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Mortality and Life Expectancy in Rendalen and Norway 1770–1900: Period and Cohort Perspectives

Svenn–Erik Mamelund

Introduction

The purpose of this paper is twofold. First, life tables for both men and women born between 1770 and 1900 in Rendalen, Norway will be established. Secondly, mortality and life expectancy in Rendalen will be compared to the mortality and life expectancy in Norway as a whole. Both period and cohort mortality will be analysed. The parish of Rendalen is situated in the deanery of Østerdalen, in an interior location in Eastern Norway, next to the Swedish border. It was a farming district, producing cereal and cattle, and well endowed with forests, hunting ground, and fishing lakes.

A previous study has shown that mortality was relatively low in the 18th and 19th centuries Rendalen (Sogner 1979). This probably makes the parish extra sensitive to the onset of the mortality decline in the first demographic transition. Several studies on regional 18th- and 19th century period mortality have been carried out in Norway. This is the very first time, however, that cohort mortality is analysed on a parish level.

Previous research and methodology

In the following, different methods estimating life expectancy in the 18th and 19th centuries will be presented. Special emphasis will be given to each method’s demand for data, and to how deaths, populations at risk and life expectancy are estimated. Some substantive
findings from studies of Europe in general, and Norway in particular, will also be presented. I will refer to five different methods: i) indirect estimation, ii) intercensal interpolation, iii) inverse projection, iv) back projection, and v) family reconstitution.

Preston and Bennett (1983) developed a technique that permits estimating adult mortality and life expectancies without vital statistics and standard life table functions, i.e. an indirect estimation technique. The data needed are age distributions and age-specific growth rates between two points in time, for instance two successive censuses not widely separated in time. The method assumes a closed population. This method was originally designed for developing countries with imperfect or no vital statistics, but it can also be used on historical populations. Cachinero-Sanchez (1985) and Letzner (1985), who applied the Preston–Bennett method to estimate levels of life expectancy in Spain and in England and Wales in the 18th and 19th centuries respectively, are examples of this. Dopico (1987), on the other hand, having parish registers of baptisms and burials available in addition to censuses (1860, 1877), estimated national mortality tables for Spain in the 1860s using the Princeton tables developed by Coale and Demeny (1966). Average life expectancy of Spaniards in the 1860s was 29.8 years, considerably lower than in other parts of Western Europe, such as England, France, Holland, or the Scandinavian countries.

Lee et al. (1995) calculated life tables for rural Liaoning, China, for sixteen intercensal periods between 1792 and 1867. Death rates were calculated following intercensal five-year age cohorts. Life expectancy at birth could not be calculated, but was, using Coale-Demenys model life–tables, estimated to be in the high twenties for women and in the low thirties for men. Life expectancy at birth in rural Liaoning at the turn of the 19th century is comparable to what was experienced in France at the same time. According to Blayo (1975), life expectancy at birth in France in the periods 1770–1779 and 1780–1789 was 28.8 and 27.5 years for males and 29.6 and 28.1 years for females respectively.

Another estimation technique, inverse projection, developed by Lee (1974), requires an estimate of the age distribution at a starting point in time, and is based on the assumption of complete registration of births and deaths and no net migration. Inverse projection allows estimating both period and cohort mortality, and the method can be used either forward or backward in time. In his study, Lee estimated life expectancy for both sexes combined for 5-year-periods and cohorts in Clayton, a parish in Devon, England 1545-1834, and in
England and Wales 1701–1841. Cohorts born in Clayton 1770–1774 and 1775–1780 had on average lived 40.1 and 43.8 years respectively. For England and Wales, cohorts born 1771–1780 and 1781–1785 had on average lived 34.9 and 36.3 years respectively. Cohort life expectancy was higher than expected at birth for the four cohorts considered. According to Wrigley and Schofield (1981), applying a modified version of inverse projection, a back projection, life expectancy at birth for both sexes combined in England were 36.3 years 1750–1775, 37.0 years 1775–1800, and 41.5 years 1800–1825. Their procedure started with the 1871 census, a population whose size and age structures are well known, and they then worked their way back to 1541 using Coale–Demeny’s North models of mortality. In back projections, as opposed to inverse projections, no assumptions about closure and reliability of births and deaths are needed.

In addition to Lee (1974), Liu (1995) is the only one known to me who has calculated life expectancy for cohorts on a low geographical level in the 18th and 19th centuries. This was done using genealogical records for five lineage populations from South China. The genealogical record does not, however, give adequate data to estimate life expectancies for other than adult males (age 20+). Life expectancies at age 20–24 for male cohorts born 1748–1797 and 1798–1822 was 39.7 and 37.0 years respectively.

Several studies on national and regional 18th- and 19th century period mortality in Norway have been carried out. National cohort mortality (1846–1994) has been analysed by Mamelund and Borgan (1996), applying data from vital registration systems and censuses, and the standard life table functions. In the period 1846–1900, national life expectancy at birth increased from 46.4 to 51.8 years for men and from 49.6 to 55.1 years for women. All but a few cohorts (1854: only women, 1858, 1860, 1879 and 1880) born in this period have lived longer on average than expected when they were born. In his pioneering study, Sundt (1855) estimated period life expectancy (1821–1850) at different geographic levels based on vital statistics and the three censuses of 1825, 1835 and 1845. National life expectancy at birth 1821–1830, 1831–1840 and 1841–1850 was estimated to 45.0, 41.8 and 44.5 years for men, and 48.0, 45.6 and 47.9 years for women (Ibid). Drake (1969) has analysed national and regional mortality in the period 1735–1865, but only death rates are presented. Sognen (1979) has estimated period life expectancy at birth (1775–1794) for both sexes for five inland and five coastal deaneries in the diocese of Akershus. She found that mortality was higher in the coastal areas compared to inland regions for all ages and for both sexes. Inland
male life expectancy at birth was 44 years, while the same figure for the coastal deaneries was 30 years. The corresponding figure for females was 47 and 34 years respectively. According to Sogner, the coastal male mortality is comparable to 18th century European mortality where the typical pattern was that only half of the male cohorts survived to their 20th birthday. In the same study, Sogner also gives estimates for life expectancy for Rendalen, the parish of particular interest in this paper. In her study of Rendalen, nominative material, parish registers of burials and the method of family reconstitution (hereafter also nick-named the three-step method) are applied. Life expectancy at birth for both sexes combined 1733–1780 and 1781–1828 was estimated to 41.4 and 48.5 years respectively. The population at risk in Rendalen was estimated following three steps. First, the number of children under the age of 15 is estimated using family reconstitution. Secondly, the adult and married or widowed population is estimated (men 40+, women 35+). Thirdly, the young and the adult and married population at risk are put together to construct a complete life table applying Coale–Demeny’s model life tables.

Methods and materials

The censuses and parish registers
Data on population at risk by age and sex are from the eleven censuses of 1769, 1801, 1815, 1825, 1835, 1845, 1855, 1865, 1875, 1891 and 1900 (see footnotes 1–11 in Table 1). Population de jure is enumerated in the censuses from 1801 to 1865, while both de jure and de facto populations are enumerated in the censuses thereafter (Det statistiske Centralbureau 1882, Dyrvik 1983). According to Kær (1900) and Statistik sentralbyrå (1982), the population in Rendalen 1875, 1891 and 1900 was 3 362, 3 529 and 3 772 respectively. The Norwegian Historical Data Centre (RHD), on the other hand, gives a total population in the same censuses of 3 530, 3 539 and 3 974. The most obvious explanation of the difference between these figures (5.0, 0.3 and 6.7 per cent respectively) is that the first two sources give de jure population while the latter one give de facto population. Why is this a relevant problem here? Why not use de jure population for the three last censuses to make them comparable to the pre-1875–censuses? The answer to this question is not as definitive and simple as it seems. First, according to Dyrvik (1983), vague definitions on de jure population in the censuses from 1801 to 1865 probably resulted in different regional enumeration practices. As a result, a person away from home at the time of the census can have been counted twice, both at the
place where he/she was presently staying and at home, or not counted at all. Secondly, data given by RHD, which is presented by one year age groups, is needed (as we will see later on) to make the age distributions in the censuses comparable. As it is impossible to find out how consequent the enumerators in Rendalen were to enumerate de facto and de jure populations, I assume that it will not make much difference for the analysis if I use de jure populations up to 1875 and de facto populations thereafter.

Table 1. Age intervals in the censuses 1769-1900.

<table>
<thead>
<tr>
<th></th>
<th>1769<em>1801</em></th>
<th>1815*</th>
<th>1825*</th>
<th>1835*</th>
<th>1845*</th>
<th>1855*</th>
<th>1865*</th>
<th>1875*</th>
<th>1891*</th>
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</tr>
</thead>
<tbody>
<tr>
<td>0-7</td>
<td>0-7</td>
<td>0-9</td>
<td>0</td>
<td>0</td>
<td>0-4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0-4</td>
<td>0</td>
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<tr>
<td>8-15</td>
<td>8-15</td>
<td>10-19</td>
<td>1-2</td>
<td>1-2</td>
<td>5-9</td>
<td>5-9</td>
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<td>16-23</td>
<td>16-31</td>
<td>20-29</td>
<td>3-4</td>
<td>3-4</td>
<td>10-14</td>
<td>10-14</td>
<td>15-19</td>
<td>15-19</td>
<td>30-44</td>
<td>30-44</td>
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<tr>
<td>24-31</td>
<td>32-47</td>
<td>30-39</td>
<td>5-9</td>
<td>5-9</td>
<td>15-19</td>
<td>15-19</td>
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<td>30-44</td>
</tr>
<tr>
<td>48+</td>
<td>80+</td>
<td>60-69</td>
<td>30-39</td>
<td>30-39</td>
<td>30-39</td>
<td>30-39</td>
<td>90+</td>
<td>90+</td>
<td>90+</td>
<td>90+</td>
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<td>60-89</td>
<td>70-99</td>
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<td>70-79</td>
<td>60-64</td>
<td>60-64</td>
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<td>100+</td>
<td>100+</td>
<td>100+</td>
<td>100+</td>
<td>100+</td>
<td>100+</td>
</tr>
</tbody>
</table>

Sources:
1 Statistisk sentralbyrå (1980): Norges første folketelling 1769. NOS B 106, table 1, page 120.
2, 8, 9, 11 Data from these nominal censuses are calculated for one-year age groups, and are available at the home page of the Norwegian Historical Data Centre, University of Tromsø (http://www.hv.uio.no/seksjon/rhd).
3 Fjerde Departement (1815), Den Norske Rigstidende 1815, NO. 19.
4 Holst (1827), Finansdepartementet (1825).
Intercensal populations at risk are calculated in the following way: First, age structures of the populations at risk are made comparable as the eleven censuses have different age intervals (Table 1). This has been done for the censuses of 1769, 1815, 1825, 1835, 1845, 1855 and 1891 by using the average one year age distribution from the nominal censuses 1801, 1865, 1875 and 1900 (data from RHD), and available information on the age structures from the estimated censuses. Secondly, population by age and sex is calculated for each calendar year between the censuses using linear interpolation following cohorts. This method does not capture people born between censuses, and the oldest individuals cannot be found in the proceeding census. The latter group is small, however, both in absolute and relative terms. This problem can be solved for the intercensal cohorts by looking at data on intercensal births (baptisms) taken from parish registers. The birth cohorts in question can be linearly interpolated if followed to the next census. Older cohorts can be interpolated if we follow rows (period) in a population at risk matrix for one age group to the last interpolated age group (same as the former age group) that are part of the last cohort followed between two censuses.

By using linear interpolation, I assume constant intercensal mortality and net migration. This can give a false impression of stable population growth. The assumption is problematic if a demographic crisis occurs, and will be particularly wrong if mortality is sex or age dependent. Children under the age of 10 (high mortality) and people in mid-life (high mobility) are probably most at risk of being wrongly estimated in linear interpolations compared to actual population.

Data on deaths: parish registers and annual population statistics
There are two sources supplying data on mortality in Rendalen, the annual population statistics presented by Statistics Norway, and parish registers of burials presented by vicars in Rendalen. The former is, however, based on the latter. In this paper, however, only parish registers of burials are used (5 473 burials 1734–1900).
Table 2. Burials and deaths in Rendalen 1866–1900.

<table>
<thead>
<tr>
<th></th>
<th>1866</th>
<th>1867</th>
<th>1868</th>
<th>1869</th>
<th>1870</th>
<th>1871</th>
<th>1872</th>
<th>1873</th>
<th>1874</th>
<th>1875</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burials (A)</td>
<td>34</td>
<td>43</td>
<td>62</td>
<td>35</td>
<td>41</td>
<td>47</td>
<td>33</td>
<td>33</td>
<td>64</td>
<td>67</td>
</tr>
<tr>
<td>Deaths (B)</td>
<td>35</td>
<td>44</td>
<td>60</td>
<td>39</td>
<td>45</td>
<td>46</td>
<td>29</td>
<td>38</td>
<td>62</td>
<td>69</td>
</tr>
<tr>
<td>Diff A - B (Abs.)</td>
<td>-1</td>
<td>-1</td>
<td>2</td>
<td>-4</td>
<td>-4</td>
<td>1</td>
<td>4</td>
<td>-5</td>
<td>2</td>
<td>-2</td>
</tr>
<tr>
<td>Diff A - B (%)</td>
<td>-2,9</td>
<td>-2,2</td>
<td>3,3</td>
<td>-10,3</td>
<td>-8,9</td>
<td>2,2</td>
<td>13,8</td>
<td>-13,2</td>
<td>3,2</td>
<td></td>
</tr>
</tbody>
</table>

II.

<table>
<thead>
<tr>
<th></th>
<th>1856–65</th>
<th>1881–85</th>
<th>1876–90</th>
<th>1886–90</th>
<th>1891–95</th>
<th>1896–00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burials (A)</td>
<td>373</td>
<td>253</td>
<td>665</td>
<td>201</td>
<td>279</td>
<td>184</td>
</tr>
<tr>
<td>Deaths (B)</td>
<td>367</td>
<td>250</td>
<td>644</td>
<td>192</td>
<td>279</td>
<td>162</td>
</tr>
<tr>
<td>Diff A - B (Abs.)</td>
<td>6</td>
<td>3</td>
<td>21</td>
<td>9</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>Diff A - B (%)</td>
<td>1,6</td>
<td>1,2</td>
<td>3,2</td>
<td>4,7</td>
<td>0,0</td>
<td>13,5</td>
</tr>
</tbody>
</table>

Sources: Parish registers of burials for Rendalen, Departementet for det indre (1869a, b), Det statistiske Centralbureau (1889, 1897, 1902, 1905).

Annual mortality statistics are available only from 1866 and onwards, but parish registers go all the way back to 1734. Mortality data from the annual population statistics are based on reported deaths, while parish registers are based on the number of burials. If vicars only give date of burial, and not date of death, it can be difficult to decide whether a death should be registered in year t, in year t-1 or year t+1. It is, however, likely that this problem is levelled out over time as an over-registration of burials at the start of a year could be balanced by an under-registration of burials at the end of the same year. This problem was nevertheless intensified in Rendalen as frozen ground made burials impossible during the coldest winter months (Søgner 1979). Under-registration of burials compared to reported deaths could also occur if corpses were not found, or if a person died far away from Rendalen. Over-registration can similarly occur if a vicar wrongly reported a stillbirth as a death of an infant. A difference between burials and deaths can also occur as a result of misreporting of deaths in the annual population statistics. The largest gap between the number of reported deaths according to annual population statistics, and the number of reported burials according to parish registers, was 14 per cent in the period 1866–1900 (Table 2).
Age definitions and age estimations

In the censuses of 1801 and 1865, age is defined as age at next birthday. This age definition is not correct for our purpose. What is needed is age of each individual at the time of the census. In order to correct this, one year is subtracted from every person’s age in the two censuses in question. In the censuses of 1875 and 1900, only year of birth is given for each person enumerated. Age in this case is calculated comparing year of census and year of birth of each enumerated individual.

The problem of age heaping, that is the preference for ages ending in 0 and 5, is reasonable if we look at the average age structure of the censuses 1801, 1865, 1875 and 1900. The digit preference is, however, as measured by Whipple’s index, larger for men than for women, 110 and 102 respectively. According to UN-tables, these scores for men and women are considered to be “fairly” and “highly” accurate, respectively (Newell 1988). The reliability of age data used to distribute the population in all censuses to one-year age groups must then, said to be good.

Average age- and sex-distribution in the actual census is applied to estimate age and sex if these variables are unknown. The same procedure is followed if sex and/or age are unknown for deceased taken from parish registers. Annual sex ratio at birth (baptism) is used to estimate sex in cases where sex is not given in the parish registers. If age is given for deaths among persons under one year in parish registers of burials, this information is used even though date of death (if given) minus date of birth (if given) indicates that a particular person is older than one year. For deceased that are older than one year according to parish registers of burials, date of death minus date of birth is considered the most correct age. This estimation of age is done under the assumption that parents with infants are quite accurate about their baby’s age, and that reported age of an older person is rougher. We should, however, keep in mind that date of birth could be incorrect, although this might happen more often for date of death than for date of birth. If only year of birth is given, date of birth is set at mid-year, that is 30th of June. Likewise, if only month of birth (and year) is given, date of birth is set at mid-month, i.e. 15th of the month. Exact age at death, the age definition needed to calculate life tables, and not age at the end of each calendar year, is calculated when I have information on both dates of birth and date of death. If only age at death is given in parish registers of burials, it is assumed that this is exact age of death.
Life table functions

Standard life table functions (see Newell 1988) are applied to construct life expectancy for periods and cohorts in Rendalen. In calculations of age specific probabilities of death, estimates on average proportion of the period lived by those who die in the period, is needed. This proportion is set at 0.5 for all ages except for those under two years. I have used estimates from Mamelund and Borgan (1996) from the period 1846–1925 on the proportion of deaths that occur in the year after birth, which occur before the first birthday (0.67), and the proportion of deaths that occur in the second year after birth, which occur before the second birthday (0.60). If one does not take into account that those who die during infancy live shorter than half a year on average, life expectancy at birth will be too high, and expectation of life of a 1-year-old too low. This correction is especially important if infant and child mortality is high, as was usually observed in the 18th – and 19th centuries Europe.

Maximum age in the life tables is set at 99 years. This means that I am able to follow cohorts born between 1770 and 1801 from cradle to grave. For cohorts that are almost extinct at the beginning of the twentieth century, it is possible to estimate cohort mortality using period mortality. This can be done by extrapolating cohort mortality from the last observed period mortality. In this paper this means the year 1900. For several reasons, this is not carried out. First, we know from experience that life expectancy has increased considerably in Norway in the twentieth century, by 23.7 years to 75.5 (1997) for men, and by 25.9 years to 81.0 years (1997) for women. An estimate of cohort mortality 1802–1900 based on constant 1900 period mortality in Rendalen would therefore be particularly wrong, probably not for the oldest cohorts, but certainly for the youngest. Secondly, if data on mortality for twentieth century Rendalen was available and ready for analysis, which is not the case today, data on observed cohort mortality in Rendalen should have been employed. As a consequence, cohort mortality in Rendalen 1802–1900 has been estimated in the following way: First, 1900 period mortality in Rendalen was held constant to 1921 for women and to 1925 for men. This was done to let the national mortality catch up with Rendalens lead in low mortality. Secondly, observed national period mortality from Mamelund and Borgan (1996) was applied to estimate cohort mortality in Rendalen after 1921 for women and 1925 for men. Mortality among cohorts born 1802–1825 will end up reasonably close to the actual cohort mortality if the oldest old only experienced minor improvements in
mortality in the period 1901–1925, as was the case for the national population (Mamelund and Borgan 1996). The youngest cohorts will of course have the highest risk of being wrongly estimated as cohort mortality in Rendalen approaches the national period mortality.

To display the general trend of the long-term development of life expectancy and other mortality variables, I will present both raw and graduated curves in the figures. In the graduated figures, I have used a 21-term moving average with coefficients from Hoem (1995).^3

Results

Period mortality
Total mortality
The crude death rates (and total deaths) in Rendalen and Norway 1735–1900 are influenced by large random variation (Figure 1a). The high mortality in Rendalen 1742 and 1773 was caused by a combination of scarcity of food, epidemics (dysentery) and general distress (Sogner 1979). In 1742, CDR in Rendalen and Norway was at the same high level, but in 1773, Rendalen experienced almost three times higher CDR than the national total. In 1893, relatively high mortality in Rendalen was probably caused by a measles-epidemic, which led to frequent complications, especially pneumonia. In the graduated curves of CDRO (crude death rate in observed populations) in figure 1b, it is shown that CDRO is lower in Rendalen compared to Norway throughout the period considered, but from 1807 and onwards, the difference decreased.

Figure 1a. Deaths in Rendalen, and crude death rate (CDR) in Rendalen and Norway 1735-1900.
The first demographic transition in Norway and Rendalen, according to figure 1b, may have started as early as in 1768 and 1771 respectively, as CDRO constantly fell until 1798 in Norway and until 1786 in Rendalen. The crisis mortality of 1773 has, however, a large influence on the results in Rendalen. If CDRO in 1773 is replaced by an average of CDRO in 1772 and 1774, the onset of the decline in CDRO is 1766, not 1771 (Figure 1b). However, if criteria of non-reversal after onset of the mortality decline are introduced, the start of the first demographic transition in Norway and Rendalen is 39 and 49 years later, in 1807 and in 1815 respectively. Before 1807, the annual average difference in CDRO between Rendalen and Norway was 6.2 deaths per 1,000 (CDRO in 1773 for Rendalen included). After 1807, this difference was reduced to four deaths per 1,000 as Norway experienced a steeper fall in mortality compared to Rendalen (Figure 1b). However, in the second half of the 18th century (1773 excluded for Rendalen) and in the 19th century as a whole, Rendalen followed more or less the same fluctuations in CDRO as in the national total.

Figure 1b. Graduated (sex specific) crude death rates in observed populations (SCDRO): Timing of the first demographic transition in Rendalen and Norway.
In Figure 1b, graduated SCDRO (crude sex-specific death rates for observed populations) in Rendalen 1770–1900 and Norway 1846–1900 are also presented (excluding the crisis of 1773 for Rendalen). Four features are worth noticing. First, SCDRO for women are lower than the SCDRO for men in both Norway and Rendalen. This is not true, however, for Rendalen before 1780 and after 1850. Secondly, male SCDRO increases 1770–1800, while the opposite is the case for the female SCDRO. Both sexes apparently experienced an increase in mortality around the napoleonic–wars in the first years of the 19th century. Fourth, after 1815 both male and female SCDRO in Rendalen declined continually, but females experienced stagnation in the years between 1825 and 1835.

Figure 2. Graduated sex-specific crude death rate in stable populations (SCDRS): Timing of the first demographic transition in Rendalen and Norway.¹

In Figure 2, sex–specific death rates for stationary populations (SCDRS), excluding the crisis of 1773 in Rendalen) are presented, as different age-sex structures (over time and space) will influence the crude sex-specific death rates for actual populations.² The SCDRS–curve for women is more or less constantly falling 1770–1900, while the SCDRS–curve for men increased in the period 1770–1813, and it is not until after 1813 that it has a continually falling trend. As a result of steeper fall in male SCDRS compared to female SCDRS in

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¹ Source: Bundi 1859, Statistik Norway 1995, Marenlund and Bogan 1996
² The 1773 crisis in Rendalen = (SCDRS 1772 + SCDRS 1774 / 2)
the years 1820–1850, male–female difference in mortality is reduced to nearly zero in Rendalen. After 1850, a more or less parallel decline in SCDRS is seen for both sexes. In Norway, sex differences in CDRS are more or less unchanged 1821–1900. If Figures 1b and 2 are compared, the difference in SCDRO between Rendalen and Norway is less than the corresponding difference in SCDRS. This means that some of the difference in SCDRO is explained by a difference in age structures.

Age–sex specific death rates

The graduated age specific death rates of men and women younger than 20 years (Figures 10 and 11) and older than 60 years (Figures 12 and 13) in Rendalen 1770–1900, show several interesting features. First, the death rates of 0-year old girls continually decline from 1770 to 1870, from 400 to 80 deaths per 1 000. The corresponding death rate for boys falls from 1770 to 1785, but thereafter it slowly increases until 1815. After 1815, a marked decline, which ends in 1860, sets in. In this period, the death rate of 0-year old boys declines from 307 to 116 deaths per 1000. The increase in mortality among men seen in figures 1a and 2 (1770–1800), was particularly evident among the 1-year olds (and as seen in figure 12, also for men 85–89 years). The trend for other males under 20 years (1770–1900), is a constant or a declining development in a wave-like form. The same is also true for women under 20 years (Figure 11). The death rates of men 85–89 years slowly decline in a wave like form throughout the 19th century (figure 12). The wave like development (slowly declining or constant death rates) is also present for the corresponding age group for women, and to a lesser degree for the other five-year age groups between 60 and 79 years (Figures 12 and 13). The wave-like development in the death rates of the oldest old might be explained by a selection effect, whereby frail individuals die while the healthiest live on. In figures 14 and 15, graduated age-specific death rates for men and women for each single year from 1770 to 1900 are presented. Both figures show a distinct u-shape, with high death rates among infants and young children, and high death rates among the oldest old. Figures 14 and 15 also show that death rates of 0-year olds 1770–1900 declined more for girls than for boys, and that death rates of 85–89 year olds declined more for men than for women (this is consistent with figure 12 and 13). Another feature that is observed in figures 14 and 15, is that death rate of men older than 50 years declined dramatically from 1890 to
1900. The same is also observed for women between 50 and 64 years. A third observation of figures 14 and 15 is that mortality for men and women in the period 1770-1783 declined for most age groups (crisis of 1773 included).

In Figure 16, male to female mortality in Rendalen 1770-1900 is presented for selected age groups. The figure shows that male mortality is higher than that for females in most age groups, particularly in the age-group 10–14 years (1820–1840: 8:1 deaths, peak 1832. 1810–1850: 16:11 deaths) and 20–24 years (1845–1885: 31:15 deaths, peak 1866. 1878–1885:14:10 deaths). The large difference in the age group 20–24 might be due to tuberculosis, which especially hit men in their twenties (Munthe 1990), and occupational accidents. The reporting of cause-specific mortality in the parish registers of burials in Rendalen 1770–1900 is poor, but if one looks at deaths that are given a cause, approximately 14 per cent are due to accidents (9 percentage drowned). Most of these deaths are related to the log industry, which was probably totally male dominated. High male mortality compared to female mortality was also particularly evident for 20–24 year olds in the national total 1846–1900 (Mamelund and Borgan 1996). In the age-groups 25–49 year, i.e. the reproductive years, females experienced a significant number of years with high mortality compared to men.

Development in life expectancy
If the 1773-crisis is included, life expectancy at birth for men increased by 18 years to 63 years in the period 1770–1900 (Figure 3). In the same 130 years, life expectancy at birth for women increased by 28 years to 63 years. If the 1773-crisis is replaced by an average of mortality in 1772 and 1774, as was done above for the CDR, the increase in life expectancy 1770–1900 is less for both sexes, but particularly for men, as life expectancy declined by 11 years 1770–1800. In the period 1821/30–1900 on a national level, life expectancy for men and women increased by seven and eight years to 52 and 56 years respectively (figure 3). In Figure 3, life expectancy in Norway at birth for both sexes combined 1770–1820 is included (estimated by inverse projection by Brunborg (1976, 1992)). It shows that life expectancy was lower in Norway compared to Rendalen in the whole period 1770–1900 (as was expected when Figure 1b is considered). The increase in life expectancy for both sexes combined, was 18 years to 56 years in Norway 1770–1900. The improvement in mortality in Rendalen and Norway followed more or less the same pattern 1846–1900 (Figure 3).
Figure 3. Graduated life expectancy at birth, both sexes Rendalen and Norway 1770-1900.¹

![Graph showing life expectancy trends for Rendalen and Norway from 1770 to 1900.]

¹For Norway 1770-1820, \( e_0 \) is estimated for both sexes combined by Borgen (1976, 1992) using a modified inverse projection developed by Law (1974). Data 1821-1840 is from Burch (1885), and data 1846-1900 is from Mømshøj and Borgan (1992).

Figure 4. Expectation of life (ex) for men in Rendalen 1770-1900 at selected ages.

![Graph showing life expectancy for men in Rendalen from 1770 to 1900 at various ages.]
Figure 5. Expectation of life ($e_x$) for women in Rendalen 1770-1900 at selected ages.

Figure 6. Age of death 25, 50 and 75 percentile for periods, Rendalen 1770-1900 and Norway 1846-1900.¹

¹ Source: Mønsted and Borgan (1896)
Figure 7. Age of death 25, 50 and 75 percentile for cohorts\textsuperscript{1}. Rendalen 1770-1900 and Norway 1846-1900.\textsuperscript{2}

Figure 8. Graduated life expectancy at birth for cohorts born in Rendalen 1770-1900.\textsuperscript{1}
Figure 9. Graduated cohort effects 1770-1900 for Rendalen and 1846-1900 for Norway.¹

Figure 10. Graduated age-specific death rates for men younger than 20 years, Rendalen 1770-1900.

Deaths per 1000
Figure 11. Graduated age-specific death rates for women younger than 20 years, Rendalen 1770-1900.

Figure 12. Graduated age-specific death rates for men older than 60 years, Rendalen 1770-1900.
Figure 13. Graduated age-specific death rates for women older than 60 years, Rendalen 1770-1900.

Deaths per 1000

Figure 14. Graduated age-specific death rates for men, Rendalen 1770-1900.¹

¹The arrows show if mortality declined or increased in a given period of time.
Figure 15. Graduated age-specific death rates for women, Rendalen 1770-1900.

The arrows show if mortality declined or increased in a given period of time.

Figure 16. Ratio of male to female mortality at selected age-groups, Rendalen 1770-1900.
Nevertheless, there were some deviations. First, the difference in female life expectancy between Rendalen and Norway was less than the corresponding difference for males. Secondly, the difference increased for both sexes from 1846 to 1860 (7.3-9.0 years for men, 6.5-8.3 years for women), decreased in the period 1860-1876 (9.0-6.4 years for men, 8.3-5.2 years for women), and increased again in the period 1876-1900 (6.4-11.5 years for men, 5.2-6.7 years for women). As noted above, men experienced larger improvements in mortality compared to women in Rendalen 1820-1850. Difference in life expectancy at birth between men and women was therefore reduced from around 10 years in 1805 to around 1.5 years in 1850. From 1850 to 1870, the difference increased to 2.7 years in favour of women, but thereafter, the sex difference was reduced to zero. On a national level, life expectancy at birth 1846-1900 was between 2.7 and 3.7 years higher for women compared to men.

As a result of high infant mortality and high mortality among children and young adults, life expectancy at birth for women was lower than expectation of life of a 20 year old woman until 1805 (Figure 5). It was not before the end of the 1840s and at the beginning of the 1860s that life expectancy at birth for women equalled or exceeded expectation of life of a 15 year- and a 10 year old girl respectively (Figure 5). As for men, life expectancy at birth for women did not clearly exceed expectation of life of a 20-year old man until after 1820 (Figure 4). From the middle of the 1830s and the beginning of the 1880s, a new-born boy could expect to live longer than 15 year- and 10 year old boys did, respectively. On a national level, life expectancy at birth (both sexes) passed expectation of life of a 10 year old (both sexes) at the end of the 19th century (Mamelund and Borgan 1996). The life expectancy at birth of boys and girls in Rendalen did not reach expectation of life of a person who had celebrated his/her first or fifth birthday in the 19th century (Figure 4 and 5). On a national level, this did not occur until after 1920 (e5), and at the end of the 1960s and the beginning of the 1970s (e1) (Mamelund and Borgan 1996).

Median age at death, the age where 50 per cent of a synthetic cohort (according to period mortality) is still alive in Rendalen, has increased from 46.8 years for males and 30.9 years for females 1770, to 74.5 and 72.6 years in 1900 respectively (Figure 6). The lower quartile, the age where a fourth of a synthetic cohort has died, increased for both sexes in Rendalen 1770-1900. The lower quartile increased in all years with the major exception of the period 1770-1805 (men) and 1760-1785.
(both sexes). According to period mortality in 1900, three out of four women would reach the age of 44.6, and three out of four men would reach the age of 54. The upper quartile, the age where only 25 per cent of a synthetic cohort are still alive, has not changed much for women in Rendalen since the beginning of the 19th century, when it reached 80 years. In 30 years, from 1770 to 1800, the upper quartile for women rose from 60 to 80 years. For men, the upper quartile did not reach 80 years before the beginning of the 1860s, that is three times slower reduction in mortality among the oldest of the old men compared to the oldest of the old women. The median, upper and lower quartiles on a national level were lower compared to Rendalen throughout the last half of the 19th century (Figure 6). One striking pattern is that the mortality differences between Rendalen and the national total diminished as the size of the hypothetical cohorts shrunk through deaths as they grew older. In other words, mortality differences among children and young adults in Rendalen and the national total are greater than the mortality differences among the older adults and the oldest old in Rendalen and in the nation as a whole.

Cohort mortality

Life expectancy at birth for cohorts born in Rendalen 1770–1900 is presented in figure 8. Women have on average lived longer than men have in the whole period except for some female cohorts born in the 1830s. Male cohort life expectancy at birth has increased by 19.6 years to 58.3 years from 1770 to 1900, while female life expectancy at birth has increased by 23.3 years to 64.1 years. Stability is the keyword for the upper quartile of women 1770–1840, which is just below 80 years (Figure 7). After 1840, it increases slowly, and passes 85 years at the end of the 19th century. Upper quartile for men increased from 60 to 80 years 1770–1880, and stabilises on 80 years thereafter. The median age at death for women and men increased from 48.2 years to 76.3 years and from 33.2 to 69.9 years, in the period 1770–1900, respectively. The median and upper quartile is higher for women compared to men throughout the period 1770–1900, except for the years around 1825 to 1840. The lower quartile does not show a clear sex-difference in Rendalen, as men lie higher in one period, women in another. As was seen for periods (Figure 7), difference in mortality between Norway and Rendalen 1846–1900 also decreased by age for cohorts.7
In Figure 9, a comparison between (graduated) period and cohort (graduated) mortality in Rendalen 1770–1900 and Norway 1846–1900 is displayed. The cohort effect is defined as the difference in cohort life expectancy at birth and the period life expectancy at birth. Of the male cohorts, those born between 1799 and 1853 and between 1866 and 1888, have experienced a positive cohort effect, that is higher average life expectancy than expected at birth. For women, cohorts born between 1770 and 1778, 1805 and 1818, and 1840 and 1900, also experienced a positive cohort effect. A negative cohort effect is probably due to high infant and child mortality. The negative cohort effect for female cohorts born 1780–1804 may for example be due to high death rates of the 1-year old and the 2–4-year old girls in this period (see Figure 11). When it comes to the nation as a whole, all cohorts born 1846–1900 have experienced a positive cohort effect (when graduated, see introduction), and from the beginning of the 1860s, the cohort effect increases, particularly for women. As a result, women gradually live longer than men based on comparison of life expectancy at birth.

Discussion...

....of some methodological issues
The three-step method (family reconstitution) Sogner (1979) used to estimate population at risk in a previous study of mortality in Rendalen, does not include the unmarried adult individuals, at least not the most mobile part of this subgroup. In addition, men between 16 and 39 years and women between 16 and 34 years are not included in the population at risk. According to Sogner, 11 per cent of the women and 19 per cent of the men stayed unmarried throughout life in Rendalen (based on a total of 1685 individuals enumerated in the 1801 census). This means that 576 persons, or 34 per cent of the total population in the 1801 census, are not included in Sogner's population at risk. Omission of these individuals will, of course, have a significant effect on the “real” age-specific mortality rates and life expectancies. This is probably so, although model life tables can be used to estimate mortality where data is imperfect or if there is a gap in the time series. Another drawback with the three-step method, correctly mentioned by Sogner, is that findings might be disturbed by the fact that married people tend to have lower mortality than unmarried people do. Life expectancy at birth for both sexes combined 1781–1821, using family
reconstitution and Coale-Demeny’s model West, level 13, was 48.5 (Sogner 1979). The corresponding life expectancy using linear interpolation following cohorts between two censuses, as presented in the present paper, is 46.5 years (50.2 for women and 43.8 for men), two years lower than Sogner’s estimate. The difference might be explained by the omission of the non-married population, which probably had higher mortality than the married one. The advantage of family reconstitution is, however, that censuses are not needed to calculate life tables. Sogner (1979) has for example calculated life expectancies in Rendalen before the first census in Norway (1733–1780) which was held in 1769.

The advantage of using linear interpolation following cohorts between two censuses, as has been carried out in this paper, is that this method covers the total population at risk, not only children under 15 years, married women above 35 years and married men above 40 years, as in the three-step method. In addition, no model–life table is needed, as all one-year age cohorts 1770–1900 are followed from one census to another or from birth to the next censuses. Lee et al. (1995) have also calculated death rates following cohorts, but as five-year age cohorts were followed, and as births between censuses was not considered, life expectancy at birth could not be given without model life tables. The method used in this paper is also a simple and straightforward method. If compared to the Preston-Bennet method, it also has the advantage that intercensal birth cohorts can be followed to the next census. The main drawback of the intercensal interpolation method, is that it requires detailed data on both deaths, births and population at risk, the two firsts variables often not available for the 18th century. The assumption of stable intercensal mortality and net migration is probably reasonable, maybe with the exception of children under the age of 10 and people in their most mobile age groups.

....of the main results
There is fair agreement that the onset of the mortality decline in Norway is 1815 (Drake 1969, Dyrvik 1979, Sogner 1979, Engelsen 1983). The peace after the napoleonic wars, the introduction and spread of potato cultivation and obligatory smallpox-vaccination in 1810, are three underlying factors behind this onset. As pointed out by Hoem (1995), however, the suggestion of the onset-year must have been given by an ocular smoothing of the raw curve of the CDR in earlier studies. The graduated curve of the CDR presented in this paper suggests
that 1807 is a more likely starting point of the first demographic transition in Norway (Figure 1b). As we have seen, a general decline in CDR may have started as early as around 1770 in both Norway and Rendalen. Drake (1969) has given 1790 as a possible turning point in mortality (in the coastal dioceses in the south-western Norway), and Dyrvik (1983) has speculated that 1815 could be the end of a process that started as early as the middle of the 18th century. The normal criteria require non-reversal after onset of the mortality decline (Hoem 1995), and mortality increased by more than 10 per cent after 1770 in both Norway and Rendalen. Because of this, the start of the first demographic transition in Norway and Rendalen cannot be said to be before 1807 and 1815 if both sexes are combined. In Rendalen, however, women experienced a continual decline from 1770 and onwards, while this did not happen for men before 1813. The decline in mortality for women may even have started before 1770, but as our time series starts in 1770, this question remains open to speculation. In most studies of the first demographic transition, CDR is presented for both sexes combined. Possible sex-differentials in the mortality decline are therefore not considered.

The only female cohorts that have experienced higher mortality than their male counterpart throughout the history of Rendalen, are those born between 1825 and 1840 (Figure 7 and 8). This pattern is not observed in the period figures (Figure 3 and 6), which must mean that this is a pure cohort-phenomena. It occurred not as a result of an increase in mortality among women, but because male cohorts, especially those born in the beginning of the 1830s, experienced a steep fall in mortality throughout life compared to their female counterpart (and neighbour male cohorts).

Sognér (1979) has explained Rendalen’s low mortality by low population densities and remoteness from sources of external infections. As epidemics usually hit the coast before the inland, and as population densities were higher along the coast compared to the inland, coastal areas experienced epidemics more frequently and intensely than the landlocked areas. The population of the inland, including Rendalen, was, however, more susceptible when exposed to epidemics. This might be the reason why Rendalen experienced three times higher mortality compared to the Norwegian national total in the crisis of 1773.

In a recent study of Rendalen, Sognér (1999) has argued that improvement in female life expectancy and a detriment in male life expectancy at the end of the 18th century and the beginning of the 19th
century, is due to forestry, a profitable, new, and partly money based industry. The forest industry brought certain affluence, but the new situation benefited women primarily, maybe to the detriment of men’s health. The new affluence may have given women the opportunity to be more housewifery and less outdoor-working, which may also have had a positive effect on their infants. A particularly marked improvement in men’s life expectancy after 1815, and a slower improvement for women, led to a lessening of sex-differentials at the end of the 19th century. The reason why females experienced higher mortality than males before 1780 is difficult to say, as data before 1770 is not available, but high maternal mortality might be the reason.

Conclusion

This paper has shown that it is important to age-standardise and graduate crude death rates in studies of the timing of the first demographic transition. It has also shown the importance to look at sex differentials in the CDR, at least on a low geographical level. The onset of the mortality decline in Rendalen started for instance more than 40 years earlier for women than for men. One interesting question is whether such sex-differentials also occurred in other parishes in Norway. A second methodological conclusion is that life expectancies might be exaggerated using family reconstitution, as the unmarried population is not included in the population at risk. The method used in this paper, intercensal interpolation following cohorts, includes the whole population at risk, also the unmarried, which tend to have higher mortality than the married (no model life-tables is thus needed). As a consequence, estimated life expectancies are lower in this paper compared to a previous study of Rendalen, which used family reconstitution (see Sogner 1979).

Other substantive findings of this paper can be summarised as follows. First, in the 18th and 19th centuries, Rendalen was a low mortality area when compared both nationally and internationally. Crisis mortality, however, was higher in Rendalen compared to the national total. The nation as a whole did not catch up Rendalens lead in low mortality before the beginning of the 1920s. Secondly, Rendalen lead in low mortality compared to the national total was most evident among children and to a lesser degree among the old and the eldest old. Thirdly, the onset of the mortality decline in the national total is 1807, eight years before the well-known year of 1815 suggested
in previous studies. If, however, the increase in mortality during the Napoleonic wars is overlooked, mortality started to decline already in 1768. This finding is in agreement with what we know from previous studies.
Notes

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2. Study included the national total, five dioceses (Christiania, Christiansand, Bergen, Trondheim and Tromsø), two deaneries (Hedemark and Gaulbrandsdalen) and three parishes (Vaage, Lom and Lesje).

3. Fleit's coefficients are optimal for a time series of 180 observations. The weights are highest for the central curve point and decrease gradually for the 10 curve points in each direction on the time scale. Except for figure 1a-b, which have 165 observations (1735-1900), I have used the coefficients on 130 observations (1770-1900). This probably has minimal impact on the results.

4. Maximum per cent reversal compared to the total mortality decline since onset is allowed. The increase in CDRO in Norway 1798-1804 (1.33 per 1 000) is 50 per cent compared to the decline in CDRO 1788-1798 (2.64 per 1 000). The increase in CDRO in Rendalen 1786-1814 (2.40 per 1 000) is 28 per cent of the decline in CDRO 1771-1786 (8.62 per 1 000). The beginning of the 1770s is thus rejected as the onset of the first demographic transition in Rendalen and Norwary if non-reversal is required (CDRO 1773 included). The increase in CDRO in Norway 1824-1834 (0.66 per 1 000) is 11.8 per cent compared to the decline in CDRO 1807-1824 (5.59 per 1 000). The increase in CDRO in Rendalen 1824-1829 (0.17 per 1 000) is 11.3 per cent of the decline in CDRO 1815-1824 (1.50 per 1 000). I do not reject 1807 and 1815 as the onset of the first demographic transition, although the reversals exceeds 10 per cent. The reason for this is that the figures hardly exceed the criteria. In addition, the long-term decline started long before 1807 and 1815.

5. In a stationary population, population is constant, i.e. the number of births equals the number of deaths, and it is no in- or out migration (or a balance between in- and out migration). The crude death rates in stationary populations are calculated by taking the inverse of life expectancy at birth (see Munthe 1990).

6. If the 1773-crisis is replaced by an average of mortality in 1772 and 1774, difference with or without the 1773-crisis is most pronounced for the median and the upper quartile.

7. The youngest cohorts in Rendalen approaches the national cohort mortality as cohort mortality in Rendalen is extrapolated by the national period mortality (see methods and materials).

8. Of the 576 persons, 270 are men 16-39 years, 42 are unmarried men 40+, 218 are women 16-34 years, and 36 are unmarried women 35+.

9. CDR of sex cannot be calculated for Norway before 1800, as deaths are not available by sex.
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