Quantifying cause-related mortality by weighting multiple causes of death
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Objective To investigate a new approach to calculating cause-related standardized mortality rates that involves assigning weights to each cause of death reported on death certificates.

Methods We derived cause-related standardized mortality rates from death certificate data for France in 2010 using: (i) the classic method, which considered only the underlying cause of death; and (ii) three novel multiple-cause-of-death weighting methods, which assigned weights to multiple causes of death mentioned on death certificates: the first two multiple-cause-of-death methods assigned non-zero weights to all causes mentioned and the third assigned non-zero weights to only the underlying cause and other contributing causes that were not part of the main morbid process. As the sum of the weights for each death certificate was 1, each death had an equal influence on mortality estimates and the total number of deaths was unchanged. Mortality rates derived using the different methods were compared.

Findings On average, 3.4 causes per death were listed on each certificate. The standardized mortality rate calculated using the third multiple-cause-of-death weighting method was more than 20% higher than that calculated using the classic method for five disease categories: skin diseases, mental disorders, endocrine and nutritional diseases, blood diseases and genitourinary diseases. Moreover, this method highlighted the mortality burden associated with certain diseases in specific age groups.

Conclusion A multiple-cause-of-death weighting approach to calculating cause-related standardized mortality rates from death certificate data identified conditions that contributed more to mortality than indicated by the classic method. This new approach holds promise for identifying underrecognized contributors to mortality.

Abstracts in العربية, 中文, Français, Русский и Español at the end of each article.

Introduction
Good understanding of mortality data is essential for developing and evaluating health policies. The causes of any death are usually reported on parts I and II of a death certificate, in accordance with the international form presented in the International classification of diseases and related health problems, tenth revision (ICD-10).\(^1\) and data are usually collected in a standardized and consistent way.\(^2\) In part I, the physician describes the causal sequence of events that led directly to the death. In part II, the physician can report any other significant morbid condition but only if that condition may have contributed to the death.

Generally, cause-of-death statistics are derived from the so-called underlying cause of death in a process hereafter referred to as the classic method.\(^3\) The World Health Organization (WHO) defines the underlying cause of death as “the disease or injury which initiated the train of morbid events leading directly to death or the circumstances of the accident or violence which produced the fatal injury”.\(^4\) However, deaths are often caused by more than one disease. Moreover, in a world characterized by an ageing population and decreasing mortality and fertility, death due to infectious disease is progressively being replaced by death due to chronic and degenerative diseases.\(^5,6\) As a result, the classic method discards potentially useful information about the contribution of other conditions to a death.

Today, analysis of mortality data increasingly uses a multiple-cause-of-death approach,\(^3,5,7–12\) which is defined as any statistical treatment that simultaneously considers more than one of the causes of death reported on a death certificate. In particular, such approaches have been used to recalculate mortality attributable to specific conditions. In practice, when cause-specific mortality is re-evaluated to take into account multiple causes of death, the number of mentions of a specific cause is usually considered – here the statistical unit is the cause of death rather than the death itself, which raises serious questions about interpretation. For example, studies examining the influence of several diseases on mortality may count a single death two or more times if two or more causes of death are mentioned on the certificate. The resulting apparent increase in mortality could yield an artificial increase in statistical power and possibly result in misleading inferences. An additional problem is that each cause of death mentioned on a certificate is given an equal weight, even though its individual contribution may not have been equally important – the relative importance of each cause of death is not considered.

In this study, we investigated an experimental approach that assigns a weight to each cause of death listed on a death certificate by analysing French death certificate data using three multiple-cause-of-death weighting methods. This approach conceptualizes death as the outcome of a mixture of conditions, as we described elsewhere.\(^13\) Consequently, each death contributes only a fraction, rather than a unit, when calculating standardized mortality rates for each cause of death – the fraction depends on the weight assigned. The approach accepts that multiple factors may contribute to a death but also reflects the relative contribution of each cause of death.\(^14\) Use of a multiple-cause-of-death weighting approach could help us identify conditions whose contribution to mortality is underestimated by the classic method.

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Methods

We examined data on all deaths reported in France during 2010. We had access to information on all the causes of death declared on death certificates, including the underlying cause of death, as coded using the ICD-10 by CépiDc–Inserm – the epidemiology centre on medical causes of death of the French National Institute for Health and Medical Research. We used the 2012 version of the European shortlist for causes of death to analyse mortality by cause-of-death category, though the list was modified slightly for the analysis. In addition, we removed codes for causes of death that were not relevant to our study, such as those that did not refer to diseases but rather to: (i) risk factors; (ii) family history; (iii) socioeconomic and psychosocial circumstances; and (iv) injury or poisoning or other external causes of death (i.e. ICD-10 cause-of-death codes beginning with S, T, U or Z, which relate to chapters XIX, XXI and XXII). Of note, none of these causes was designated an underlying cause of death.

First, we classified the data using cause-of-death categories and determined whether each cause was reported as an underlying or a contributory cause. We also examined the number of causes reported on each death certificate, whether in both parts of the certificate or only in part II. Then we calculated age- and sex-standardized mortality rates for each cause-of-death category using: (i) the classic method, which considered only the underlying cause of death; and (ii) three multiple-cause-of-death weighting methods that assigned a weight to each cause of death, as described below. For the analysis, we used the Eurostat Europe and European Free Trade Association standard population for 2013. All analyses were performed using SAS v. 9.3 (SAS Institute Inc., Cary, United States of America).

Multiple-cause weighting

The first multiple-cause-of-death weighting method, MCW, attributes a weight to each cause of death reported on a death certificate. Thus, if cause i is mentioned on certificate i, on which a total of n_i causes are reported, the weight attributed to cause c, w_{c,i}, is given by:

\[ w_{c,i} = \frac{1}{n_i} \]  

(1)

Here, the underlying cause is not given a greater weight than other causes.

The second weighting method, MCW, attributes a weight w_{UC} to the disease selected as the underlying cause of death, with w_{UC} having a fixed value between 0 and 1. The total remaining weight (i.e. 1 - w_{UC}) is distributed among all other causes of death mentioned on the certificate (i.e. n_i - 1). Hence, the weight attributed to cause c on certificate i, w_{c,i}, is given by:

\[ w_{c,i} = w_{UC} \]  

(2)

if c is the underlying cause, and by:

\[ w_{c,i} = \frac{1 - w_{UC}}{n_i - 1} \]  

(3)

if c is not the underlying cause.

With the classic method, w_{UC}=1, the death is wholly attributed to the underlying cause regardless of other causes mentioned on the certificate. In contrast, the first two weighting methods enable all diseases mentioned on the death certificate to be included in the analysis. Although the attributed value of w_{UC} is subjective, so is choosing w_{UC} to be 1. Therefore, the effect of different choices of w_{UC} should be examined in a sensitivity analysis. In our analysis, we set w_{UC} equal to 0.5 to give a good illustration of the impact of the weighting method on standardized mortality rates. Choosing an intermediate weight between 0.5 and 1 would lead to mortality rates between those based on the classic method and those based on a weighting method with w_{UC} set to 0.5.

The third weighting method, MCW, is similar to the second except that all causes of death mentioned in part I of the death certificate other than the underlying cause are given a weight of zero. Hence, the weight attributed to cause c on certificate i, w_{c,i}, is given by:

\[ w_{c,i} = w_{UC} \]  

(4)

if c is the underlying cause, by:

\[ w_{c,i} = 0 \]  

(5)

if c is mentioned in part I and is not the underlying cause, and by:

\[ w_{c,i} = \frac{1 - w_{UC}}{n_i - 1} \]  

(6)

if c is mentioned in part II and is not the underlying cause, where w_{UC} is the weight attributed to the underlying cause of death and n_{ci} is the number of causes reported on part II of the death certificate (apart from the underlying cause if it is reported on part II, as could occur with some ICD-10 coding rules). The aim of this approach was to take into account the underlying cause of death and only other causes of death that were regarded as being on a different causal pathway from the main morbid process initiated by the underlying cause. Studying separate disease processes in this way is more meaningful from a causal perspective.

For both MCW and MCW methods, when only one cause is reported, that cause is necessarily the underlying cause and its weight w_{c,i} is 1. In addition, with all three weighting methods, the sum of the weights for all the different causes of death on each death certificate is 1. Moreover, the sum of the weights across individuals equals the total number of deaths. Consequently, each death has an equal influence on mortality estimates. Table 1 illustrates how the classic method and the three weighting methods are applied (additional examples are available from the corresponding author on request).

After we assigned weights to each cause of death on each death certificate using a weighting method, we calculated age- and sex-standardized mortality rates for each cause. First, the sum of the weights attributed to cause c mentioned on death certificates across all individuals i was computed for specific age (a) and sex (s) groups:

\[ w_{a,s} = \sum_i w_{c,i} \]  

(7)

where w_{a,s} is the weight attributed to cause c on the certificate of individual i. Then, the standardized mortality rate for cause c was obtained as:

\[ R_i = \left(\frac{1}{\sum_{a,s} p_{a,s} \cdot w_{a,s}}\right) \sum_{a,s} w_{a,s} \left(\frac{p_{a,s}}{p_{a,s}^{std}}\right) \]  

(8)

where R is the standardized mortality rate, p_{a,s}^{std} and p_{a,s} are the number of
Table 1. Weights applied to causes of death on a death certificate calculation method

| Cause of death on death certificate | Weights applied to causes of death |
|-------------------------------------|-----------------------------------|
|                                    | Classic method\(^a\) | Multiple-cause-of-death weighting method\(^b\) | MCW\(_1\) | MCW\(_2\) | MCW\(_3\) |
| Part I                             |                      |                                               |
| a. Pneumonia                       | 0                    | \(1/5 = 0.2\)                                | 0.5/4 = 0.125 | 0       |
| b. Chronic respiratory failure     | 0                    | \(1/5 = 0.2\)                                | 0.5/4 = 0.125 | 0       |
| c. Chronic obstructive pulmonary disease\(^c\) | 1                    | \(1/5 = 0.2\)                                | \(w^a = 0.5\) | \(w^b = 0.5\) |
| d. No cause listed                 | NA                   | NA                                             | NA           | NA      |
| Part II                            |                      |                                               |
| Diabetes                           | 0                    | \(1/5 = 0.2\)                                | 0.5/4 = 0.125 | 0.5/2 = 0.25 |
| Dementia                           | 0                    | \(1/5 = 0.2\)                                | 0.5/4 = 0.125 | 0.5/2 = 0.25 |

MCW: Multiple-cause-of-death weighting method; NA: not applicable; \(w^c\): weight attributed to the underlying cause of death.

\(^a\) With the classic method, only the underlying cause of death specified on the death certificate is considered when calculating mortality rates.

\(^b\) Details of the three multiple-cause-of-death weighting methods, MCW\(_1\), MCW\(_2\), and MCW\(_3\), are given in the main text.

\(^c\) Underlying cause of death mentioned on the death certificate.

Fig. 1. Number of causes of death on each death certificate, by age and sex, 2010, France

Results

In total, 552,571 deaths were reported in France in 2010. On average, 3.4 causes of death were mentioned on each death certificate (standard deviation: 1.92; median: 3; interquartile range: 2 to 4). The variation in the mean number of causes of death by age was low; it varied between 3.2 and 3.6 per individual over the age range 55 to 93 years, within which 80% of deaths occurred (Fig. 1). However, the mean was lower in individuals aged 15 to 35 years, varying between 2.6 and 3.1 causes in each certificate. Some categories of the underlying cause of death appeared more frequently than others on certificates that mentioned a high number of causes: a high mean number of causes was associated with conditions in the categories of musculoskeletal diseases, skin diseases, endocrine and nutritional diseases, and blood diseases (Table 2). Moreover, when one of these conditions was mentioned as the underlying cause of death, the ratio of the number of mentions of the condition to the number of mentions as the underlying cause was also high. However, the category symptoms, signs, ill-defined causes was associated with the highest ratio and with the lowest mean number of causes reported.

Here, we report mainly our findings with the MCW\(_2\) method, which are the easiest to interpret and the most interesting. We found that the increase in the standardized mortality rate derived using this method relative to the classic method exceeded 20% in five cause-of-death categories: skin diseases, mental disorders, endocrine and nutritional diseases, blood diseases, and genitourinary diseases (Table 3). The overall increase in the standardized mortality rate we observed for mental disorders was due in a large part to increases in specific subcategories: for other mental and behavioural disorders the increase was 112% and for alcohol abuse (including alcoholic psychosis), it was 43% (Table 4; available at: http://www.who.int/bull/letin/volumes/94/121/16-172189). In contrast, the increase for drug dependence and toxicomania was 28% and for dementia, 12%. Notable increases were also observed in other disease subcategories: rheumatoid arthritis and osteoarthritis increased by 44%, other diseases of the circulatory system by 19%.
and viral hepatitis by 19%. There was either no change or a small decrease in the standardized mortality rate in categories such as diseases of the circulatory system, diseases of the respiratory system and perinatal diseases. However, as expected, our analysis found a decrease in the contribution of conditions that are almost systematically specified as the underlying cause of death: for example, external causes of morbidity and mortality, neoplasms, congenital malformations and digestive system diseases. These decreases were most marked with the MCW, method (Table 3), particularly when the number of other causes of death mentioned was high, because this method does not attribute a greater weight to the underlying cause relative to other causes.

In addition, the MCW method also enabled us to highlight the increase in the mortality burden associated with certain conditions in specific age groups. For example, the increase in the standardized mortality rate derived using the MCW method relative to the classic method was as high as 48% for endocrine and nutritional diseases in people aged 60 to 69 years. The increase was very small in those aged 0 to 34 years, large in those aged 35 to 74 years and smaller again in those 75 years of age or older (Fig. 2). For mental disorders, the increase in mortality burden was much greater for people aged 0 to 34 years and 35 to 74 years than for those aged 75 years or older (Fig. 3). The increase in mortality burden for rheumatoid arthritis and osteoarthritis was found to be greatest in people 75 years of age or older (Fig. 4).

Analysing mortality data by sex using the MCW method did not reveal any other increases in the mortality burden associated with particular conditions in addition to those already identified in the overall analysis. Similar increases were observed for men and for women with the MCW method relative to the classic method, except for mental disorders, where the increase was 40% in men and 27% in women and for genitourinary diseases, where it was 29% and 15%, respectively.

### Discussion

Our analysis of all death certificates in France for 2010, in which we used three multiple-cause-of-death weighing methods to derive standardized mortality rates, aimed to provide a better estimate of the actual causes of death than the classic method. In particular, we confirmed the findings of previous studies that some conditions that are rarely designated as the underlying cause of death actually make a substantial contribution to mortality: namely, diabetes, skin disease, blood disease and renal disease. However, as previously observed, the increase in the standardized mortality rate we found for each condition varied widely with the disease category. In contrast, other conditions that we revealed to have contributed more to mortality than previously recognized were little mentioned in the literature, such as mental disorders and diseases of the musculoskeletal system, especially rheumatoid arthritis and osteoarthritis. Moreover, application of the MCW method showed that the contribution of certain conditions to mortality varied even in young people: in particular, mental disorders contributed more in young people than indicated by the classic method. The contribution of conditions in other categories such as endocrine and nutritional diseases varied even in young people: in particular, mental disorders contributed more in young people than indicated by the classic method.

### Table 2. Causes of death mentioned on death certificates, 2010, France

| Cause-of-death category | Total no. of mentions of cause on death certificates | No. of mentions of cause as underlying cause of death on certificates | Ratio of no. of mentions of cause to no. of mentions as underlying cause | Mean no. of all causes of death per certificate |
|-------------------------|----------------------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------|-----------------------------------------------|
| Musculoskeletal diseases | 11 692                                             | 3 744                                                          | 3.12                                                          | 4.58                                          |
| Skin diseases            | 10 506                                             | 1 459                                                          | 7.20                                                          | 4.37                                          |
| Endocrine and nutritional diseases | 87 782 | 20 069 | 4.37 | 4.27 |
| Blood diseases            | 14 957                                             | 2 313                                                          | 6.47                                                          | 4.17                                          |
| Digestive system diseases | 71 738                                             | 23 954                                                         | 2.99                                                          | 3.97                                          |
| Genitourinary diseases   | 49 293                                             | 9 979                                                          | 4.94                                                          | 3.90                                          |
| Infectious diseases      | 48 977                                             | 11 129                                                         | 4.40                                                          | 3.88                                          |
| Congenital malformations | 3 072                                              | 1 548                                                          | 1.98                                                          | 3.78                                          |
| Mental disorders         | 65 044                                             | 18 265                                                         | 3.56                                                          | 3.70                                          |
| External causes of morbidity and mortality | 50 000 | 38 671 | 1.29 | 3.65 |
| Respiratory system diseases| 140 936                                           | 32 640                                                         | 4.32                                                          | 3.55                                          |
| Circulatory system diseases | 442 166                                           | 140 057                                                        | 3.03                                                          | 3.49                                          |
| Nervous system diseases  | 73 247                                             | 32 850                                                         | 2.23                                                          | 3.48                                          |
| Neoplasms                | 149                                                | 74                                                             | 2.01                                                          | 3.47                                          |
| Perinatal conditions     | 308 445                                            | 162 113                                                        | 1.90                                                          | 3.43                                          |
| Symptoms, signs, ill-defined causes | 5 137 | 1 457 | 3.53 | 3.33 |
| Other                    | 353 068                                            | 35 356                                                         | 9.99                                                          | 1.40                                          |

NA: not applicable

* The cause-of-death categories are those listed in the European shortlist for causes of death, 2012.

* In total, 552 571 deaths were reported in France in 2010.
Table 3. Standardized cause-related mortality rates, by calculation method and cause-of-death category, 2010, France

| Cause-of-death category                                      | Standardized mortality derived using the classic method, per 100 000 population | Change in standardized mortality with the multiple-cause-of-death weighting method relative to the classic method, % |
|--------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| Infectious diseases                                          | 19.2                                                                            | MCW<sub>1</sub>: 22, MCW<sub>2</sub>: 16, MCW<sub>3</sub>: -14                                                                                           |
| External causes of morbidity and mortality                   | 65.2                                                                            | MCW<sub>1</sub>: -40, MCW<sub>2</sub>: -31, MCW<sub>3</sub>: -13                                                                            |
| Digestive system diseases                                    | 40.8                                                                            | MCW<sub>1</sub>: -15, MCW<sub>2</sub>: -10, MCW<sub>3</sub>: -11                                                                                 |
| Neoplasms                                                    | 287.0                                                                          | MCW<sub>1</sub>: -36, MCW<sub>2</sub>: -26, MCW<sub>3</sub>: -7                                                                 |
| Respiratory system diseases                                  | 59.3                                                                            | MCW<sub>1</sub>: 22, MCW<sub>2</sub>: 15, MCW<sub>3</sub>: -5                                                                 |
| Circulatory system diseases                                  | 250.1                                                                          | MCW<sub>1</sub>: -9, MCW<sub>2</sub>: -8, MCW<sub>3</sub>: -1                                                                 |
| Perinatal conditions                                         | 1.8                                                                             | MCW<sub>1</sub>: 7, MCW<sub>2</sub>: 6, MCW<sub>3</sub>: 2                                                                 |
| Pregnancy or childbirth complications                        | 0.1                                                                             | MCW<sub>1</sub>: -31, MCW<sub>2</sub>: -22, MCW<sub>3</sub>: 3                                                                 |
| Congenital malformations                                     | 2.2                                                                             | MCW<sub>1</sub>: -41, MCW<sub>2</sub>: -31, MCW<sub>3</sub>: 4                                                                 |
| Nervous system diseases                                      | 53.1                                                                            | MCW<sub>1</sub>: -29, MCW<sub>2</sub>: -23, MCW<sub>3</sub>: 5                                                                 |
| Musculoskeletal diseases                                     | 6.2                                                                             | MCW<sub>1</sub>: -28, MCW<sub>2</sub>: -20, MCW<sub>3</sub>: 11                                                                 |
| Symptoms, signs, ill-defined causes                          | 58.4                                                                            | MCW<sub>1</sub>: 253, MCW<sub>2</sub>: 194, MCW<sub>3</sub>: 15                                                                 |
| Gastrointestinal diseases                                    | 18.0                                                                            | MCW<sub>1</sub>: 26, MCW<sub>2</sub>: 15, MCW<sub>3</sub>: 24                                                                 |
| Blood diseases                                               | 3.9                                                                             | MCW<sub>1</sub>: 60, MCW<sub>2</sub>: 40, MCW<sub>3</sub>: 26                                                                 |
| Endocrine and nutritional diseases                           | 33.7                                                                            | MCW<sub>1</sub>: 3, MCW<sub>2</sub>: 6, MCW<sub>3</sub>: 33                                                                 |
| Mental disorders                                            | 30.1                                                                            | MCW<sub>1</sub>: 2, MCW<sub>2</sub>: 0, MCW<sub>3</sub>: 34                                                                 |
| Skin diseases                                                | 2.4                                                                             | MCW<sub>1</sub>: 69, MCW<sub>2</sub>: 44, MCW<sub>3</sub>: 42                                                                 |

MCW: Multiple-cause-of-death weighting method

a The cause-of-death categories are those listed in the European shortlist for causes of death, 2012.14
b With the classic method, standardized mortality was calculated using only the underlying cause of death specified on the death certificate.
c Details of the three multiple-cause-of-death weighting methods, MCW<sub>1</sub>, MCW<sub>2</sub>, and MCW<sub>3</sub>, are given in the main text.

disease categories, such as diseases of the circulatory system, was found to be unaffected, or only slightly affected, by application of the MCW<sub>1</sub> method, which again confirmed literature findings.1 In contrast to published results,1 we found that the contribution to mortality of some conditions, for example influenza, was less than indicated by the classic method. In particular, the contribution of conditions in the category external causes of death was much less. Although this finding may be surprising at first, it reflects the possibility that, even when the underlying cause of death was categorized as an external cause of death, the physician thought some other condition contributed to the death and chose to mention it on the death certificate.

One limitation shared by all studies on multiple causes of death is that data quality and comparability are not perfect and numerous studies have tried to identify the flaws.21-25 In addition, the numerous coding rules and the multiplicity and complexity of possible disease combinations listed on a death certificate could lead to misinterpretations. Nevertheless, mortality databases are essential for monitoring public health and all attempts to improve their use should be welcomed, especially those taking into account multiple causes of death. The weighting approach described in our study could help clarify the impact of various conditions on mortality in countries that collect multiple-cause-of-death data. For other countries, the existence of weighting methods could encourage a more systematic approach to the collection of data on multiple causes of death.

Another limitation is that the MCW<sub>1</sub> method takes into account only the contributing causes of death mentioned in part II of the death certificate (in addition to the underlying cause) that are regarded as being on different causal pathways from the main morbidity process. However, this assumption is correct only if the death certificate is properly completed, which may not be certain. Moreover, some information is lost by not attributing weights to all causes of death listed on part I. The MCW<sub>3</sub> method may be less appropriate when the research question concerns a complication of a disease rather than the disease itself. Furthermore, when researchers are investigating a specific topic, the set of disease codes considered when implementing a weighting method can be adapted: for example, a study on the external causes of death could include ICD-10 cause-of-death codes that refer to types of injury or poisoning (i.e. codes beginning with S and T), which were excluded in the present study. Although we studied standardized mortality rates, the weighting method could also be applied in other ways. For instance, some policy-makers may be more interested in the crude number of deaths.

To date, we have not estimated the statistical variance of the indicators obtained using a weighting method. This may be a problem if a study is comparing mortality distributions between, for instance, several locations. One solution would be to use a nonparametric bootstrap approach. However, as our analysis considered a large number of deaths, sampling variability should not affect the interpretation of the results.

The main limitation of our study is that the process of weighting multiple causes of death provides only a synthetic view of the causal process by which diseases act together to bring about death.26 Consequently, the values given to the weights are subjective and weighting methods could be used to carry out a sensitivity analysis that takes into account different possibilities. In the future, the assignment of weights to items listed on a death certificate could be done by international consensus. Research is needed to determine the value of the weights that should be attributed to the different causes of death contributing to a death, although this process may also be based on a subjective view of how causal responsibility is distributed among different causes of death.26 Further, this process would require large longitudi-
nal databases that record pathological conditions and health events over time. Finally, it would be useful to have international rules that assign a specific role to each cause of death mentioned on a death certificate. In particular, the weight given to ill-defined causes of death and cardiac arrest should probably be smaller than that given to other causes. These international rules could also help to systematically distinguish causes of death on separate causal pathways. Moreover, death certification by physicians should be standardized both within and between countries to improve the comparability of the statistics obtained.

In conclusion, although it is valuable to know the underlying cause of death, the contribution of other possible causes of death listed on a death certificate should not be neglected. The multiple-cause-of-death weighting methods we used in this study to assess the contribution of different conditions to mortality are promising. Previously, we applied a similar weighting approach to study the burden of mortality, and the etiological processes, associated with individual diseases using survival regression models.13

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Competing interests: None declared.

Table 4. Standardized cause-related mortality rates, by calculation method and cause-of-death subcategory, 2010, France

| Cause-of-death category and subcategory* | Standardized mortality derived using the classic method,7 per 100 000 population | Change in standardized mortality with the multiple-cause-of-death weighting method relative to the classic method, % |
|----------------------------------------|---------------------------------------------|---------------------------------------------------------------|
|                                        |                                             | MCW₁            | MCW₂          | MCW₃          |
| Infectious and parasitic diseases      |                                             | −45            | −32           | 1             |
| Tuberculosis                           | 1.1                                         | −49            | −25           | −4            |
| AIDS (HIV disease)                     | 0.8                                         | 0              | 2             | 19            |
| Viral hepatitis                        | 1.1                                         | 31             | 23            | −17           |
| Other infectious and parasitic diseases| 16.2                                        | −54            | −41           | −9            |
| Neoplasms                              |                                             | −53            | −40           | −9            |
| Malignant neoplasm of lip, oral cavity, pharynx | 7.4                      | −55            | −41           | −10           |
| Malignant neoplasm of oesophagus       | 7.3                                         | −57            | −43           | −9            |
| Malignant neoplasm of stomach          | 8.6                                         | −60            | −44           | −9            |
| Malignant neoplasm of colon, rectum and anus | 30.1                       | −55            | −41           | −10           |
| Malignant neoplasm of liver and intrahepatic bile ducts | 14.9                     | −54            | −41           | −9            |
| Malignant neoplasm of pancreas         | 16.1                                        | −51            | −39           | −6            |
| Malignant neoplasm of larynx           | 2.3                                         | −56            | −42           | −10           |
| Malignant neoplasm of trachea, bronchus, lung | 54.7                        | −63            | −46           | −7            |
| Malignant melanoma of skin             | 3.1                                         | −61            | −44           | −5            |
| Malignant neoplasm of breast           | 17.7                                        | −60            | −44           | −7            |
| Malignant neoplasm of cervix uteri     | 1.2                                         | −58            | −43           | −7            |
| Malignant neoplasm of other unspecified parts of uterus | 3.5                     | −61            | −45           | −7            |
| Malignant neoplasm of ovary            | 5.2                                         | −54            | −40           | −4            |
| Malignant neoplasm of prostate         | 21.4                                        | −61            | −45           | −9            |
| Malignant neoplasm of kidney           | 6.3                                         | −57            | −42           | −9            |
| Malignant neoplasm of bladder          | 9.9                                         | −44            | −35           | −6            |
| Malignant neoplasm of brain and central nervous system | 5.9                     | −55            | −41           | −4            |
| Hodgkin’s disease and lymphomas        | 8.3                                         | −49            | −37           | −8            |
| Leukaemia                              | 9.9                                         | −50            | −38           | −7            |
| Other malignant neoplasm of lymphoid and haematopoietic tissue | 5.4                       | −52            | −39           | −8            |
| Other malignant neoplasms              | 35.4                                        | 103            | 81            | 4             |
| Nonmalignant neoplasms (benign and uncertain) | 11.7                    | −40            | −31           | −4            |

(continues...)

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| Cause-of-death category and subcategory | Standardized mortality derived using the classic method,\(^a\) per 100 000 population | Change in standardized mortality with the multiple-cause-of-death weighting method\(^b\) relative to the classic method, % | \(MCW_1\) | \(MCW_2\) | \(MCW_3\) |
|----------------------------------------|-----------------------------------------------|--------------------------------------------------|--------|--------|--------|
| **Diseases of the blood**              |                                               |                                                  |        |        |        |
| Endocrine, nutritional and metabolic diseases |                                               |                                                  |        |        |        |
| Diabetes mellitus                      | 19.2                                          | −25                                              | −9     | 30     | 38     |
| Other endocrine, nutritional and metabolic diseases | 14.5                                          | 39                                               | 25     |        |        |
| **Mental and behavioural disorders**   |                                               |                                                  |        |        |        |
| Dementia                               | 19.4                                          | −33                                              | −25    | 12     |        |
| Alcohol abuse (including alcoholic psychosis) | 5.2                                           | 10                                               | 2      | 43     |        |
| Drug dependence, toxicomania           | 0.3                                           | −9                                               | −8     | 28     |        |
| Other mental and behavioural disorders | 5.1                                           | 124                                              | 92     | 112    |        |
| **Diseases of the nervous system and sense organs** |                                               |                                                  |        |        |        |
| Parkinson disease                      | 8.9                                           | −42                                              | −32    | 6      |        |
| Alzheimer disease                      | 28.0                                          | −42                                              | −33    | 5      |        |
| Other diseases of the nervous system and sense organs | 16.3                                          | 1                                                | −1     | 6      |        |
| **Diseases of the circulatory system** |                                               |                                                  |        |        |        |
| Ischaemic heart diseases: acute myocardial infarction | 31.1                                          | −50                                              | −38    | −17    |        |
| Other ischaemic heart diseases         | 33.1                                          | −41                                              | −30    | −4     |        |
| Other heart diseases                   | 87.2                                          | 24                                               | 16     | 1      |        |
| Cerebrovascular diseases               | 54.5                                          | −32                                              | −25    | −11    |        |
| Other diseases of the circulatory system | 44.3                                          | 7                                                | 4      | 19     |        |
| **Diseases of the respiratory system** |                                               |                                                  |        |        |        |
| Influenza                              | 0.2                                           | −64                                              | −43    | −20    |        |
| Pneumonia                              | 19.2                                          | 10                                               | 5      | −13    |        |
| Asthma                                 | 1.6                                           | −32                                              | −25    | 8      |        |
| Other chronic lower respiratory diseases | 15.6                                          | −41                                              | −29    | −2     |        |
| Other diseases of the respiratory system | 22.7                                          | 80                                               | 58     | −1     |        |
| **Diseases of the digestive system**   |                                               |                                                  |        |        |        |
| Ulcer of stomach, duodenum and jejunum | 1.6                                           | −47                                              | −27    | −15    |        |
| Cirrhosis, fibrosis and chronic hepatitis | 12.8                                          | −44                                              | −29    | −6     |        |
| Other diseases of the digestive system | 26.4                                          | 1                                                | 1      | −13    |        |
| **Diseases of the skin and subcutaneous tissue** |                                               |                                                  |        |        |        |
| Diseases of the musculoskeletal system or connective tissue | 2.4                                           | 69                                               | 44     | 42     |        |
| Rheumatoid arthritis and osteoarthritis | 0.8                                           | −11                                              | −8     | 44     |        |
| Other diseases of the musculoskeletal system or connective tissues | 5.3                                           | −30                                              | −22    | 6      |        |
| **Diseases of the genitourinary system** |                                               |                                                  |        |        |        |
| Diseases of kidney and ureter          | 13.9                                          | 42                                               | 26     | 34     |        |
| Other diseases of the genitourinary system | 4.1                                           | −27                                              | −19    | −9     |        |
| **Complications of pregnancy, childbirth and puerperium** | 0.1                                           | −31                                              | −22    | 3      |        |
| Certain conditions originating in the perinatal period | 1.8                                           | 7                                                | 6      | 2      |        |
| Congenital malformations and chromosomal abnormalities | 2.2                                           | −41                                              | −31    | 4      |        |
| Symptoms, signs, ill-defined causes     | 58.4                                          | 253                                              | 194    | 15     |        |
| External causes of morbidity and mortality | 65.2                                          | −40                                              | −31    | −13    |        |

\(^a\) The cause-of-death categories and subcategories are those listed in the European shortlist for causes of death, 2012.\(^b\) With the classic method, standardized mortality was calculated using only the underlying cause of death specified on the death certificate.\(^c\) Details of the three multiple-cause-of-death weighting methods, \(MCW_1\), \(MCW_2\), and \(MCW_3\), are given in the main text.
Quantifying cause-related mortality

Clara Piffaretti et al.

ABSTRACT

Aim

To assess a new method for calculating cause-related standardized mortality ratios (SMRs) that takes into account the multiple causes of death reported on death certificates.

Methods

We used death certificate data from France in 2010 to calculate cause-related SMRs for five different disease categories: skin diseases, mental disorders, endocrine and nutritional diseases, blood diseases, and urogenital diseases. We used three different methods to calculate the multiple causes of death: (i) the classical method, which considers only the underlying cause; and (ii) two novel methods that assign weights to each cause of death reported on death certificates: in the first method, all causes are assigned weights, whereas in the second method, only the underlying cause and other causes not directly related to the underlying cause are assigned weights. The sum of the weights for each case is 1, and the SMR is calculated as the ratio of the observed number of deaths to the expected number of deaths.

Results

On average, 3.4 causes of death were reported on each death certificate. The SMR calculated using the second method was 20% higher than that calculated using the classical method for the following five disease categories: skin diseases, mental disorders, endocrine and nutritional diseases, blood diseases, and urogenital diseases. This method also highlighted the increasing burden of certain diseases in specific age groups.

Conclusion

The new methods for calculating cause-related SMRs are more accurate than the classical method and more likely to identify the underlying cause of death. These methods could be useful for identifying unknown causes of death.

RéSUMÉ

Quantifier la mortalité due à différentes causes en pondérant les causes multiples de décès

Objectif

Étudier une nouvelle approche permettant de calculer des taux comparatifs de mortalité due à différentes causes en pondérant chaque cause de décès déclarée sur les certificats de décès.

Méthodes

Nous avons calculé des taux comparatifs de mortalité due à différentes causes à partir des données de certificats de décès émis en France en 2010 suivant : (i) la méthode classique, où nous avons uniquement tenu compte de la cause sous-jacente de décès ; et (ii) trois nouvelles méthodes de pondération de causes multiples de décès, qui consistaient à appliquer une pondération aux différentes causes de décès mentionnées sur les certificats de décès : les deux premières méthodes tenant compte de plusieurs causes de décès consistaient à appliquer une pondération autre que zéro à toutes les causes mentionnées et la troisième consistait à appliquer une pondération autre que zéro uniquement à la cause sous-jacente et à d’autres causes aggravantes, extérieures au processus pathologique principal. La somme des pondérations pour chaque certificat de décès était de 1. Ainsi, chaque décès avait la même influence sur les estimations de la mortalité, sans changer le nombre total de décès. Les taux de mortalité obtenus suivant ces différentes méthodes ont ensuite été comparés.

Résultats

En moyenne, 3,4 causes étaient mentionnées sur chaque certificat de décès. Le taux comparatif de mortalité calculé selon la troisième méthode de pondération de causes multiples de décès était plus de 20% supérieur à celui calculé selon la méthode classique pour cinq catégories de maladies : maladies de la peau, troubles mentaux, maladies endocriniennes et nutritionnelles, maladies du sang et maladies uro-génitales. En outre, cette méthode a mis en relief la charge de mortalité associée à certaines maladies dans des groupes d’âge spécifiques.
Conclusion L’approche consistant à pondérer des causes multiples de décès afin de calculer des taux comparatifs de mortalité due à différentes causes à partir des données figurant sur des certificats de décès a permis de repérer les pathologies qui contribuaient plus à la mortalité que ce qu’indiquait la méthode classique. Cette nouvelle approche devrait permettre d’identifier les facteurs peu reconnus qui contribuent pourtant à la mortalité.

Resumen

Cuantificación de la mortalidad relacionada con las causas utilizando varias causas de muerte

Objetivo Investigar un nuevo enfoque para calcular las tasas estandarizadas de mortalidad relacionada con las causas que implique la asignación de variables de cada causa de muerte indicada en los certificados de defunción.

Métodos Se derivaron las tasas estandarizadas de mortalidad relacionada con las causas de certificados de defunción en Francia en 2010 utilizando: (i) el método clásico, que consideraba únicamente la causa subyacente de la muerte; y (ii) tres nuevos métodos de evaluación de múltiples causas de muerte, que asignaban variables a varias causas de muerte mencionadas en los certificados de defunción: los primeros dos métodos de múltiples causas de muerte asignaron variables nulas en todas las causas mencionadas, y el tercero asignó las mismas variables sólo a la causa subyacente y otras causas contribuyentes que no formaban parte del proceso mórbido principal. Dado que la suma de las variables de cada certificado era 1, cada defunción tenía la misma influencia en las estimaciones de mortalidad y el número total de muertes permaneció intacto. Se compararon las tasas de mortalidad derivadas utilizando los distintos métodos.

Resultados De media, cada certificado enumeraba 3,4 causas por muerte. La tasa de mortalidad estandarizada calculada utilizando el tercer método de evaluación de múltiples causas de muerte fue más de un 20% superior a la calculada utilizando el método clásico para cinco categorías de enfermedades: enfermedades cutáneas, trastornos mentales, enfermedades endocrinas y nutricionales, enfermedades sanguíneas y enfermedades genitourinarias. Asimismo, este método destacó el umbral de mortalidad relacionado con determinadas enfermedades de grupos de edades en particular.

Conclusión Un enfoque de evaluación de múltiples causas de muerte para calcular las tasas estandarizadas de mortalidad relacionada con las causas de datos recopilados de certificados de defunción identificó las condiciones que contribuyeron más a la mortalidad que las indicadas en el método clásico. Este nuevo enfoque promete identificar contribuyentes no reconocidos a la mortalidad.

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Fig. 2. Change in standardized mortality for endocrine and nutritional diseases with multiple-cause-of-death weighting methods relative to the classic method, by age, 2010, France

Fig. 3. Change in standardized mortality for mental disorders with multiple-cause-of-death weighting methods relative to the classic method, by age, 2010, France

MCW: Multiple-cause-of-death weighting method.

Notes: Details of the three multiple-cause-of-death weighting methods, MCW\textsubscript{1}, MCW\textsubscript{2}, and MCW\textsubscript{3}, are given in the main text. With the classic method, standardized mortality was calculated using only the underlying cause of death specified on the death certificate.
MCW: Multiple-cause-of-death weighting method.

Notes: Details of the three multiple-cause-of-death weighting methods, MCW₁, MCW₂, and MCW₃ are given in the main text. With the classic method, standardized mortality was calculated using only the underlying cause of death specified on the death certificate.
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