2

Literature Review

2.1 Introduction

This literature review is divided into two major parts. First, a causal chain is constructed which outlines how a change in temperature triggers certain biomedical reactions in the body, which may lead to morbidity and ultimately to mortality, and how social factors can mediate this impact. Secondly, an overview of the development of seasonal mortality over time is given. It starts with studies on Roman Egypt, and presents results from the 16^{th} to the 19^{th} century, based on family reconstitution data. Results are shown from the first studies based on census data in the middle of the 19^{th} century and, finally, points at recent development in Western countries. The Appendix starting on page 177 gives a sketch on how the literature review has been conducted methodologically.

2.2 Causal Chain

2.2.1 Introduction

The influence of the seasons on human mortality has been known since Hippocrates' seminal essay "On Airs, Waters, and Places" written more than 2000 years ago. Surprisingly, misconceptions are still commonplace. For example, in the summer of 2003, excess mortality from heat was heavily covered in the media. While the number of cold-related deaths typically receives less attention, although the latter far outnumbers the former in many countries in almost every year. It has been noted, for instance, that in Great Britain 40,000 cold-related deaths occur annually [16]. Also noteworthy is the often predicted risk of an increase of heat-related mortality due to global warming during the following decades is unlikely. "Populations in Europe [. . .] can be expected to adjust to global warming predicted for the next half century with little sustained increase in heat related mortality." [190, p. 670]. On the contrary, the number of excess deaths can even be expected to shrink. In the words of Keatinge et al: "Our data suggest that any increases in mortality due to increased temperatures would be outweighted by much larger short term declines in cold related mortalities" [190, p. 672].

Besides the timing of deaths, mistaken ideas also prevail about the causes of deaths. It is a widespread belief in the general public that deaths peak in winter because of the high suicide rate. This assumption is wrong for two reasons: suicides only make a small contribution to the overall death pattern: between one and two percent of all deaths are attributable to that cause.[1] This contribution is not enough to cause the observed differences between the seasons. Secondly, Durkheim's well-known studies in the 19^{th} century show that suicides do not peak (late) in winter but in late spring and early summer. Another cause of death often put forward to explain seasonal mortality are deaths from influenza. This might have been true for long periods of time.[2] In Western countries in recent decades, however, the influence of influenza on cold-related mortality is highly overestimated. Donaldson and Keatinge calculated that only 2.4% of all excess winter deaths during the last 10 years were directly or indirectly due to influenza [78].

This section should therefore outline which causes of deaths are responsible for the observed pattern, which biomedical reactions are happening in the body and what we do know so far to fight the annual cold-related death toll.

2.2.2 A Simple Chain of Causality for Seasonal Mortality: Biomedical Factors

A relatively naive approach would assume a very short chain of causality: the cold decreases the body temperature under a certain level below which the body ceases functioning and then dies of hypothermia. Only a very small proportion of all cold-related deaths are induced by hypothermia, though. In the year 1998, more than 2.34 million people died in the US aged 50 years or older. Only in 316 cases the stated cause of death was hypothermia. This makes it an even less likely cause of death than dying of breast cancer for men.

A view which is a bit more elaborated takes only natural/biological forces and their consequences into account. This causal chain, where climate (and most notably cold temperatures) triggers a biomedical reaction in the body which may lead to an elevated mortality risk and, ultimately, to death, is outlined in Figure 2.1. Although the detrimental influence of cold on the body is known for ages, the actual underlying mechanism is not yet fully understood. As pointed out by Bull and Morton: "The studies to this point have not established a clear chain of events leading from a change in external temperature to

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[1] All results are based on own calculations if no explicit reference is given.

[2] See, for example, Vaupel et al. (1997) where the effect of the Spanish Flu in various countries in the years 1918 and 1919 is easily visible on Lexis surface maps [388].

death. Nevertheless, it remains very likely that changes in external temperatures *cause* changes in death rates especially in the elderly" [37, p. 223]. More than 20 years have passed since this assessment and many studies on seasonal mortality have been conducted in the meantime. Yet, James Mercer and Sigurd Sparr come to the unsatisfying conclusion in their editorial to a special issue of the "International Journal of Circumpolar Health" dedicated to understanding excess winter mortality in the elderly: "The mechanisms by which seemingly mild exposure to cold ambient conditions can increase the risk of death does not seem to be much clearer today than when Bull & Morten were investigating the problem in 1978" [258, p. 152].[3] Thus, the exact mechanism can not be described here, but only the current state of knowledge.

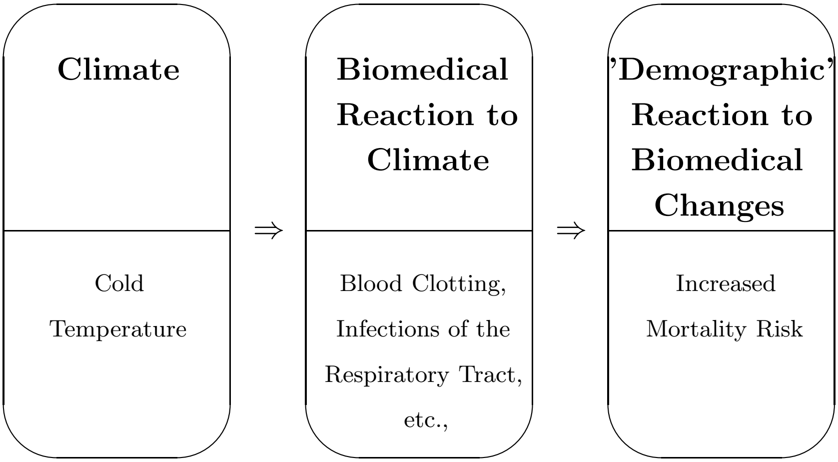


Fig. 2.1. A Simple Chain of Causality for Seasonality in Mortality

Many studies confirm the provocative judgement of Kunst et al. [209, p. 338]: "Man is a tropical animal". Lowest mortality is usually recorded when the ambient temperature is between 18° and 20°C. Despite dependencies on the geographic location ("Europe": 18°C [98], Germany: 20°C [220], Southeast England 18°C [77], Netherlands, nursing home patients: 15-19°C [232], Barcelona, Spain: 21°C [322], England and Wales [37]), the "optimal" temperature is also determined by humidity [322] and by the age of the people [57]. The World Health Organization, for example, mentions that sedentary elderly face lowest mortality risks if the temperature is 2–3°C higher. If the temperature drops below or rises above this optimal level, death becomes more likely. This increase in mortality is well-documented [e.g. 209]. The most thorough investigation in this direction is the so-called "Eurowinter" study headed by William Keatinge. Table 2.1 shows how mortality increases in percent for each 1°C fall from 18°C. Mortality in this model is lowest at 18°C, yet, there is still

[3] In this article, the name "Morten" (instead of Morton) has been misspelled in the source document.

considerable variation concerning the proportional increase in mortality with a drop in temperature.The most moderate increase in mortality is observed in southern Finland where mortality rises 0.27% for each drop of 1°C in temperature below 18°C. The steepest increase is recorded in Athens (increase higher than 2%). It should be mentioned, however, that this phenomenon can not be applied universally. In Yekaterinburg, Russia, mortality increased only at temperatures below 0°C [81], in Yakutsk (Russia), the world's coldest city, mortality was completely independent in the temperature range of 10.2°C to −48.2°C [76, 185].

Table 2.1. Increase of Mortality by Fall in Temperature in Selected European Regions

Region	Deaths per 10^6 Population (per day at 18°C)	Percent Increase in Mortality for Each 1°C Fall from 18°C
North Finland	42.8	0.29
South Finland	43.0	0.27
Baden-Württemberg	31.0	0.60
Netherlands	36.5	0.59
London	40.3	1.37
North Italy	34.3	0.51
Athens	34.4	2.15
Palermo	—	1.54

Source: Eurowinter Study 1997 [98, p. 1343]

It has already been mentioned that the often associated causes of death, influenza and suicides, play only a negligible or no role at all for the increase in mortality late in winter. The causes of deaths which are of crucial importance to explain the mortality peak in winter are cardiovascular, cerebrovascular and respiratory diseases. The latter group has the strongest seasonal pattern among all major groups of causes of death [102, 148, 319]. Aubenque et al., for example, standardized mean annual mortality in France for the years 1968–72 to an index of 100 [13]. All cause mortality varied between 120 (January) and 87 (August) whereas deaths from respiratory diseases showed a peak of 172 (January and February) and a trough of 51 in August. However, respiratory diseases are not the leading cause of death in Western developed countries [e.g. 264]. Thus, they do not the largest share to the number of excess winter deaths — despite their highly seasonal pattern. About half of the cold-related mortality can be attributed to ischaemic heart disease and cerebrovascular diseases [82, 98, 376]. If all cardiovascular diseases are included, the share of circulatory diseases increases to about 2/3 of the whole cold-related mortality based on estimates for the Netherlands in the years 1979–1987/88 [208, 235]. Consequently, research on seasonal mortality mainly focused on cardiovascular, cerebrovascular and respiratory diseases. Deaths from circulatory diseases peak usually one or two days after the peak of a cold spell; respiratory deaths rise more slowly, peaking about ten days after the peak of cold period [37, 185]. Section A.2.1 in the Appendix gives an overview which study analyzed which disease/cause of death.[4]

So far, the first and the last box in Figure 2.1 have been discussed, namely the change in temperature and the elevated mortality risks for various causes of death. The following paragraphs explain the biomedical reactions in the body caused by detrimental environmental conditions, resulting in a higher chance of dying from those aforementioned diseases. It is probably best to differentiate between the triggering effects for cardio- and cerebrovascular diseases on the one hand and for respiratory diseases on the other hand.

If respiratory diseases lead to death during winter, two effects are usually mentioned [eg. 97, 98, 169]: On the one hand, low temperatures facilitate the survival of bacteria in droplets. On the other hand, cold has adverse effects on the immune system's resistance against respiratory infections. As a result from breathing cold air, the risk for a pulmonary infection rises due to bronchoconstriction [169]. "Bronchospasm precipitated by breathing cold air is now well recognised, and the finding of inflammatory cells in sputum after breathing cold air has raised the possibility that cold air breathing might induce this by causing inflammatory changes in the airways" [97, p. 155].

Deaths due to circulatory diseases is a large group consisting of cardiovascular diseases on the one hand and cerebrovascular diseases on the other hand. Cold stress acts on the body in two ways: either on the blood vessels ("vasoconstriction" [e.g. 97, 169]) or on the composition of the blood ("haemoconcentration" [e.g. 76, 81, 98, 169, 187]). Several indicators which cause these changes in blood viscosity have been singled out: an increase in white blood cells and red blood cells [97, 169, 188], hypertension [187, 199, 322, 340, 412], platelet [97, 188], plasma fibrinogen [16, 81, 97, 169, 199, 411], and plasma cholesterol [169, 188, 322, 340] — and especially high density lipoproteins [413].

2.2.3 A More Advanced Chain of Causality for Seasonal Mortality: Social and Biological Factors

The causal model, so far, is still too simple. At this point it would be logical permitted to conclude: if cold temperatures determine excess winter deaths, then countries where a colder climate prevails have to face higher seasonal fluctuations in mortality. The opposite is true, though. Figure 2.2 shows a scatterplot based on results of the study by McKee [252]. Similar findings have been also described in [135] or [147]. On the x-axis, the minimum monthly

[4] For sure, the literature mentioned there is not a complete bibliography on cause-specific seasonal mortality among adults in developed countries during recent decades. It provides, nevertheless, a good starting point on cause-specific studies on winter excess deaths.

temperature is plotted, and the y-axis displays "Excess Winter Deaths". This "[e]xcess winter mortality was defined as the percentage by which observed deaths exceeded those which would be expected if the death rate during June to September pertained throughout the year" [252, p. 179]. A country specific scatterplot shows the paired values of the two variables for 18 Western and Central European countries for the years 1976–1984.[5] What could be observed in this graph is seemingly a seasonality paradox: the higher the minimum monthly temperature, the larger the extent in cold-related deaths as indicated by the gray dashed linear regression line.[6] Countries with relatively warm or moderate climate like Spain, Portugal, and Italy or the UK and Ireland experience much larger excess winter mortality than countries with harsh climatic conditions during winter such as Finland and Norway.

This leads to a more advanced chain of causality which is outlined in Figure 2.3. The three elements of Figure 2.1 have been preserved. Still, the triggering event is the fall in temperature; also the increased mortality risk is, finally, caused by some biomedical reactions to the cold in the body. Intervening social factors, however, play a crucial role in mediating the effects of the cold on the body — otherwise this "seasonality paradox" as depicted in Figure 2.2 would not have been possible. As Gemmell et al. [121] point out in their analysis of Scotland: "[...] the strength of this [seasonal mortality] relationship is a result of the population being unable to protect themselves adequately from the effects of temperature rather than the effects of temperature itself " (p. 274).

These intermediate factors can be alternatively also described as "man-made" influences. Most of them can be modified on the individual level. The only true exception is tackling the detrimental effects of air pollution.[7] The amount of literature giving evidence for the impact of air pollution on mortality is overwhelming as reflected in the two review essays by Tenías Burillo et al. [361] and Holland et al. [152]. The pollutant most often analyzed is particulate matter (PM) [e.g. 8, 33, 42, 137, 175, 191, 206, 282, 327, 328, 337, 364, 365, 366, 397]. Especially "fine suspended particulates, smoke and fume" (diameter of matter $< 10\mu m$) are of interest to researchers, as their "settling velocity in circulation of ambient air is negligible and [they] can be inhaled" [152, p. 534]. Sulfur dioxide (SO_2) [e.g. 42, 152, 175, 217, 327, 364, 365], nitrogen dioxide (NO_2) [e.g. 42, 361], carbon monoxide (CO) [e.g. 361, 364, 365], and ozone (O_3) [e.g. 8, 42, 329, 361] were the pollutants most frequently analyzed besides particulate matter. While high ozone concentrations are rather

[5] A more recent cross-country analysis for the years 1988–1997 is given by [147] but it has the disadvantage that fewer countries are covered and that the excess mortality measurement is more complicated. Nevertheless, the same trends are covered in both publications.

[6] Results from the linear regression of Minimum Monthly Temperature (MMT) on Excess Winter Deaths (EWD): EWD $= \alpha + \beta$ MMT are $\alpha = 7.72$, $\beta = 0.67$, $p_\beta < 0.0014$, $r^2 = 0.4502$.

[7] Another exception is the impact of "space proton flux" in seasonal mortality [359]. This effect is considered by me (R.R.) to be only of marginal importance if at all.

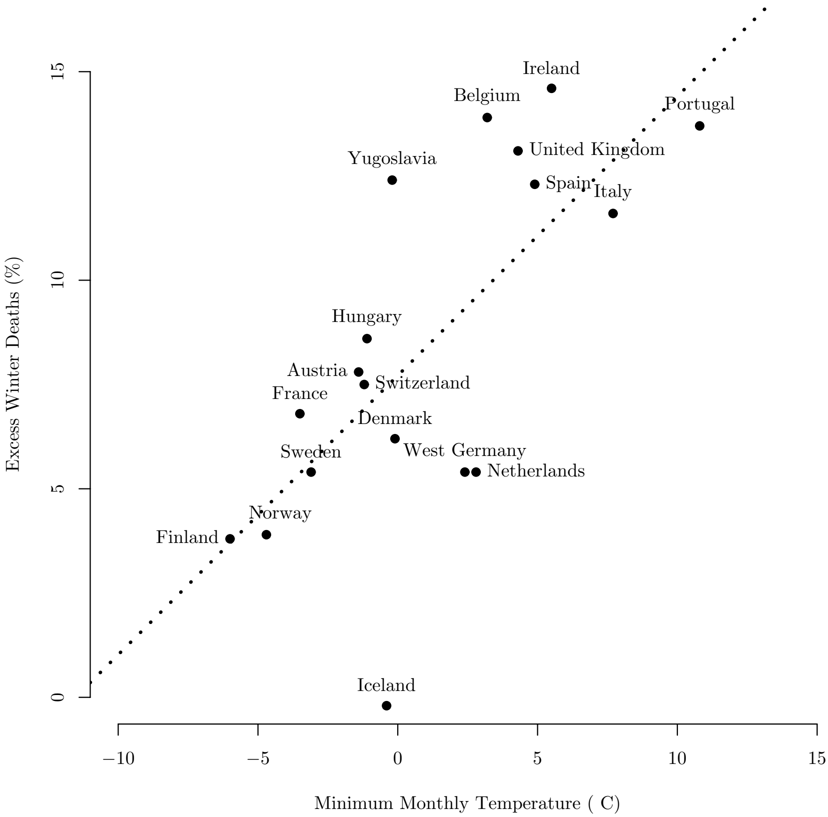


Fig. 2.2. Excess Winter Mortality in Several European Countries
Data Source: McKee 1989 [252, p. 179]

common during summer, the other substances can be labeled "winter type" air pollution [365, p. 547]. As nicely presented in Touloumi et al. [364] for SO_2, smoke and CO_2, the emission of these pollutants peaks typically in winter. The main reason for these peaks is the extensive usage of fossil fuels during the cold season for heating. The two causes of deaths which are most often associated with air pollution are also the two main causes of winter excess mortality: respiratory diseases [e.g. 33, 92, 93, 94, 137, 175, 206, 282, 328, 338, 364] and cardiovascular diseases [e.g. 33, 92, 94, 137, 175, 206, 328, 338]. The effects that "[s]mall particles penetrate deeply into sensitive parts of the lungs and can cause or worsen respiratory disease, such as emphysema and bronchitis, and aggravate existing heart disease" [92, p. 2] is questionable, though. Keat-

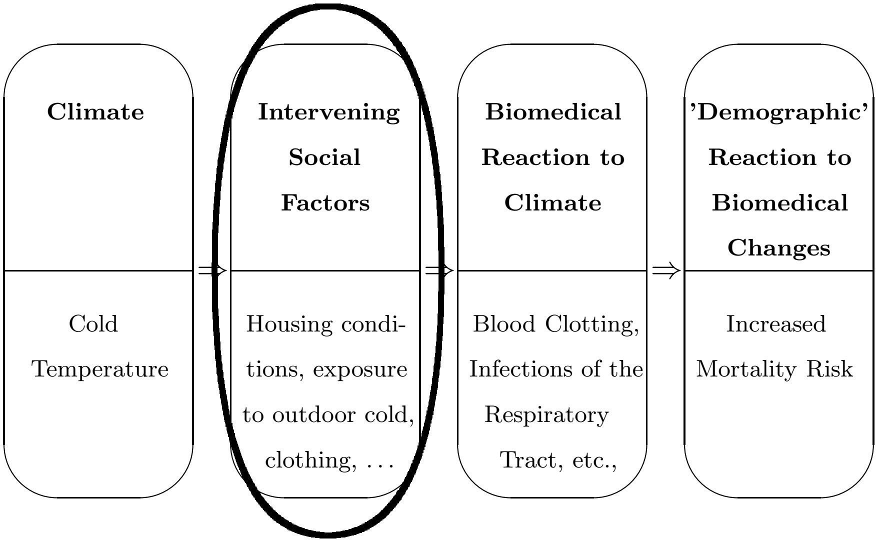


Fig. 2.3. A More Advanced Chain of Causality for Seasonality in Mortality

ing and Donaldson, arguably the two most prominent reseachers on seasonal mortality, point out in their study "Mortality Related to Cold and Air Pollution in London After Allowance for Effects of Associated Weather Patterns" that an "analysis on our data confirmed that the large, delayed increase in mortality after low temperature is specifically associated with cold and is not due to associated patterns of wind, rain, humidity, sunshine, SO_2, CO, or smoke" [189, p. 214]. Of course, it depends on the subjective point of view to decide whether an increase in mortality is due to cold or due to higher concentrations of air pollutants that have been emitted to heat houses and flats during exceptional cold spells.

Less controversially discussed is the impact of influenza vaccinations on seasonal mortality [235]. It has been shown that "vaccination against influenza is associated with reductions in the risk of hospitalization for heart disease, cerebrovascular disease, and pneumonia or influenza as well as the risk of death from all causes during influenza seasons" [273, p. 1322]. As these vaccinations are effective and cost effective to reduce influenza deaths [68], it is not surprising that an important part is attributed to them for the decreasing incidence of influenza during recent decades [e.g. 75, 78].

The remaining social factors influencing seasonal mortality can be summarized as avoiding indoor as well as outdoor cold. Various factors have been associated with a positive influence on reducing the annual cold-related death toll. Some researchers remained relatively general about the exact causes. Kunst et al. argue "that a fundamental role is played by factors closely related to socioeconomic progress" [208, p. 971]. This point of view is reiterated by Gemmell et at. [120]. Most other studies have focussed on factors associated with housing conditions [e.g. 18, 54]. The spread of central heating is argued to be the main cause for the decline in seasonality of mortality during recent decades [e.g. 16, 75, 77, 188, 251, 324, 325, 340]. District heating schemes as common in Russia [253] where heating is provided for a fixed annual sum might serve as an explanation for the small fluctuations in mortality in Russia.[8] With a heating system where your apartment can be heated as much as wanted irrespective of the costs, would avoid the often cited "fuel poverty" (=a household has to spend more than 10% of its disposable income to keep the home heated) in the UK [121, 178, 280].[9] People suffering from fuel poverty often find themselves in a vicious circle. They tend to live in houses of lower quality with poor insulation which means that they have to invest proportionally more in fuel for heating than higher quality apartments. The risk of dying during winter is further increased as dampness, condensation and mould in those apartments are more likely [121, 245, 404]. Fighting fuel poverty including poor housing conditions might not be enough, though. The behavioral component of the people should not be neglected. As shown by Keatinge for elderly people with unrestricted home heating, mortality rose for them during winter in the same manner as for individuals without this possibility — due probably to the "residents' preference for open windows and no heating at night" [187, p. 732].

But "warm housing is not enough" [186, p. 166]. It is equally important to avoid exposure to outdoor cold as its impact is independent of indoor cold [98]. From a public policy perspective, this can be performed by building windproof bus shelters and in extreme cases heated waiting rooms [186]. On the individual level, increased car ownership has probably also influenced the decrease in seasonal mortality fluctuations over time [75, 77, 188]. The most influential component on the individual level is adequate clothing worn outdoors. Several articles give evidence that people in colder regions wear warmer clothes when they leave the house during winter than their counterparts in warmer regions [76, 80, 81, 97, 98, 186]. In addition, on extremely cold days, the mortality risk is lowered if the time spent outdoors is reduced [76].[10]

Surprisingly, there is not much literature in the field of seasonal mortality on the "classical" social mortality determinants such as income, deprivation, wealth, marital status, education, occupation, ... [e.g. 124, 168, 195, 210, 234, 314]. To my knowledge no study at all so far has addressed the question whether married people experience smaller annual fluctuations in mortality

[8] I would like to thank Arseniy Karkach for explaining to me the Russian system of heating. Another reason for the minor differences between winter and summer mortality in Russia is, unfortunately, the relatively high summer mortality due to accidents [253].

[9] The British government started a programme that by 2010 "no vulnerable household [...] need to risk ill health, or worse, because of a cold home" [178, p. 510].

[10] Again, British people present divergent behavior: the study of Goodwin et al. [127] showed that the duration of outside excursions of younger as well as elderly people did not differ between summer and winter.

than divorced, widowed or single individuals, an association which could be expected from previous studies on mortality in general [e.g. 125, 129, 163]. The analyses in Chapters 4 and 5 include besides other factors also marital status. They represent therefore a novel approach in seasonal mortality research.

While the negative social gradient is well known for mortality in general, the impact of economic factors such as deprivation, income, wealth, social class, etc. is still discussed ambiguously [16, 79, 147, 213, 214, 215, 342, 376]. Surprisingly most of these analyses — regardless of whether they support or oppose an effect — studied the same country (UK) using similar methods based on ecological data.

Literature on the influence of nutrition on seasonal mortality is sparse. Woodhouse and Khaw hypothesize that low Vitamin C intakes during the cold season may increase cardiovascular risk by raising fibrinogen levels in the blood [194, 411]. As pointed out in the review article of Ness and Powles [272, p. 1], "[a]lthough null findings may be underreported the results are consistent with a strong protective effect of fruit and vegetables for stroke and a weaker protective effect on coronary heart disease." Thus, the seasonal consumption of fruits and vegetables (lower in winter than in summer) may also play an important role for seasonal mortality [60]. The other side of the coin is highlighted by Kloner et al [199]. They assume that "overindulgence" in food, salt and alcohol consumption during the Christmas period might contribute to excess winter mortality.

2.2.4 Summary

The influence of seasonal factors on mortality has been well-known for more than 2000 years. Surprisingly, the exact mechanism of how a change in ambient temperature increases mortality is not yet full understood. Only a negligible proportion of these excess winter deaths is actually caused by hypothermia. The causes of death that contribute most to the seasonal mortality pattern are cardiovascular, cerebrovascular, and respiratory diseases. Contradicting intuition, the often cited influenza (which belongs, of course, to respiratory diseases) causes less than two percent of excess winter deaths either directly or indirectly. The major biomedical reactions to cold temperature in the body which have been singled out so far are increased risks for blood clotting via higher haemoconcentration (⇒ cardiovascular and cerebrovascular diseases) and for infections of the airways (⇒ respiratory diseases). This approach, however, could not explain the "seasonality paradox": countries with relatively cold winter temperatures (e.g. Sweden, Canada) experience consistently lower excess winter mortality than countries with warm or moderate climate (e.g. Portugal or the UK). Therefore, social factors have be referred to. Influenza vaccinations may have helped to reduce seasonal mortality over time. But as this cause of death is only of borderline significance nowadays and inoculations are available all over Europe, this can not be used as an argument to explain the observed large differences within Europe in the 1990s.

Also the impact of air pollution is questioned. If there is any agreement at all in the literature on seasonal mortality, it is the positive impact of a warm indoor climate in connection with central heating and a high standard in the quality of housing. This constitutes a "conditio sine qua non" as no scientist in this field denies the importance. It is usually supplemented by the advice to also avoid cold stress outdoors by wearing adequate clothing, reduced time spent outdoors and using bus shelters or possibly a car. The impact of socio-economic factors measured, for example, as social class or deprivation, finds support as well as opposing opinions in the literature on cold-related mortality. Other factors, such as lack of exercise, smoking [246], or the amount of public spending on health care [147] have not been investigated in detail so far. The impact of marital status has not been investigated so far at all. The question whether people who are living alone face higher excess mortality risks during winter has only been addressed once so far — without any significant finding [405]. Although many studies have been completed up to this point, further research is required in order to reduce the annual number of excess winter deaths — a figure, which outnumbers heat-related deaths considerably.

2.3 Seasonal Mortality from a Historical Perspective

2.3.1 Introduction

The following sections review the literature on seasonal mortality from a historical perspective. The main results are briefly presented over time and by age. Special attention is given to the potential impact of social factors already in historical times. The division of sub-chapters is driven by the origins of data:

Seasonal Mortality before 1400. No written records are available for the time before 1400. Therefore, mainly archaeological studies exist.

Seasonal Mortality between 1400 and 1800. Most studies using parish register data to disclose the annual fluctuations in mortality start in the 15th or 16th century.

Seasonal Mortality from 1800 until the Present. With the introduction of modern censuses, the quality of the data improved greatly. Therefore, it was useful to make another distinction for the turn of the 19thcentury. Since the middle of the 20th century, these aggregate level government statistics have been gradually supplemented and or substituted with retrospective surveys, prospective follow-up studies, register data, etc. Both kinds of data sources have greatly improved our understanding of seasonal mortality.

2.3.2 Seasonal Mortality before 1400

Introduction, Data & Methods

The main problem researchers face when analyzing (seasonal) mortality patterns for this period is the lack of written death records. Two data sources, which have been extensively studied by Walter Scheidel [330, 331, 332, 333, 334] provide, nevertheless, a sound basis for the analysis of seasonal mortality: for Roman Egypt, information can be derived from mummy labels or from funery inscriptions. Several samples have been collected there covering between 109 and 172 individuals. Data from the ancient city of Rome provide the best data-source for the analysis of antique seasonal mortality: Below the streets, thousands of inscriptions were found in the Chrisian catacombs, where the early Christians buried the deceased in niches.The trustworthiness of these data stem on the hand from the large sample-size: depending on the study between 568 and 3,725 inscriptions originating from the 3^{rd} to the 6^{th} century were analyzed [331, 343]. On the other hand, the reported dates of death and/or burial are expected to be considerably accurate. As Scheidel points out "[T]hese early Christians were anxious to record precise days of death and/or burial of the deceased since the moment of death was considered the beginning of true life in eternity" [331, p. 139]. These early Christians did not only report date of burial, they also frequently denoted the approximate length of life. Therefore a rough analysis by age-group can be performed as well.

In contrast to these studies set in countries with a warm, Mediterranean climate, Fichter and Volk analyzed a population with harsher environmental conditions in a region which would now be part of South-West Germany and France [106].

Results

We can see in Figure 2.4 that Roman Egypt, as well as the ancient city of Rome, both exhibit a summer peak. The one in Ancient Rome (Figure 2.4) is mainly generated by infectious diseases. It has been argued before and is now verified by modern biomolecular methods that the single most important cause of death in Rome was endemic falciparian malaria [326, 330, 333]. In addition to the relatively high temperatures in the Mediterranean climate, the spread of these diseases was facilitated by the poor sanitary standards in conjunction with a high population density [339].

The earlier peak in Egypt as shown in Figure 2.4 is misleading. At a first glance, it would suggest that the same infectious diseases of Rome — which are dependent on stable high temperatures — "would have spread, killed, and run out of steam earlier in the year than in Italy" [331, p. 153]. There is little doubt that the population in Egypt also had to suffer from high mortality in summer. However, we now know that the peak was even earlier

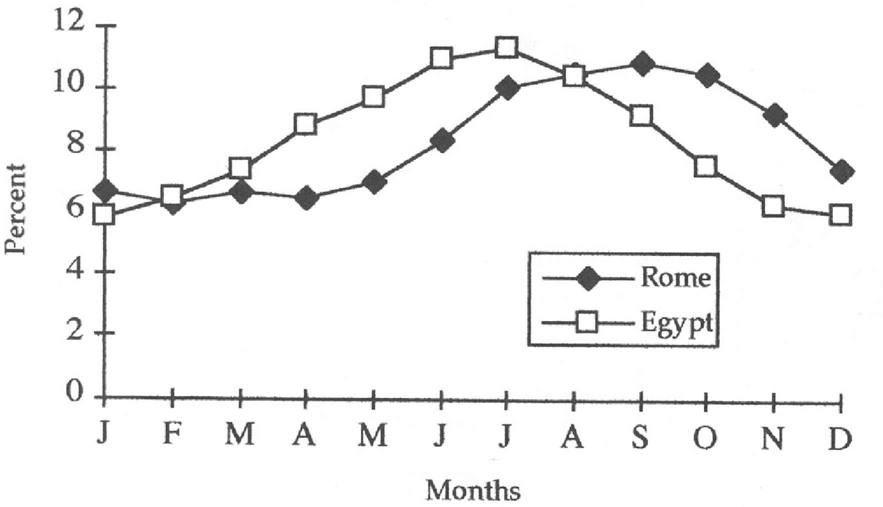
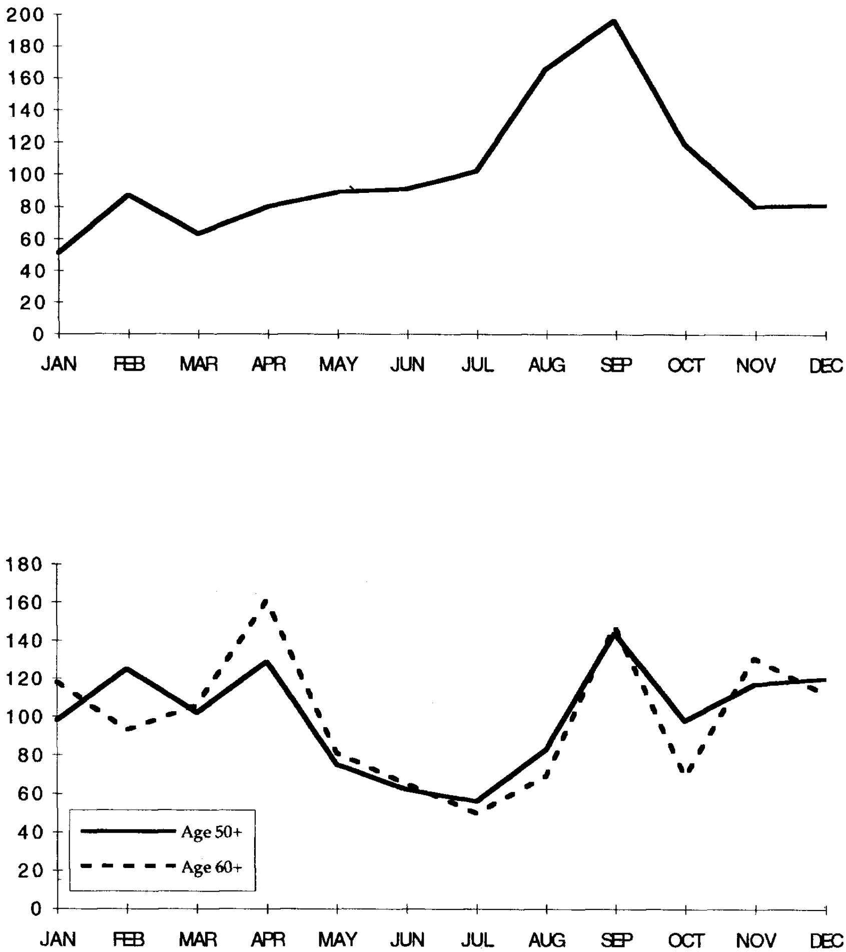


Fig. 2.4. Seasonal Distribution of Deaths: Rome and Egypt
Source: Scheidel 1996 [331, p. 155]

than Figure 2.4 suggests: While the date of death has been recorded in the Roman catacombs, the dates on the mummy labels in Egypt usually indicate the end of the mummification process [332]. This means that the actual death occurred about 70 days before the given date, implying a peak in mortality not in summer but in April/May. One can only speculate about the main causes of death: dysentery, typhoid, and tuberculosis. The main "killer" in Rome - malaria - seems to be unlikely as Walter Scheidel pointed out [334]: The annual onset of Malaria usually coincided with the fall of the Nile which happened in the fall and not in sping. However, we are far from being able to generalize that this peak is a general population pattern: adult ages are over-represented while children and elderly people are hardly among the mummies.[11]

With the presence of some information on age, we are able to further investigate the seasonal pattern, at least for Ancient Rome. Figure 2.5 shows the seasonal distribution of deaths for 20–49 year old people in the upper picture and in the lower picture for people above age 50 and 60, respectively. Elderly people still exhibit a peak in summer. However, the extent is less pronounced than at younger ages (cf. Fig. 2.5: 20–49years: 180; 50+years: 140). The risks for the elderly lurk in other months: While their younger counterparts show a below-par mortality in winter, mortality is elevated for people above age 50 during that period. Brent Shaw attributes this rise in winter to the higher susceptibility of elderly people to "winter" diseases such as respi-

[11] I would like to thank Prof. Walter Scheidel, now at Stanford University, for the valuable information he gave in our e-mail correspondence.



Upper Graph: Ages 20–49 (N=857);
Lower Graph: Ages 50+, 60+ (N=313);

Fig. 2.5. Seasonal Mortality in Ancient Rome by Age
Source: Shaw 1996 [343, p. 120]

ratory infections [343]. It is interesting to note that the differences between men and women have been fairly small. Figure 2.6 shows that both sexes have highest mortality late in summer. With the exception of the months August to October, mortality is evenly distributed throughout the year.[12] The only difference we have observed is that women's susceptibility towards the environmental hazards of summer begins earlier and is not as excessively high as men's fluctuations.

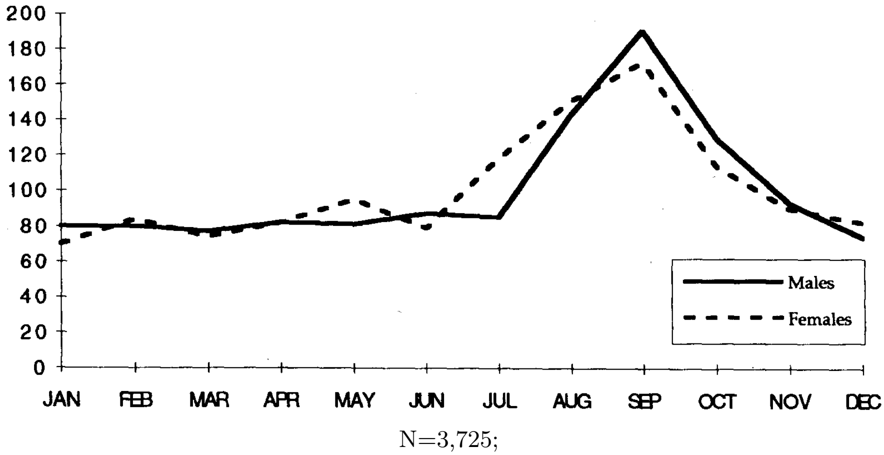


Fig. 2.6. Seasonal Mortality in Ancient Rome by Sex
Source: Shaw 1996 [343, p. 117]

The study of Fichter and Volk of the cemeteries in Sasbach-Behans and Bischof-fingen-Bigärten had to be conducted carefully [13] and resulted in a peak in winter. More specifically, the mortality maximum was reached "in the last phase of winter and in the portions of spring and autumn closest to winter" [106, p. 57]. Similar to the Roman findings, no significant differences could be detected for women and men.[14] The authors suggested that the peak in winter was probably caused by infectious diseases. However, their reasoning is founded on a vague basis: especially bones with a "winter orientation" showed malformations which are typical of severe anemia. "This blood disease causes a deficiency of those components which convey in the blood the vital oxygen

[12] The less stable pattern of women may be explained by a smaller sample size. A separate number of women and men in addition to the whole sample size is not given in the literature.

[13] They had to overcome several methodological problems since the date of death has been derived from the angle people have been buried. According to Fichter and Volk [106], people in that region during that era were buried in the direction where the sun rose in the morning on the day of the interment. Consequently, people could have been buried in the same direction although the burial seasons were different. The maximum difference is 6 months, when person A died on 21 March and person B on 21 September.

[14] Also children showed the same pattern.

to the tissues. The chronic oxygen deficiency in the tissues leads to a severly increased susceptibility to infection as a consequence of lowered resistance" [106, p. 56].

Problematic Studies

Besides these studies with relatively large sample sizes, there are several, mainly archaeological, approaches using indirect methods to estimate the seasonal distribution of deaths in pre-historic populations.

The study for the period that is probably the longest time ago is the analysis by Klevezal and Shislina of cementum annual layers in teeth from human skeletons [198]. They analyzed five skeletons from the Bronze Age found in Kalmyckia. Two out of them had no cementum layers. The remaining three individuals are supposed to have died in spring/early summer (2) and in late winter (1). This approach can be questioned in several perspectives. Obviously, a sample of three does not allow to for any conclusions to be drawn about the general seasonal pattern in a population. One may also doubt the methodological approach. This so-called Tooth Cementum Annulation (TCA) Method allows to estimate the age of the subject better than previous morphological methods [409, 410]. As shown in Figure 2.7,[15] teeth display similar patterns as trees. The biological basis for these rings is still questioned. According to Lieberman [222] it is related to seasonal variation in diet and growth. Consequently, Klevezal and Shislina tried to use this method to assess the season of death of humans, as done successfully before for several mammalian species [100]. The opinion of experts on the TCA method for human seasonal mortality studies [100, 408] and the fact that only one study has been conducted so far raises serious doubts about the validity of the method.

Another indirect approach has been performed by Christine White in 1993 [401]. She analyzed the hair of 15 mummies found in the Nubian desert (part of The Sudan) dating from AD 350–1300. The rationale of the study is the differential carbon composition of C_3- and of C_4-plants which are seasonally cultivated and consumed.[16] These C_3 and C_4 diets have a strong influence on the $\delta^{13}C$ content of hair. Analyzing the $\delta^{13}C$ of hair near the root and the skin of these mummies reflects relatively accurately the diet at about the time of death [401]. "The point in the seasonal cycle when the individual died is determined by how the $\delta^{13}C$ value closest to the scalp relates to values representing previous months. An individual whose $\delta^{13}C$ becomes increasingly lighter from the first to the fourth segments must have died well into the season when more C_4 plants were consumed" [401, p.664]. Christine White's

[15] I would like to thank Prof. Dr. Ursula Wittwer-Backofen, Dr. Alexander Fabig and Uta Cleven from the Tooth Laboratory at the Max Planck Institute for Demographic Research for the picture.

[16] C_3 such as wheat, barley as well as most fruits and vegetables are eaten in winter; C_4-plants such as sorghum and millet are part of the summer diet.

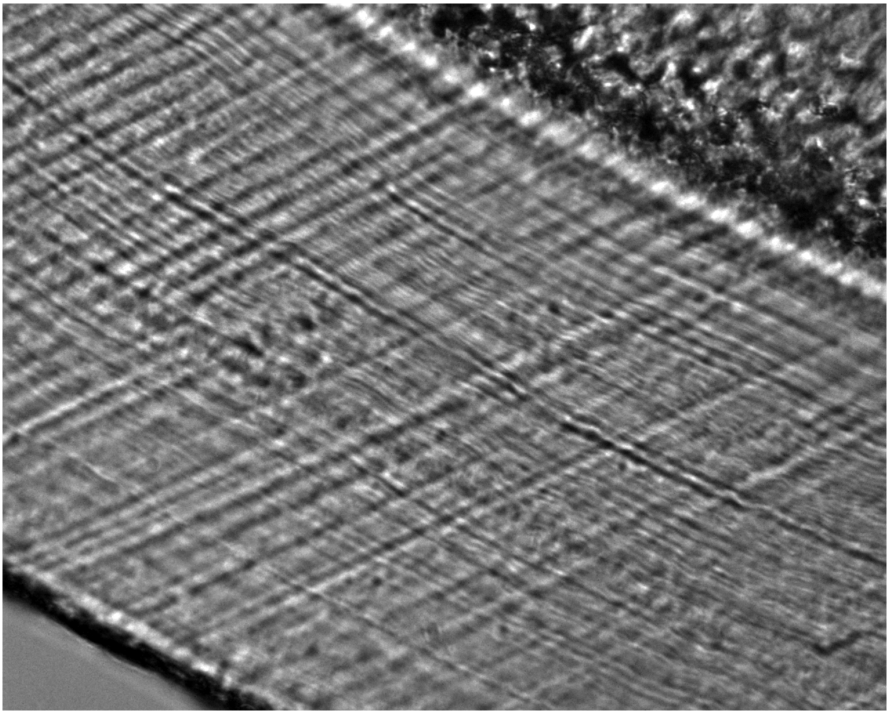


Fig. 2.7. Human Tooth Cementum under the Light Microscope

results echo the previous results for Rome and Roman Egypt, though on a less statistical foundation due to the small sample size. First, 11 out of 15 mummies died in summer indicating a peak in mortality during the warm season. Secondly, no substantial differences between women and men could be detected.

Summary

The available evidence lets us conclude that during these early historical times, there were two opposing seasonal mortality regimes: In rather warm regions (Roman Egypt, Rome, The Sudan) mortality peaked during the warm season. This peak was probably caused by infectious diseases such as falciparian malaria. Higher temperatures caused an earlier spread of diseases and, consequently, hotter regions experienced the peak earlier in the summer. Cold regions, contrastingly, showed maximum mortality in winter. The season with the least number of deaths was spring and early summer.

Demographic phenomena can be explained by three mechanisms: bad data (Level-0), direct effect (Level-1) and compositional effects (Level-2) [382, 383]. One must be very careful to avoid Level-0 and Level-2 effects when interpreting and, especially, generalizing the results of the archaeological studies. There are too many potential trapdoors for an unrepresentative sample [155]: First, samples with less than 100 analyzable individuals are unlikely to yield satisfactory interpretations of mortality patterns. Secondly, does the sample really resemble the population in its age-structure? As we have seen briefly (ancient Rome), people at different ages show different seasonal patterns. Thirdly, is the sample representative for the whole period? Maybe it was a special burial site for people with certain characteristics? "Given that most samples will be subject, differentially, to biases at a variety of levels, comparative studies based on palaeodemographic data cannot realistically be considered reliable ***without careful control for those biases.***" [155, page 151, emphasis in original document].

2.3.3 Seasonal Mortality Between 1400 and 1800

Introduction

The first modern census has been conducted in Sweden in 1748 [360]. Most European countries did not follow until the beginning or the middle of the 19th century. Statistical analyzes of seasonal mortality, however, did not have to rely on archaeological data and methods any longer to study (seasonal) mortality between (about) 1400 and 1800. The introduction of parish registers enabled researchers to investigate historical population patterns. Two approaches have been used since: First, parish registrations have been aggregated to give weekly figures for vital events. These counts have been published in England as *Bills of Mortality* [154, p. 145]. The scientific value of these numbers had been recognized as early as 1662, when John Graunt first published *Natural and Political Observations Mentioned in a Following Index and Made Upon the Bills of Mortality* [130], which displays "all of the characteristics of modern, empirical research" [406, p. 5][17]. These bills of mortality did not only include the number of deaths but also the cause of death.The second approach started after World War II, when "French scholars began to apply a new technique to nominative records of the période préstatistique, i.e. the period for which government statistics were not readily available" [323, p. 537]. The most prominent among these researchers was Louis Henry. His method of applying the method of family reconstitution to parish registers has been named after him, the *Henry method* [318]. Even the critics [320] acknowledge that the approach to reconstruct the population history by using parish registers provides valuable results [146]. Depending on the country and region one could estimate the seasonal variation in mortality starting in about 1400.

[17] Peter Laslett actually wrote "To the trained reader Graunt writes statistical music"[212].

Seasonal Mortality over Time

Figure 2.8 shows the results of seasonal mortality over time in England between 1580 and 1837 by [415]. Each line — with the exception of the first and last interval — represents 50 years of pooled data. The first thing we can recognize is the relative stable pattern over time where we observe a winter peak and a summer trough. Mortality usually peaks late in winter and reaches a trough around July/August. Similar results have been reported for medieval times for Westminster Abbey by Harvey and Oeppen [144]. This basic pattern — with relatively high winter and relatively low summer mortality — is not only stable over time but also across different geographic locations as studies from Canada, Estonia, Finland, and France suggest [27, 45, 182, 216, 298]. The stability of seasonal mortality is even more surprising when one keeps in mind the general mortality pattern during the *ancien régime*: First, death rates were relatively high during that period reflected by a low level of the parameter e_0 of about 35 years. Secondly, these high levels of mortality were subject to immense annual fluctuations [109, 143, 161] caused by "Epidemical Diseases" superimposing "Chronic Diseases" as already pointed out by Graunt [130].

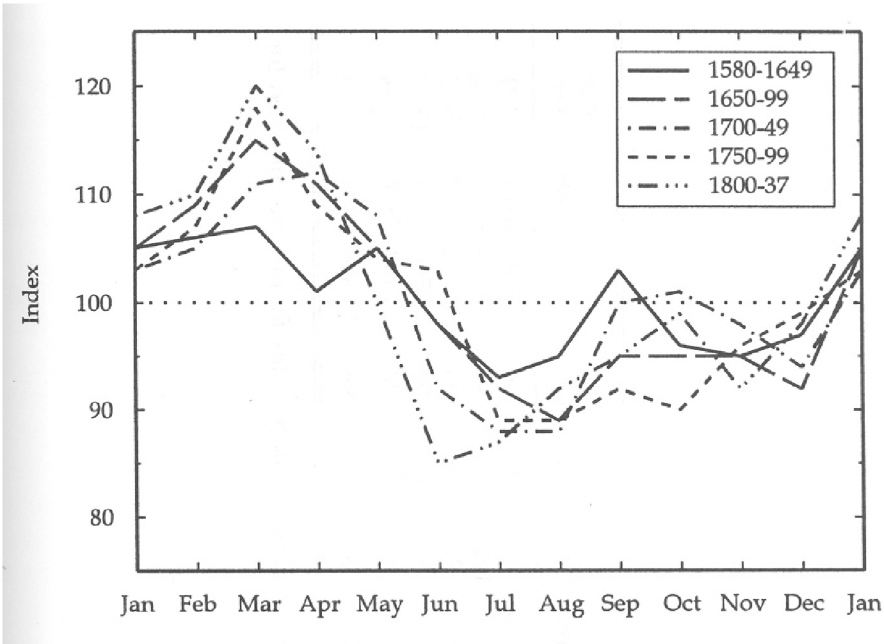


Fig. 2.8. The Seasonality of Deaths by Half-Century Periods
Source: Wrigley et al. 1997 [415, p. 325]

By comparing this modern pattern, with a peak in winter and trough in summer, to results from Italy [331], Spain [353] and parts of France [27], we detect that the following finding of Dobson for south-east England can not be attributed to being a universal phenomenon. She wrote: “The seasonal rise and fall of burials worked in the opposite direction of the movement of the thermometer — an inverse relationship that was maintained throughout the seventeenth and eighteenth centuries” [73, p. 203]. These more southern countries displayed a seasonal pattern similar to the one found in Rome 1500 years earlier: highest mortality in summer and lowest mortality in winter. Although this might lead one to assume that the main influence was the Mediterranean climate, it should be stressed that social factors were also of crucial importance in that period. By looking at Philadelphia’s (Table 2.2) differences in seasonal mortality between blacks and whites, we can see that climate could not possibly shape two totally different patterns for the same time and place [197].

Table 2.2. Seasonal Mortality Ratios for Blacks and Whites in Philadelphia, 1722 and 1730

	Standardized Numbers		Standardized Ratio	
	White	Black	White	Black
Winter	81	22	86	166
Spring	75	10	86	75
Summer	122	7	130	53
Fall	98	14	104	106

Source: Klepp 1994 [197, p. 479]

While blacks seem to suffer from the highest mortality during the cold season (standardized ratio in winter and fall 166 and 106, respectively), whites experience the largest risk of death during summer (standardized ratio in summer: 130).

Two causal explanations come to mind:

- The relatively low summer mortality among blacks might by linked to a *selection effect*: Many blacks were brought to the US as slaves and have already survived some contagious diseases which typically occur during summer. As a consequence, they were immune to them.
- It can be expected that a larger proportion of this seasonal mortality differential can be explained by *social factors*: Keeping in mind the poor socio-economic conditions blacks had to suffer from during that period, one can easily imagine that blacks had insufficient protection against the

cold in winter: they were more likely to work outside and to have bad or no heating at all in their homes compared to whites.[18]

The importance of other factors other than climate on seasonal mortality during that period is also supported by other sources. As Bideau et al. showed in Dupâquier's monograph series *Histoire de la population française* [27], France varied largely in its seasonal mortality fluctuations geographically. However, the major cleavage was not between north and south but between urban and rural areas.

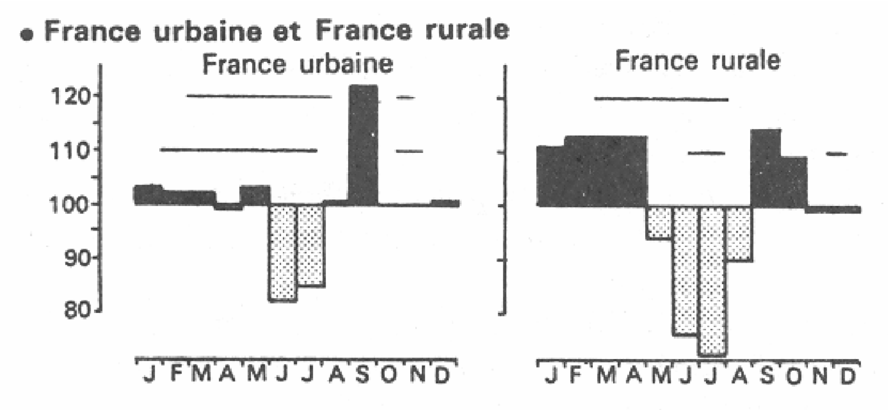


Fig. 2.9. Urban vs. Rural Seasonal Mortality Patterns in France 1740–89
Source: Bideau et al. 1988 [27, p. 240]

Rural areas in France showed a relatively modern pattern with maximum mortality during the colder half of the year and minimum mortality in summer. "Pour la France urbaine au contraire, les indices de saison froide dépassent à peine de moyenne, le creux d'été est moins marqué, mais la pointe de septembre est exceptionellement forte, sans doute parce que la conservation des ailments est encore pire en ville qu'à la campagne" [27, p. 242].[19]

This pattern and its causal explanation is not exclusively present in France. Studies from the United Kingdom point in the same direction as well: The studies from the "Cambridge Group for the History of Population and Social Structure", which focussed on the countryside of England, show a shape similar to *France rurale* [416, p. 294], whereas Landers' analysis of London resembles, rather, *France urbaine* with its summer peak until the middle of the

[18] Theresa Singleton's review article gives an overview of historical living conditions of blacks in the United States [348].

[19] Author's translation: "In urban France, on the contrary, the indices of the cold season were above the average, the summer trough is less pronounced, but the peak in September is exceptionally strong, without any doubt because the conservation of food was even worse in towns and cities than on the countryside".

eighteenth century [211, p. 206]. As indicated by Bideau's quotation above, we can recognize that the higher temperatures during summer were not the actual cause of death for the people. The hot weather only provided the basis for certain bacteria to develop. Only in conjunction with social factors such as high population density and bad hygienic and sanitary conditions, diseases could spread among humans and actually wipe out considerable proportions of the population. For example, during the epidemic of 1665–66, 70,594 individuals died of plague in London [12], a typical summer disease [353] transmitted by rats and flies. By the end of the 1670s, the plague was almost non-existent in London. Slack gives three possible explanations for this [350]:

- Rats, as the main carrier of the disease, became immune to the bacterium *Pasteurella Pestis*. But he considers this to be rather unlikely. He favors two other explanations:
- On the one hand, improvements had been made in the housing and living conditions such as building brick houses instead of wooden houses. There, rats had more problems spreading. But also on the individual level, major improvements had been made such as the increased usage of soap and changing bed linen more frequently.
- On the other hand, public health policies were — as surprising as it may sound — also in effect. For example, in Edinburgh 1664 restrictions were imposed on ships coming from infected ports. Almost simultaneously, the number of plague deaths diminished remarkably [350].

The erosion of the summer peak in urban areas can be nicely illustrated by the example of London. Fig. 2.10 shows the development of seasonal mortality in the capital of the British Empire between 1670 and 1779 by 25-year-periods. In the first period 1670–99 (solid black line), maximum mortality was reached in September. During the next century this peak gradually transformed into a local maximum. By the end of the eighteenth century, excess mortality during summer was almost non-existent. It is quite likely that this development can also be traced back to improvements in living conditions (hygiene, public health policies, etc.).

Seasonal Mortality by Age

Besides the development over time, it is also worthwhile to investigate the trend in seasonal mortality in various age-groups. Unfortunately, not many studies have analyzed death by month and age. In addition, it is seriously doubted whether adult mortality can be accurately estimated from the existing data. Finlay, for example, assumes that this is not possible for parts of the London Parish Registers [107]. Nevertheless, I would like to present a short analysis by age as most studies showed relatively congruent results.

Figure 2.11 presents selected age-groups from [415]. One can easily recognize two features:

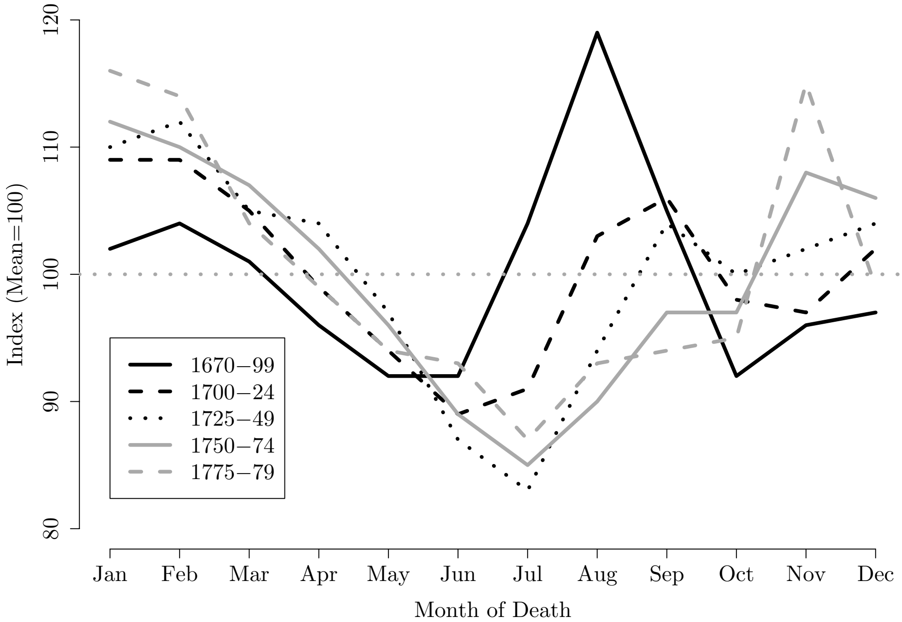


Fig. 2.10. Monthly Burial Indices in London 1670–1779 Based on Weekly Bills of Mortality

Data Source: Landers 1993 [211, p. 206]

- The older people become, the larger the differences between winter and summer.
- Except for the oldest people we can see an intermediary summer peak.

This is in accordance with Dobson who stated that the elderly were particularly susceptible to cold winter conditions [73, p. 216]. Similar results have been found for France and Canada [27, 45, 216]. The higher susceptibility of the elderly is reflected by the actual causes of death: As shown by [153] for plague mortality rates by age, younger people have a higher propensity towards summer diseases than elderly people. Whereas the proportion of plague deaths from all deaths was probably over 50 percent for children, the percentage was less than 10 percent for people aged 60 years and more [153]. The latter, however, were more affected by typical air-borne winter diseases such as tuberculosis [114, 211]. Typical diseases of winter were influenza, whooping cough, typhus, and respiratory tuberculosis. These diseases, which were mainly responsible for the winter peak, were harder to combat than just using better sanitary conditions. Duncan et al. conclude that the evolution of the whooping cough epidemics in London are directly related to two factors: pop-

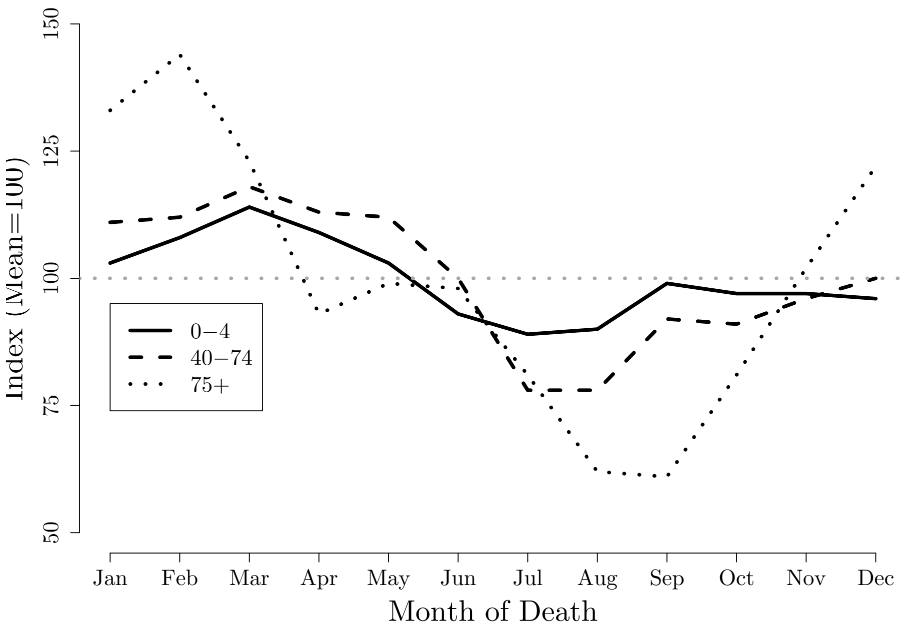


Fig. 2.11. Seasonality of Deaths by Age, England, 1580–1837
Data Source: Wrigley et al. 1997 [415, p. 326]

ulation density and malnutrition [83, p. 450]. Malnutrition is often especially singled out as one of the main causes of mortality during those times [e.g. 116, 218].[20] Richards [307], for example, estimates that the price of wheat was more important to determine mortality than winter or summer temperature. Livi-Bacci [225] also ascribes the nutritional level a clear influence on tuberculosis, whooping cough and respiratory diseases in general. This causal linkage between malnutrition, infectious diseases and high mortality has been documented well for populations during that historical period [43, 254, 399]. "Malnutrition progressively enhances infection in an individual, and [...] infection often causes further malnutrition. An ill person does not eat well, even though his metabolic needs are greater. Similarly, poorly nourished individuals rapidly exhaust protein and caloric reserves in the process of fighting infection" [43, p. 249]. It can be assumed that this mechanism did not only work during crisis years with especially poor harvest but also seasonally each year when late in winter the possibility of malnutrition was highest.

[20] Vladimir Shkolnikov re-iterated this assumption in a discussion during the workshop "Seasonality in Mortality", Duke University, NC, 07–08 March 2002.

Summary

The major advantage of studies examining seasonal mortality patterns between 1400 and 1800 is the basis of the data: Researchers no longer had to rely on archaeological methods to make inferences about population histories. French and British researchers (most notably Louis Henry and the "Cambridge Group for the History of Population and Social Structure") used parish registers to reconstruct demographic events of populations.

The general pattern observed for seasonal mortality in many countries resembles modern findings rather closely: deaths peak late in winter and hit a trough around July/August. English data suggest that seasonality was not equal across all age-groups. The older the people the higher the differences between winter and summer mortality.

The modern pattern with a peak in winter and a trough in summer is not found everywhere, though. Several examples show that within the same climatic region, different seasonality regimes persist which could not be explained, consequently, by climatic variation but rather by social factors: socioeconomic differences may be the root for the differential in seasonal mortality between blacks and whites in 18th century Philadelphia. Poor hygienic situations allowed a summer peak in urban regions of France and the UK ($\sim$ London). Malnutrition is the most likely cause for excess mortality during winter for the elderly.

2.3.4 Seasonal Mortality from 1800 until Present Times

Introduction

The beginning of the 19thcentury was chosen — similar to the previous cut-off point 1400 — rather for methodological reasons rather than for a general change in seasonal mortality regimes. Sweden started to collect demographic data resembling the first modern census [360] in 1748.[21]. Many other European countries followed in subsequent decades, so researchers no longer had to rely on archaeological methods or on parish reconsitution data to construct demographic patterns. In addition to retrospective articles using those newly available country-wide official data written during recent decades, some original articles written at that time were already analyzing seasonal mortality.

With the new wealth of available data in the 19thcentury, scientific knowledge expanded rapidly. It is worth adding that this time period was also heavily influenced by "back to nature" ideas exemplified by Thoreau's "Walden" [24]. It comes, thus, as no surprise that scientists became interested in the impact of nature on human health [156]. A typical example is the article "An Attempt to Determine the Influence of the Seasons and Weather on Sickness and Mortality" by Guy and Cantab in 1843 [136] or the analysis of mortality

[21] The population count of Quebec in 1666 can merely be called a prototype of a census [9]

in "Remote Corners of the World" by Westergaard in 1880 [400] as he called the Faroe Island and Greenland.

Since the middle of the 20th century, new data collection methods have become widespread. The introduction of retrospective surveys, prospective cohort follow-ups,... allowed to investigate phenomena in more detail. One major dimension is the analysis of individual level data. While previously, data were typically aggregated, the usage of individual level data allowed relating the phenomenon of interest with covariates without the problem of the ecological fallacy [311]. The other major dimension is the time-horizon: data have typically been cross-sectional. By following cohorts over time or by asking retrospective questions in surveys, it was possible to reconstruct individuals' life-courses which makes it easier to find out which variables (e.g. long-time smoker) change the risk for an individual to experience a certain event (e.g. death). Typical examples in the field of seasonal mortality are van Rossum et al. [376] for a cohort follow up and Donaldson et al. [81] for a retrospective survey. The various (social) factors which have been associated with excess winter mortality have been discussed in Section 2.2.

Seasonal Mortality over Time

The analysis of seasonal mortality by period exhibits two patterns and one unconfirmed recent pattern:

Pattern 1: Loss of Summer Peak An intermediary summer peak disappeared over time if it existed at the beginning of the observation period. European countries with colonies were especially prone to such a sudden increase in mortality during the hot season. McKeown and Record (1962) [255] suggest for England that typical summer epidemics such as cholera were brought to Europe from India. An illustrative example is shown in Figure 2.12. The gray dashed line displays the seasonality pattern observed for the urban French population in the middle of the 19th century. It is reminiscent of Figure 2.9 (page 25) which plotted the pattern of France observed less than one hundred years earlier: a bimodal pattern is exhibited with a minor peak in February and a maximum in September. This kind of pattern with relatively high summer mortality has been reported for London and other parts of England [11, 221, 304], too. Roughly sixty years later, summer excess mortality was no longer persistent in France as indicated by the solid black line. The highest number of deaths was observed in February, whereas September has been transformed from the month with highest mortality to minimum mortality. This shift, of course, can not be the outcome of a climatic change during such a short period of time. Clearly, social factors have to be attributed to this development. The cause for this loss of the summer peak is most likely a considerable improvement in hygiene which almost completely eradicated intestinal diseases, the major reason for excess summer mortality [26, p. 283].[22]

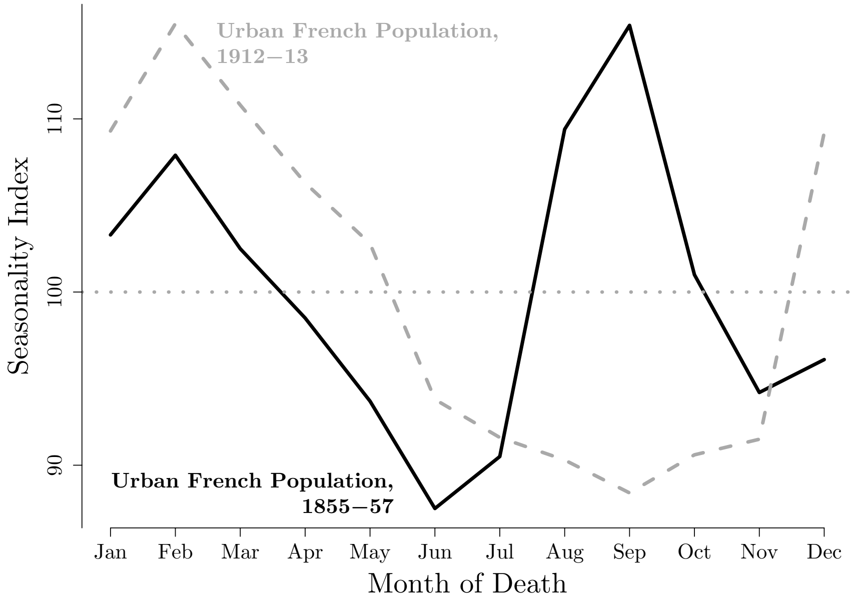


Fig. 2.12. Seasonality of Deaths in Urban France 1855–57 and 1912–13
Data Source: Bideau et al. (1988, p. 285) [26]

Pattern 2: Decline in Seasonality In 1912, March [240] noted that no European country he had analyzed showed a local summer peak.[23] Highest mortality was found between January and March, minimum mortality typically occured late in summer. One consequence of the disappearance of the summer peak was an increase in the differences between winter and summer deaths. During the following decades the annual mortality amplitude remained relatively stable. Only by the middle of the 20thcentury did seasonal fluctuations decrease. This development has been reported for various countries such as Japan, the United States, Spain, the Netherlands, Germany, the GDR, Northern Italy, Finland ... [17, 99, 119, 208, 220, 224, 231, 241, 242, 268, 269, 319, 325]. The decrease

[22] "Le point essentiel, c'est la disparition, pour tous les ensembles considérés et pour tous le groupes d'âges [...], de la surmortalité d'août-septembre : l'hygiene est venue presque à bout des maladies intestinales" [26, p. 283].

[23] Those countries were: Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Italy, Norway, Scotland, Spain, Sweden.

over time did not start, however, simultaneously in all countries. Figure 2.13 displays this by giving two examples. Both panels show a measurement of seasonality where winter mortality is related to summer mortality. Because those methods differed, one can not directly compare the results in the left panel for the United Kingdom with the right panel for Finland. This nordic country shows a decreasing trend since the 1930s whereas the differences between winter and summer mortality in the UK started to become smaller only in the 1970s [63, 251].

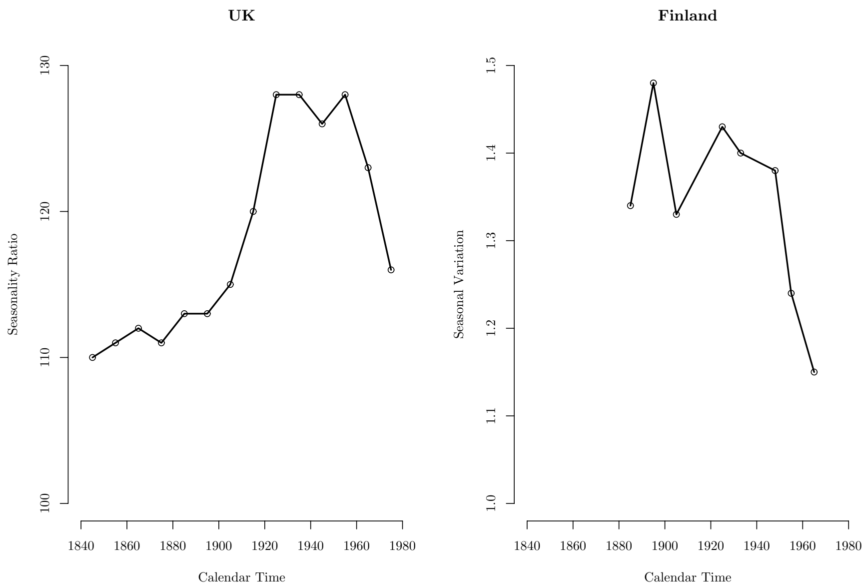


Fig. 2.13. Seasonal Mortality in the UK and Finland over Time
Coefficients for the UK and Finland are not directly comparable.
Data Source for UK: McDowall 1981 [251, p. 16]
Data Source for Finland: Näyhä 1980 [268, p. 44]

The general trend towards de-seasonalization was related to the changing composition of causes of death over time — most notably the reduction of diseases of the respiratory tract [2, 255]. Various arguments are proposed in the literature as causal factors that have influenced this decline in respiratory-related mortality. On the one hand, public health measures such as influenza vaccinations are mentioned. It is argued, though, that the remarkable declines in mortality do not coincide with the introduction of any public health measures [402]. It can be assumed, rather, that the general trend towards improved diagnosis [115] and better living conditions, especially the spread of central heating, for instance, is more likely to be the cause of this change [208, 220]. Also the possibility of less air pollution over time has been attributed to the decline in seasonality over time [e.g. 251]. Nevertheless, this decrease in seasonality did not result in a uniform distribution of mortality during the year. With the exception of Iceland, considerable differences still exist between mortality during the hot and cold season in all countries [135, 147, 252].[24]

Unconfirmed recent development: Recently, a new trend has been observed for the United States: Feinstein [102] reports an increase in seasonality of mortality for the elderly since the mid-1970s, a finding for which Seretakis et al. [340] found some indications as well in their analysis of seasonal mortality from coronary heart disease. It is argued that this is not caused by an increase of mortality during winter but by an accelerated decrease of mortality during summer: "If the reversal is real, then it could reflect the increase in use of air-conditioning" [340, p. 1014].

Seasonal Mortality by Age

The first detailed analysis of seasonal mortality by age was conducted for Belgium by Adolphe Quetelet [300] in his study: "De l'influence des saisons sur la mortalité aux différens ages dans la Belgique".[25] Data from the Appendix of his monograph were taken to produce the two panels in Figure 2.3.4. Results are shown in the left part of the figure for women and in the right part for men. A dashed gray line indicates the value for a uniform distribution ($\frac{1}{12} = 8.\overline{3}\%$). In both cases the relative contribution of the numbers of death from each month have been calculated, standardizing each month to the same length. The general trend is easily visible: seasonal fluctuations become bigger with increasing age. The youngest age-group shown here still displays a slight secondary peak during summer. Nevertheless this sudden rise is still below average mortality (=lower than the dashed gray line). At more advanced ages, this peak is non existent. Excess mortality during winter is steadily increasing with age. Although January and February make up only one sixth of the whole year, their contribution to all deaths for women as well as for men above age 90 (gray dashed line) is about one quarter of all deaths for each sex.

During recent decades, studies of seasonality in mortality have rarely focused on the influence of age — despite its paramount influence on mortal-

[24] The lack of differences in mortality between winter and summer in Iceland has been attributed to the widespread availability of low cost geothermal energy which makes it easy to keep a warm indoor climate [252].

[25] It is worth mentioning a few highlights of Adolphe Quetelet's biography [cf. 177]: Among his professors were Poisson and Laplace; the *Quetelet Index* was invented by him, nowadays often called *Body-Mass-Index* (BMI); while he is mostly remembered for his work as a social statistician, he started as a mathematician, changed to physics where he specialized in astronomy; this brought him to meteorology. The study of climate was the stepping stone for him to analyze the influence of the seasons on mortality.

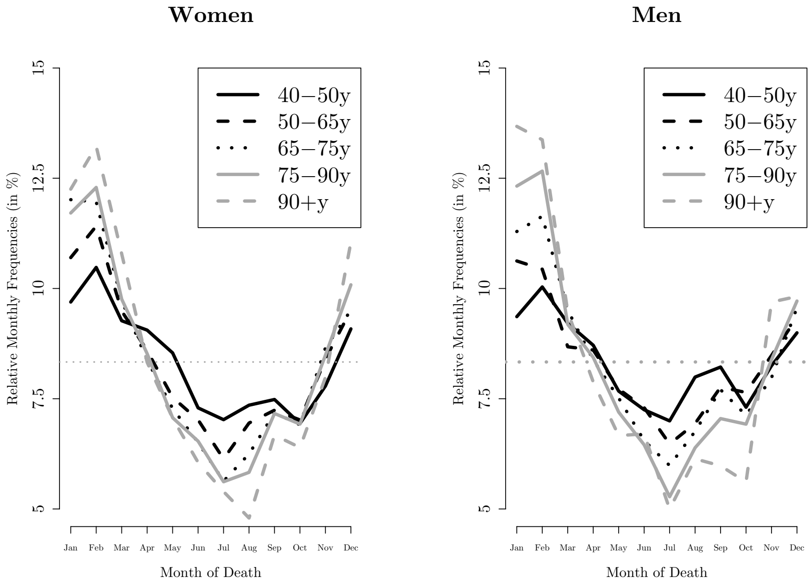


Fig. 2.14. Seasonal Distribution of Deaths, Belgium, 1830s
Data Source: Quetelet 1838 [300, p. 37–38]

ity in general [cf. 314]. Sometimes no age distinction was made at all [e.g. 13, 21, 319, 367] which turns out to be especially problematic if comparisons are made over time or across countries. If any age-effect exists, such comparisons may lead to erronenous conclusions because of the varying age-composition in the analyzed populations. Many other studies controlled for age or performed analyses for separate age-groups. Unfortunately, the highest included age or the beginning of the last, open-ended, age-category is chosen at an age after which most deaths in a population occur. For instance, Huynen et al. [169] uses a category "≥ 65 years of age", the maximum age-category in the "Eurowinter Study" was "65–74 years" [98]; at those ages, however, most people are still alive in Western populations at present [cf. 165]. The conclusions drawn from those studies are not necessarily wrong, but they may simplify or blur the relationship between age and seasonal fluctuations in mortality. Only a few studies investigated seasonal mortality into advanced ages [102, 232, 251, 262, 268]. One study [309] even analyzed seasonal mortality among centenarians and supercentenarians (110 years and older).

According to Robine, demographers assume that "mortality measures essentially the current conditions: the quality of the ecological and social environment. For biologists, mortality measures mainly the ageing process" [310, p. 911]. If we combine these two assumptions, we could postulate that during winter, when environmental conditions are especially challenging, mortality is

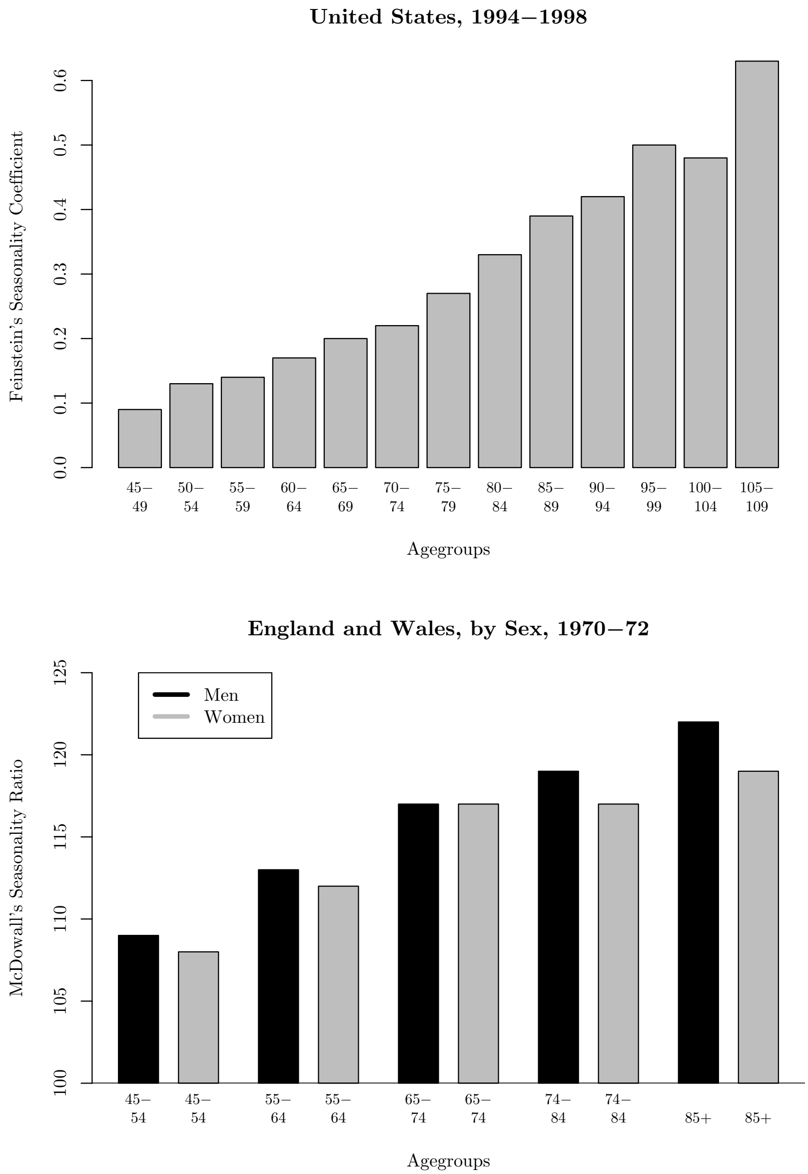


Fig. 2.15. Seasonal Mortality by Age in the United States, 1994–98, and by Age and Sex in England & Wales, 1970–72

Data Source for the Unites States: Feinstein 2002 [102, p. 472]

Data Source for England & Wales: McDowall 1981 [251, p. 17] higher than in summer. In addition to the increasing mortality at higher ages, we can assume that seasonal mortality fluctuations increase with age. This hypothesis finds support in most studies which incorporated age. In Figure 2.15, results are plotted by age for the United States for the years 1994–1998 in the upper panel based on the study by Feinstein [102]. The lower panel shows data from McDowall [251] covering England and Wales during the years 1970–1972 for women (gray) and men (black). Feinstein's [102] study has been chosen as an example as it contains detailed results until 109 years of age. These estimates are based on Social Security data and are therefore considered to be very reliable. We can see that seasonality gradually increases with age. With the exception of people 100–104 years old, every age-group seems to be more susceptible to seasonal effects than women and men five years younger. By looking at the lower panel with the results for England and Wales, we can recognize that the pattern observed over age in the United States is not obfuscated by a sex effect. Still, an increase of seasonality with age is detected with women and men showing relatively similar results. This sounds puzzling to mortality researchers as women and men vary considerably throughout their whole life course in their age-specific mortality rates. Thus, one could assume that women are less susceptible to environmental effects than men and should, consequently, display smaller differences between winter and summer mortality. The lack of any significant sex differences with regard to seasonal mortality is, however, a common finding in many studies [e.g. 98, 121, 262, 419].

Summary

With the introduction of the census, it was possible to obtain more reliable information than previously with indirect methods. Starting in the middle of the 20th century, new data collection methods became commonplace like cohort follow-ups and retrospective surveys. This enabled researches to conduct longitudinal analyses based on individual level data.

Over time two major developments can be outlined. If a summer peak still existed in the 19th century, it disappeared until the beginning of the 20th century. The decline of this intermediary rise in mortality can be most likely attributed to less incidences of intestinal diseases due to improvements in hygiene. The following decades were marked by a decreases in the winter/summer mortality differences. Most articles, as already pointed out in Section 2.2, traced this development back to the widespread introduction of central heating or general improvements in living conditions. This development did not lead to an evening out of differences between mortality in winter and summer. With the exception of Iceland, remarkable differences still exist between the cold and the hot season with respect to mortality. Recent analyses for the US found an increase in seasonality again which is probably caused by an accelerated decrease of mortality during summer with the increased use of air-conditioning.

The first detailed study on the effect of the season in mortality which took the factor age explicitly into account was conducted by Quetelet in 1838 [300]. His findings are still in accordance with modern studies: With increasing age, seasonal fluctuations in mortality are gradually becoming larger. This is in accordance with the theory that mortality measures the aging process of the body as well as the subjective environmental conditions for the individual. Common sense suggests that women should have smaller seasonal fluctuations than men as their lower age-specific mortality rates throughout their whole life-course reflect less susceptibility to environmental hazards. Surprisingly, many studies could not detect any significant differences between the seasonal fluctuations in mortality of women and men.