Cause-of-death decomposition of old-age mortality compression in France, 1979-1994

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Abstract

Previous studies have shown that the significant decline in old-age mortality in high-income countries during the last few decades was accompanied by mortality compression among the oldest old. The compression is associated with the accelerating pace of age-related mortality increase, which can be more properly measured by the logistic rate of mortality rise, denoted by b, than by the conventional exponential rate. In this paper, we decompose the increase in b in France during the ICD9 period (1979-1994) into level effects and slope effects of cause-specific mortality, using the line-integral method of decomposition. The results show that the rise in all-cause b is due to slope effects: b increased for a wide range of various causes, including both high-b and low-b causes, which may suggest an increasing resistance to further longevity extension. Although we predicted less pronounced declines in mortality from causes with high b's, we found no such tendency. This may suggest a positive prospect for further longevity extension, since those causes are considered closely related to senescent processes.

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1. Introduction

The last few decades of the twentieth century witnessed substantial declines in old-age mortality in high-income countries (Kannisto et al. 1984), which continued during the first decade of the twenty-first century (Human Mortality Database, viewed as of March 11, 2012). An important question is whether the longevity extension is accompanied by a steepening of survival curve in the oldest old age, as it may be an indication of increasing "resistance" to further longevity extension.

Concentration of deaths in old age and rectangularization of survival curves proceeded substantially in high-income countries during the first three quarters of twentieth century (Fries 1980, Comfort 1956). The mortality compression is attributed to pronounced reduction of mortality among children and reproductive age adults, which resulted primarily from considerable decline in mortality from infectious and parasitic diseases, as well as maternal, perinatal and nutritional disorders. The compression, however, noticeably slowed down as mortality at young ages reached very low levels. The dominant trend in the last few decades was shifts of death distributions and survival curves to the right (Bongaart 2005; Wilmoth and Horiuchi 1999; Yashin et al. 2001), reflecting significant declines in mortality at old ages from cardiovascular diseases, chronic liver and kidney diseases, and some cancers.

These previous studies examined trends in the dispersion of deaths over the entire lifespan, or in a broad range of adult age. However, in order to investigate relationships between longevity extension and mortality compression, it is important to focus on death distribution *within* old age. Using a measure of mortality dispersion above the modal age at death, Kannisto (2000, 2001) showed that death distribution among the very old was increasingly compressed in a number of high-income countries, although the pace of compression was relatively slow and gradual. Further studies have demonstrated similar trends in more recent periods and for additional countries (Cheung et al. 2005, 2008, 2009; Cheung and Robine 2007).

In those studies, data on total mortality, with all causes combined, was analyzed. In order to understand the old-age mortality compression in more detail, different causes of death (CODs) should be taken into consideration. Did particular types of cause of death contribute significantly to the old-age mortality compression? If so, what are those causes, and in what manners did they contribute to the compression? This study is undertaken in order to investigate these questions.

2. Hypotheses

In the analysis of old-age mortality compression, Kannisto examined mortality patterns

above the adult modal age at death (M), using SD(M+), the square root of mean squared difference from M for deaths above M. Thatcher et al. (2010) have found that SD(M+) is closely related to the life expectancy at the modal age, e(M), and the relation is well approximated by SD(M+) = 1.233 e(M). Studies using SD(+) and e(M) show that although M has been rising in high-income countries, survival time above M has been becoming shorter, and deaths above M have been increasingly concentrating in narrower age ranges after M, as illustrated for French males in Figure 1.

A limitation to the use of SD(M+) and e(M) in mortality compression research is the fact that the force of mortality at the modal age, μ(M), is not necessarily constant. It has been fairly stable, but increasing slowly in a number of countries. An increase of μ(M) may automatically reduce e(M) and SD(M+).

Thus, as an alternative approach to old-age mortality compression, Thatcher et al. (2010) examined trends in the pace of age-related mortality increase among the old, on the ground that if mortality rises more steeply with age, deaths will be compressed into a narrower range of old age. The logistic rate of age-related mortality increase for the two-parameter logistic model (Kannisto model), denoted by *b*, was used as a measure of steepness of mortality rise. *b* has generally been on upward trends in high-income countries, as illustrated for French males and females in Figure 2.

In this paper, we analyze effects of cause-specific death rates on the steepening of age-related mortality rise. Previous studies have shown that CODs differ noticeably in the pace of old-mortality increase (Horiuchi 2006; Horiuchi and Wilmoth 1997; Horiuchi et al. 2003). CODs with steep rises in old age include congestive heart failure, infarctive stroke, pneumonia, influenza, septicemia, renal failure, accidental falls, and inhalation and ingestion accidents. These causes seem to be strongly associated with senescent processes that eventually raise the general vulnerability of almost all individuals to multiple pathologies. CODs with moderate increases include various cancers, multiple sclerosis, acute myocardial infarction, hemorrhagic stroke, emphysema, and liver cirrhosis. These diseases tend to be strongly related to some risk factors and tend to develop selectively and prematurely in some high-risk individuals.

Based on this COD typology, we can consider two possible reasons for the rise of all-cause b. First, if it is difficult to slow or delay senescence, death rates from high-b CODs may decline more slowly than death rates from low-b CODs. This will increase the proportion of deaths in old age from high-b CODs, raising the value of all-cause b. Second, if mortality rises from various CODs, including many of both high-b and low-b CODs, become steeper, all-cause b will increase.

These two mechanisms are illustrated in Figure 3. In this paper, they are labeled the

level-effect hypothesis (focusing on differential declines of cause-specific mortality *levels*) and the slope-effect hypothesis (focusing on increases in the pace of cause-specific mortality rise with age, which can be measured as steepening of cause-specific logit-mortality *slope*) . It is possible for these two mechanisms to operate simultaneously, but one may be more dominant than the other.

3. Method

A widely used measure of mortality-curve steepness is the exponential rate of age-related mortality increase, which can be obtained by fitting the Gompertz model to age-specific death rates. However, a number of studies have shown that the Gompertz model does not capture significant decelerations of mortality increase at old ages (Horiuchi and Wilmoth 1998) and logistic models fit mortality data in many countries noticeably better than the Gompertz model (Horiuchi and Coale 1990; Thatcher et al. 1998). Furthermore, it can be shown that if old-age mortality curve follows a logistic equation and shift to higher ages, the exponential rate estimated from the data in a fixed age range rises over time as a statistical artifact, even if the logistic rate remains unchanged. Thus in this study, the logistic rate of increase is considered more appropriate than the exponential rate.

The logistic model has a few different versions. Thatcher, Kannisto and Vaupel

(1998) fitted several widely-used mortality models to death rates at old ages for 13 countries in various periods and showed that the full four-parameter logistic model fits the data best. The close second was a simpler two-parameter version (Kannisto model), which is written in the form:

$$\mu(x) = \frac{ae^{bx}}{1 + ae^{bx}} \qquad (1)$$

where $\mu(x)$ is the force of mortality at age x, and a and b are model parameters. This two-parameter version seems suitable for this study: in addition to the fact that the model fits data very well, it enables to express the estimated all-cause b as a simple function of cause-specific death rates. Thus, in this study, b in the Kannisto model is adopted as a measure of age-related mortality increase.

The model (1) is linearized as

$$\text{logit}\,\mu(x) = \ln \mu(x)/\big(1 - \mu(x)\big) = \ln a + bx \,. \qquad (2)$$

Note that the mathematical upper limit of $\mu(x)$ is positive infinity, not one. To our knowledge, however, $\mu(x)$ estimated from reliable empirical data never exceeded unity as far as the time unit of age is one year.

Now the logistic rate of increase can be obtained from

$$b = \big[\text{logit}\,\mu(y) - \text{logit}\,\mu(x)\big]/(y - x)\,, \qquad (3)$$

where y and x (y > x) are ages in the range in which the age trajectory of mortality

follows equation (1). Thus the logistic rate can be approximated by

$$b \approx \hat{b} = \left[\text{logit}\ {}_{\text{n}}M_y - \text{logit}\ {}_{\text{n}}M_x)\right] / (y - x)\,, \tag{4}$$

where ${}_{\text{n}}M_x$ is the death rate for age group [x, x+n) .

If causes of death are classified into k categories that are exhaustive and mutually exclusive, the all-cause b is a function of cause-specific death rates:

$$\hat{b} = \left[\text{logit} \sum_{\text{i}} {}_{\text{n}}M_y^i - \text{logit} \sum_{\text{i}} {}_{\text{n}}M_x^i\right] \Big/ (y - x)\,, \tag{5}$$

where ${}_{\text{n}}M_x$ is the death rate from cause i (i = 1, 2, 3, …, k) for age group [x, x+n).

We use the general method for decomposing a change in the variable of interest into effects of its determinants (Horiuchi, Wilmoth and Pletcher 2008) for analyzing effects of cause-specific mortality trends on all-cause b. The method is based on the concept of line integral and applicable to any relationship that can be expressed as

$$w = f(z_1, z_2, z_3, ..., z_k)$$

as far as w is a differentiable function of z's. It should also be applicable if w can be reasonably assumed as, or well-approximated by, such a differentiable function. Making use of line integral, the change in w(t) between two time points, t1 and t2, is decomposed as

$$w(t_2) - w(t_1) = \int_{t_1}^{t_2} \frac{\partial w}{\partial z_1}\frac{dz_1}{dt} + \int_{t_1}^{t_2} \frac{\partial w}{\partial z_2}\frac{dz_2}{dt} + ... + \int_{t_1}^{t_2} \frac{\partial w}{\partial z_k}\frac{dz_k}{dt}$$

where the additive terms on the right hand side are effects of the z's. Thus, application of the method to equation (5) makes it possible to decompose a change in all-cause b into additive effects of cause-specific death rates for the two age groups.

However, results of such a decomposition cannot be directly related to the two hypotheses presented earlier, the level-effect hypothesis and rate-effect hypothesis. In this study, two different kinds of cause-specific effects, i.e., effects of changes in the level of cause-specific mortality and effects of changes in the cause-specific rate of mortality increase, need to be distinguished. For this purpose, we rewrite equation (5) in terms of the sum and difference of cause-specific death rates for the two age groups,

$$\begin{aligned} s_i &= \text{logit}\ {}_nM_y^i + \text{logit}\ {}_nM_x^i \\ d_i &= \text{logit}\ {}_nM_y^i - \text{logit}\ {}_nM_x^i \end{aligned} \qquad (6)$$

s_i may be considered a measure of cause-specific mortality level for the age range from x to y+n, because s_i /2 is the mean logit of death rates from cause i for the two age groups, and if mortality from cause *i* follows the two-parameter logistic model, s_i /2 is the the geometric mean of ${}_nM_x^i$'s in the age range. d_i is a measure of age-related mortality increase between the two age groups. If the cause-specific mortality follows the Kannisto model in the age range, d_i */(y-x)* is the logistic rate of mortality increase for the COD.

Making use of these terms, the estimated all-cause b can be expressed as

$$\hat{b} = \frac{\text{logit}\sum_{\text{i}}{}_{\text{n}}M_y^i - \text{logit}\sum_{\text{i}}{}_{\text{n}}M_x^i}{y-x} = \frac{\text{logit}\sum_{\text{i}}\frac{e^{(s_i+d_i)/2}}{1+e^{(s_i+d_i)/2}} - \text{logit}\sum_{\text{i}}\frac{e^{(s_i-d_i)/2}}{1+e^{(s_i-d_i)/2}}}{y-x} \quad (7)$$

Thus, we have the general form for the line-integral decomposition,

$$\hat{b} = g(s_1, s_1, ..., s_k, d_1, d_2, ..., d_k)$$

so that a change in b can be decomposed as

$$\hat{b}(t_2) - \hat{b}(t_1) = \int_{t_1}^{t_2}\frac{\partial\hat{b}}{\partial s_1}\frac{ds_1}{dt} + \int_{t_1}^{t_2}\frac{\partial\hat{b}}{\partial s_2}\frac{ds_2}{dt} + ... + \int_{t_1}^{t_2}\frac{\partial\hat{b}}{\partial s_k}\frac{ds_k}{dt} + \int_{t_1}^{t_2}\frac{\partial\hat{b}}{\partial d_1}\frac{dd_1}{dt} + \int_{t_1}^{t_2}\frac{\partial\hat{b}}{\partial d_2}\frac{dd_2}{dt} + ... + \int_{t_1}^{t_2}\frac{\partial\hat{b}}{\partial d_k}\frac{dd_k}{dt}$$

The level-effect hypothesis in the previous section predicts that the change in b is primarily attributable to the level effects, $\sum_i\int_{t_1}^{t_2}\frac{\partial\hat{b}}{\partial s_i}\frac{ds_i}{dt}$, and the rate-effect hypothesis predicts that it is mainly due to the rate effects, $\sum_i\int_{t_1}^{t_2}\frac{\partial\hat{b}}{\partial d_i}\frac{dd_i}{dt}$.

Based on previous studies, particularly that by Thatcher et al. (2010), 70-74 and 90-94 were selected as the two age groups. The line-integral decomposition analysis was conducted using an R program previously developed by John R. Wilmoth.

4. Data

In this study, data on cause-specific mortality in France were used, because the country has a large elderly population, data on ages of the very old in France are

considered quite accurate, and it has been shown that old-age mortality compression proceeded in France (also see Figures 1 and 2). In addition, there are many previous studies on cause-specific mortality in France.

Changes in the classification of causes of death make it difficult to analyze trends in cause-specific mortality. Thus, we limited the analysis to the ICD9 period, 1979-1994 in France. The 16-year period seemed sufficiently long for analyzing mortality trends.

ICD9 has a four-level organization of COD categories: level-I group (e.g., Neoplasms), level-II group (e.g., malignant neoplasm of digestive organs and peritoneum), three-digit category (e.g., 153 malignant neoplasm of colon), and four-digit category (e.g., 153.3 malignant neoplasm of sigmoid colon). The data set contained statistics on deaths by gender and five-year age group for about two thousand CODs, which were mostly four-digit categories but included some three-digit categories. For each COD category, death rates by gender, age (70-74 and 90-94) and period (1979 and 1994) were obtained, and also the proportion of deaths in each of the eight period-gender-age groups that is attributable to the cause was computed.

For the decomposition analysis, we selected relatively frequent CODs and grouped the other CODs according to the ICD9 classification scheme in the following way: four-digit categories were grouped into three-digit categories; a three-digit category was

adopted for the decomposition analysis if the maximum of its eight proportions (four proportions for a gender-specific disease) is greater than 1% and the minimum is greater than 0%; three-digit categories that did not meet the numerical criteria were combined together within the level-I group or level-II group to which they belong. (For example, the level-II group "ischemic heart disease" has five three-digit categories, 410-414. "410 acute myocardial infarction" met the numerical criteria and was selected, and the other four categories, 411-414, were combined together as "other ischemic heart disease" because none of them met the numerical criteria.)

However, if a third-digit category meets the frequency criteria and most of deaths in the category are due to a particular four-digit COD, then the four-digit category was adopted (e.g., "154.1 malignant neoplasm of rectum", instead of "154 malignant neoplasm of rectum, rectosigmoid junction and anus".) Cervix uteri and Parkinson's disease did not meet the criteria, but they were selected as exceptions, partly because deaths due to those diseases were fairly frequent and because cervix uteri is a major adult disease and Parkinson disease is considered an important senescence-related disease. The selection and grouping processes resulted in exhaustive and mutually exclusive 52 COD categories for females and 50 for males.

5. Results

Tables 1 and 2 display cause-specific death rates by gender in age intervals 70-74 and 90-94 during the years 1979 and 1994. Cause-specific b values were computed from death rates for 70-74 and 90-94. Although there are some gender differences and period variations in cause-specific b, generally the following CODs have relatively high b values: disorders of fluid, electrolyte and acid-base balance; other endocrine, metabolic, nutritional and immunity disorders (excluding diabetes mellitus); senile dementia; cardiac dysrhythmias; heart failure; occlusion of cerebral arteries; other cerebrovascular diseases (excluding intracerebral hemorrhage as well); atherosclerosis (excluding atherosclerosis of cerebral, coronary, mesenteric, or pulmonary arteries); pneumonia; other diseases of the respiratory system (excluding COPD); nephritis, nephrotic syndrome and nephrosis; other diseases of the genitourinary system; diseases of the skin and subcutaneous tissue; symptoms, signs, and ill-defined conditions; and non-transport accidents. The list is fairly consistent with previous studies of cause-specific mortality at old ages.

Table 3 shows decomposition results for females. Estimated value of b for females was increased from 0.1261 (about 13.4% increase of logit death rate per year of age) in 1979 to 0.1318 (about 14.1% increase of logit death rate per year of age) in 1994. The increment of 0.0057 was decomposed into 53 cause-specific level effects and 53

cause-specific slope effects. The total level effect is -0.0114, the negative sign of which suggests that the level-effect hypothesis was a wrong prediction. Overall, the levels of mortality from high-b causes decreased more than those from low-b causes, which had an effect of lowering all-cause b. This was overridden by the total slope effect of 0.0171, which lends strong support to the slope-effect hypothesis.

Table 4 indicates that similar results were obtained for males. The rise of all-cause b by 0.0059 from 0.1009 (about 10.6% increase of logit death rate per year of age) in 1979 to 0.1068 (about 11.3% increase of logit death rate per year of age) in 1994 is the sum of total level effects, -0.0098, and total slope effects, 0.0157.

CODs with the strongest slope effects for females and males are heart failure, acute myocardial infarction, cerebrovascular diseases other than intracerebral hemorrhage and occlusion of cerebral arteries, and ischemic heart diseases other than acute myocardial infarction. The dominance of cardiovascular diseases is partly due to their high proportion of deaths at old ages. For females, they were followed by diseases of the digestive system other than liver cirrhosis, senile dementia, and diabetes mellitus. CODs with strong slope effects among males include COPD, prostate cancer, and cancer of trachea, bronchus and lung.

Figure 4 helps to understand the failure of the level-effect hypothesis. There is no

clear tendency for logit death rates for CODs with higher b in 1979 to fall less between 1979 and 1994. The association appears slightly negative, which is opposite to the expected direction.

Figure 5 show that the cause-specific b increased between 1979 and 1994 for the majority of COD categories. There seems to be no strong association between b in 1979 and change in b from 1979 to 1994. Cause-specific b rose for a number of CODs, including both those with relatively high b's and those with relatively low b's.

6. Discussion

Implications of this analysis for prospects of longevity extension seem mixed. On the one hand, our results suggests that the logistic rate b of age-associated increase in all-cause old-age mortality in France rose during the ICD9 period from 1979 to 1994 because cause-specific b's for many CODs rose. The rise in cause-specific rate of age-related increase was not limited to some particular types of CODs, but observed for different types of CODs, and for CODs with relatively high , medium, and low b values. This seems to suggest that for various diseases and injuries, logit death rate decreased less at older old ages than younger old ages. Probably, even in the last quarter of the twentieth century, marked by substantial declines in old-age mortality, mortality reduction at older

old ages was more difficult than at younger old ages. Thus, the results seems to be consistent with Kannisto and Thatcher's notion that old-age mortality compression reflects an increasing resistance to further longevity extension.

On the other hand, contrary to our prediction, we found no tendency for the old-age mortality decline to be less pronounced for CODs with higher b's, which are generally considered to be more senescence-related and less preventable CODs. Actually, the direction of association was rather opposite to the expected direction. This seems to suggest a positive prospect for further reduction of senescent mortality.

Furthermore, a few recent studies have shown that the old-age mortality compression appear to have ceased or slowed down in some populations, including Japanese females, a front runner of longevity extension (Cheung and Robine 2007; Ouellette and Bourbeau 2011). As the age pattern of mortality decline in high-income countries changed fundamentally during the third quarter of the twentieth century, it may be possible to enter an era of longevity extension without old-age mortality compression.

In this paper, we analyzed cause-specific mortality during the ICD9 period, partly because ICD9 covers the longest period in many countries, and partly because it is the period in which simultaneous progression of old-age mortality decline and old-age mortality compression is clearly noticeable. As the period of available cause-specific

mortality data by ICD10 is growing, the next step may be an extension of this analysis to recent ICD10 years, particularly in low mortality countries that recently witnessed discontinuation of the old-age mortality compression.

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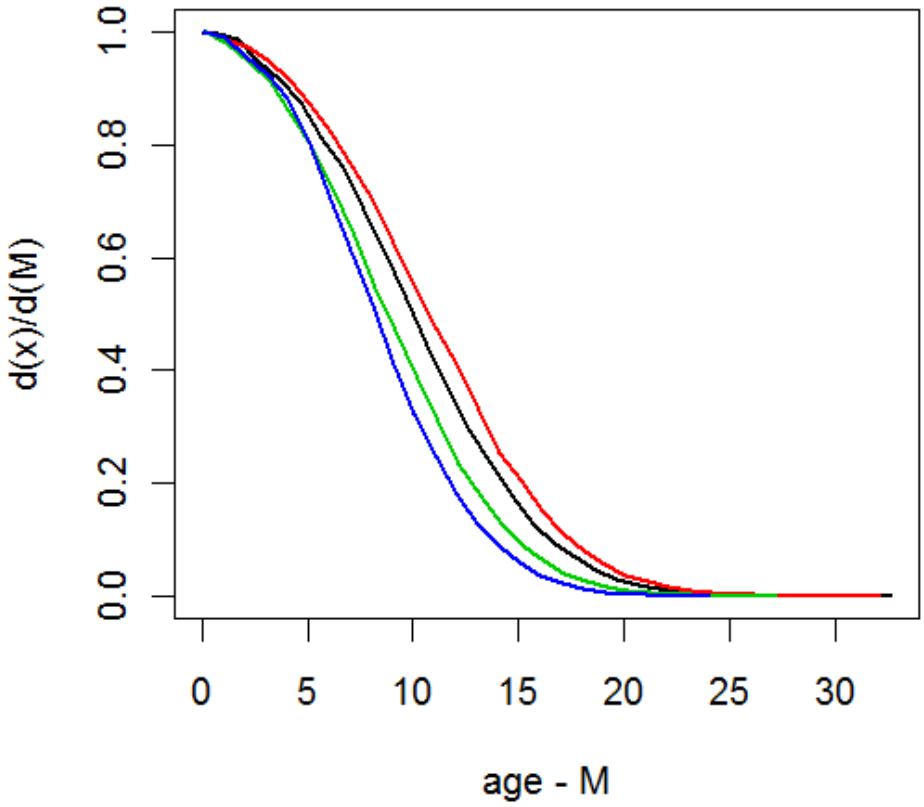
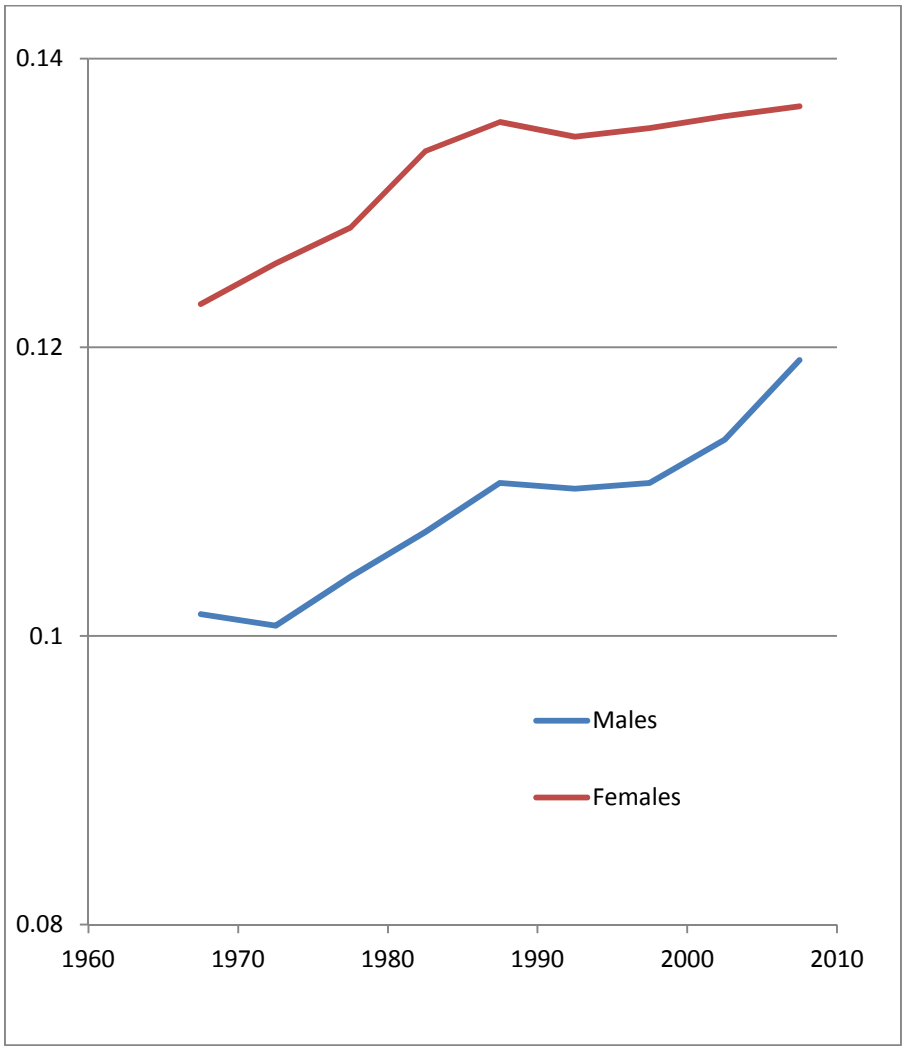
Figure 1. Distribution of deaths above the modal age (M) for French males in selected five-year periods: 1960-64 (red), 1975-79 (dark blue), 1990-94(green) and 2005-09 (blue)



Source: Human Mortality Database.

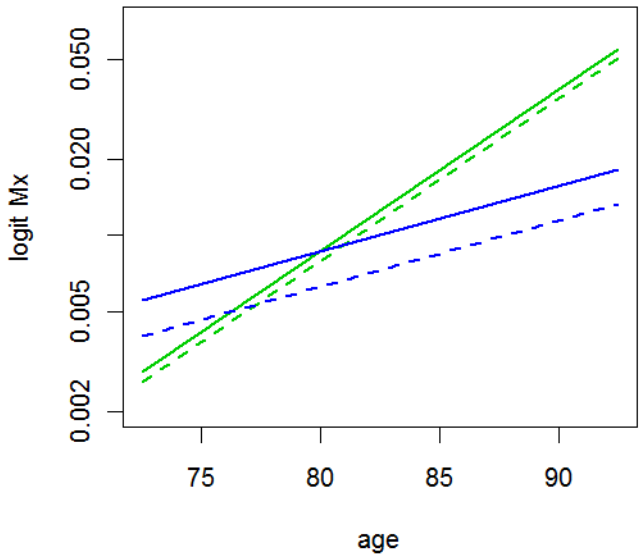
Figure 2. The estimated logistic rate of age-related mortality increase: French females and males, 1965-69 to 2005-2009.



Source: Human Mortality Database.

Figure 3. Hypotheses on cause-specific effects on the steepening of old-age mortality curve. (Solid lines are for an earlier period and dashed lines are for a later period.)

(A) Level-effect hypothesis



(B) Slope-effect hypothesis

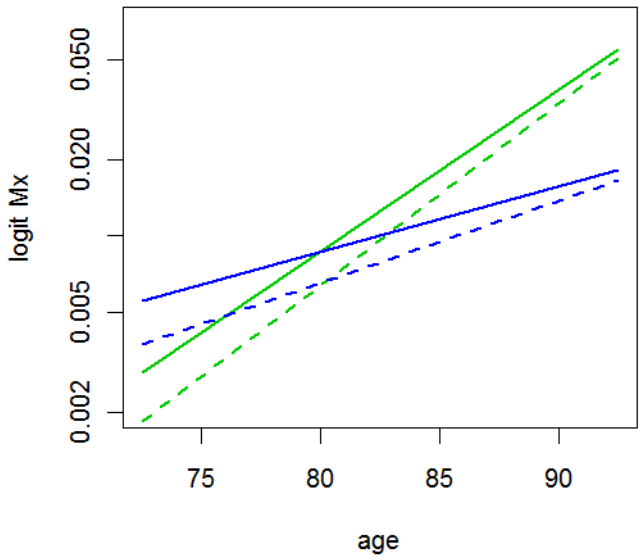
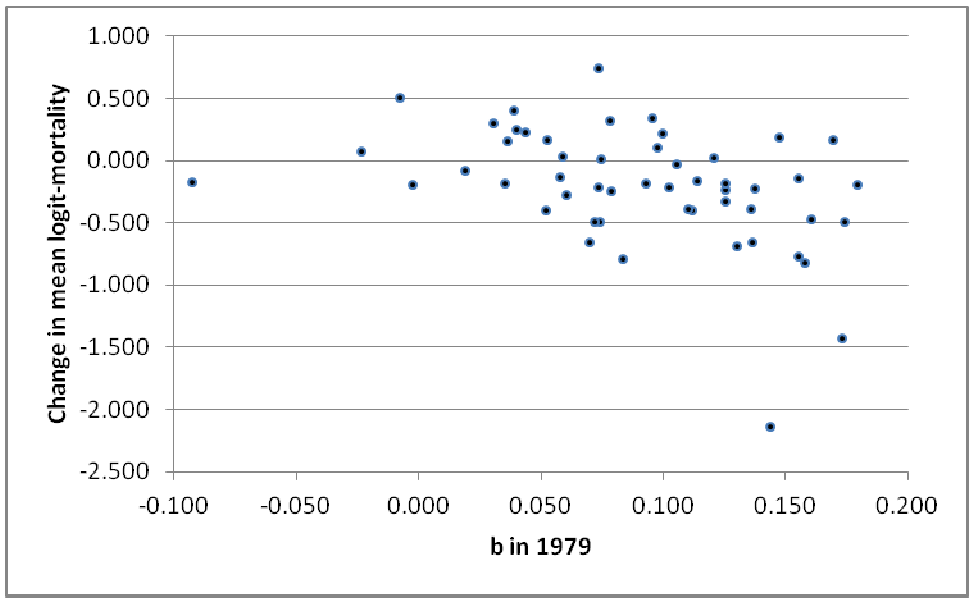


Figure 4. Relation between cause-specific b and change in the mean logit death rate for ages 70-74 and 90-94 between 1979 and 1994, for females and males in France.

(A) Females



(B) Males

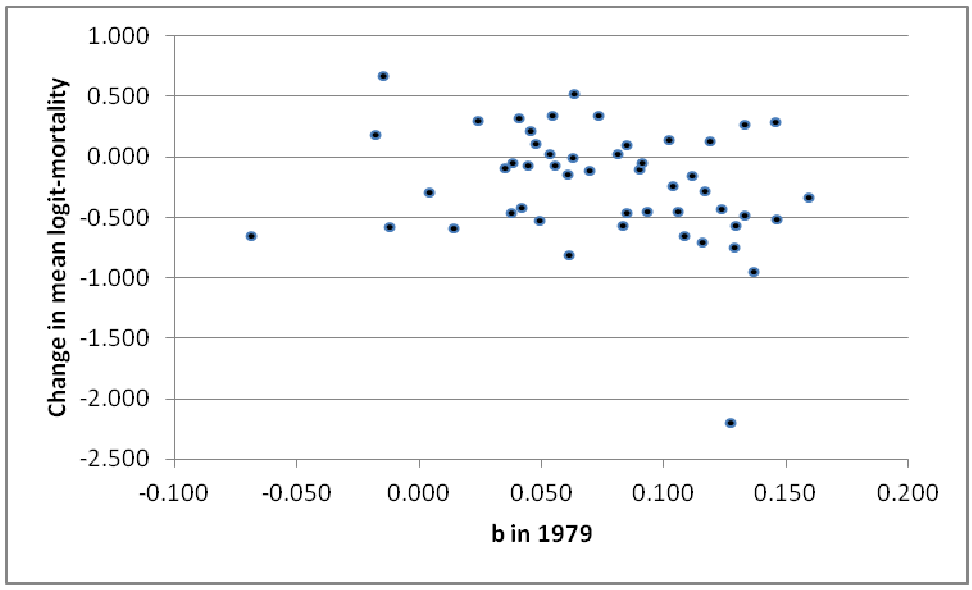
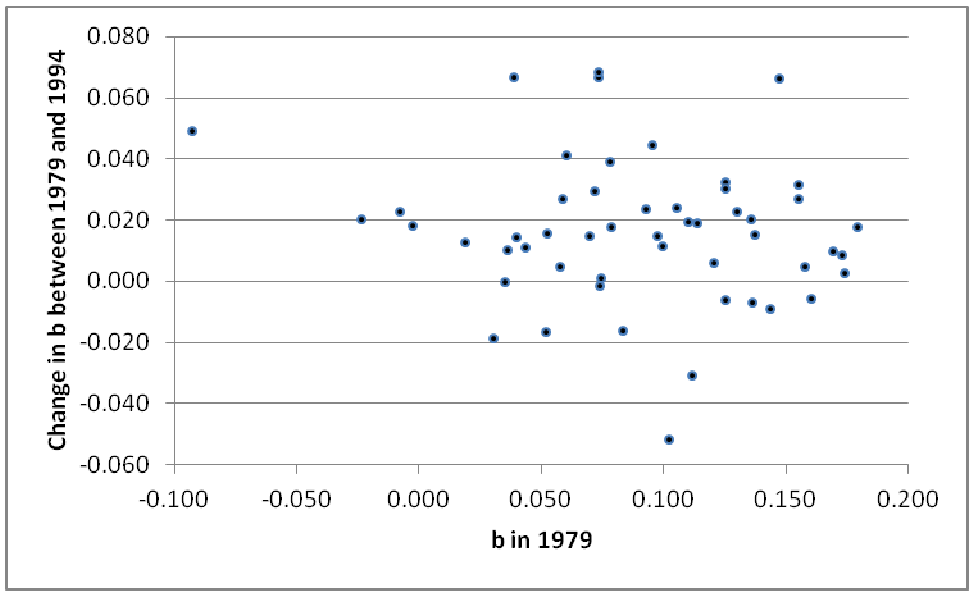


Figure 5. Relation between cause-specific b and change in b between 1979 and 1994, for females and males in France.

(A) Females



(B) Males

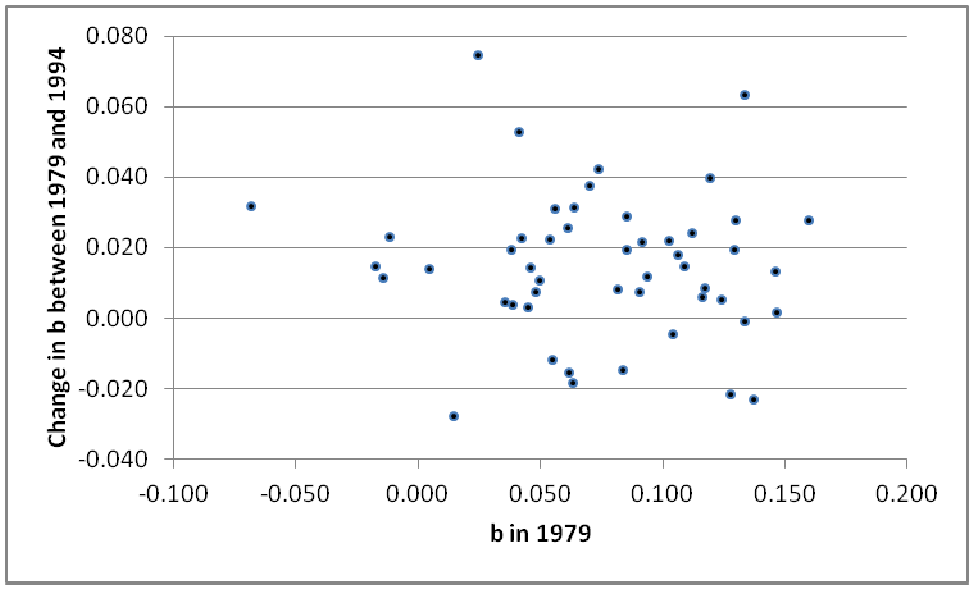


Table 1. Cause-specific death rates (x1000) for French females aged 70-74 and 90-94 in 1979 and 1994.

Causes of death	ages 70-74		ages 90-94	
	1979	1994	1979	1994
All causes	22.535	15.101	223.182	176.379
Septicemia	0.117	0.049	0.510	0.808
Other infectious and parasitic diseases	0.184	0.204	1.346	1.885
Malignant neoplasm of esophagus	0.073	0.058	0.238	0.321
Malignant neoplasm of stomach	0.467	0.210	1.892	1.141
Malignant neoplasm of colon	0.572	0.576	2.525	2.608
Malignant neoplasm of rectum	0.209	0.131	0.915	0.556
Malignant neoplasm of liver	0.208	0.173	0.422	0.351
Malignant neoplasm of pancreas	0.289	0.322	0.642	0.953
Malignant neoplasm of larynx	0.011	0.016	0.088	0.043
Malignant neoplasm of trachea, bronchus and lung	0.239	0.390	0.440	0.496
Malignant neoplasm of female breast	0.920	0.976	1.892	2.458
Malignant neoplasm of cervix uteri	0.078	0.064	0.114	0.120
Malignant neoplasm of ovary	0.296	0.392	0.255	0.530
Malignant neoplasm of bladder	0.238	0.239	0.677	0.936
Other malignant neoplasms	2.403	2.006	7.584	6.989
Other neoplasms	0.230	0.151	1.109	1.043
Diabetes mellitus	0.566	0.285	1.900	2.180
Disorders of fluid, electrolyte and acid-base balance	0.066	0.046	2.375	2.351
Other endocrine, metabolic, nutritional and immunity disorders	0.194	0.111	2.384	2.608
Diseases of blood and blood-forming organs	0.105	0.080	0.862	1.069
Senile dementia	0.116	0.072	2.200	5.134
Other mental disorders	0.132	0.140	0.572	2.394
Parkinson's disease	0.117	0.090	0.255	0.744
Other diseases of the nervous systems and sensory organs	0.469	0.430	4.393	2.180
Hypertensive diseases	0.294	0.208	2.865	2.958
Acute myocardial infarction	2.098	0.956	8.807	7.250
Other ischemic heart diseases	0.493	0.447	3.334	7.352
Pulmonary embolism	0.273	0.180	1.742	1.851
Cardiac dysrhythmias	0.420	0.290	6.502	6.096
Heart failure	1.322	0.450	28.853	18.612
Other heart diseases	0.647	0.496	7.886	5.382
Intracerebral hemorrhage	0.553	0.296	2.939	1.146
Occlusion of cerebral arteries	0.309	0.040	5.428	0.594
Other cerebrovascular diseases	2.266	0.911	29.700	19.103
Atherosclerosis	0.077	0.017	2.446	0.641
Aortic aneurysm	0.056	0.054	0.396	0.509
Other diseases of the circulatory system	0.468	0.260	7.003	5.852
Pneumonia	0.225	0.241	6.636	8.676
Chronic obstructive pulmonary diseases	0.395	0.380	4.395	4.777
Other diseases of the respiratory system	0.317	0.133	7.366	3.407
Liver cirrhosis	0.435	0.224	0.068	0.094
Other diseases of the digestive system	0.995	0.556	8.985	7.434
Nephritis, nephrotic syndrome and nephrosis	0.256	0.143	3.889	1.902
Other diseases of the genitourinary system	0.088	0.054	1.082	1.223
Diseases of the skin and subcutaneous tissue	0.072	0.048	1.619	1.842
Diseases of the musculoskeletal system and connective tissue	0.130	0.122	0.625	1.282
Congenital anomalies and perinatal conditions	0.019	0.015	0.053	0.030
Symptoms, signs, and ill-defined conditions	0.894	0.536	28.399	18.210
Transport accidents	0.154	0.136	0.097	0.128
Non-transport accidents	0.656	0.436	16.035	9.605
Suicide and self-inflicted injury	0.231	0.159	0.220	0.218
Other external causes	0.092	0.104	0.221	0.312

Table 2 Cause-specific death rates (x1000) for French males aged 70-74 and 90-94 in 1979 and 1994.

Causes of death	ages 70-74		ages 90-94	
	1979	1994	1979	1994
All causes	48.214	33.977	276.081	229.584
Septicemia	0.206	0.127	0.829	1.085
Other infectious and parasitic diseases	0.424	0.400	2.149	2.390
Malignant neoplasm of esophagus	0.852	0.626	1.136	0.481
Malignant neoplasm of stomach	1.177	0.624	3.163	2.074
Malignant neoplasm of colon	1.036	1.077	2.702	3.269
Malignant neoplasm of rectum	0.545	0.283	1.167	0.893
Malignant neoplasm of liver	0.578	1.016	0.430	0.948
Malignant neoplasm of pancreas	0.572	0.527	1.228	1.222
Malignant neoplasm of larynx	0.665	0.297	0.522	0.371
Malignant neoplasm of trachea, bronchus and lung	3.157	3.269	2.211	3.063
Malignant neoplasm of prostate	1.471	1.338	8.014	10.754
Malignant neoplasm of bladder	0.877	0.948	2.180	3.131
Other malignant neoplasms	3.887	3.524	9.427	9.078
Other neoplasms	0.348	0.287	1.013	1.305
Diabetes mellitus	0.593	0.408	1.812	2.307
Disorders of fluid, electrolyte and acid-base balance	0.106	0.057	2.549	2.417
Other endocrine, metabolic, nutritional and immunity disorders	0.252	0.170	2.364	2.582
Diseases of blood and blood-forming organs	0.178	0.165	1.382	1.978
Senile dementia	0.117	0.082	1.689	4.175
Other mental disorders	0.396	0.254	0.645	1.840
Parkinson's disease	0.230	0.187	0.522	1.222
Other diseases of the nervous systems and sensory organs	0.814	0.533	4.300	2.101
Hypertensive diseases	0.394	0.332	2.401	2.349
Acute myocardial infarction	4.844	2.539	11.116	9.188
Other ischemic heart diseases	1.195	1.469	4.268	9.793
Pulmonary embolism	0.369	0.174	2.027	1.703
Cardiac dysrhythmias	0.776	0.541	7.984	6.579
Heart failure	2.318	0.999	30.148	22.744
Other heart diseases	1.097	0.905	8.659	6.551
Intracerebral hemorrhage	0.941	0.490	3.224	1.236
Occlusion of cerebral arteries	0.505	0.070	6.418	0.577
Other cerebrovascular diseases	3.779	1.713	32.363	19.874
Atherosclerosis	0.215	0.105	3.316	1.030
Aortic aneurysm	0.258	0.408	0.768	0.961
Other diseases of the circulatory system	1.135	0.606	9.335	7.142
Pneumonia	0.526	0.617	9.593	14.599
Chronic obstructive pulmonary diseases	1.566	1.206	9.703	11.492
Other diseases of the respiratory system	1.018	0.473	10.244	5.402
Liver cirrhosis	1.813	0.688	0.461	0.330
Other diseases of the digestive system	1.745	0.990	11.239	8.062
Nephritis, nephrotic syndrome and nephrosis	0.490	0.307	7.032	4.340
Other diseases of the genitourinary system	0.307	0.120	4.023	2.335
Diseases of the skin and subcutaneous tissue	0.091	0.070	0.983	1.662
Diseases of the musculoskeletal system and connective tissue	0.113	0.104	0.491	1.058
Congenital anomalies and perinatal conditions	0.018	0.012	0.061	0.069
Symptoms, signs, and ill-defined conditions	1.764	1.038	31.796	19.599
Transport accidents	0.396	0.258	0.430	0.371
Non-transport accidents	1.239	0.764	14.616	10.067
Suicide and self-inflicted injury	0.634	0.556	1.290	1.236
Other external causes	0.187	0.225	0.660	0.549

Table 3. Cause-of-death decomposition of change in the logistic rate (x1000) of age-related mortality increase between 70-74 and 90-94: French females, 1979-1994.

Causes of death	Level efffect	Slope effect	Total effect
All Causes	-11.398	17.098	5.700
Septicemia	0.001	0.282	0.283
Other infectious and parasitic diseases	-0.008	0.124	0.116
Malignant neoplasm of esophagus	-0.003	0.073	0.070
Malignant neoplasm of stomach	0.269	0.199	0.467
Malignant neoplasm of colon	-0.016	0.030	0.014
Malignant neoplasm of rectum	0.114	-0.009	0.104
Malignant neoplasm of liver	0.075	-0.001	0.074
Malignant neoplasm of pancreas	-0.154	0.159	0.005
Malignant neoplasm of larynx	0.004	-0.030	-0.026
Malignant neoplasm of trachea, bronchus and lung	-0.223	-0.190	-0.413
Malignant neoplasm of female breast	-0.318	0.342	0.024
Malignant neoplasm of cervix uteri	0.013	0.030	0.043
Malignant neoplasm of ovary	-0.429	0.247	-0.182
Malignant neoplasm of bladder	-0.068	0.147	0.079
Other malignant neoplasms	0.505	0.417	0.922
Other neoplasms	0.043	0.155	0.197
Diabetes mellitus	0.131	0.732	0.862
Disorders of fluid, electrolyte and acid-base balance	-0.112	0.160	0.048
Other endocrine, metabolic, nutritional and immunity disorders	-0.090	0.391	0.301
Diseases of blood and blood-forming organs	-0.001	0.136	0.135
Senile dementia	0.162	0.907	1.068
Other mental disorders	0.022	0.547	0.569
Parkinson's disease	-0.056	0.291	0.235
Other diseases of the nervous systems and sensory organs	0.106	-0.693	-0.587
Hypertensive diseases	-0.037	0.305	0.269
Acute myocardial infarction	0.716	1.925	2.641
Other ischemic heart diseases	0.109	1.316	1.425
Pulmonary embolism	0.008	0.284	0.293
Cardiac dysrhythmias	-0.222	0.454	0.232
Heart failure	-3.847	2.974	-0.873
Other heart diseases	-0.156	-0.217	-0.373
Intracerebral hemorrhage	0.421	-0.277	0.144
Occlusion of cerebral arteries	-0.693	-0.090	-0.784
Other cerebrovascular diseases	-2.299	2.643	0.344
Atherosclerosis	-0.449	0.044	-0.405
Aortic aneurysm	-0.001	0.044	0.043
Other diseases of the circulatory system	-0.404	0.612	0.208
Pneumonia	0.300	0.307	0.607
Chronic obstructive pulmonary diseases	0.008	0.155	0.164
Other diseases of the respiratory system	-0.849	0.104	-0.744
Liver cirrhosis	0.144	0.443	0.587
Other diseases of the digestive system	-0.193	0.912	0.719
Nephritis, nephrotic syndrome and nephrosis	-0.219	-0.097	-0.316
Other diseases of the genitourinary system	-0.031	0.169	0.138
Diseases of the skin and subcutaneous tissue	-0.055	0.194	0.139
Diseases of the musculoskeletal system and connective tissue	-0.020	0.255	0.235
Congenital anomalies and perinatal conditions	0.014	-0.010	0.004
Symptoms, signs, and ill-defined conditions	-2.499	0.263	-2.236
Transport accidents	-0.029	0.089	0.060
Non-transport accidents	-1.125	-0.300	-1.425
Suicide and self-inflicted injury	0.090	0.111	0.201
Other external causes	-0.045	0.040	-0.005

Table 4. Cause-of-death decomposition of change in the logistic rate (x1000) of age-related mortality increase between 70-74 and 90-94: French males, 1979-1994.

Causes of death	Level effect	Slope effect	Total effect
All causes	-9.829	15.735	5.906
Septicemia	-0.005	0.176	0.171
Other infectious and parasitic diseases	0.002	0.095	0.097
Malignant neoplasm of esophagus	0.437	-0.319	0.118
Malignant neoplasm of stomach	0.228	0.191	0.419
Malignant neoplasm of colon	-0.067	0.166	0.099
Malignant neoplasm of rectum	0.110	0.152	0.263
Malignant neoplasm of liver	-0.579	0.136	-0.443
Malignant neoplasm of pancreas	0.017	0.040	0.056
Malignant neoplasm of larynx	0.267	0.163	0.430
Malignant neoplasm of trachea, bronchus and lung	-0.632	0.714	0.083
Malignant neoplasm of prostate	0.066	0.846	0.912
Malignant neoplasm of bladder	-0.108	0.271	0.163
Other malignant neoplasms	0.160	0.219	0.380
Other neoplasms	-0.003	0.161	0.158
Diabetes mellitus	0.006	0.368	0.374
Disorders of fluid, electrolyte and acid-base balance	-0.187	0.214	0.027
Other endocrine, metabolic, nutritional and immunity disorders	-0.060	0.225	0.165
Diseases of blood and blood-forming organs	0.031	0.148	0.179
Senile dementia	0.169	0.551	0.720
Other mental disorders	-0.031	0.539	0.508
Parkinson's disease	-0.015	0.260	0.245
Other diseases of the nervous systems and sensory organs	0.023	-0.247	-0.224
Hypertensive diseases	-0.016	0.083	0.067
Acute myocardial infarction	0.791	1.655	2.446
Other ischemic heart diseases	0.024	1.112	1.136
Pulmonary embolism	-0.077	0.241	0.164
Cardiac dysrhythmias	-0.303	0.232	-0.071
Heart failure	-2.750	2.453	-0.297
Other heart diseases	-0.169	-0.145	-0.314
Intracerebral hemorrhage	0.272	-0.221	0.051
Occlusion of cerebral arteries	-0.797	-0.196	-0.993
Other cerebrovascular diseases	-2.160	1.465	-0.695
Atherosclerosis	-0.303	-0.164	-0.466
Aortic aneurysm	-0.069	-0.078	-0.147
Other diseases of the circulatory system	-0.490	0.582	0.092
Pneumonia	0.710	0.521	1.231
Chronic obstructive pulmonary diseases	-0.046	0.996	0.949
Other diseases of the respiratory system	-0.773	0.179	-0.594
Liver cirrhosis	0.895	0.502	1.397
Other diseases of the digestive system	-0.371	0.494	0.122
Nephritis, nephrotic syndrome and nephrosis	-0.467	-0.016	-0.483
Other diseases of the genitourinary system	-0.424	0.211	-0.213
Diseases of the skin and subcutaneous tissue	0.032	0.180	0.211
Diseases of the musculoskeletal system and connective tissue	0.020	0.144	0.164
Congenital anomalies and perinatal conditions	0.000	0.009	0.010
Symptoms, signs, and ill-defined conditions	-2.470	0.144	-2.325
Transport accidents	0.089	0.074	0.163
Non-transport accidents	-0.843	0.238	-0.605
Suicide and self-inflicted injury	0.038	0.050	0.088
Other external causes	0.000	-0.079	-0.079