Denmark: the lowest excess mortality during the influenza pandemic of 1918.

Vladimir Canudas-Romo¤ & Annette Erlangsen*†

Abstract

The objective of this project is to study the influenza pandemic of 1918 at the population level with an international perspective. The influenza of 1918 (H1N1 virus) had an unusual strong effect on young adults, ages 15 to 50. This excess adult mortality also occurred in Denmark. However, the adult mortality levels were lower there than in any other region of the world. These low levels of adult mortality are also observed in Denmark in the years before and after the pandemic. An in-depth examination of the mortality data for Scandinavian countries which share a lot of similarities brings some insights to the reasons why Denmark had such low mortality in 1918. The facts that made Denmark successful in terms of the lowest excess mortality could help prevent avoidable deaths in a situation of a future influenza pandemic. Furthermore, the results presented here suggest that current levels of mortality in the world could help predicting deaths caused by the threatening avian influenza epidemic in the near future.

Keywords: Pandemic, influenza 1918, Denmark, decomposition,

¤ *Population, Family and Reproductive Health, Johns Hopkins Bloomberg School of Public Health, USA.*

* National Centre for Register-based Research, University of Aarhus, Aarhus, Denmark.
†Center for the Study and Prevention of Suicide, Psychiatry, University of Rochester Medical Center, Rochester, New York, USA.

Corresponding author: Vladimir Canudas-Romo. Department of Population, Family & Reproductive Health. Johns Hopkins Bloomberg School of Public Health. 615 N Wolfe Street, Room E4634. Baltimore MD 21205. Ph: 410-955-8694. Fax: 410-955-2303. E-mail: vcanudas@jhsph.edu

Denmark: the lowest excess mortality during the influenza pandemic of 1918.

1. Introduction.

The influenza virus of 1918 caused the death of a great number of young adults all over the world. It is estimated that approximate 1 billion people were infected worldwide and that 50 million died from the virus [1]. However, the levels of excess mortality were very different from country to country. Recent studies have, by comparing international mortality levels for 1918, noted that Denmark stands out as the country with the lowest levels of excess mortality [2,3].

The virus of the 1918 influenza, the H1N1 virus [4], affected the mortality patterns in an unusual manner. Young adults between the ages of 15 to 50 experienced a very high mortality [3]. Furthermore, gender differences in mortality patterns changed in the years to follow, probably caused by increased tuberculosis mortality in men [5]. The epidemic had rapid succession of waves with a very infectious first wave but not as deathful as the second wave in the fall of 1918 [4,6]. Causes of death associated with the virus are: influenza, pneumonia and other respiratory diseases. However, death figures are in many cases inflated by a "harvesting" effect where influenza merely hastens the death of already sick individuals by other causes [7].

Many cities in the United States were able to postpone or reduce the virulence of the influenza by implementing public health interventions, such as closure of public places as schools, churches, and theaters, banning of mass gatherings, mandate mask wearing, case isolation, and disinfection/hygiene measures [8]. There are no indications of public health interventions to reduce the impact of the influenza in Denmark. Two hypotheses are tested in this project. The first hypothesis tests that the Danish population's escape of the deadliest virus in the twentieth century is due to the levels of mortality already achieved by this Scandinavian country in certain ages and causes of death before the 1918 pandemic. Secondly, we will test the hypothesis that a cohort effect of previous exposure to a similar influenza improved the Danish young adults' immunity against the H1N1 virus.

The purpose of the current study is to examine the reasons why Denmark experienced low excess mortality compared to other countries. We compare the Danish mortality patterns with those of countries with available accurate data. For a more detailed analysis of causes of death, Denmark is compared to Norway and Sweden. The latter countries share many social and cultural similarities with Denmark and were also neutral countries during the years of World War I, before the 1918 pandemic.

The Avian flu outbreaks in the early years of the 21st century [9] have caused great concern among health specialists and decision makers into the threatening situation of a new flu pandemic [10]. Revising our knowledge of the influenza pandemic of 1918 could help us prevent future pandemics by understanding the contributing factors for the relatively low mortality in Denmark in 1918.

The following parts of this manuscript presents in Section 2 data and applied methods. Section 3 presents a period and cohort comparison of mortality and the decomposition of life expectancy by age and cause. Finally, section 4 brings a discussion of the findings.

2. Data and methods

Data from the Human Mortality Database (HMD) [11] was used for the overall mortality analysis. The influenza was particularly virulent for young adults between 15 and 50 years of age. Cohort information on mortality is analyzed to identify exposure to previous influenzas, which could have created special immunity in the population. All countries with available data in period format for the years 1916-1921 – i.e. around the year of the 1918 influenza pandemic – were used. As well as data in cohort format data for Danes, Swedes and Norwegians born between the years of 1868 and 1903 – i.e. the cohorts that were between age 15 and 50 in the 1918 – were included in the analysis.

Data on causes of death derives from the Ministry of Health and the National Statistical Offices in Denmark [12], Norway [13] and Sweden [14]. Age and cause-specific data for the three countries were obtained for the years 1917 and 1918. Although, the age-groups differed in each country this limitation was avoided by comparing aggregate level data of life expectancies. Norwegian data was, however, only available for the total population. For comparison purposes data on females and males from Denmark and Sweden were aggregated and the cause of death analysis is carried out for the total population. Two causes of death were selected for the comparison across countries and time, namely influenza and tuberculosis. The latter cause of death was termed as “Phthisis pulmonum” in Denmark, “Lungetuberkulose” in Norway, and “Tuberkulos (därav lungsot)” in Sweden.

To analyze the impact by causes of death to the change in life expectancy at birth we use a new decomposition technique developed by Beltrán-Sánchez, Preston and Canudas-Romo [15]. Two broad research approaches are employed in this technique: “cause-deleted” life tables and cause-decomposition to changes in life expectancy.

Let a dot over a variable denote the derivative with respect to time. Assuming that the radix of the survival function be 1, $\ell(0,t)=1$, the change over time in life expectancy is calculated as:

$$\dot{e}^o(t)=\int_0^{\omega}\dot{\ell}(a,t)da \tag{1}$$

where, $e^o(t)$ is the life expectancy at birth at time *t*. If there are *n* independent causes of death under study then the survival function can be seen as the product of all the cause specific survival functions: $\ell(a,t)=\ell^1(a,t)\ell^2(a,t)\cdots\ell^n(a,t)$, and equation (1) is simply:

$$\dot{e}^o(t)=\sum_{i=1}^{n}\int_0^{\omega}\dot{\ell}^i(a,t)\ell^{-i}(a,t)da \tag{2}$$

where $\ell^i(a,t)$ and $\ell^{-i}(a,t)$ are the probabilities of surviving from birth to age a at time t when only cause of death i and all other causes $-i$ were operating.

3. Results

3.1. Period analysis.
The mortality in the HMD countries in the years around the 1918 pandemic is summarized by their life expectancies in 1917, 1918 and 1919.

[Table 1]

As shown in Table 1, there is a dramatic increase in mortality for all examined countries. In Italy we find an extreme with 19 years of life expectancy lost for females. By 1919 most of the countries had recovered to the mortality level of 1917. In 1917 Denmark is holding the fifth position in the ranking of the highest life expectancies, for both males and females. Nevertheless, in 1918 the four countries which had higher life expectancies, New Zealand (non-Maori), Sweden, Norway and Iceland, reached levels below 56.25, i.e. level of Denmark in that year. The declines in life expectancy for countries that were at higher levels than the Danish and the small excess mortality observed in the latter country is evident when comparing the Danish life expectancy trend with that of the record life expectancy as shown in Figure 1.

[Figure 1]

In Figure 1 we see that in the years before and after the influenza there is on average a difference of 5 years between the highest life expectancy and the Danish levels. However, no country surpasses the Danish life expectancy in 1918. Furthermore, as shown in Table 1 the change in life expectancy between 1917 and 1918 is smaller in Denmark than in any other place of the world.

Denmark has higher infant and child mortality than in other examined countries in all examined years. However, it is precisely among the young adults that Denmark seems to be doing the best by holding most of the lowest age-specific death rates from ages 15 to 50. It should be remembered that the influenza of 1918 was particularly virulent for these ages. Figure 2a and 2b show the lowest age-specific death rates in 1918 for countries with available data.

[Figure 2a and 2b]

Included in Figure 2 are the numbers of lowest age-specific death rates in the range between age 15 and 50 for each country. Most of the lowest death rates in this year are found in Denmark. A stronger effect is observed among males, 18 female records versus 31 for males. Nevertheless, the mortality at younger ages was lower in New Zealand and Iceland for females and males, respectively.

Was this differential in mortality between Denmark and the rest of the world present years before 1918 or was it a unique performance of the pandemic year? The next section compares the age-specific death rates for cohorts that were present in 1918. The remaining of the analysis focuses on three countries: Denmark, Norway and Sweden. These countries, together with New Zealand and Iceland, were among the top 5 life expectancies in the world. The latter two have, however, been excluded from the rest of the analysis. In New Zealand, as in the rest of the southern hemisphere, flu epidemics are lagged by some months [16]. Unless more detailed mortality information is available, e.g. death counts by week/month for all the countries, this lagged effect makes difficult to draw comparisons across hemispheres. Another impediment is that we would need to control for cultural and social differences. Iceland had in 1918 a total population of over 91,000 persons. For some age groups, the small numbers of deaths caused mortality rates to be very erratic and difficult to compare with other countries.

3.2. Cohort analysis.

Similar to Figure 2, Figures 3a and 3b are Lexis surfaces[1] comparing the cohort age-specific death rates for Denmark, Norway and Sweden. The cohorts included are those born between 1868 and 1903 who where between age 15 and 50 in 1918, and the years included are from 1868 to 1918. For each combination of age and year, there is a colored square identifying the country that had the lowest age-specific death rate.

[Figure 3a and 3b]

Figures 3a and 3b show similar trends over time and ages with a clear predominance of the Danish lowest death rates. However, there seems to be a cutting point when this Danish predominance begun. It is timed around the last great pandemic of the nineteenth century, which occurred between 1889 and 1894, called the “Asian flu” [17]. This suggests that the Danish population was already prepared for experiencing the low mortality in 1918. The impact is seen even when infant mortality, which has a big toll in summary measures as life expectancy, was not the lowest in these years. The excess infant mortality partially explains why life expectancy in the years before the flu was lower in Denmark than in other countries. However, in the year of 1918 the high levels of mortality at ages 15 to 50 in countries other than Denmark counterbalance the higher Danish infant mortality.

Is it a cohort effect of previous exposure to a similar influenza that left the Danish young adults with some immunity against the H1N1 virus? This hypothesis seems unlikely given that the influenza of 1890 also was present in other northern European countries and the United States [17]. Thus, the same effect should have been observed there. Another option is a selection effect where the Danish excess mortality in the years around 1890 only let a group of very healthy young people survive. This second hypothesis is contradicted by the low mortality predominance among the young Danes also seen for the cohorts born after the 1890 flu (see Figure 3a and 3b).

Is the pattern observed in Denmark due to a particular low cause of death rate among respiratory diseases? The next section addresses this question by analyzing the information on cause of death for the three selected Scandinavian countries.

3.3. Cause of death analysis.

Figure 4a and 4b present the age distribution of the proportions of deaths by influenza and tuberculosis (TB) respect to all causes observed in 1917 and 1918. The common age-pattern of these proportions in the three populations is remarkable. However, in Norway we observe less proportional deaths of influenza than the other two countries (not shown). The peak proportion of more than 70% of the deaths in 1918 is reached

---

[1] A Lexis surface is a simple graphical presentation used by demographers to observe age-specific rates. The surface includes years in the horizontal axis and in the vertical axis the ages in observation. Each row shows levels across year (period) for people within a given age. Each column reveals age variation in a year. The diagonals permit tracking single birth cohorts over time.

in the age groups 20 to 34 (see Figure 4b). Opposing this result is Figure 4a with proportions of deaths by these causes at around 50% for 1917, although similar age pattern. TB accounts for the great majority of the deaths in 1917 in all three countries as opposed to less than half in 1918.

[Figure 4a and 4b]

To disentangle the impact by these two diseases on the change in life expectancy from 1917 to 1918 we apply the decomposition technique outlined in equation (2). Table 2 shows the cause-decomposition for the three countries. An additional benefit of this technique is to obtain the cause-eliminated life expectancy, which is included in Table 2.

[Table 2]

The cause-eliminated analysis shows that the Danish population lost 1 year of life expectancy from 1917 to 1918, as opposed to 7.5 years in Norway and 9.1 years in Sweden. From these numbers of years lost, 4.6, 5.5 and 8.8 are due to influenza and TB, respectively. For Norway and Sweden the contribution by other causes of death further reduces the life expectancy, although in a negligible way. In Denmark, the other causes of death increases life expectancy by 3.5 years, thus, opposing the damaging effect of influenza and TB. This finding supports the "harvesting hypothesis" where influenza merely hastens the death of already sick individuals by other causes [7], creating a competing risk situation of excess deaths assigned to influenza and TB. More detailed data on other causes of death is needed to test this hypothesis. However, the cause of death decomposition also shows the strong effect of the low Danish mortality level already described in the period and cohort analysis. In other words, the small increase in mortality by influenza or by any other cause of death is partially explained by the already observed low mortality respect to other countries. Figure 5a and 5b show the life table distribution of deaths due to influenza and tuberculosis, and other causes for Denmark, Norway, and Sweden in 1918. The two Figures present the same finding – only the order of the stacked causes of death is reversed.

[Figure 5a and 5b]

Except for the high infant mortality and the higher mortality after age 50, the lowest life table death counts by influenza and TB, and by any other cause of death are found in Denmark. This emphasizes the relevance of the mortality level and not only the cause-specific examination.

4. Discussion

The advances in molecular biology have lead to isolation of most of the influenza viruses that have occurred during the twentieth century, particularly the deadly virus of 1918 [18-19]. It is by far the best strategy to pursue proper vaccination for prevention of future pandemics. Concerning the creation of vaccinations, the World Health Organization comments "Vaccines are considered the first line of defense for reducing the excess morbidity and mortality that invariably accompany pandemics. For several reasons, no country will have adequate supplies of vaccine at the start of a pandemic and for many months thereafter. Large-scale commercial vaccine production is not expected to commence until about three to six months following the emergence of a pandemic virus" [20]. In a matter of weeks the 1918 influenza virus covered most of Europe [21]. If a new virus with a similar diffusion and virulence power as the H1N1 virus of 1918 was to appear it could lead to a great number of human loses. Particularly, if vaccinations would take as long to be created as warned by WHO. Alternative prevention strategies should be developed to delay the virus, for example studying the country with the lowest excess mortality.

What made Denmark a special case of high survival among the young adults in 1918? Results from this study suggest the important effect of the level of mortality already present in the Danish population as opposed to other countries. The low mortality levels observed in Denmark are crucial in 1918 because they correspond to the ages where the 1918 pandemic hit the hardest, that is 15-50. If a new influenza pandemic was arrived now the number of lowest age-specific death rates would be less of a predictor among countries of low mortality. For example, based on the data from HMD for 2005 the Netherlands, Sweden and Switzerland would observe the least problems. Nevertheless the great differential in mortality will likely be between all these countries with low mortality and countries with high mortality. In other words; the rich versus the poor countries [3].

How was the low Danish mortality level attained? This remains to be studied, but here we have shown that the strong impact by the "Asian-flu" around 1890s should be carefully studied. This study also demonstrated the cause-decomposition analysis as a tool for understanding which causes of death affected the low impact in Denmark. The facts that made Denmark a successful case, in terms of the lowest excess mortality, could help prevent avoidable deaths in future influenza pandemics.

References

1. J.S. Oxford, R. Lambkin, A. Elliot, R. Daniels, A. Sefton, D. Gill. (2006). Scientific lessons from the first influenza pandemic of the 20th century. *Vaccine* 24 (44-46).

2. J. Oeppen, J.W. Vaupel. (2002). Broken Limits to Life Expectancy. *Science* 296(5570): 1029 – 1031.

3. C. Murray, A. Lopez, B. Chin, D. Feehan, K. Hill. (2006). Estimation of potential global pandemic influenza mortality on the basis of vital registry data from the 1918–20 pandemic: a quantitative analysis. *The Lancet* 368 (9554): 2211-2218.

4. A.H. Reid, J.K. Taubenberger, T.G. Fanning . (2001). The 1918 Spanish influenza integrating history and biology. *Microbes and Infection* 3: 81-87.

5. A. Noymer, M. Garenne. (2000) .The 1918 Influenza Epidemic's Effects on Sex Differentials in Mortality in the United States**.** *Population and Development Review* 26(3): 565-581

6. M.C. J. Bootsma, N.M. Ferguson. (2007). The effect of public health measures on the 1918 influenza pandemic in U.S. cities. PNAS 104 (18): 7588-7593

7. J. Dushoff, J.B. Plotkin, C. Viboud, D.J.D. Earn, L. Simonsen. (2006). Mortality due to influenza in the United States—An annualized regression approach using multiple-cause mortality data. American Journal of Epidemiology 163:181–187.

8. R.J. Hatchett , C.E. Mecher, M. Lipsitch**.** (2007). Public health interventions and epidemic intensity during the 1918 influenza pandemic. PNAS 104 (18): 7582-7587.

9. WHO. (2006). Cumulative number of confirmed human cases of avian influenza A (H5N1) reported by WHO.

10. The White House. (2006). Statement on US pledge of $334 million in global fight against bird flu. Washington, D.C.

11. Human Mortality Database (1/29/2008). University of California, Berkeley and Max Planck Institute for Demographic Research, www.mortality.org.

12. Sundhedsstyrelsens Medicinalstatistiske Kontor (1918-1919). *Dødsaarsagerne, Kongeriget Danmarks Byer, I Aaret* (1917-1918). Kjøbenhavn.

13. Utgitt Av Det Statistiske CentralByrå (1921,1922). *Statistisk Årbok for Kongeriket Norge* (1919,1921). Kristiania (Oslo).

14. Sveriges Officiella Statistik, Folkmängden och dess Förändringar (1917-1918). *Dödsorsaker År (1917-1918), Av Kungl. Statistiska CentralByrån*. Stockholm.

15. H. Beltrán-Sánchez, S.H. Preston and V. Canudas-Romo. (2008). "An Integrated Approach to Cause-of-Death Analysis: Cause-Deleted Life Tables and Decompositions of Life Expectancy." Presented at the PAA 2008 conference held in New Orleans.

16. Viboud, C., P.-Y. Boëlle, K. Pakdaman, F. Carrat, A-J. Valleron. (2004). "Influenza Epidemics in the United States, France, and Australia, 1972–1997." *Emerging Infectious Diseases* [Available at http://www.cdc.gov/ncidod/EID/vol10no1/02-0705.htm.]

17. Jordan, E.O. (1927). *Epidemic Influenza; a Survey*. Chicago, American Medical Association: 599 p.

18. Taubenberger, J.K., A.H. Reid, R.M. Lourens, R. Wang, G. Jin & T.G. Fanning. (2005). "Characterization of the 1918 influenza virus polymerase genes." Nature 437: 889 – 893.

19. Tumpey, T.M., C.F. Basler, P.V. Aguilar, H. Zeng, A. Solórzano, D.E. Swayne, N.J. Cox, J.M. Katz, J.K. Taubenberger, P. Palese, A. García-Sastre. (2005). "Characterization of the Reconstructed 1918 Spanish Influenza Pandemic Virus." *Science* 310(5745): 77 – 80.

20. WHO. (2005). Vaccine research and development: current status. Epidemic and Pandemic Alert and Response (EPR). Available at:
http://www.who.int/csr/disease/avian_influenza/vaccineresearch2005_11_3/en/index.html

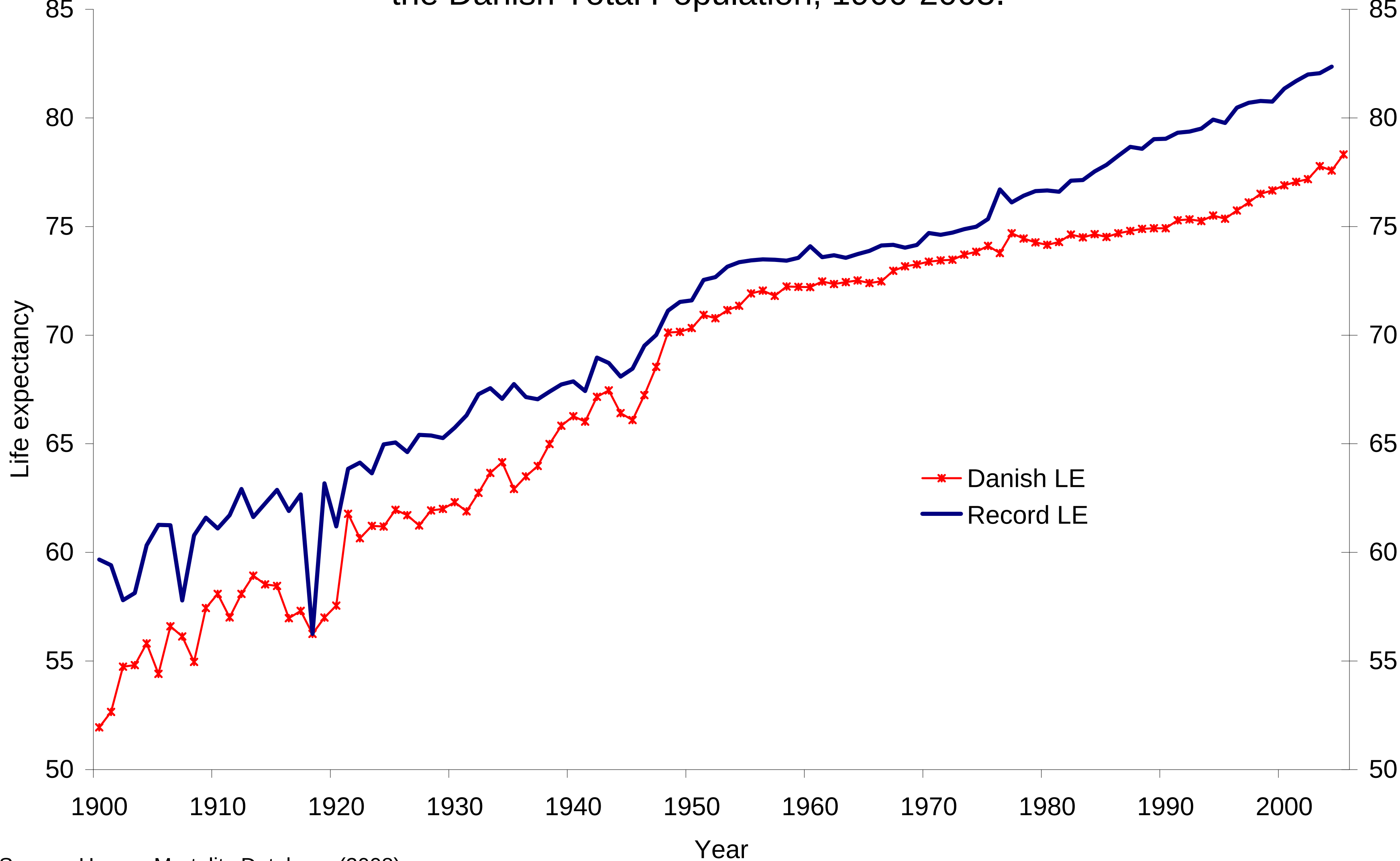
21. Patterson, K.D., G.F. PYLE. (1991). "The Geography and Mortality of the 1918 Influenza Pandemic." *Bulletin of the history of medicine* 65(1): 4-21

Table 1. Period life expectancy at birth in 1917, 1918 and 1919 and the difference between 1917 and 1918, and life expectancy in 1918 and 1919, for countries with available data.

Country	Females			Males			Difference in life expectancy			
	Period life expectancy			Period life expectancy			e(1918)-e(1917)		e(1919)-e(1918)	
	1917	1918	1919	1917	1918	1919	Female	Male	Female	Male
Denmark	58.5	57.3	57.8	56.0	55.2	56.2	-1.2	-0.9	0.5	1.0
England&Wales	57.2	50.3	56.6	37.2	33.4	51.5	-7.0	-3.8	6.4	18.1
Finland	48.3	43.6	45.6	44.7	26.3	40.6	-4.7	-18.3	2.0	14.3
France	52.0	43.0	50.8	35.6	28.4	44.3	-9.0	-7.2	7.8	16.0
Iceland	61.5	52.7	60.4	56.4	49.4	56.4	-8.8	-7.0	7.7	7.0
Italy	47.5	28.4	45.6	45.8	29.7	43.9	-19.1	-16.1	17.2	14.3
The Netherlands	56.7	48.6	55.8	54.6	46.6	54.2	-8.1	-8.0	7.2	7.5
New Zealand	64.2	57.4	64.9	61.3	50.6	61.7	-6.8	-10.6	7.5	11.1
Norway	59.3	52.1	58.1	56.1	48.6	55.5	-7.3	-7.5	6.0	6.9
Spain	43.5	30.7	42.3	41.6	29.8	39.9	-12.8	-11.8	11.6	10.1
Sweden	60.1	51.4	58.0	57.6	48.2	55.1	-8.7	-9.4	6.6	6.9
Switzerland	57.4	49.0	56.0	54.1	43.8	53.8	-8.5	-10.3	7.0	10.0

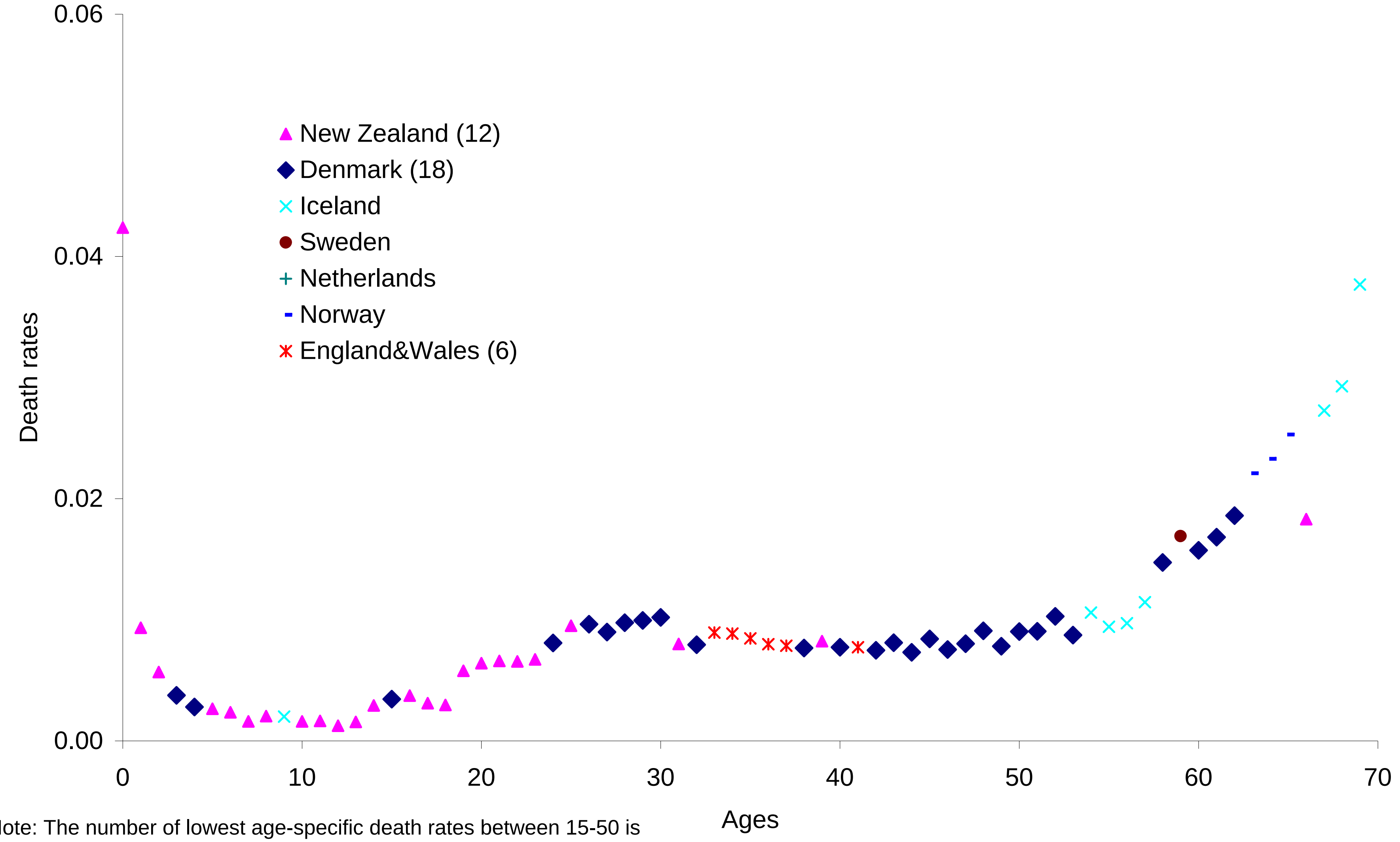
source: Human Mortality Database (2008)

Figure 1. Record Life Expectancy at Birth and Life Expectancy at Birth for the Danish Total Population, 1900-2005.



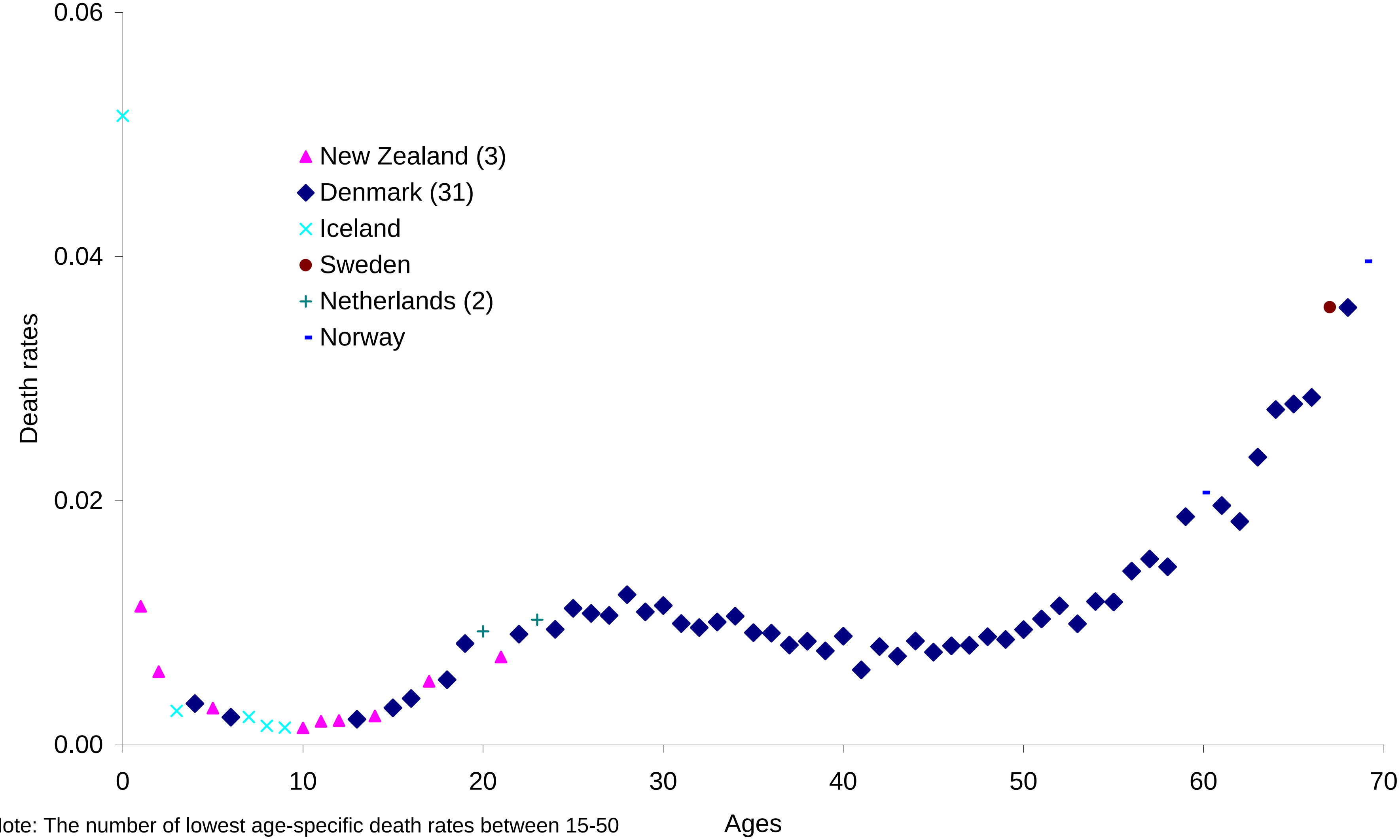
Source: Human Mortality Database (2008)

Figure 2a. Lowest age-specific death rates for females from countries with available data from 1918, ages 0 to 70.



Note: The number of lowest age-specific death rates between 15-50 is indicated in the parenthesis. Source: Human Mortality Database (2008).

Figure 2b. Lowest age-specific death rates for males from countries with available data from 1918, ages 0 to 70.



Note: The number of lowest age-specific death rates between 15-50 is indicated in the parenthesis. Source: Human Mortality Database

Figure 3a. Lexis map of the lowest females age-specific death rates in Denmark, Norway and Sweden for cohorts born between 1868 and 1903, from 1868 to 1918.

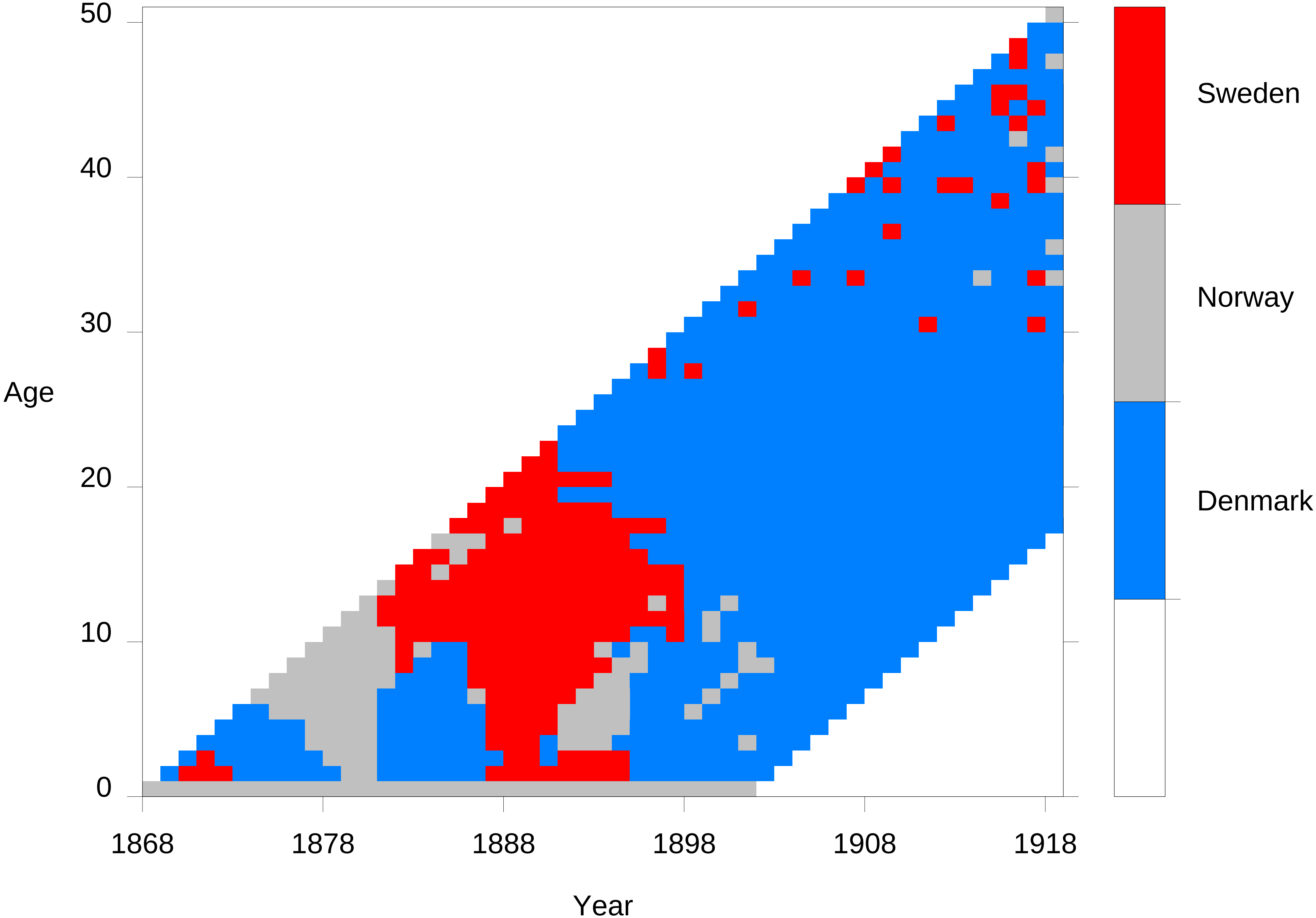


Figure 3b. Lexis map of the lowest male age-specific death rates in Denmark, Norway and Sweden for cohorts born between 1868 and 1903, from 1868 to 1918.

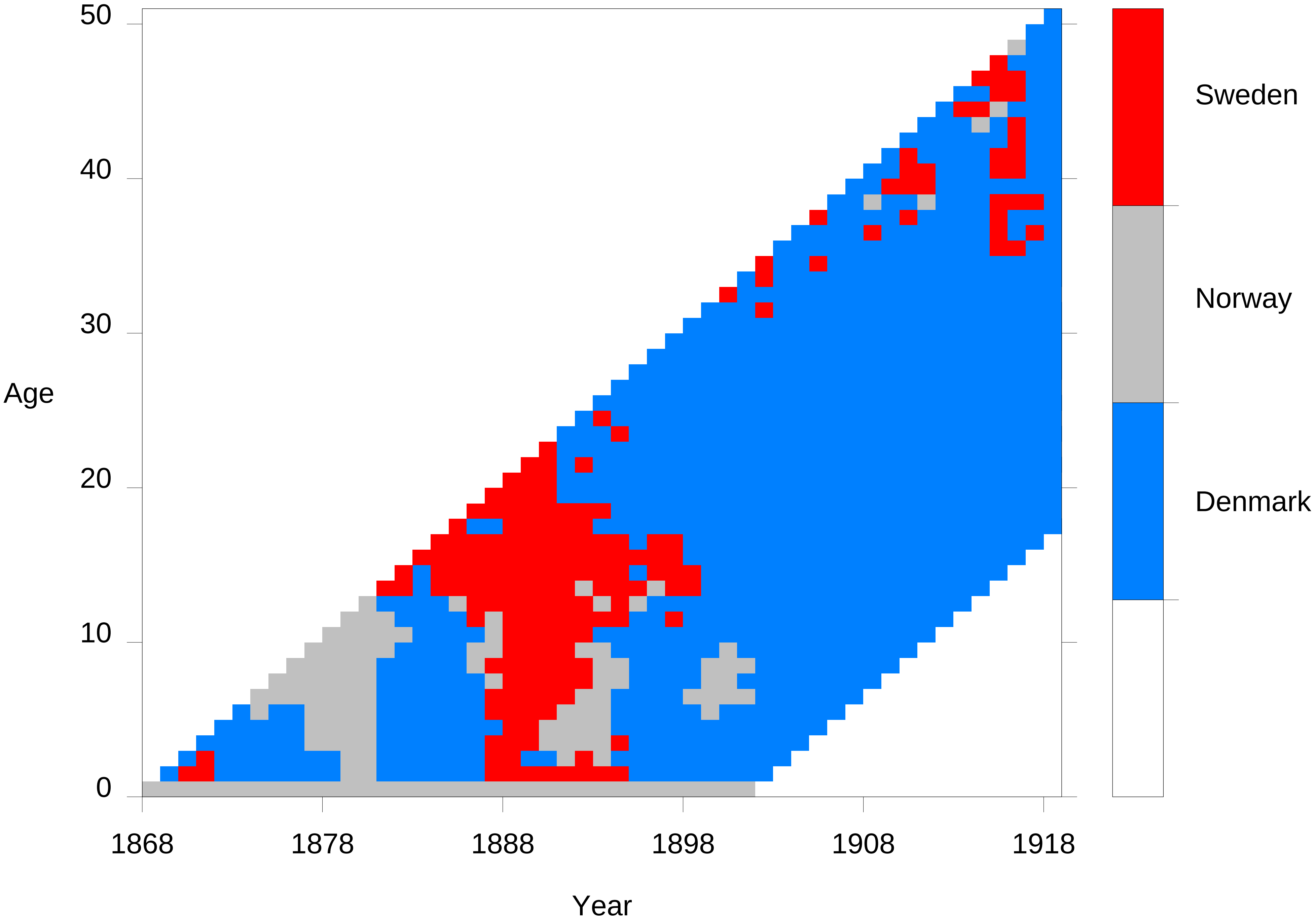
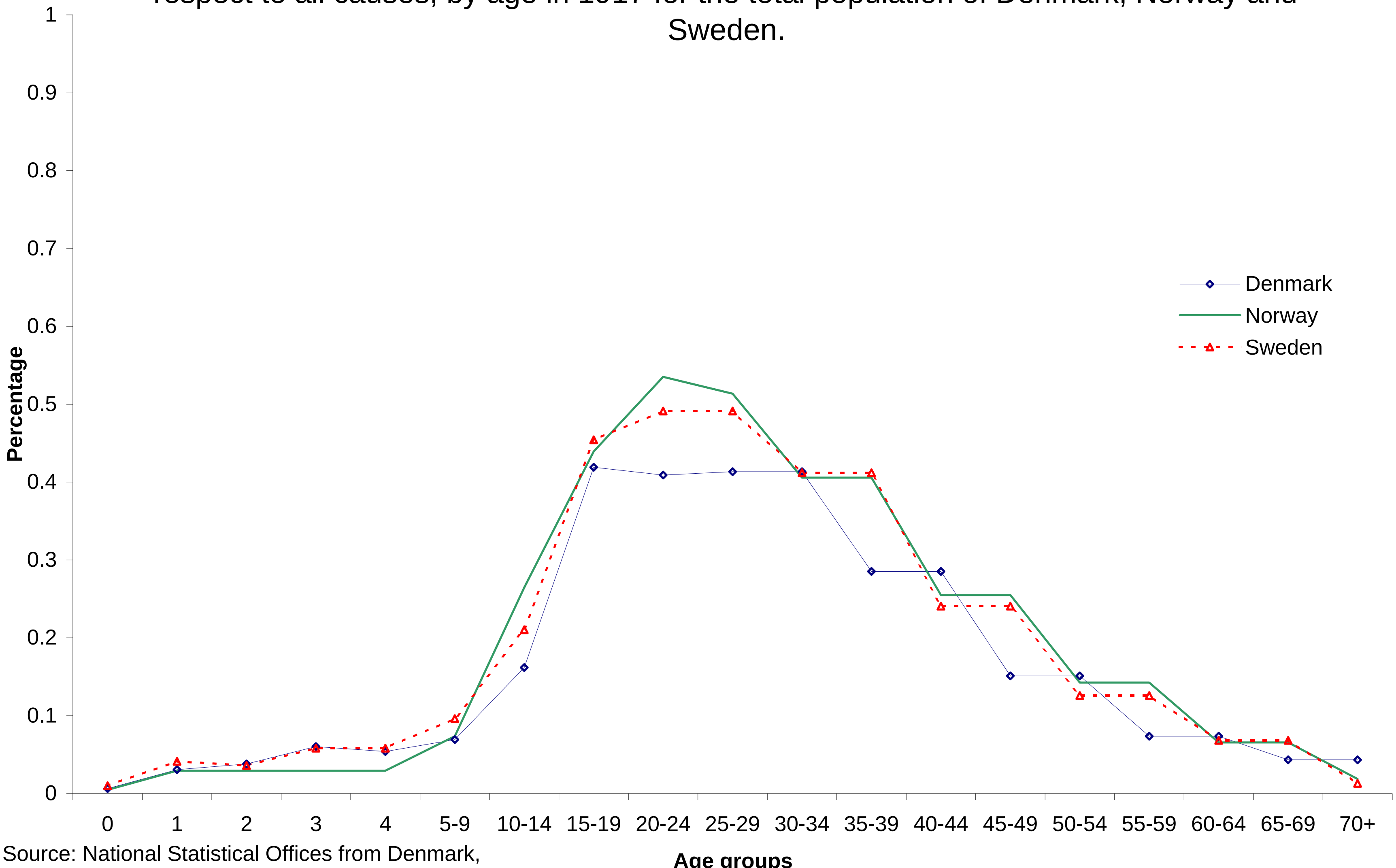
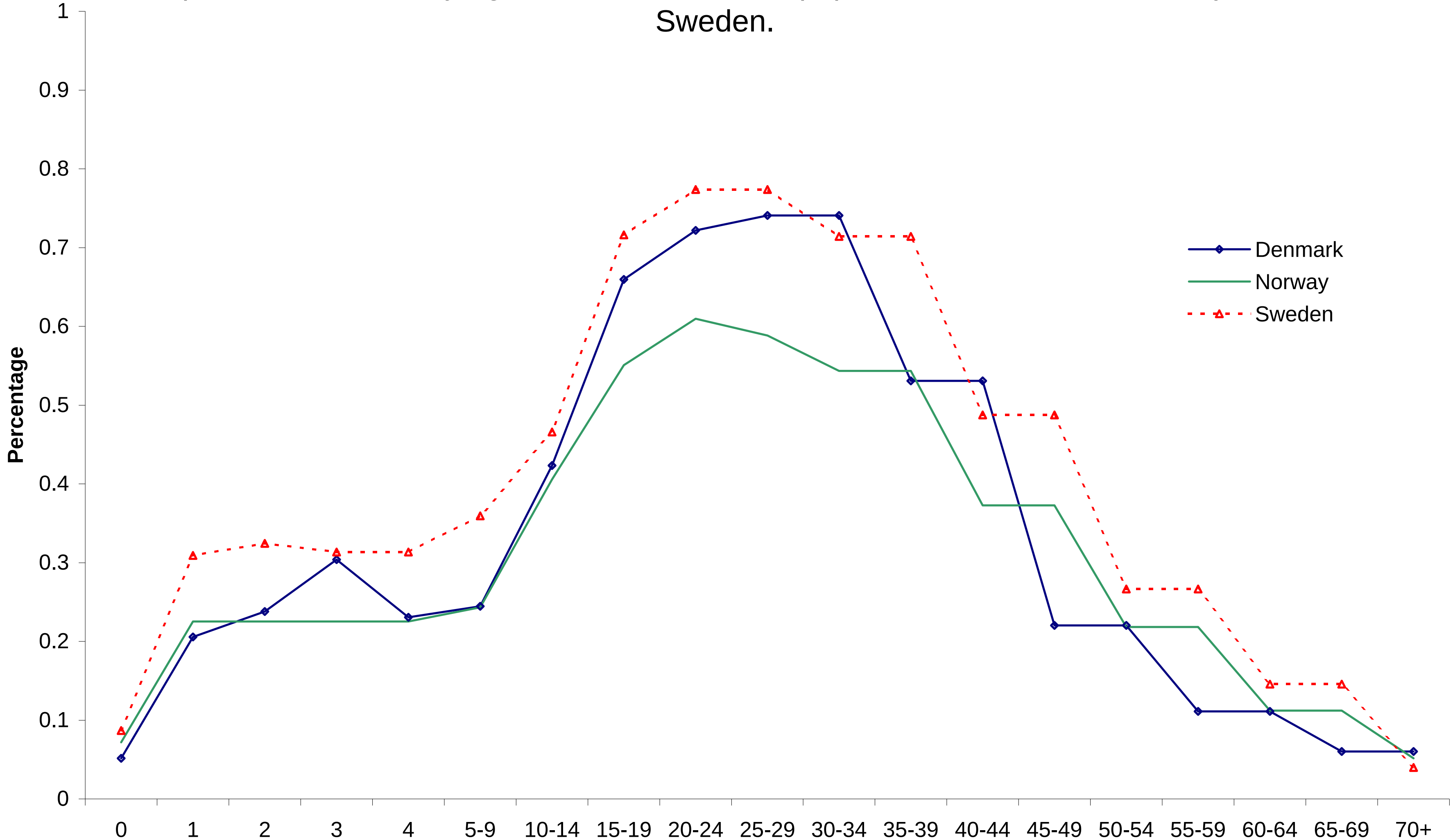


Figure 4a. Age distribution of the proportions of deaths by influenza and tuberculosis respect to all causes, by age in 1917 for the total population of Denmark, Norway and Sweden.



Source: National Statistical Offices from Denmark, Norway and Sweden [12-14].

Figure 4b. Age distribution of the proportions of deaths by influenza and tuberculosis respect to all causes by age in 1918 for the total population of Denmark, Norway and Sweden.



Source: National Statistical Offices from Denmark, Norway and Sweden [12-14].

Table 2. Life expectancy, LE, the influenza&Tuberculosis, F&TB, contribution to changes in LE and F&TB-eliminated LE for Denmark, Norway and Sweden in 1917 and 1918.

	Year of 1917		
	observed e0	Cause Eliminated e0	Difference
Denmark	57.31	59.80	2.49
Norway	57.75	61.91	4.16
Sweden	58.90	62.40	3.50

	Year of 1918		
	observed e0	Cause Eliminated e0	Difference
Denmark	56.25	63.79	7.54
Norway	50.30	59.55	9.25
Sweden	49.81	61.98	12.17

	Difference in LE(1918)-LE(1917)		
	difference in LE	due to F&TB	due to other causes
Denmark	-1.06	-4.57	3.52
Norway	-7.45	-5.47	-1.98
Sweden	-9.09	-8.75	-0.35

Figure 5a. Life table distribution of deaths of influenza and tuberculosis (F&TB) and other causes (Other) by age for Denmark (DK), Norway (NOR) and Sweden (SWE) in 1918.

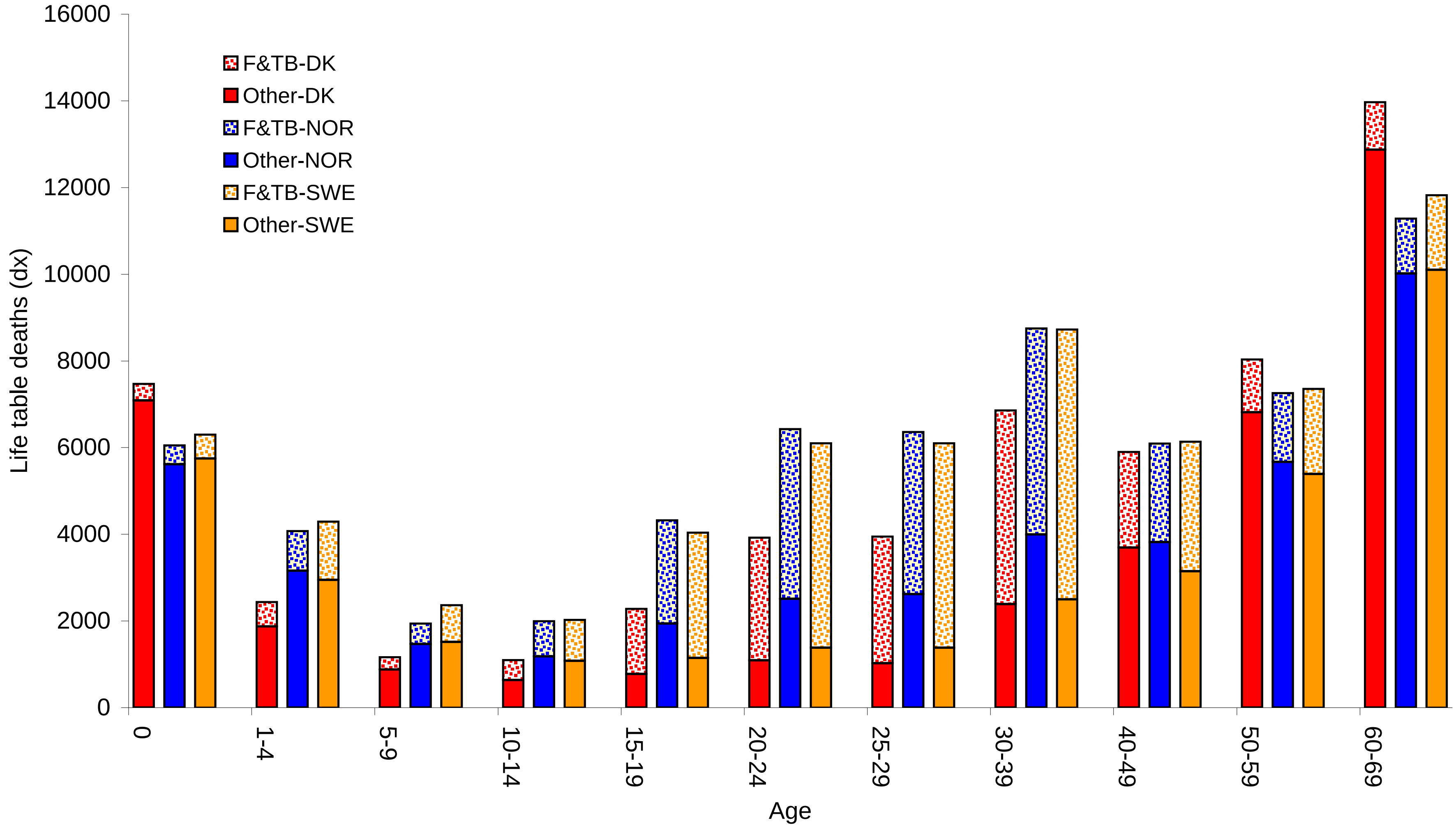


Figure 5a. Life table distribution of deaths of influenza and tuberculosis (F&TB) and other causes (Other) by age for Denmark (DK), Norway (NOR) and Sweden (SWE) in 1918.