaissent pas nécessairement dans les mêmes arrondissements. À partir de l'adolescence, il y avait aussi de grandes différences dans le classement des arrondissements selon la mortalité par sexe. Cela suggère l'importance des déterminants spécifiques par sexe de santé et de mortalité à ces âges.

INDEX

Mots-clés: mortalité, causes de décès, variation géographique, Belgique, différences de sexe
Keywords: mortality, causes of death, spatial variation, Belgium, sex differences

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