Session 15 : Mortality and ag<u>ee</u>ing

A comparison of French and US old-age mortality patterns using multiple cause-of-death data

Aline Désesquelles and France Meslé
INED, Paris

Paris, INED,
2001

The biggest and ever growing part of all deaths now occurs at old and even very old ages. However our knowledge of the morbid process that finally leads to death at old ages is very scarce. Several reasons may explain this manifest indifference towards the understanding of causes of death among the oldest old. One is that beyond a certain age death is considered to be so inevitable that even health professionals do not perceive identification of its exact cause as a priority. Yet the highly favourable trend in mortality at advanced ages since the 1970s is probably due in part to changes in the attitude of the medical profession towards these old people. The acknowledgement that a person over 70 could suffer from well-defined and treatable pathologies was in fact the prelude to a reduction in mortality at those ages (Meslé and Vallin, 1998).

A further point is that those who are familiar with the pathologies of the oldest old are often sceptical about the reliability of the data. It ~~is often~~can be difficult to establish the cause of the death at advanced ages, notably because it is not always possible to identify among the several coexisting conditions the one that actually led to death. The selection of the underlying cause of death, on which most cause-of-death statistics are based, is thus of limited value in the case of very old people since a large part of the pathological process may be left out of the analysis. A more complete clinical picture can be built up by considering all the conditions recorded at the time of death through an analysis of multiple cause-of-death statistics. Two main approaches are usually used to perform such an analysis.

One possible approach is to calculate the total contribution of a particular cause of death to mortality taking into account all records of this condition on the death certificate. The role played by some conditions that are rarely reported as underlying cause but are often involved in the morbid process, shall then be highlighted. For instance, Wing and Manton (1981) studied the impact of hypertension on US mortality. Nizard and Munoz-Pérez (1993) tried to evaluate the influence of alcoholism. Another approach consists in examining combinations of causes. The goal is to identify particular associations of causes that frequently lead to death. Mackenbach and his colleagues (1995) showed that, in the Netherlands, cardiovascular conditions were often associated with other health problems while cancers or external causes were less often reported with other causes. This approach gives more information on the morbid process itself.

In this paper, we successively use these two approaches to study mortality at ages over 70 for two countries where data are available: France and the United States. After a rapid description of both countries data, we examine how the profile of mortality by cause is modified when taking into account all the mentioned causes on death certificates. In a third

part, we investigate combination of causes, specially through a multiple correspondence analysis.

1. France and the United States : two different sets of data

Two sets of data are available for the study of multiple causes. For France, INSERM[1] provides computerized records for the period 1979-1996 that give for each death the underlying cause, the direct cause and two contributory causes[2]. A maximum of four causes is thus available for each death. When more than four causes are recorded on the death certificate, INSERM coders make a selection and retain only four. In the case of the United States, we were able to use a CD-ROM prepared by the NCHS that gives for all deaths occurring in 1994 the full information recorded on the death certificate. Up to 20 causes may be recorded for each death but no distinction is made between direct and contributory causes.

In both countries and for all ages, deaths with two reported causes are the most frequent situation (45% of all 1996 deaths in France and 29% of all 1994 deaths in the US). But the similarity between the two countries goes no further. In France, this two-cause profile is by far the most prevalent one. Deaths with one reported cause account for only 28%, deaths with three causes for 20% and deaths with four causes for 7%. In the United States, a much more balanced distribution between the different profiles is observed (1 cause: 23%, 3 causes: 24%, and 4 or more causes: 24%). This reflects a major difference in terms of statistical practices. In France, the most common procedure is to record a direct cause in addition to the underlying cause, and that is all. The death certificate usually does not indicate the contributory causes, and in any case INSERM records a maximum of two causes. In the United States, by contrast, the recording of all the information contained in the death certificate and probably also a fuller completion of this certificate by medical doctors, result in the transmission of a much richer information.

The same contrast is observed in the age distribution of these different profiles (figure 1). As age increases, so does the complexity of the pathological processes. Consequently one would expect that the proportion of deaths that mention more than one cause, increases with age. This is indeed what we find in the United States : the proportion of

---

[1] Institut national de la santé et de la recherche médicale, in charge of the French cause-of-death statistics.
[2] According to WHO, the direct cause is immediately responsible for the death whereas the contributory causes are supposed to have participated in the morbid process but have not directly induced the death. The direct cause

deaths attributed to 3 or 4 causes increases substantially after age 60 up to over 85 years. In France, this proportion also increases at advanced ages up to around 80 years but beyond this age it starts to decrease. More importantly, this relative increase in deaths attributed to 3 or 4 causes is very small compared with the very large decrease in deaths with 2 causes. Over 60, the proportion of those deaths declines sharply from over 50% to under 35%, while that of deaths with only one reported cause increases by an identical proportion. This probably indicates that the distinction between underlying and direct cause is gradually abandoned at higher ages.
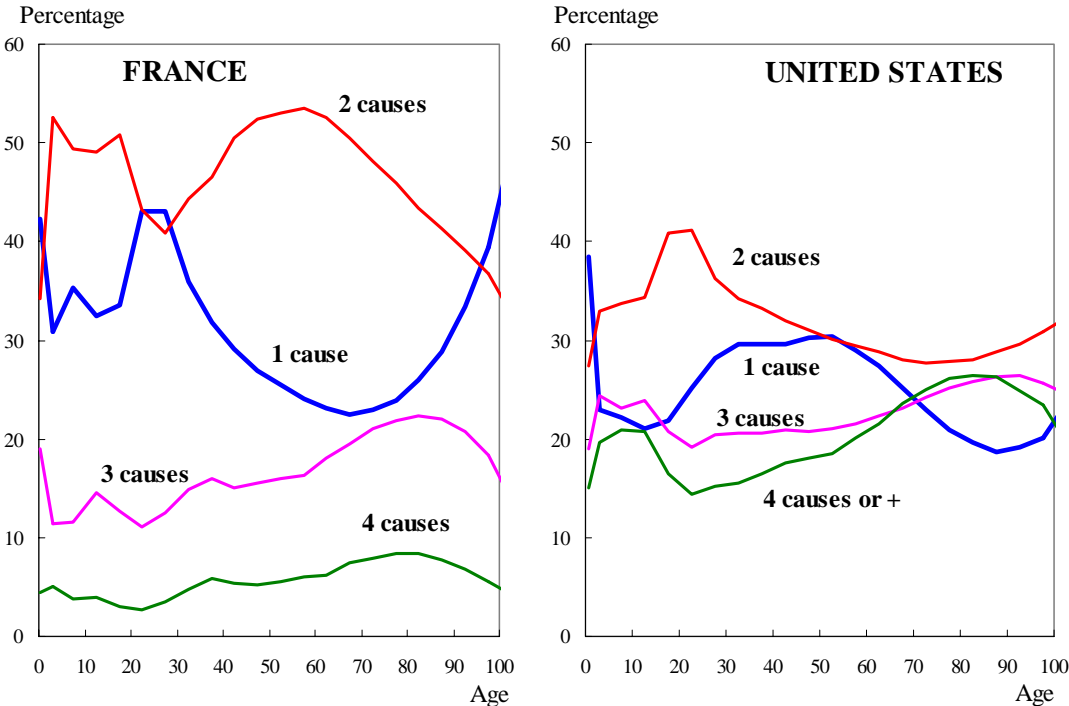
**Figure 1. Number of causes reported by age.
United States, 1994 and France, 1996.**

This brief comparison of French and US multiple cause-of-death statistics clearly shows that the conception of these two databases is very different. Therefore, the comparison of the results obtained for both countries seems to be uneasy. It is however interesting to go a little further in the analysis and to examine if, despite those differences, some common features can be identified.

---

is reported on the first line of Part I of the death certificate while contributory causes are mentioned in Part II (~~OMS~~WHO, 1977)

2. A slightly modified hierarchy of the causes of death

A total of 781,843 conditions are coded for the 379,416 deaths over age 70 registered in France in 1996. In the United States, in 1994, there are 3,961,021 conditions coded for 1,455,279 deaths at age 70+. Thus, there are about 2 conditions per death in France and 2.7 in the States. This higher ratio in the US is not surprising in so far as 20 causes (vs only 4 in France[3]) may be coded in the US mortality database.

To study the impact of the multiple-cause approach, we first calculated the proportion of all deaths that mention one particular condition as underlying or secondary[4] cause at least once and we compared it to the distribution of all deaths taking the underlying cause only into account (Table 1). We chose to classify all conditions according to the ICD-9 chapters. In France, one-in-two deaths over age 70 mentions a cardiovascular disease as an underlying or a secondary cause. This proportion is 39% when the underlying cause only is taken into account. This increase is quite noticeable but it is much more pronounced for most other ICD-9 chapters. The prevalence at death of an ill-defined condition is particularly reinforced by the multiple-cause approach. When taking into account all recorded mentions, ill-defined conditions (23% of all mentions) rank third after cardiovascular diseases (52%) and neoplasms (25%), right before respiratory diseases (17 %). Ill-defined conditions are indeed quite often reported as the direct cause of the death : in France, 15% of all deaths with a known underlying cause that is not an external cause have an ill-defined direct cause.

Two other ICD-9 chapters emerge from the analysis : "Endocrine, nutritional and metabolic diseases and immunity disorders" and "Mental disorders". Those chapters that represent a very small part of all underlying mentions, are now among the most frequently stated mentions : nearly one-in-ten deaths mentions one of these chapters.

In the US, the effect of taking into account all recorded mentions is very similar. The proportion of all deaths over 70 that mention a cardiovascular disease is however much higher in the US (69% of all deaths over 70 vs 52 % in France) than in France. In the US as in France, the multiple cause analysis highlights the contribution to death of "endocrine, nutritional and metabolic diseases and immunity disorders" and "mental disorders" but a third ICD-9 chapter emerges from the analysis. 9,3% of all deaths over 70 mention a " disease of

---

[3] In the case of violent deaths, in France, only three conditions can be registered ; the fourth place in the database is reserved to the coding of the nature of the injury.

[4] *i.e.* the direct or the contributory causes

the genitourinary system" ; this proportion is only 2,3 % when the secondary causes are not taken into account.

Table 1 : Proportion of all deaths (%) in France (1996) and in the United States (1994) with at least one coded condition in the following ICD-9 chapters*

ICD-9 chapter	France		United States	
	Underlying cause	All coded conditions	Underlying cause	All coded conditions
Infectious and parasitic diseases	1,5	3,4	1,4	5,5
Neoplasms	22,6	25,2	21,0	24,6
Endocrine, nutritional and metabolic diseases and immunity disorders	**3,1**	**9,7**	**3,3**	**13,5**
Diseases of blood and blood-forming organs	0,6	1,7	0,4	3,0
Mental disorders	**2,7**	**7,6**	**2,0**	**7,7**
Diseases of the nervous system and sense organs	2,5	5,5	2,4	6,5
Diseases of the circulatory system	**38,5**	**52,1**	**49,3**	**69,1**
Diseases of the respiratory system	**9,7**	**16,8**	**11,3**	**25,8**
Diseases of the digestive system	4,3	7,5	3,0	7,4
Diseases of the genitourinary system	**1,7**	**4,9**	**2,3**	**9,3**
Diseases of the skin and subcutaneaous tissue	0,6	2,0	0,2	1,0
Diseases of the musculoskeletal system and connective tissue	0,6	1,5	0,4	2,7
Congenital anomalies	0,0	0,1	0,1	0,2
Symptoms, signs and ill-defined conditions	**5,5**	**22,5**	**0,4**	**17,1**
Injury and poisoning	5,1	7,2	2,1	4,9
Unknown	1,0	-	0,4	1,0

For example : in France, 52,1% of all deaths mention a disease of the circulatory system as underlying or secondary cause of the death.

Thus, the multiple-cause approach highlights the contribution to the morbid process of some ICD-9 chapters that are not stated frequently as underlying cause of the death. To investigate further the contribution of these chapters to the total mortality, we calculated cause-specific mortality rates as follows. We first classified all conditions according to the ICD-9 chapters. Then, we calculated the number of occurrences of each ICD-9 chapter. As our objective was to measure the contribution of each ICD-9 chapter to the total mortality, we decided to count several mentions of the same chapter only once for each death. These counts were calculated by sex and five-year age groups. To create rates we divided them by the population estimates, by sex and 5-year age groups, at the midpoint of year 1996 for France and 1994 for the US. To make all rates comparable, age-adjusted rates at age 70+ for men and women were finally calculated using a simple standardization method[5].

---

[5] The reference of those rates is the French male and female population aged 70 and over.

The figures we have obtained depend of course on the level of aggregation of the recorded conditions we have chosen. Our choice ensures that "redundant" conditions on the death certificate are only counted once. The WHO coding rules aim to avoid any duplication of information among the several coded conditions but they cannot avoid that the information brought by the secondary causes is to some extent already contained in the underlying cause. However, this may be not as frequent as one would expect. In France, the direct cause does not belong to the same ICD-9 chapter as the underlying cause in 62% of all deaths with a direct cause and 79% of all deaths with a contributory cause have at least one contributory cause that does not belong to the same ICD-9 chapter than the underlying cause.

Table 2 presents the age-adjusted death rates by cause at ages over 70 for both sexes and for France, when (1) the underlying cause only, (2) all coded conditions are taken into account. Table 3 gives the same indicators for the US in 1994. In both countries, the top three well-defined causes of death (circulatory diseases, neoplasms and respiratory diseases) do not change when taking into account all coded mentions. Mortality rates by respiratory diseases increase more than mortality rates by circulatory diseases and neoplasms. This increase is especially strinking in the US : mortality rates by respiratory diseases are twice higher when the secondary causes are taken into account. As a consequence, deaths rates by respiratory diseases turn out to be higher than death rates by cancer for both men and women in the US. Respiratory conditions are indeed very often the final stage of the morbid process and, as such, are frequently mentioned as secondary cause of the death.

The increase is more moderate for neoplasms (+13% in France and +21% in the US for men / +10% in France and +16 % in the US for women) and for cardiovascular diseases (+40% in France and +43% in the US for men / +32% in France and +37% in the US for women). In France, most rates for other groups of causes are multiplied by two or even three. Not surprisingly, the increase is even more pronounced in the US where more conditions contributing to death may be reported.

As a consequence, the hierarchy of the causes of death does not remain unchanged when all coded conditions are taken into account. In France, "endocrine, nutritional and metabolic diseases " do not rank seventh but fifth, for both men and women, immediately followed by "mental disorders" for women and by "diseases of the digestive system" for men[6]. In the US, the multiple cause analysis highlights the same groups of causes with one

---

[6] In a previous explanatory paper (Désesquelles and Meslé, 2000), we found that diabetes mellitus is responsible for more than half of the death rates by "endocrine, metabolic and nutritional diseases" increase when all coded conditions are taken into account. For mental disorders, the role of alcoholism and senility is prominent.

noticeable exception : "diseases of the genitourinary system" that rank ninth in France, are the sixth most frequently reported underlying or secondary cause of death in the US.

Table 2 : Age-adjusted cause-specific mortality rates over age 70 by sex (p. 100,000) France , 1996

ICD-9 chapter	Women		Men	
	Underlying cause (1)	All coded conditions (2)	Underlying cause (1)	All coded conditions (2)
Infectious and parasitic diseases	74	162	116	270
Neoplasms	915	**1009**	2048	**2306**
Endocrine, nutritional and metabolic diseases and immunity disorders	171	**521**	195	**659**
Diseases of blood and blood-forming organs	30	82	49	135
Mental disorders	159	**404**	150	**507**
Diseases of the nervous system and sense organs	132	277	176	399
Diseases of the circulatory system	1948	**2572**	2792	**3912**
Diseases of the respiratory system	417	**708**	868	**1531**
Diseases of the digestive system	216	357	318	**581**
Diseases of the genitourinary system	75	205	150	462
Diseases of the skin and subcutaneous tissue	37	117	34	116
Dis. of the musculoskeletal syst. And connective tissue	36	88	31	81
Congenital anomalies	2	4	2	5
Symptoms, signs and ill-defined conditions	304	**1112**	347	**1693**
Injury and poisoning	248	353	386	550

Table 3: Age-adjusted cause-specific mortality rates over age 70 by sex (p. 100,000). United States, 1994

ICD-9 chapter	Women		Men	
	Underlying cause (1)	All coded conditions (2)	Underlying cause (1)	All coded conditions (2)
Infectious and parasitic diseases	82	324	105	436
Neoplasms	1041	**1206**	1850	**2235**
Endocrine, nutritional and metabolic diseases and immunity disorders	210	**820**	227	**984**
Diseases of blood and blood-forming organs	25	176	38	253
Mental disorders	132	**491**	136	**576**
Diseases of the nervous system and sense organs	139	374	194	539
Diseases of the circulatory system	2907	**3994**	3921	**5588**
Diseases of the respiratory system	590	**1312**	1046	**2414**
Diseases of the digestive system	184	433	224	578
Diseases of the genitourinary system	140	**497**	192	**840**
Diseases of the skin and subcutaneous tissue	12	61	13	69
Dis. of the musculoskeletal syst. and connective tissue	28	201	19	144
Congenital anomalies	5	11	8	16
Symptoms, signs and ill-defined conditions	27	**969**	30	**1399**
Injury and poisoning	97	257	206	447

Another interesting fact is the very moderate increase of death rates by injury and poisoning. Thus, death rates based on the underlying cause underestimates only slightly the part played by injuries in the deaths of the elderly (Fife, 1987).

3. Combinations of causes

3.1 Prevalence at death of each combination of causes

Our second objective was to examine what are the most frequent combinations of causes. For that purpose, we first calculated for each underlying cause the prevalence rates at death of each secondary cause classified according to the ICD-9 chapters. When two conditions belonging to the same ICD-9 chapter were mentioned as secondary cause, we counted them only once. Tables 4 and 5 give the results of this calculation for France and the US. These prevalence rates are generally lower in France than in the US where more causes contributing to death may be reported. But emerging combinations of causes are very similar for both countries.

Diseases of the circulatory system turn out to be the most frequently (roughly one-in-three deaths in France, one-in-two in the US) mentioned secondary cause of death. The prevalence at death is especially high when the underlying cause is either a disease belonging to the chapter "endocrine, nutritional and metabolic diseases and immunity disorders" (42% in France, 77% in the US) or a disease of the circulatory system (44% in France, 66% in the US). The first association probably corresponds to the cardiovascular complications of diabetes mellitus. The second one illustrates a more general observation : prevalence rates are often higher when the underlying and the secondary cause belong to the same ICD-9 chapter. This rule applies in particular for neoplasms in both countries (40% in France, 24% in the US): metastatic cancers are indeed often reported as the direct cause of a primary localization. This is also the case of diseases of the digestive system : in France, 20% of all deaths due to a disease of the digestive system[7] (29% in the US) mention a disease belonging to that same ICD-9 chapter as secondary cause of the death. In the US, prevalence rates on the diagonal line are also high for disease of the muskuloskeletal system (17%) and for diseases of blood and blood-forming organs (17%). Is the information recorded as secondary cause different from the information coded as the underlying cause of death or is it

---

[7] i.e. the underlying cause of the death is a disease of the digestive system.

redundant with it ? An analysis at a lower level of classification alone would bring an answer to that question.

SBut some associations out of the diagonal line are notable too. For instance, following associations underlying / secondary cause are very frequent :

- "diseases of the skin or the subcutaneous tissue" / "infectious or parasitic disease" (30% in France, 70% in the US) ;

- "diseases of the nervous system and sense organs" / "diseases of the respiratory system" (17% in France, 31% in the US) ;

- "mental disorders" / "diseases of the respiratory system" (14% in France, 34% in the US).

- "diseases of the musculoskeletal system and connective tissue" / "diseases of the respiratory system" (13% in France, 33% in the US).

As mentioned before, diseases of the respiratory system are probably often mentioned as direct cause of the death. We find here an indication that this must be especially the case when the underlying cause is a non necessarily lethal and mainly age-related disease.

Two other combinations of causes are more specific of the French mortality at old ages :

"Diseases of the musculoskeletal system and connective tissue" / "injury and poisoning" (20%) : accidental falls are probably involved in those deaths. According to WHO rules, accidental falls should always be registered as the underlying cause and their eventual consequences as secondary causes. It is possible that, in some cases, the reverse rule is applied(Meslé, 1995).

"Injury and poisoning" / " Mental disorders" (14%) : alcoholism and senile dementia are likely to increase the risk for accidents and falls. (Meslé, 1995).

The interpretation of these associations raises two kinds of problems. First, we must question the quality of the multiple cause-of-death data. There are indeed many reasons to believe that the recording of the multiple causes of death is not perfect. Theoretically, all causes that have contributed to death should be reported. In practice, there is probably an underreporting of those causes. But at the same time, certifying physicians may also report some conditions that they know the decedent was suffering from, even if those conditions did not take part in the process leading to death. This would explain why neoplasms would have contributed to deaths by cardiovascular diseases or to deaths by injury and poisoning (tables 4 and 5). This practice is obviously not systematic and all underlying causes are probably not affected in the same way.

Table 4 : Prevalence at death of each cause - classified by ICD-9 chapters- by underlying cause of death
France, 1996

Underlying cause :	Infectious and parasitic diseases	Neoplasms	Endocrine, nutritional and metabolic diseases and immunity disorders	Diseases of blood and blood-forming organs	Mental disorders	Diseases of the nervous system and sense organs	Diseases of the circulatory system	Diseases of the respiratory system	Diseases of the digestive system	Diseases of the genitourinary system	Diseases of the skin and subcutaneaous tissue	Diseases of the musculoskeletal system and connective tissue	Congenital anomalies	Symptoms, signs and ill-defined conditions	Injury and poisoning	Underlying cause only
Infectious and parasitic diseases	**3%**	5%	13%	2%	8%	5%	28%	14%	6%	6%	2%	2%	0%	32%	2%	17%
Neoplasms	2%	**40%**	5%	2%	2%	2%	15%	7%	7%	3%	0%	0%	0%	13%	2%	21%
Endocrine, nutritional and metabolic diseases and immunity disorders	3%	4%	**12%**	1%	10%	4%	42%	9%	3%	8%	5%	1%	0%	22%	2%	16%
Diseases of blood and blood-forming organs	5%	6%	7%	**6%**	4%	2%	34%	10%	7%	5%	2%	2%	0%	21%	1%	22%
Mental disorders	2%	2%	11%	1%	**3%**	6%	21%	14%	2%	2%	5%	1%	0%	22%	2%	31%
Diseases of the nervous system and sense organs	2%	2%	8%	1%	8%	**4%**	20%	17%	2%	2%	5%	1%	0%	24%	3%	27%
Diseases of the circulatory system	1%	3%	8%	1%	4%	3%	**44%**	9%	2%	4%	1%	1%	0%	18%	2%	27%
Diseases of the respiratory system	3%	4%	9%	1%	10%	5%	38%	**15%**	2%	3%	2%	1%	0%	31%	2%	17%
Diseases of the digestive system	4%	4%	10%	2%	5%	3%	31%	8%	**20%**	5%	1%	1%	0%	21%	9%	17%
Diseases of the genitourinary system	9%	4%	14%	2%	8%	4%	36%	8%	5%	**8%**	3%	2%	0%	25%	4%	17%
Diseases of the skin and subcutaneaous tissue	30%	2%	14%	1%	14%	5%	20%	6%	2%	3%	**1%**	2%	0%	28%	2%	19%
Diseases of the musculoskeletal system and connective tissue	6%	3%	9%	2%	6%	4%	34%	13%	4%	6%	5%	**3%**	0%	18%	20%	14%
Congenital anomalies	2%	3%	4%	3%	3%	2%	46%	8%	12%	21%	2%	1%	**4%**	12%	7%	9%
Symptoms, signs and ill-defined conditions	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	**4%**	0%	95%
Injury and poisoning	1%	4%	5%	1%	14%	4%	22%	4%	2%	2%	1%	1%	0%	4%	**2%**	46%
*All deaths**	*2%*	*12%*	*7%*	*1%*	*5%*	*3%*	*31%*	*9%*	*4%*	*3%*	*1%*	*1%*	*0%*	*17%*	*2%*	*28%*

* In that particular case, the direct cause is not taken into account : when the underlying cause is an external cause (ICD-9 items E800 to E999), the information mentioned as direct cause always concerns the nature of the injury (ICD-9 items N800 to N999).
** Excluding deaths with no underlying cause

Table 5 : Prevalence at death of each contributory cause - classified by ICD-9 chapters- by underlying cause of death
US, 1994

Underlying cause :	Infectious and parasitic diseases	Neoplasms	Endocrine, nutritional and metabolic diseases and immunity disorders	Diseases of blood and blood-forming organs	Mental disorders	Diseases of the nervous system and sense organs	Diseases of the circulatory system	Diseases of the respiratory system	Diseases of the digestive system	Diseases of the genitourinary system	Diseases of the skin and subcutaneaous tissue	Diseases of the musculoskeletal system and connective tissue	Congenital anomalies	Symptoms, signs and ill-defined conditions	Injury and poisoning	Underlying cause only
Infectious and parasitic diseases	**4%**	6%	15%	4%	7%	6%	45%	21%	13%	15%	2%	3%	0%	27%	3%	18%
Neoplasms	3%	**24%**	8%	4%	3%	2%	28%	15%	6%	5%	0%	1%	0%	13%	2%	34%
Endocrine, nutritional and metabolic diseases and immunity disorders	9%	4%	**12%**	3%	8%	5%	77%	15%	5%	19%	1%	3%	0%	16%	3%	4%
Diseases of blood and blood-forming organs	12%	5%	11%	**17%**	4%	3%	51%	19%	13%	13%	1%	4%	1%	19%	3%	16%
Mental disorders	6%	3%	21%	3%	**4%**	4%	35%	34%	5%	8%	3%	4%	0%	22%	7%	17%
Diseases of the nervous system and sense organs	5%	3%	13%	2%	5%	**5%**	34%	31%	3%	6%	2%	3%	0%	21%	6%	23%
Diseases of the circulatory system	2%	5%	11%	2%	6%	5%	**66%**	16%	4%	7%	1%	2%	0%	13%	3%	19%
Diseases of the respiratory system	7%	6%	10%	2%	10%	6%	46%	**18%**	4%	7%	1%	3%	0%	36%	3%	16%
Diseases of the digestive system	17%	5%	13%	6%	6%	4%	47%	19%	**29%**	13%	1%	3%	0%	22%	8%	13%
Diseases of the genitourinary system	20%	3%	16%	4%	8%	6%	54%	16%	6%	**12%**	1%	2%	0%	20%	3%	14%
Diseases of the skin and subcutaneaous tissue	70%	4%	15%	4%	13%	8%	42%	14%	4%	15%	**4%**	4%	0%	26%	4%	4%
Diseases of the musculoskeletal system and connective tissue	13%	4%	16%	6%	9%	6%	50%	33%	9%	12%	5%	**17%**	0%	29%	9%	6%
Congenital anomalies	6%	8%	10%	13%	4%	4%	61%	18%	12%	16%	1%	3%	**1%**	15%	5%	11%
Symptoms, signs and ill-defined conditions	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	**10%**	0%	90%
Injury and poisoning	3%	4%	6%	2%	7%	5%	32%	11%	3%	4%	1%	3%	0%	14%	**4%**	1%
*All deaths**	*4%*	*9%*	*11%*	*3%*	*6%*	*4%*	*52%*	*17%*	*5%*	*7%*	*1%*	*2%*	*0%*	*17%*	*3%*	*21%*

** Excluding deaths with no underlying cause

TTables 4 and 5 show that the proportion of deaths with no secondary cause varies much with the underlying cause. Variations are more pronounced in the US than in France. In the US, the proportion of deaths due to a neoplasm with no secondary cause is for instance 34% while only 4% of all deaths due to an "endocrine, a nutritional, a metabolic disease or an immunity disorder" or a "disease of the skin and subcutaneous tissue" and 6% of all deaths due to "a disease of the musculoskeletal system" do not have any secondary cause. These differences may truly reflect the circumstances leading to death. In the case of cancer for instance, the underlying cause may often be sufficient to describe the circumstances leading to death. But it is very likely that certification practices play a great part in these differences. The certifying physician will probably report more conditions when the underlying cause is not considered as lethal than when it is known to be a life-threatening disease. How does it affect the interpretation of our findings ? The prevalence at death of each secondary cause may be more or less biased up or downward depending on the underlying cause. Thus, comparisons between underlying causes must be done with great caution[8].

The understanding of the associations we have highlighted is also made difficult by the fact that the ICD-9 chapters we have used here to classify causes of death, gather very diverse pathologies. It is of course possible to calculate prevalence rates at a lower level of classification but then, it is probably necessary to focus on a particular ICD-9 chapter. As our goal is to make a general description of old-age mortality patterns, we chose to regroup all causes of deaths into 2952 categories (Table 6) and to use a multiple correspondence analysis to provide a visual representation of the combinations of causes leading to death.

3.2 Multiple correspondence analysis

Multiple correspondence analysis is a data analytic technique for studying associations among categorical variables. The results of this analysis are displayed graphically: individuals (here decedents) characterized by a set of variables are projected on a two dimensions graph which axes (also called factors) are determined so as to minimize the contraction of the distance between individuals induced by the projection. Variables that are taken into account to determine the axes are called "active" variables. Other variables are called "supplementary" variables. In our study, each individual is described by the following set of variables : age, sex, underlying cause of death, secondary cause of death. Age and sex were included as supplementary variables. The underlying and the secondary causes were included as active

---

[8] In any case this comparison would require the standardization of the observed prevalence rates to take into account possible differences in the age distribution of people which death is due to different underlying causes.

variables. On each axis, the coordinate for each cause of death is the average of the coordinates for the people that died from that cause. The origin of the graph represents the average of each variable.

Table 6. List of the groups of causes used in the multiple correspondence analysis

Group of causes	ICD- 9 items (detailed list)
Infectious intestinal diseases	001.0 to 009.3
Septicaemia	038.0 to 038.9
Other infectious diseases	010.0 to 037; 039.0 to 139.8
Cancer of stomach	151.0 to 151.9
Other cancers of the digestive system	140.0 to 150.9; 152.0 to 159.9
Cancers of the respiratory system	160.0 to 165.9
Cancer of breast	174.0 to 174.9
Cancer of uterus	179 to 182.8
Cancer of prostate	185
Other cancers	170.0 to 173.9; 175; 183.0 to 184.9; 186.0 to 239.9
Diabetes	250.0 to 250.9
Other endocrine, nutritional and metabolic diseases	240.0 to 249.9; 251.0 to 279.9
Alcoholism	291.0 to 291.9; 303; 305.0
Other mental disorders	290.0 to 290.9; 292.0 to 302.9; 304.0 to 304.9; 305.1 to 319
Hypertensive diseases	401.0 to 405.9
Ischaemic heart diseases	410 to 414.9
Other heart diseases	390 to 398.9; 415.0 to 429.9
Cerebrovascular diseases and other diseases of the circulatory system	430 to 459.9
Diseases of the respiratory system	460 to 519.9
Lever cirrhosis	571.0 to 571.9
Other diseases of the digestive system	520.0 to 570.0;572.0 to 579.9
Diseases of the skin and bones	680.0 to 739.9
Other diseases	280 to 289.9; 320.0 to 389.9; 580.0 to 676.9; 740.0 to 779.9
Ill defined causes	780.0 to 796.9; 798.0 to 799.8
Senility	797
Accidental falls	880.0 to 888
Other accidents and homicide	800.0 to 879.9; 890.0 to 949.9; 960.0 to 999
Suicide	950.0 to 959
Unknown cause	799.9

We distinguished three groups of deaths depending on the underlying cause (diseases of the circulatory system, neoplasm, other causes) and we performed the analysis for these three groups separately. On all graphs we obtained (see figures 2 to 13), the points corresponding to women and men are located near the origin of the graphs: in other words, men and women patterns of mortality at old ages are very close. For that reason, we decided not to perform the multiple correspondence analysis for both sexes separately.

For France, we completed the multiple correspondence analysis with a cluster analysis. Cluster analysis is a classification method: the coordinates of the individuals calculated by the multiple correspondence analysis, are used to create groups of people that are as homogenous and meaningful as possible.

Figures 2 and 3 give the results of the multiple correspondence analysis performed on the French mortality database, restricted to deaths which underlying cause is a disease of the circulatory system. Each dimension accounts for less than 10 % of the total inertia. In other words, the deformation induced by the projection is quite important. However, the first figure opposes very clearly following patterns of death :

- ischaemic heart diseases that are frequently associated with ischaemic and other heart diseases (class 3);
- cerebro-vascular diseases (class 5) that are spatially closed from hypertensive heart diseases (positive values of factor 2) and with causes that we previously have considered as age-related causes (positive values of factor 1 : septicemia, diseases of the skin and the musculoskeletal system, accidental fall, diseases of the respiratory system). Not surprisingly, ages over 90 are located on the right side of the axis ;
- other heart diseases that are also frequently associated with these age-related causes (class 1);

Figure 2 highlights two other frequent combinations of causes :

- heart diseases as underlying cause of the death / ill-defined causes as secondary cause (class 4) ;
- hypertensive heart disease as underlying cause / other endocrine, nutritional and metabolic diseases as secondary cause (class 2) : diabetes mellitus is probably frequently involved in those deaths.
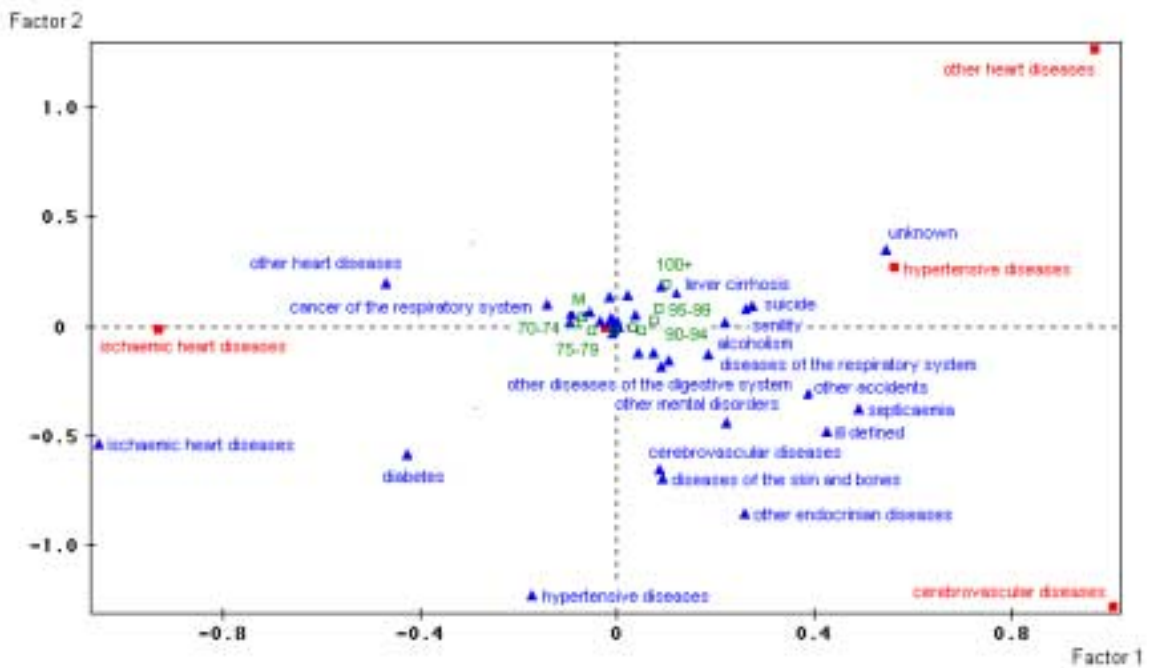
The same analysis performed on US data (figures 4 and 5) leads to very similar results.
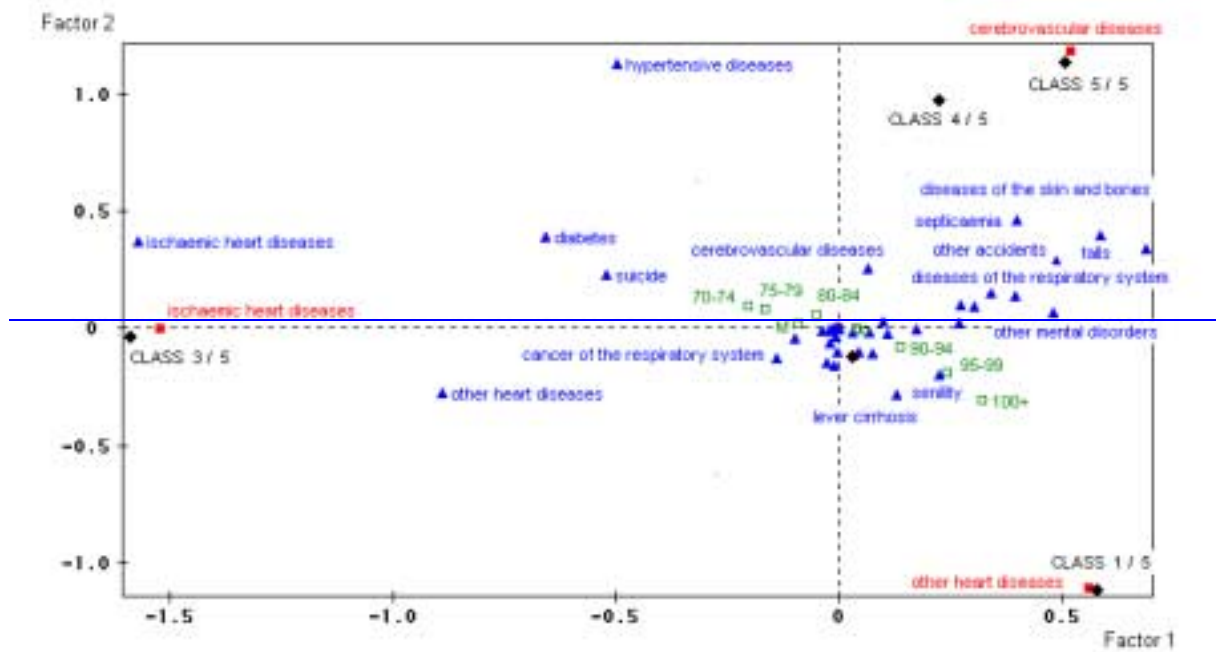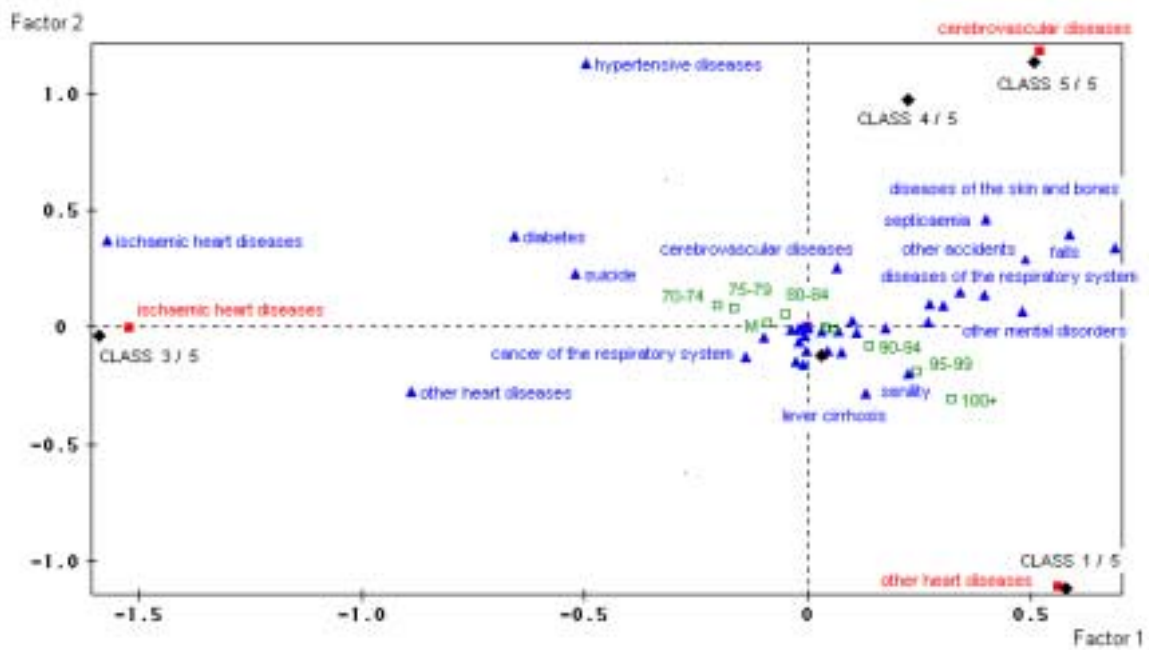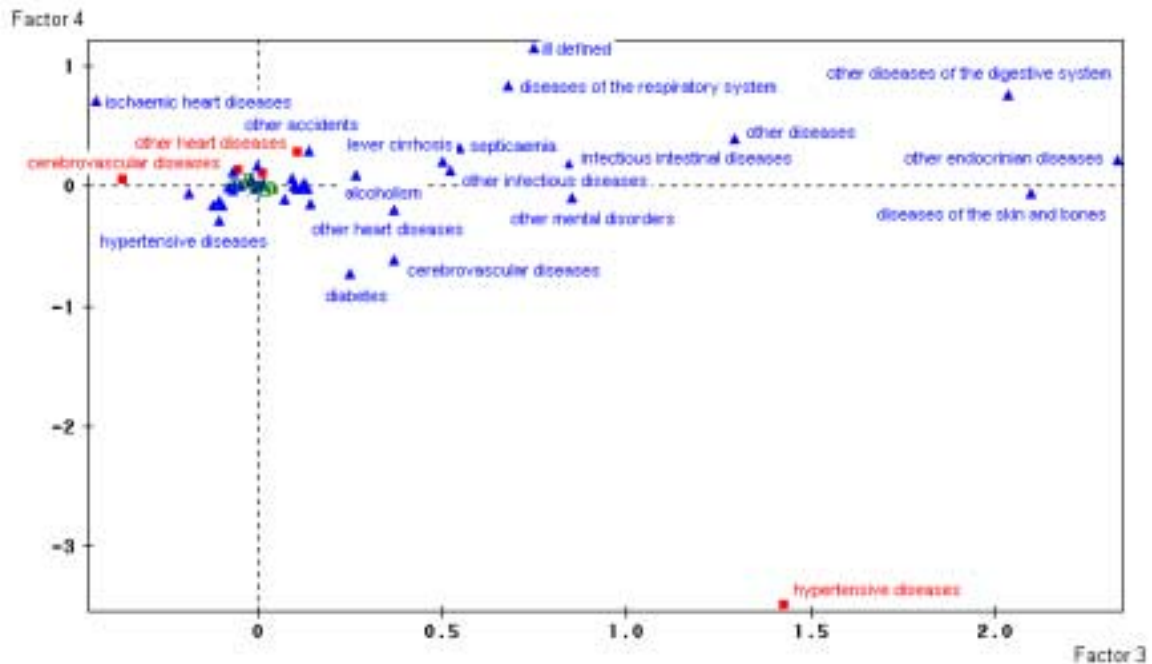
**Figure 2 : Multiple correspondence analysis : axis 1 and 2
Underlying cause of death : disease of the circulatory system - France-, 1996**
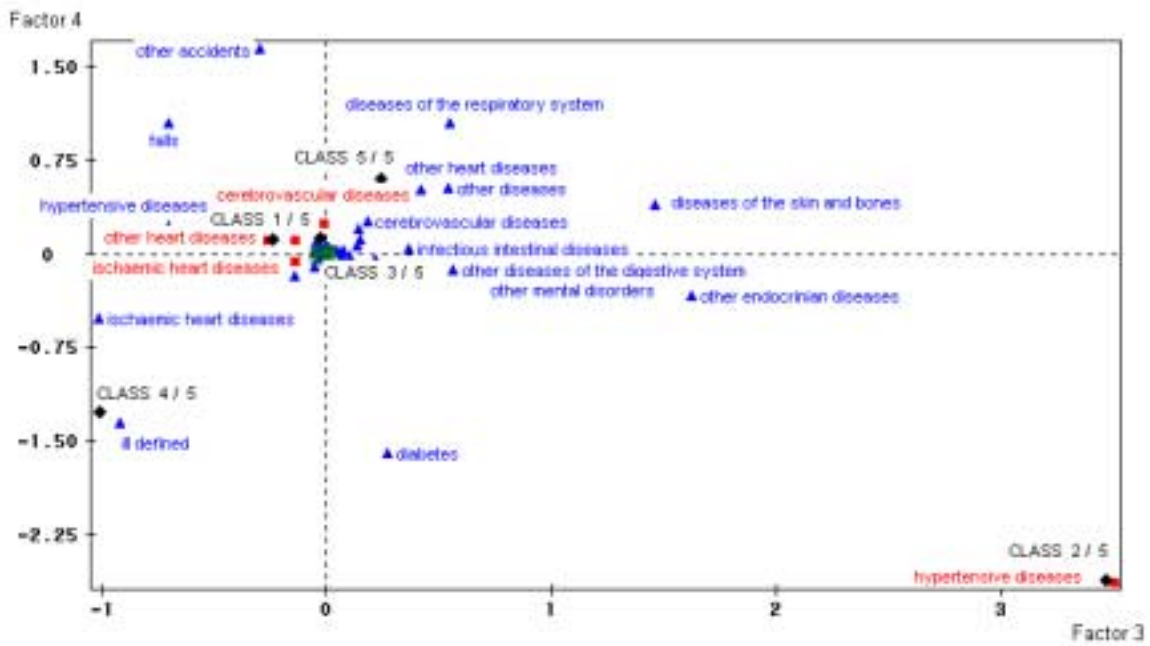
**Figure 3 : Multiple correspondence analysis : axis 3 and 4
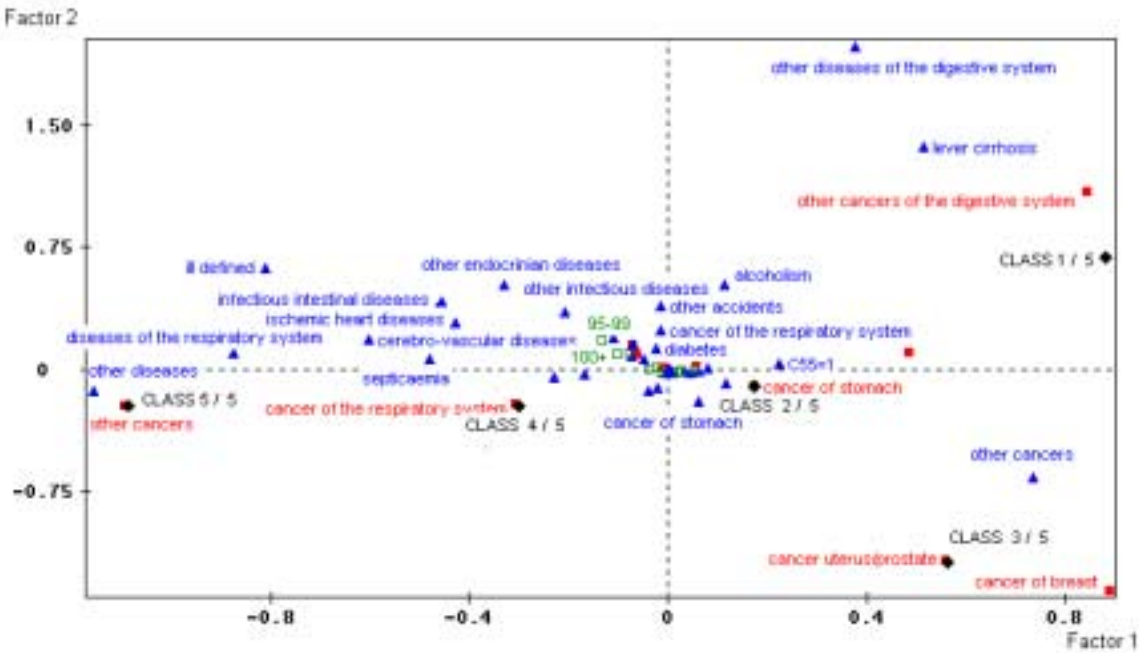Underlying cause of death : disease of the circulatory system - France, 1996**

**Figure 4 : Multiple correspondence analysis : axis 1 and 2
Underlying cause of death : disease of the circulatory system - US, 1994**

Figure 5 : Multiple correspondence analysis : axis 3 and 4
Underlying cause of death : disease of the circulatory system - US , 1994

Figures 6 and 7 give the results of the same analysis performed on all deaths due to a neoplasm that occurred in France in 1996. Again, each dimension accounts for less than 10 % of the total inertia.

The first and the second dimensions distinguish :

- "other neoplasms of the digestive organs" that are frequently associated with liver cirrhosis and "other diseases of the digestive system" (class 1) ;

- "neoplasms of other or unspecified sites" (class 5 : negative values of factor 1). Ages over 95 and most points corresponding to secondary causes of deaths (diseases of the respiratory system, other diseases…) are located on the left side of the axis too. The understanding of this proximity requires to split the group "neoplasms of other or unspecified sites" into more precise groups of causes;

- "neoplasms of uterus and prostate" that are frequently associated with "neoplasms of other or unspecified sites" (class 3). On figure 6, "neoplasm of breast" as underlying cause of the death is spatially closed from these points. The fourth dimension (figure 7) however opposes both type of neoplasm and reveals a frequent association between "heart diseases" and "neoplasms of uterus and prostate". It is very likely that this association mostly brings into play "neoplasms of the prostate" that, as a male disease, are likely to be often associated with "heart diseases".

Axis 3 highlights a link between "neoplasms of respiratory organs" and " diseases of the respiratory system" (class 4). It also reveals a frequent association between "neoplasms of other or unspecified sites" as underlying cause of the death and "other diseases of the digestive system" and "other diseases" as secondary cause. On both figures, the points corresponding to "neoplasms of the stomach" as underlying or secondary cause of death are spatially closed to "suicide". One may argue that the link between these two causes of death is likely to be alcoholism.

Most of these results apply to the US situation (figures 8 and 9). Again, we find a strong association between "neoplasms of the respiratory organs" and "diseases of the respiratory system" (negative values of factor 1) as well as an association between "other neoplasms of the digestive organs" and "other diseases of the digestive system" (positive values of factor 1). We were able to highlight these "organic" associations because we used a much more detailed classification of the causes of death than in tables 4 and 5. On figure 8, the points corresponding to "neoplasms of the stomach", "suicide" and "cirrhosis of the liver" tend to cluster together, which gives support to the hypothesis we made previously that alcoholism plays a major part in the association between "neoplasm of the stomach" and "suicide".

Figure 6 : Multiple correspondence analysis : axis 1 and 2
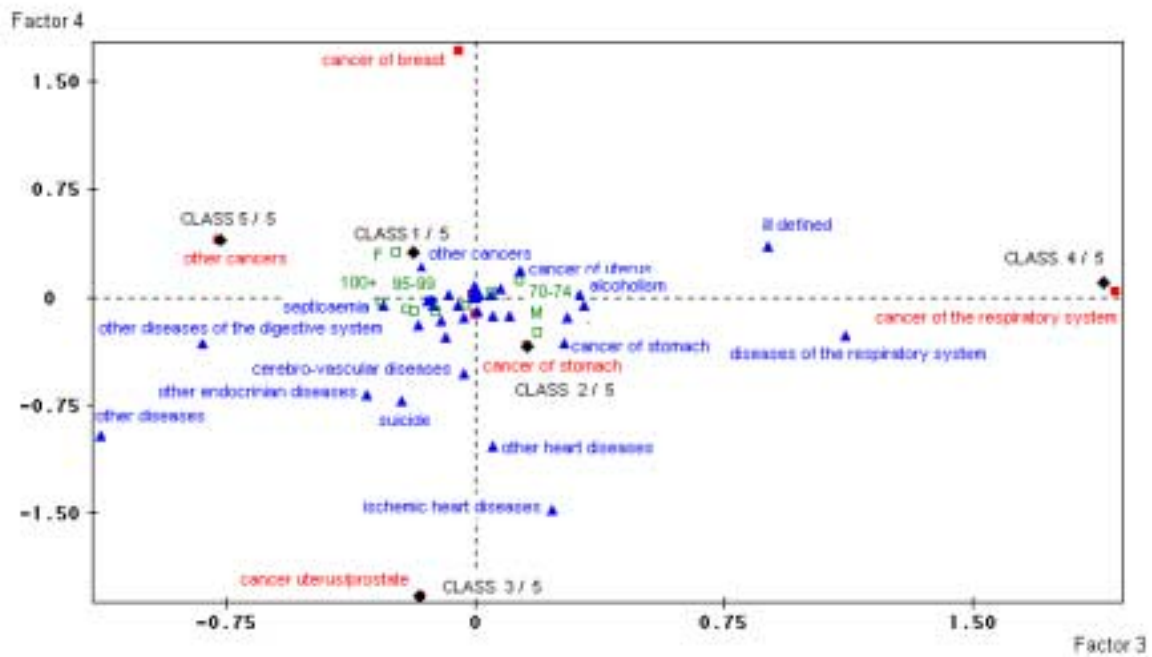**Underlying cause of death : neoplasm - France, 1996**

**Figure 7 : Multiple correspondence analysis : axis 3 and 4
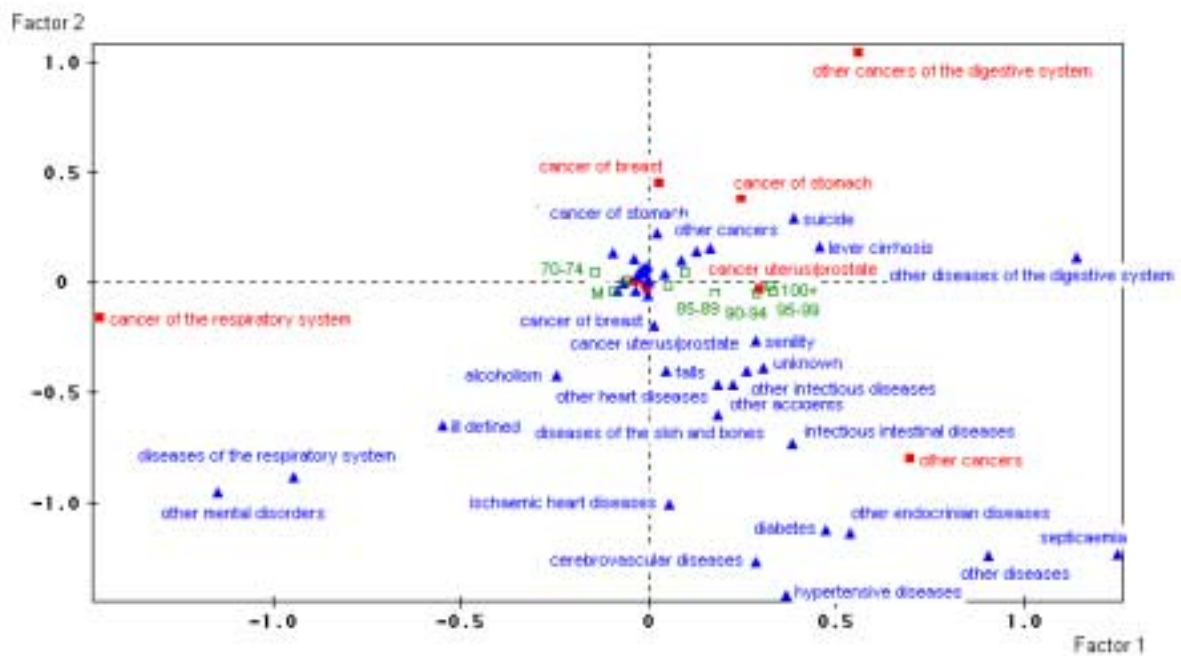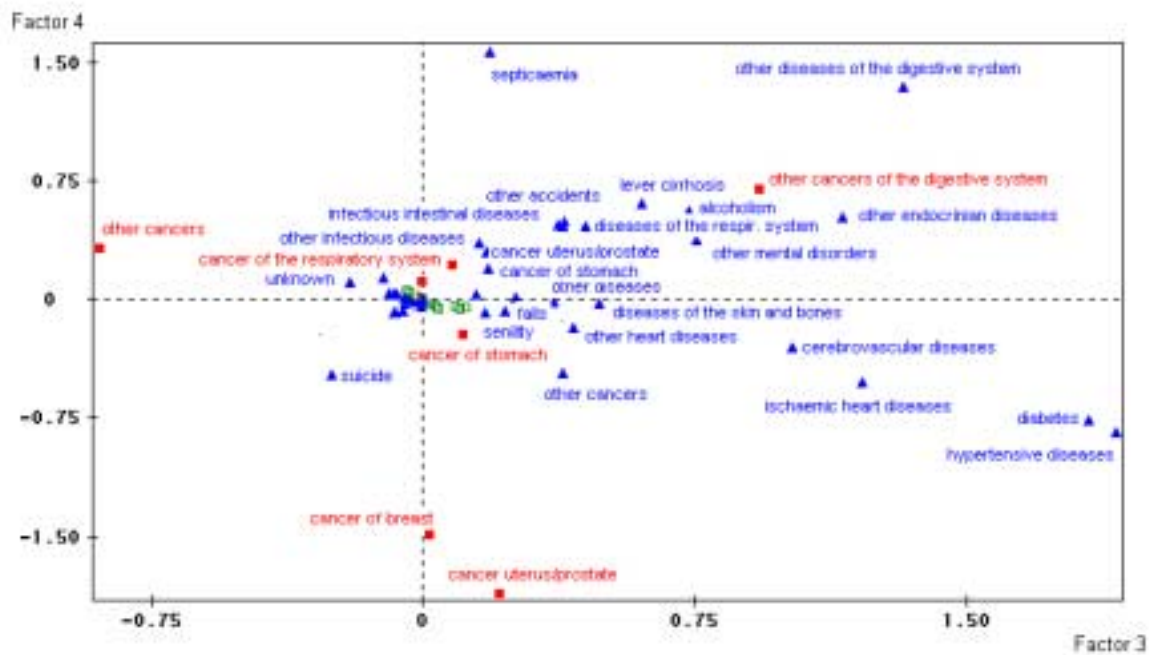Underlying cause of death : neoplasm - France-, 1996**

**Figure 8 : Multiple correspondence analysis : axis 1 and 2
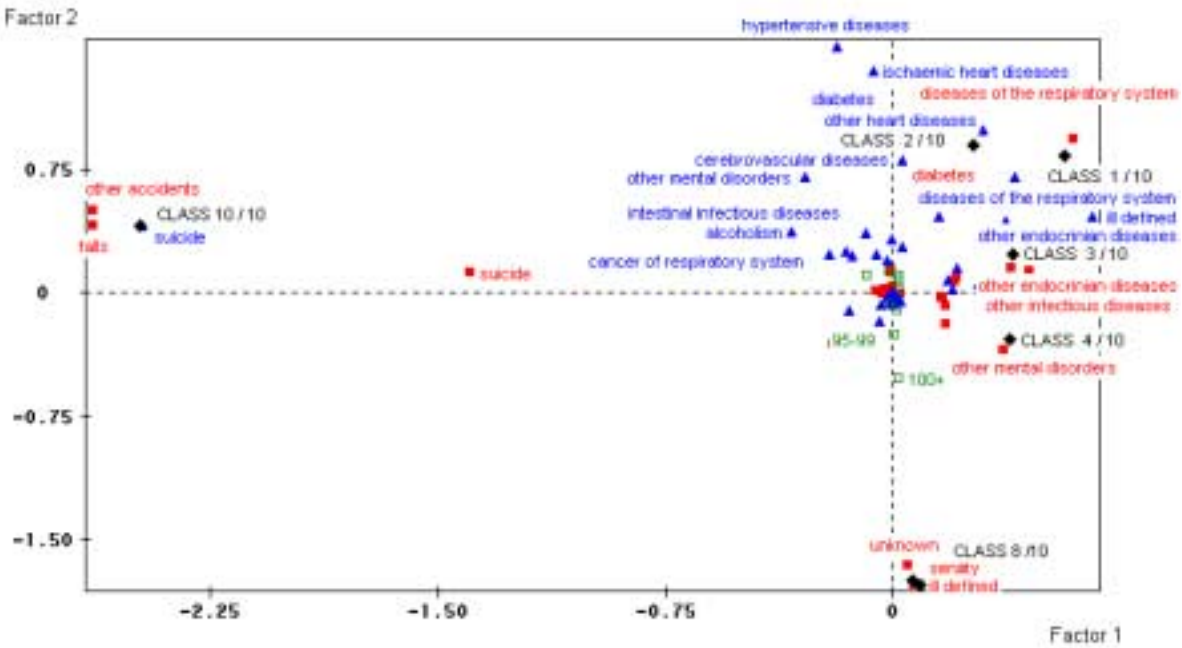Underlying cause of death : neoplasm - US-, 1994**

Figure 9 : Multiple correspondence analysis : axis 3 and 4
Underlying cause of death : neoplasm - US , 1994

Finally, we performed the multiple correspondence analysis on all deaths due to other causes than a cardiovascular disease and a cancer. In France, the first axis (figure 10) highlights the association between accidents (including accidental falls) as underlying cause of the death and suicide as secondary cause (class 10). This association does not emerge from the same analysis performed on US data (figures 12 and 13). One possible explanation to this French particularity may be a consequence of a French specificity in terms of coding practice : as mentioned before, in France, when the underlying cause of the death is an external cause, the place in the database that is reserved to the direct cause, gives information on the nature of the injury (N List, items 800 to 999). Consequently, we did not use this information in our analysis. It is however possible that sometimes French coders do not follow this rule and put the nature of the injury at one of the two places reserved for the contributory causes that are normally classified according to the E list. In that classification, suicide corresponds to items 950 to 959. In the N list, these items corresponds to injuries of the nerves and spinal cord and traumatic complications. Thus, it is possible that the association between accidents and suicide results from a classification mistake.

"Diseases of the respiratory system" (class 1) are significantly associated with the positive values of axis 2 (figure 10). The more frequently stated secondary causes in class 1

are "ill defined causes" (30%) and "other heart diseases" (26%). Negative values of axis 2 are mainly characterized by the points corresponding to "senility" and "ill defined causes" as underlying cause of the death (class 8 and 9). Not surprisingly, unknown secondary causes of death and ages over 95 have also a negative coordinate axis 2.

On figure 11, it is possible to identify several other frequent patterns of mortality at ages over 70. Positive values of axis 3 are significantly associated with "other diseases of the digestive system" as underlying cause (class 6). "Other accidents" and "other diseases of the digestive system" as secondary cause of the death are located near this point. We find the same proximity in the US on figure 12 (negative values of axis 2). The association between "diabetes mellitus" as underlying cause of the death and "hypertensive diseases" and "ischaemic heart diseases" as secondary cause of the death is also a common feature of the French (class 2) and the US (positive values of axis 1 and 2 on figure 12) mortality at old ages. It is also true for the association between "diseases of the respiratory system" as underlying cause of the death and "ill-defined cause" and "mental disorders" as secondary cause (negative values of axis 3 on figure 10 for France and negative values of axis 1 on figure 12 for the US).

Figure 10 : Multiple correspondence analysis : axis 1 and 2
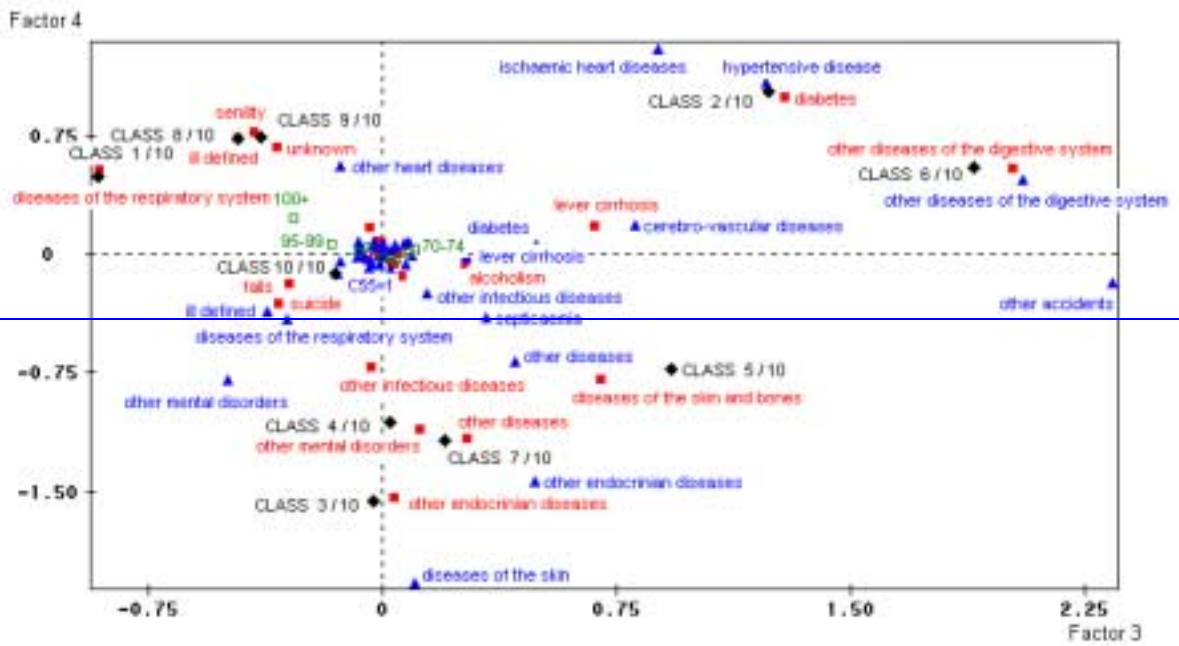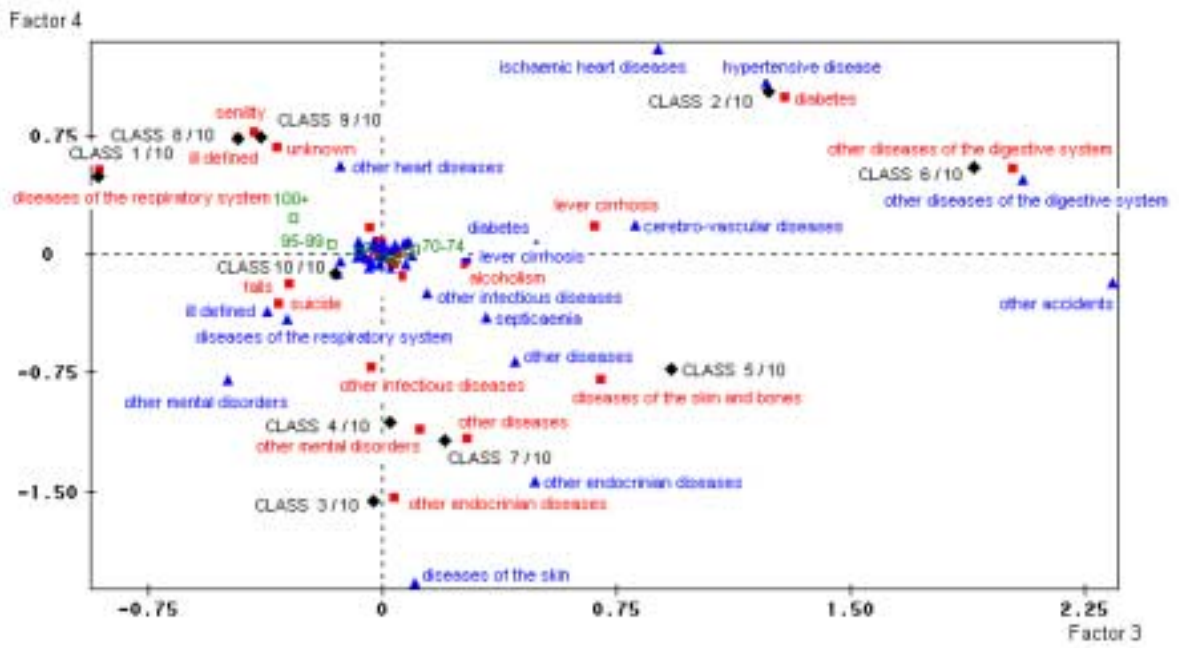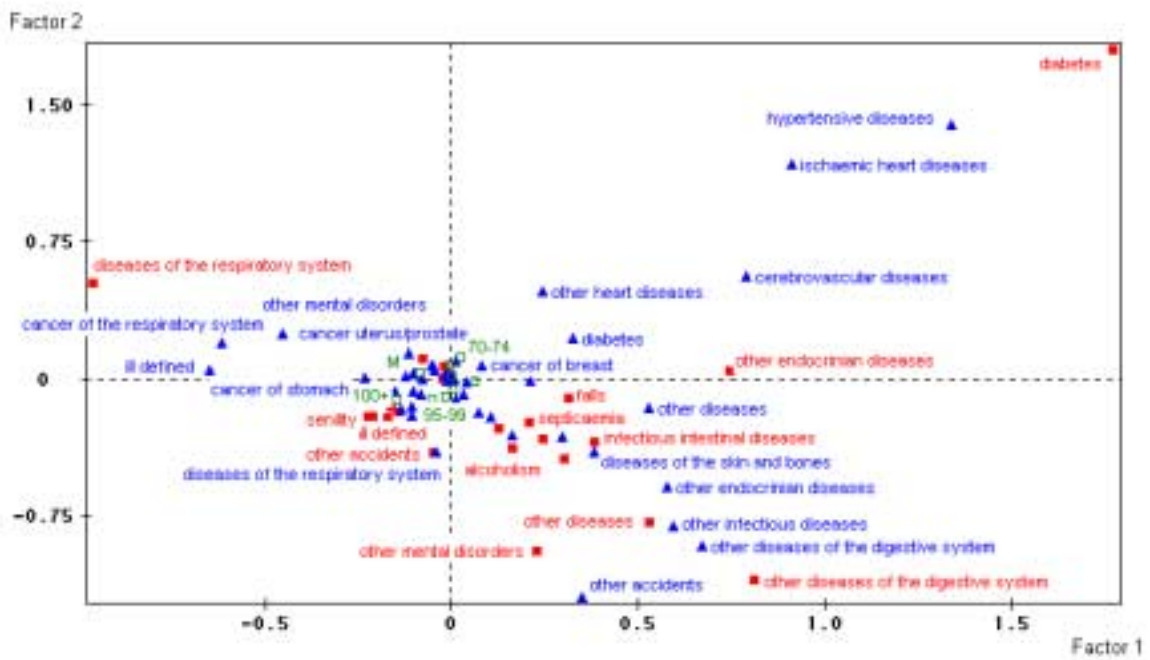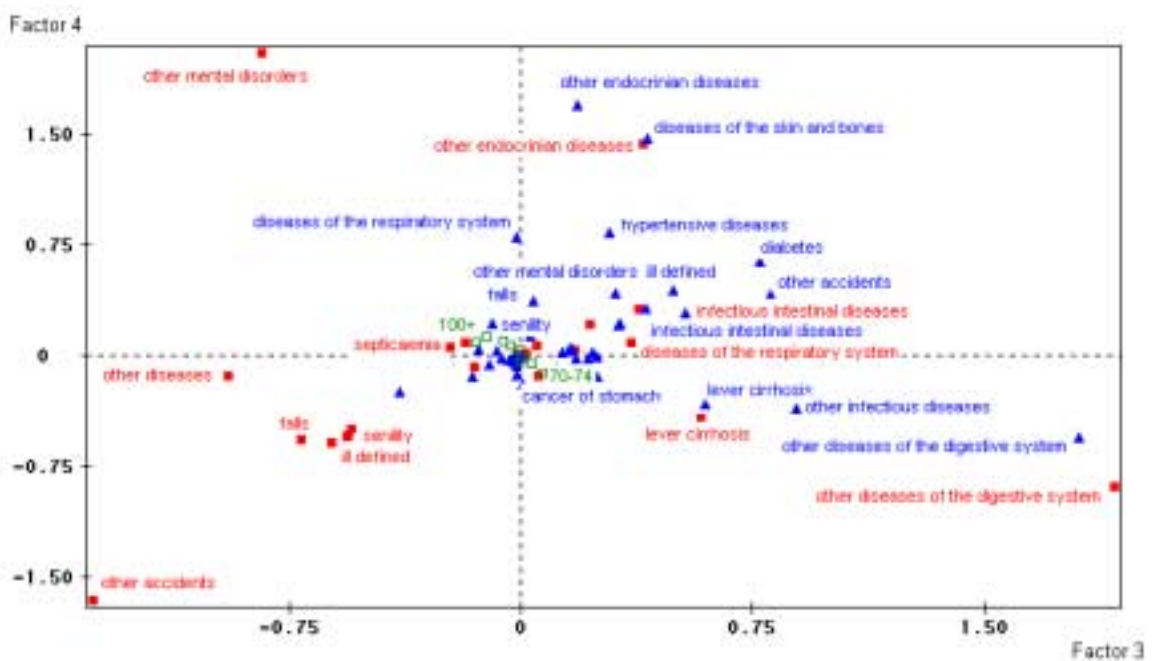**Underlying cause of death : other causes – FranceFrance, 1996**

Figure 11 : Multiple correspondence analysis : axis 3 and 4
Underlying cause of death : other causes - France , 1996

Figure 12 : Multiple correspondence analysis : axis 1 and 2
Underlying cause of death : other causes - US-, 1994

Figure 13 : Multiple correspondence analysis : axis 3 and 4
Underlying cause of death : other causes - US-, 1994

Finally, figure 11 highlights the proximity between points that correspond to non-fatal diseases ("diseases of the skin and the subcutaneous tissue", "other mental disorders", "other infectious diseases", "other endocrine and metabolic disease") reported as underlying or secondary cause of the death (classes 3, 4, 5 and 7). This cluster of causes is less visible in the US than in France. However, the positive values of axis 4 (figure 13) reveal a quite similar pattern. As mentioned before, this pattern of mortality may be considered as a marker of an aging population. At very old ages, death does often not result from one particular disease but rather from the accumulation of several diseases that probably contribute to weaken the person. Future gains in life expectancy will probably depend on the progresses that will be made in the treatment and the prevention of this multi-causal frailty.

4. Conclusion

The multiple-cause approach modifies significantly the cause-based profile of deaths occurring in France and in the US at ages over 70. First, it reinforces the weight of cardiovascular diseases among all causes of death. At the same time, the multiple-cause approach draws the attention to the importance of some conditions that are overlooked when the analysis is confined to the underlying cause. At ages over 70, it is especially the case of diseases belonging to the two following ICD-9 chapters : "endocrine, nutritional and metabolic diseases and immunity disorders" and "mental disorders". As it is not possible to investigate precisely the whole content of each ICD-9 chapter in a single study, we more generally encourage studies that focus on a particular disease. We found in the literature good examples for this kind of approach. In the U.S., hypertension (Wing, 1981), cancer (Wrigley, 1987), cirrhosis (Speizer, 1977), tobacco use (Nam, 1993) as well as nosocomial infections (White, 1993) or Creutzfeldt-Jakob disease (Holman, 1995) have been the targets of a multiple-cause analysis. In France, this approach is still very infrequent (Nizard, 1993) (Coste, 1994).

The same conclusion applies for the study of combinations of causes. If a very general overview of patterns and trends of multiple causes-of-death is needed, groups at the level of the ICD-9 chapters may be sufficient. However, the understanding of the complex processes leading to death requires an analysis at a lower level of classification. Again, an in-depth analysis is only possible if we focus on very specific diseases. In France, up to four causes classified according to the 5,600 ICD-9 rubrics may be coded for each death. Thus, about 10^{15}

combinations are theoretically possible. Of course not all deaths have a secondary cause and some rubrics are never used. But still, there were in 1996 about 200,000 different combinations of causes coded according to the 4-digit ICD-9 rubrics !

Whatever the methodological problems are, we are convinced that the analysis we performed here, deserves further developments. Despite the important differences that exist between the French and the US data collection and codification system, results for both countries turn out to be singularly close and coherent just as well for the study of total mentions as for that of combinations of causes. This finding suggests that the validity of both statistics is higher than one would expect, given all warnings we made. To make multiple cause-of death statistics fully comparable, a set of common rules governing the selection and classification of multiple causes, similar to those specified by WHO for the selection of the underlying cause of death, needs to be elaborated. Then, a rigorous comparative analysis between countries will be possible. Such an analysis would certainly help to understand the main determinants of mortality at old ages.

References

COSTE J., JOUGLA E., 1994. – Mortality from rheumatoid arthritis in France, 1970-1990. *Int J Epidemiol*, 23(3):545-552.

DÉSESQUELLES Aline and MESLÉ France, 2000.– *First insight into the patterns and trends of old-age mortality using French multiple cause of death statistics*. – Paris, INED, 25 p. (Paper presented at the REVES 12ᵗʰ meeting "healthy life expectancy, linking policy to science", Los Angeles; march 2000).

FIFE D, 1987. – Injuries and death among elderly persons, *American Journal of Epidemiology*, 126(5): 936-941.

GOURBIN Catherine and WUNSCH Guillaume, 1999. – *Old age dementia : a European perspective*. – Louvain-la-Neuve, Institute of Demography, 6 p. (Paper presented at The Hague European Conference).

HOLMAN R.C., KHAN A.S., KENT J., STRINE T.W., SCHONBERG L.B., 1995 . – Epidemiology of Creutzfeld-Jakob disease in the United States 1979-1990 : analysis of national mortality data. *Neuroepidemiology*, 14(4):174-181.

MACKENBACH J.P., KUNST A., LAUTENBACH H., BIJLSMA F.and OEI Y. B, 1995. – Competing causes of death:an analysis using multiple-cause-of-death data from the Netherlands. *American Journal of Epidemiology*, 141 (5): 466-475.

MESLE France, 1995. – L'enregistrement des causes de décès en Europe, *in :* Josianne DUCHENE and Guillaume WUNSCH (eds.)*, Collecte et comparabilité des données démographiques et sociales en Europe,* p. 401-431. – Louvain-la-Neuve, Academia/L'Harmattan, 671 p.

MESLE France, 2000. – *Causes de décès aux grands âges : validité et comparabilité.* – Paris, INED, 22 p. (Paper presented at the IUSSP Seminar "Human longevity, individual life duration and the growth of the oldest-old population", Montpellier, 23-25 October 2000).

MESLE France and VALLIN Jacques, 1998. – *L'évolution de la mortalité aux âges élevés en France depuis 1950.* – Paris, INED, 42 p. (Dossiers et recherches n° 68).

NAM C.B, HUMMER R.A., ROGERS R.G., 1993. – *Underlying and multiple causes of death related to smoking*. (Paper presented at the XXIInd general population conference of the International Union for the Scientific Study of Population, Montreal, Canada; 1993).

NIZARD Alfred and MUNOZ-PÉREZ Francisco, 1993 – Alcool, tabac et mortalité en France depuis 1950 - Essai d'évaluation des décès dus à la consommation d'alcool et de tabac en 1986. *Population*, 3: 571-607.

SPEIZER F.E., TREY C., PARKER P., 1977. – The uses of multiple causes of death data to clarify changing patterns of cirrhosis mortality in Massachusetts. *American Journal of Public Health*; 67(4):333-336.

VALLIN Jacques and MESLE France, 1998. – Comment suivre l'évolution de la mortalité par cause malgré les discontinuités de la statistique. Le cas de la France de 1925 à 1993, *in :* Gérard PAVILLON (ed.)*, Enjeux des classification internationales en santé ,* p. 113-156. – Paris, Éditions INSERM, 220 p. (Coll. Questions en santé publique).

WHITE M.C., 1993. – Mortality associated with nosocomial infections : analysis of multiple cause-of-death data. *J Clin Epidemiol*. 46(1):95-100.

WHO, 1977.– *International Classification of Diseases*, *9ᵗʰ revision*. – Geneva, Switzerland, World Health Organization, 773 p.

WING S. and MANTON K.G., 1981. – A multiple cause of death analysis of hypertension-related mortality in North Carolina, 1968-1977. *American Journal of Public Health*, 71 (8):823-830.

WRIGLEY J.M., NAM C.B., 1987. – Underlying versus multiple causes of death : effects on interpreting cancer mortality differential by age, sex and race. *Population research and policy review*, 6(2).