THE RECENT STAGES OF THE EPIDEMIOLOGIC TRANSITION IN CANADA: WHICH HYPOTHESES ARE ACCURATE AND WHICH ARE NOT?

The last century has been the witness to numerous changes in population evolution, including an important decline of fertility, paired with a regression of mortality due in part to the changing nature of causes of death. Among other things, the study of the theory of the epidemiologic transition has allowed better insight of the processes behind the evolution of mortality and causes of death in developed countries. However, this theory of the epidemiologic transition has also been a controversial issue among researchers in the last few decades.

The object of this analysis is to study the evolution of the last stages of the epidemiologic transition in Canada, and to find out whether the country has experienced the fourth stage, during which deaths by degenerative diseases are postponed to older ages. Therefore, this research paper will examine age-specific causes of death and will look specifically at the course Canada has taken through the recent stages of the epidemiologic transition.

The Epidemiologic Transition Theory: variants on the Number of Stages and their Characteristics

In 1971, following the incomparable decline of mortality in developed countries, Omran put forward a theory describing for the first time the decrease of infectious diseases, gradually replaced by chronic diseases. It was labelled the "epidemiologic transition" and was initially comprised of three phases spread throughout the last few centuries describing this shift between the main causes of death. According to Omran, the first phase, called the "age of pestilence and famine" lasted until the middle of the 19th century and was characterized by high and fluctuating mortality due mostly to infectious diseases. The second phase (the "age of receding pandemics") ended in the middle of the 20th century for most developed countries and is distinguished by the onset of the shift from infectious to chronic diseases, and the increase of life expectancy. The third phase, identified as the "age of degenerative diseases", is characterized by the predominance of chronic diseases and the stabilization of mortality at a low level.

In the mid-1980s, a fourth stage of the epidemiologic transition was suggested when researchers found that, contrary to what Omran had predicted, the decline of mortality never stopped (Olshansky and Ault, 1986; Rogers and Hackenberg, 1987). Subsequently, other researchers put forward either variants or additions to the third stage of Omran and the fourth stage of Olshansky and Ault (Olshansky and al., 1998; Omran, 1998; Robine, 2001; Meslé and Vallin, 2002).

More specifically, Olshansky and Ault (1986) were the first ones to propose a fourth stage after observing an uninterrupted increase in life expectancy. They thought this trend was significant enough to distinguish it from Omran's three previous phases. The fourth stage suggested by Olshansky and Ault is summarized by three general characteristics:

1. "Rapidly declining death rates that are concentrated mostly in advanced ages and which occur at nearly the same pace for males and females".

2. "The age pattern of mortality by cause remains largely the same as in the third stage, but the age distribution of deaths for degenerative causes is shifted progressively toward older ages".

3. "Relatively rapid movements in survival are concentrated among the population in advanced ages".

This fourth stage is referred to as the "age of delayed degenerative diseases", since the probability of death from these causes is shifted toward older ages. When Olshansky and Ault wrote their article in 1986, they argued that the United States were already into the fourth stage of the epidemiologic transition, although they did not specify since when.

In an article published in 1998, Omran recognizes the existence of one and possibly two additional stages to his initial theory of the epidemiologic transition. According to him, the fourth stage is characterized by an ongoing rise in life expectancy until it reaches 80 to 85 years old; by a stabilization, followed by a decrease, of cardiovascular diseases as a cause of death; as well as by the emergence of new diseases (HIV, hepatitis B and C, Ebola, Lyme disease, Hantaan virus, new forms of E.Coli, etc.) and by the revival of former diseases (cholera, malaria, dengue, diphtheria, tuberculosis, plague, and Chagas disease).

Rogers and Hackenberg (1987) also put forward a fourth stage of the epidemiologic transition. They agree with Olshansky and Ault on the fact that degenerative diseases remain the leading cause of death, but the point they stress the most is the fact that Omran did not include violent deaths in his theory, or deaths due to social pathologies (accidents, suicides, homicides).

Robine (2001) is even harsher than the previous researchers on his critique of the theory of the epidemiologic transition. Particularly, Robine doubts the very existence of the last two stages (Omran's third stage and Olshansky and Ault's fourth stage) after studying the evolution of dispersion of life spans.

As for Meslé and Vallin (2002), they revised the theory into two stages only. They acknowledge Omran's first stage during which the improvement in survival is mostly due to the collapse of infectious diseases and the rise of chronic diseases. The end of this first stage would lead directly to the decline of cardiovascular diseases, which would be the main factor underlying the growth of life expectancy during the second stage. They refer to this stage as the "cardiovascular revolution".

In addition to the different points of view among researchers as to the number of stages of the epidemiologic transition, the attributes of the stages have been thrown back into question (Rogers and Nelson, 1997; Mackenbach, 1994; Caselli and Egidi, 1991; Burgio and Frova, 1995) as well as the undertaking of predicting the evolution of causes of death (Meslé, 1997). Moreover, Fetter (1997) challenges the actual concept of an epidemiologic or demographic transition theory. Therefore, since this theory is controversial and has been fuelling debates over the last few decades, we thought it would be pertinent to clarify the status of the epidemiologic transition in Canada.

The Empirical Work in Canada

A few Canadian studies have attempted to determine whether Canada had actually experienced the theoretical assertions of the last stages of the epidemiologic transition.

Nagnur and Nagrodski's analyses (1987; 1990) showed that the evolution of the epidemiologic transition described by Omran can be observed for Canada between 1931 and

1981, but they did not venture on the status of the fourth stage, or provide temporal indications on the switch from the second to the third stage or from the third to the fourth. However, Bah and Rajulton (1991) claimed that Nagnur and Nagrodski's research (1987; 1990) showed that Canada reached the third stage of the epidemiologic transition in the 1950s, even though Nagnur and Nagrodski themselves did not explicitly give any estimation on that matter. The ambiguity of these statements, along with the fact that the time frame during which Canada progressed from the second to the third stage remains vague, will prompt us to clarify this situation.

It certainly appears that a deeper analysis, at the Canadian level, is needed in order to confirm, or refute, the claims of researchers on the epidemiologic transition.

Research Questions

As it has just been mentioned, we will start by establishing more precisely when Canada made the transition from Omran's second to third phase. Then, the objectives of our research will focus on what happened exactly beyond Omran's third stage of the epidemiologic transition since there is no consensus among researchers. The following questions are inspired by the allegations brought up by researchers:

1. Was mortality's decline concentrated mostly in advanced ages and did the decline occur at nearly the same pace for males and females? (Olshansky and Ault, 1986)

2. Did the pattern of mortality by cause stabilized (Olshansky and Ault, 1986)?

3. Did specific changes occur within chronic disease groups?

4. Did a gradual shift towards older ages of mortality by chronic diseases take place? (Olshansky and Ault, 1986)

5. Have we observed a decline of mortality by social pathologies? (Rogers and Hackenberg, 1987)

6. Was the impact of AIDS on mortality significant? Did a resurgence of infectious diseases like cholera, diphtheria and dengue take place?[1] (Omran, 1998)

7. Could mortality due to pneumonia and influenza have increased? (Olshansky and al. 1998)

Question 3, related to possible changes within chronic diseases, is the only one that did not arise from one of the researchers. Indeed, it is probable that mortality by chronic diseases did not change on the whole as Olshansky and Ault affirm, but that within specific groups of chronic diseases (cancer, cardiovascular diseases, etc.), some significant variations have occurred. Besides, we have not included Meslé and Vallin's proposal (2002) on the "cardiovascular revolution" because the evolution of cardiovascular mortality will be fully examined by questions 2 and 3. We will refer back to Meslé and Vallin's suggestion in the conclusion.

Therefore, we will attempt to test the validity of the researchers' assertions on the final stage of the epidemiologic transition (Olshansky and Ault, Rogers and Hackenberg, Omran, and Olshansky and al.). In other words, we will examine whether their observations apply to Canada. For that reason, we will analyse the modifications happening within different groups of diseases. After assessing each of these aspects, we will be better positioned to give a verdict on the true status of the epidemiologic transition in Canada.

DATA AND METHODS

Period of study

The first year of our data is 1958, which is the first year of the 7th revision of the International Classification of Diseases (ICD) in Canada, and which falls shortly before the slowing down of the decline of mortality observed in the 1960s (Bourbeau and Smuga, 2003; Chasteland and Chesnais, 1997). The final year of our analysis is 1999, which corresponds with the last year

[1] Cholera, diphtheria and dengue are three of the infectious diseases identified by Omran (1998) as having a comeback. We chose these three diseases over others for two reasons: the compatibility between ICD-7, ICDA-8 and ICD-9 are the least complex for these three diseases; in addition, diphtheria and dengue are two of the four infectious diseases that Olshansky et al. (1998) believe are resurfacing in North America.

of the 9th revision of the ICD in Canada. Indeed, the fact that we had to deal with the changes in revisions by the ICD was the largest difficulty met in this research.

Source of data

The data on causes of death that we used came from Statistics Canada. The data was available by 5-year age groups (0-1, 1-4, 5-9, 10-14, …, 100+) and by sex, from the year 1950 until the year 2001. Moreover, the database recorded all causes of death, including 4-digit rubrics. As for the under-estimation of deaths, it is very low considering the requirement of death registering, and is mainly due to a delay of registration rather than an omission. In addition, we distributed some deaths for which the sex, the age or the cause was unknown. Therefore, there are no unknown cases in the database we used.

Definitions

When Omran suggested his epidemiologic transition theory, he spontaneously used the term "degenerative diseases" although he never precisely described this term. Then, the researchers who worked on the epidemiologic transition adopted the term "degenerative diseases" without questioning its definition and still without specifying the diseases it is suppose to comprise. Afterwards, the expression "chronic diseases" became increasingly used to define the most prevalent diseases within the population. Moreover, the idioms "civilization diseases", "man-made diseases" or "Western diseases" have been somewhat employed.

We decided to hold onto one definition (and its array of diseases) that will be used for the remainder of this research paper. We instinctively eliminated the expressions "civilization diseases", "man-made diseases" or "Western diseases" simply because they are not employed enough by researchers. Although there is definitely a similarity between the definitions of "chronic diseases" and "degenerative diseases", it appears that the term "chronic diseases" is more appropriate than "degenerative diseases". The use of "chronic diseases" is more widespread in the literature and has a definition that is more universal and renowned in dictionaries, encyclopaedias and medical literature as well as among researchers working in the public health field. "Chronic diseases" is less often mistook for "degenerative diseases" or "civilization diseases" than the opposite, and this designation is more consistently used. As for the causes of death that we will consider as being chronic diseases within the framework

of this research paper, we have decided to keep those that were unanimous amongst several sources we examined (The Natural Health Perspective, 2004; Hoerni, Bernard, 2004; Wolleswinkel-Van Den Bosch, J.H. et al, 1996; Santé Canada, 2004; Institut National de Santé Publique du Québec, 2004; Ministère de la Santé et des Services Sociaux du Québec, 2004; Medical Research Council South Africa, 2004 ; Center for Diseases Control and Prevention, 2004; Brownson, R.C. et al., 1993 ; Trowell, H.C. and Burkitt, D.P., 1981).

Thus, six groups of chronic diseases were established: malignant tumours; cardiovascular diseases; diabetes; chronic obstructive pulmonary diseases ($COPD^2$); osteo-articular, muscular and conjunctive tissue diseases (which include osteoporosis and arthritis); and Alzheimer's disease. Henceforth, when we will discuss "chronic diseases" without further detail, we will be referring to these six groups of diseases.

In addition, it is important to describe in more detail the causes of death involved in the expression "social pathologies" since it relates to one of our research questions. According to Rogers and Hackenberg's paper, it is possible to identify suicides, homicides and accidents as being the causes of death implied in "social pathologies".

Causes of death and compatibility in the long-term: The international classification of diseases and its revisions

The study of the epidemiologic transition implies that two steps must be taken with a great deal of circumspection: the choice of causes of death and their follow-up in the long-term.

As it was mentioned earlier, we had to convert the causes of death of the 7^{th}, 8^{th} and 9^{th} revisions of the International Classification of Diseases (ICD-7, ICDA-8 and ICD-9) to make them compatible. When a change of ICD revision occurs, Statistics Canada and the World Health Organisation (WHO) provide some basic documents to help make the transition between the old and new revision. Many other countries are faced with the same problem, namely the scarcity of manuscripts that detail the change of revisions (Wolleswinkel-Van Den Bosch, and al., 1996). Since a double-coding is not available (corresponding to the old and new revision), we need to proceed with the reclassification *a posteriori* (Vallin and Meslé, 1996).

Moreover, Statistics Canada warns the researchers to be cautious when confronted with ICD's changes of revisions (Statistique Canada, 1984). Meslé (1997) agrees with Statistics Canada and admits that tackling the discontinuity of ICD's sequences can be complex. Fortunately, Vallin and Meslé have published a document establishing the compatibility of the statistical series between ICD-7 and ICDA-8; but their work is still in progress for the changes introduced by ICD-9. Their work consisted of looking up, for each rubric of a revision, all the rubrics of the other revision that had a condition in common with it, and reciprocally; therefore building "correspondence tables" (Vallin and Meslé, 1996). Then, "elementary associations" of rubrics were created from these correspondence tables, by associating the categories with the same medical content, which allows for a statistical continuity. We have followed their model to insure the compatibility of our causes of death between the 7th and 8th revision of the ICD.

Unfortunately, no work as exhaustive as Vallin and Meslé's (1987) intended for the reconstruction of sequences of causes of death between ICDA-8 and ICD-9 has been published. However, we had the help of an article and a report in the elaboration of ICD 8 and 9's matching of rubrics. The article (Vallin and Meslé, 1996) provided useful examples of detailed associations of rubrics between ICDA-8 and ICD-9, which were the result of the beginning of Vallin and Meslé's work on the transition between these two revisions. In addition, we had access to a report on the equivalence of rubrics between the 7th, 8th and 9th revision from Statistics Canada that was not published. Nevertheless, these documents did not provide all the necessary information, and we had to carry out the task of rubric association ourselves. This was done by looking up the title(s) of the rubric(s) that were the closest to the title(s) of the former revision, most often with the help of the alphabetical indexes. In spite of our careful attention, we are aware that this method is not the most scrupulous, but we used it only as a last resort. As a whole, the causes of death concerned by this method were not significant enough to make a difference.

Making sure the causes of death we used in this research paper were compatible through three of the revisions of the International Classification of Diseases, and converting all the data into the 9th revision standards, was a long and delicate process. The compatibility between the causes of death through time might not be perfect, but we consider that the work has been done with as much thoroughness as considered necessary.

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[2] COPD examined: emphysema, asthma and chronic bronchitis.

Analysis methods

Given the nature of the research, classical demographic indicators were used as analysis methods in order to answer our research questions. We used standardized mortality rates, by cause and/or by age or total; proportion of deaths due to chronic diseases; contribution of the different age groups to the variation of life expectancy, that is to say the "breakdown of life expectancy"; evolution of proportions of causes of death through time; distribution of deaths according to the type of chronic disease; mean age at death by chronic disease; and the evolution of distributions of deaths by age groups (0-64 years, 65-84 years, and 85 years and over) according to the chronic disease cause of death.

In addition, we also used a Lexis surface on question 6, which is related to the impact of AIDS and resurgence of some infectious diseases. Such figures help visualize the trend in three dimensions: age groups, years or periods, and the level of intensity. A color scale determines the levels of intensity. For example, if we are studying mortality rates, they can be grouped into 10 categories with a 25‰ amplitude (0‰ to 24‰, 25‰ to 49‰, 50‰ to 74‰, ….175‰ to 199‰, and 200‰ and over). The various colors circumscribe the levels of intensity of mortality.

RESULTS

The third phase of the epidemiologic transition in Canada

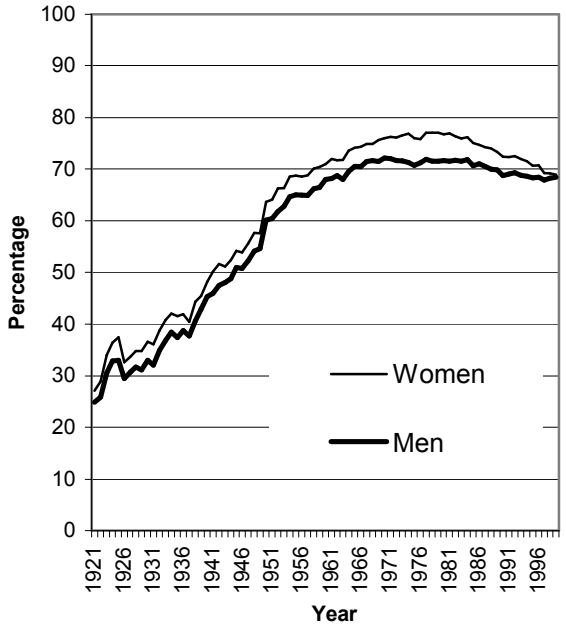
The shift from the second to the third stage in Canada did not arouse much interest from researchers. Most have assumed that this transition was completed by the middle of the 20th century. Since our research questions relate to what happens after the third stage, we believe it is important to determine with more precision when the change from the second to the third stage took place.

In order to do so, we will use two of Omran's main attributes describing the third stage: the predominance of mortality by chronic diseases, and the stabilization of mortality at a low level. Since Omran does not state exactly what he implies by predominance, we will assume, in the context of this study, that the predominance starts the year when 50% or more deaths

are due to chronic diseases. The stabilization of mortality at a relatively low level will be analyzed with standardized mortality rates.

As a reminder, the chronic diseases identified earlier are drawn from ICD-9, but the time frame we will examine in order to determine the period during which chronic diseases started their preponderance covers ICD-3 through ICD-9. Moreover, some chronic diseases are more difficult to isolate than others. Therefore, we settled on eight categories of chronic diseases for the time frame 1921-1999: malignant tumours; diabetes; cerebral haemorrhage, embolism and thrombosis (only from 1921 to 1968); circulatory system diseases; chronic bronchitis; asthma; pulmonary emphysema; and bone and movement organ diseases. We understand that the compatibility of chronic diseases between the ICD-3 and the ICD-9 is probably perfectible (ex. we did not isolate Alzheimer's disease), but our objective at this point is only to identify the approximate period of transition between the second and third stages.

Figure 1. Percent of deaths due to chronic diseases by sex, Canada, 1921-1999



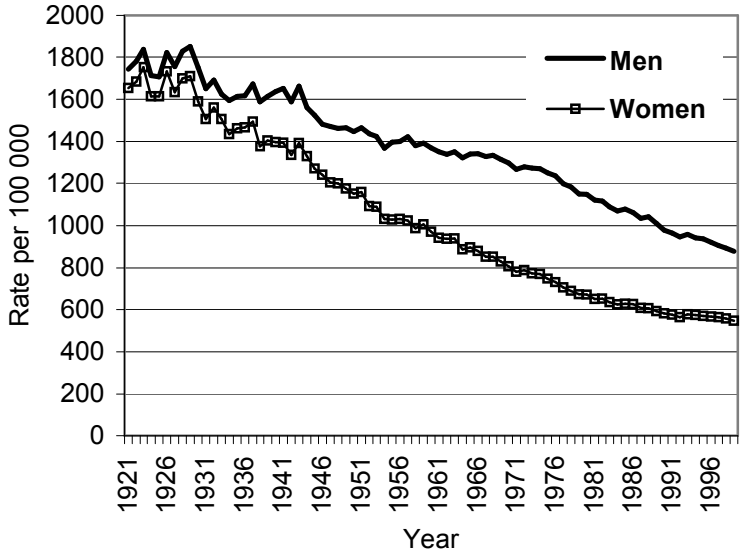
Sources: Dominion Bureau of statistics, 1923-1947. Bureau fédéral de la statistique, 1948-1969. Statistique Canada, Catalogues 84-206 (1970-1986), 84-204 (1978-1986), 82-003S (1987-1989), 82-003S15 (1989-1990), 82-003S11 (1990), 84-208 (1991-1993), 84-211 (1991-1992), 84-210-XPB (1993-1995), 84-208-XPB (1994-1995), 84-209-XPB (1995-1999), 84F0210XPB (1996-1997), 84F0208 (1996-1999), 84F0211XPB (1998-1999).

We note, on figure 1, that chronic diseases began to cause half of female deaths in 1941; the men's trend followed their counterparts' four years later. Therefore, we can claim that this

first aspect of the third stage of the epidemiologic transition started towards the middle of the 1940s in Canada.

As far as Omran's second criteria, we can observe on figure 2 that mortality never completely stabilized. Until the middle of the 1940s, standardized rates[3] evolved erratically, but the overall trend was definitely declining. During the last 50 years, the decline has been steady. There were some short interruptions in the reduction of mortality, but they were never long enough to bring about a level of stagnation.

Figure 2. Standardized mortality rates by sex, Canada, 1921-1999



Sources: Same as figure 1.

Overall, we can assert that one of the two criteria describing the switch from the second to the third stage took place, which is the one regarding the predominance of chronic diseases. The other criterion, the stabilization of mortality, did not occur. There was indeed a slowing down of the decrease of mortality during the 1950s and 1960s, but the decline never completely stopped. The invalidation of Omran's second criterion forces us to reject the third stage as he initially suggested it. Nevertheless, the mere fact that chronic diseases emerge so clearly

[3] We used the direct standardization method and employed the Canadian population in 1996 as the reference population. We obtained the expected deaths by multiplying age-specific mortality rates of each year by the same age-specific reference population. The standardized rate is the sum of these expected deaths by age divided by the total reference population.

indicates the beginning of a third stage of the epidemiologic transition which, however, cannot be the one suggested by Omran.

WHAT HAS BEEN HAPPENING SINCE CANADA STARTED THE THIRD STAGE?

The purpose of this study is to clarify the evolution of the epidemiologic transition since the beginning of the third stage in Canada. Since it has been established that only one out of Omran's two criteria describing the third stage can be observed for Canada, we must focus on further development since the epidemiologic transition seems to extend beyond the beginning of the third stage. Thus, we will attempt to answer the researchers' hypotheses as well as our own research question. We would like to specify that the results depend on the type of indicators we choose. Although different indicators can lead to different results, we think that if there is no ambiguity or uncertainty associated with the result, then most probably all possible indicators would come to equivalent conclusions.

1. Did the decline of mortality benefit mostly the elderly, and did the decline occur at nearly the same pace for males and females? (Olshansky et Ault, 1986)

The first sign of the delay of degenerative diseases stage, suggested by Olshansky and Ault in 1986, is a decrease of mortality, which occurs primarily among the elderly and at the same pace for men and women. By breaking down the life expectancy by age groups, we can first estimate if a decline of mortality has occurred, then we can evaluate which age groups have contributed the most to the gain of life expectancy at birth between 1958 and 1999.

As we expected, the decline of mortality is confirmed throughout the entire period by a continuously growing life expectancy (table 1). In addition, during the period 1958-1979, results differ greatly between men and women. The growth of the male life expectancy between 1958 and 1979 is much more attributable to the decline of infant mortality than to the decrease of mortality among older ages. But this is not the case for women. Even though the decline of mortality at young ages was not negligible in the increase of female life expectancy between 1958 and 1979, the input of the older age groups to their life expectancy growth proved to be even more significant.

Table 1. Contribution of age groups (in years and in percent) to the growth of life expectancy at birth, men and women, Canada, 1958-1979 and 1979-1999

Age groups	1958-1979				1979-1999			
	Men		Women		Men		Women	
	Gain	%	Gain	%	Gain	%	Gain	%
0-1 year	1.6	47.5	1.4	28.5	0.5	10.5	0.4	13.1
1-14 years	0.3	9.9	0.3	5.5	0.3	5.1	0.2	6.3
15-34 years	0.0	-1.0	0.1	2.3	0.6	13.2	0.2	7.8
35-64 years	0.8	24.8	1.0	19.5	2.1	43.1	1.0	33.8
65 years and over	0.6	18.8	2.2	44.2	1.4	28.2	1.2	39.1
Total	3.4	100.0	4.9	100.0	4.9	100.0	3.1	100.0

Source: Canadian Human Mortality Database, 2004.

Between 1979 and 1999, women aged 65 years and over contributed to a lesser degree in the increase of life expectancy than the previous period, but the growth remained the highest amongst this age group. As for men, their situation evolved significantly during the second time frame. The input of older age groups escalated compared to the prior period, but this age group was once again preceded by the adult age group (34-64 years), which showed the most significant mortality decrease.

Since the results regarding the preponderant contribution of the elderly to the improvement of survival are not completely conclusive, we decided to take a look at what the outcome would turn out to be for the most recent period, 1990-1999. We found that 35% of men's life expectancy increase recorded between 1990 and 1999 is attributable to greater survival among people aged 65 years and over. For the same period, the improvement of survival among elderly females compared to the other age groups was even greater since their input on the growth of life expectancy stood at 45%.

As for Olshansky and Ault's second premise of their first hypothesis, the decline of mortality occurring at the same pace for men and women, we used standardized mortality rates illustrated on figure 2. During the first half of the period, the decrease of female mortality is more pronounced. Nevertheless, between the middle of the 1970s and 1999, the decline of mortality among men accelerates and that of women's slows down, which brings the two mortality curves closer together. These trends are confirmed by observing, on table 2, the variations of two indicators (standardized mortality rates and life expectancy at birth) during the entire period 1958-1999 on the one hand, and during its breakdown into two periods, 1958-1979 and 1979-1999, on the other hand. Both indicators reveal that the reduction of mortality is favourable to women between 1958 and 1979 and to men from 1979 to 1999.

Table 2. Variation of life expectancy at birth (increase in years) and of standardized mortality rates (decrease in percent) by sex, Canada, 1958-1999, 1958-1979, 1979-1999

Variations in:	1958-1999		1958-1979		1979-1999	
	Men	Women	Men	Women	Men	Women
Life expectancy	8.4	8.0	3.4	4.9	5.0	3.1
Standardized mortality rates	36.4	44.7	16.8	32.0	23.6	18.7

Sources: Canadian Human Mortality Database, 2004; Statistics Canada, Cat. 91-209F, 2001.

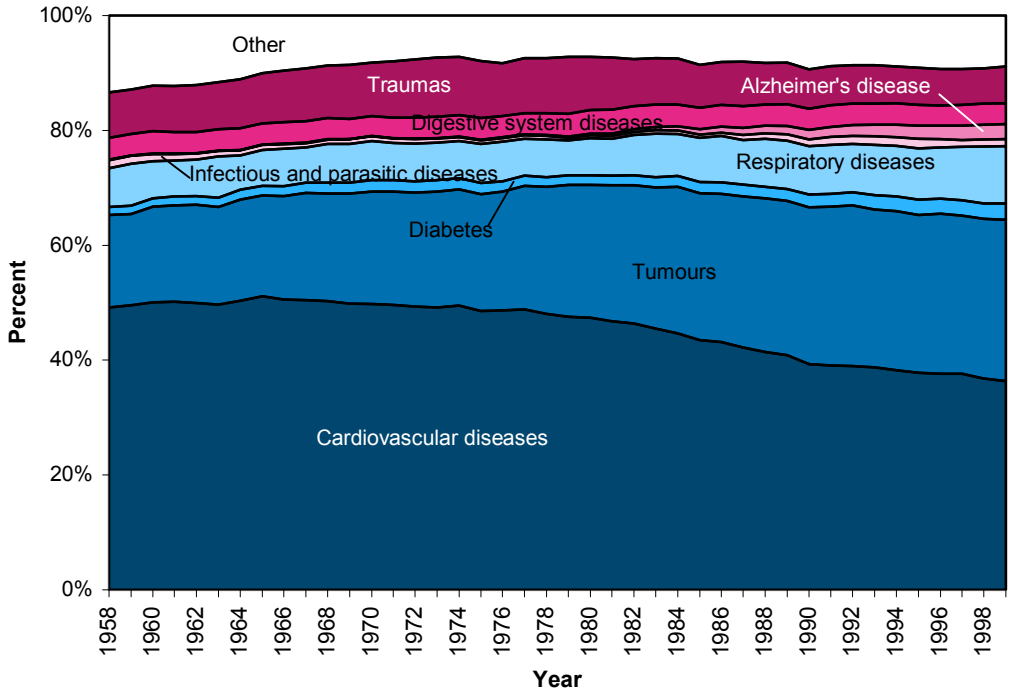
2. Did the pattern of mortality by cause remain largely the same (Olshansky and Ault, 1986)?

One of the conditions to Olshansky and Ault's fourth stage is that the pattern of mortality by cause stays the same as the third stage, but that the age distribution of deaths due to chronic diseases is progressively shifted toward older ages.

Distribution of deaths by cause

We will first analyze the proportions of causes of death through time, in order to estimate whether the pattern of causes of death remained roughly unchanged. According to figure 3, between 1958 and 1999, the main alteration has been the gradual reduction of the supremacy of cardiovascular diseases (CVD), which were mostly replaced by the increasing importance of malignant tumours. The weight of "other diseases" among the totality of causes of death lessened, as well as that of traumas (mainly accidents, suicides and homicides) which, however, recorded an increase of their importance in mid-period before starting their descent. After completely disappearing in the early 1980s, infectious and parasitic diseases (IPD) resurfaced following the emergence of AIDS. Similarly, the importance of respiratory diseases slightly intensified, as well as that of diabetes and Alzheimer's disease which, however, was not differentiated until the introduction of ICD-9. The significance of digestive system diseases among all causes of death has been quite stable throughout the entire period.

Figure 3. Distribution of deaths according to the cause, Canada, 1958-1999



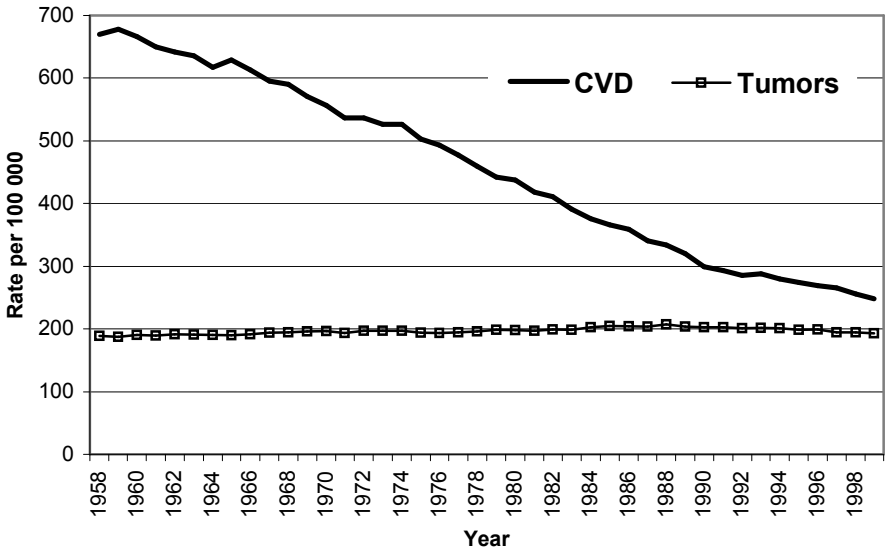
Sources: Bureau fédéral de la statistique, 1958-1969. Statistique Canada, Catalogues 84-206 (1970-1986), 84-204 (1978-1986), 82-003S (1987-1989), 82-003S15 (1989-1990), 82-003S11 (1990), 84-208 (1991-1993), 84-211 (1991-1992), 84-210-XPB (1993-1995), 84-208-XPB (1994-1995), 84-209-XPB (1995-1999), 84F0210XPB (1996-1997), 84F0208 (1996-1999), 84F0211XPB (1998-1999).

Standardized mortality rates by cause

We will examine the standardized mortality rates by cause in order to extend our analysis on the pattern of causes of death. We split the mortality rates into two figures (with two different scales), representing standardized mortality rates for the broad causes of death in figure 3, so the trends would be more easily readable.

It can be noted that the steady decline of mortality by cardiovascular diseases is striking on figure 4. The probabilities of dying from a cardiovascular disease have been decreasing significantly: the mortality rate has dropped from 670 per 100 000 in 1958 to 250 per 100 000 in 1999. In addition, mortality rates by cancer have not decreased, they have actually risen slightly despite the reduction of overall mortality since 1958. The combination of these two trends caused the two mortality curves to border each other by the end of the period, which would have been thought of as highly impossible in the late 1950s since the standardized mortality rate of CVD was 3.5 times that of tumours.

Figure 4. Standardized mortality rates by cardiovascular diseases and malignant tumours, both sexes, Canada, 1958-1999



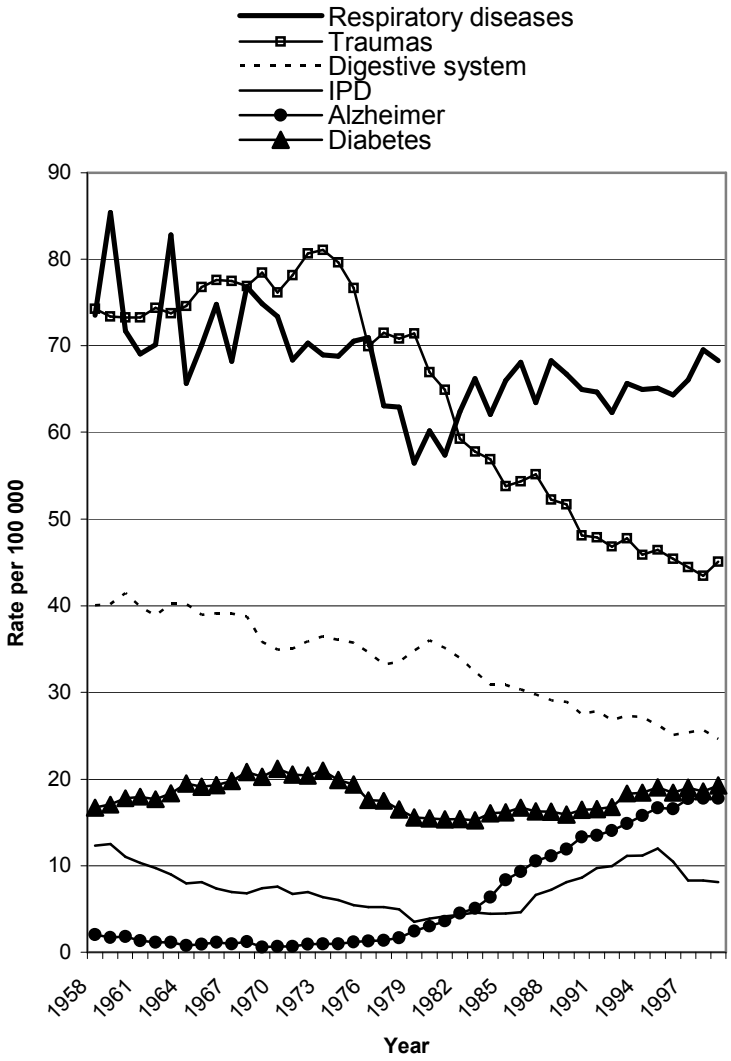
Sources : Deaths : Bureau fédéral de la statistique, 1958-1969. Statistique Canada, Catalogues 84-206 (1970-1986), 84-204 (1978-1986), 82-003S (1987-1989), 82-003S15 (1989-1990), 82-003S11 (1990), 84-208 (1991-1993), 84-211 (1991-1992), 84-210-XPB (1993-1995), 84-208-XPB (1994-1995), 84-209-XPB (1995-1999), 84F0210XPB (1996-1997), 84F0208 (1996-1999), 84F0211XPB (1998-1999). Populations: Statistique Canada, Catalogues 91-512 (1921-1971), 91-518 (1971-1986), 91-210 (1987-1992), 91-213 (1993-1994), 91-213-XPB (1995-1999).

We note, on figure 5, that violent and accidental mortality decreased a lot starting from the 1970s. The evolution of mortality by respiratory diseases was more irregular, but the general trend was a decline as well. But at the end of the 20th century, a Canadian had more chances of dying from a respiratory disease than from an accident or a trauma, whereas the probabilities were more or less equal at the beginning of the period.

The standardized mortality rate from digestive system diseases had a steady reduction during the entire time. Moreover, mortality rate from diabetes did not grow progressively as we might have thought they would. It first decreased in the 1970s, and then it had a modest increase beginning in the 1990s. Besides, the emergence of AIDS had a surprising impact on standardized mortality rate by infectious and parasitic diseases (IPD). Between 1986 and 1991, the mortality rate from IPD doubled. It continued rising until 1995, and then dropped substantially. Mortality rate from Alzheimer's disease soared, even though the standardized

rate eliminates the aging effect of the population. The progress was quite astonishing: the rate was multiplied by nine in only twenty years[4].

Figure 5. Standardized mortality rates by traumas, respiratory diseases, digestive system diseases, infectious and parasitic diseases (IPD), diabetes and Alzheimer's disease, both sexes, Canada, 1958-1999



Sources: Same as figure 4.

[4] However, this growth is biased by the fact that Alzheimer's disease was not specified until ICD-9 in 1979, and by the fact that this disease has been a popular diagnosis among doctors needing to determine the initial cause of death (Vallin and Meslé, 1996).

3. Did specific changes occur within chronic diseases groups?

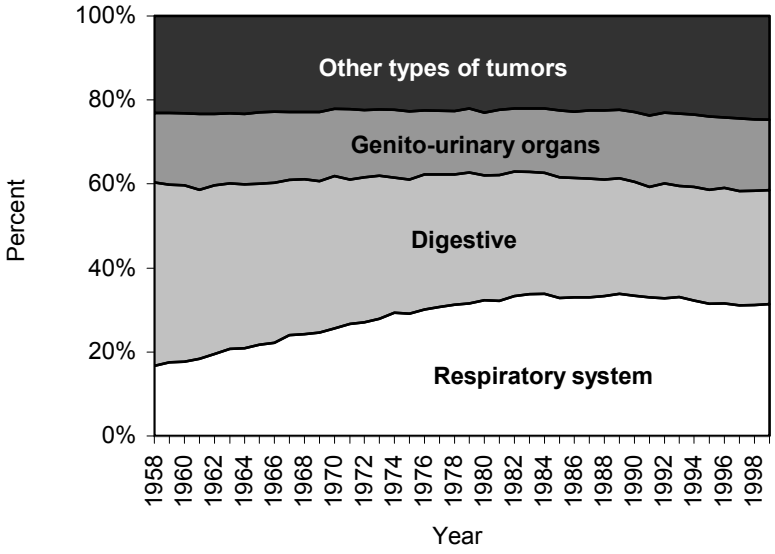
When Olshansky and Ault suggested that the pattern of causes of death remained mostly the same, they meant the stabilization of large causes of death. But what happens with variations that might have occurred within these large groups of causes of death? We found that Olshansky and Ault's second hypothesis was not corroborated. We will go even further: not only did the pattern of large groups of causes of death did not remain stable, but there were specific changes within these same large groups of causes of death. We settled on three main groups of chronic causes of death only: cardiovascular diseases, malignant tumours and respiratory diseases.

The study of malignant tumours was done according to the sex since men and women have different seats of cancer, and have their own cancer pattern. Therefore, four sub-categories were created for men and five for women (figures 6 and 7). Tumours of the respiratory system among men increased in scale until the 1980s, after which their weight among tumours stabilized, then slightly decreased at the end of the last century. The growing importance of respiratory system tumours among men was counterbalanced by the decrease of digestive system tumours.

Women's mortality rates by cancer had similar transformations but, unlike men, their digestive system tumours remained dominant throughout the entire period despite an exceptional increase in the importance of respiratory system tumours starting in the early 1970s (figure 7). Moreover, the weight of genito-urinary organs' cancer dropped by half between 1958 and 1999, that of breast cancer decreased by 3% and that of "other tumours" went from 18% to 23% of the total amount of tumours.

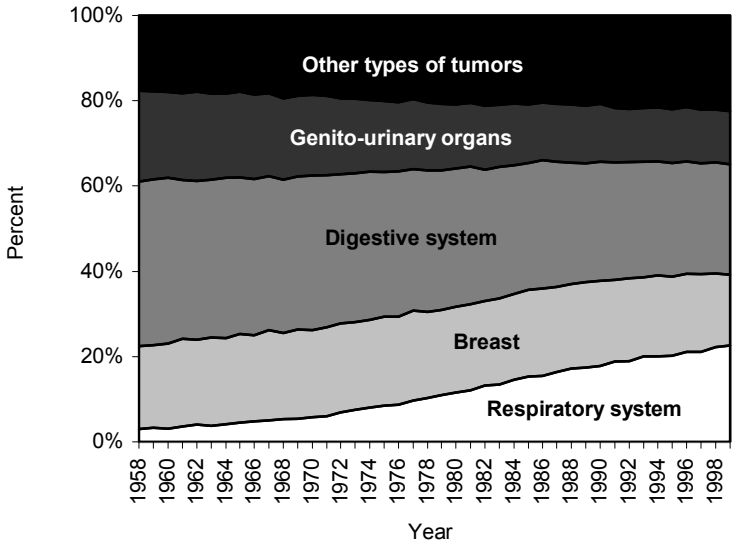
As for cardiovascular diseases, the only clear change between 1958 and 1999 proves to be the significant decrease of hypertensive diseases (not illustrated). The incidence of ischemic cardiopathies and of cerebro-vascular diseases within all CVD slightly declined, whereas that of "other diseases" grew a lot. Finally, the segment of diseases of the arteries remained quite stable proportionally.

Figure 6. Distribution of deaths by malignant tumours according to the type of tumour, men, Canada, 1958-1999



Sources: Same as figure 4.

Figure 7. Distribution of deaths by malignant tumours according to the type of tumour, women, Canada, 1958-1999



Sources: Same as figure 4.

Diseases of the respiratory system were split up into three groups (not illustrated): pneumonia and influenza; chronic obstructive pulmonary diseases (emphysema, asthma, chronic bronchitis); and other. The general trend was characterized by a steady decrease in the

proportion of pneumonias and influenza and, in return, by an increase of chronic obstructive pulmonary diseases. The weight of the latter within the whole respiratory diseases group has been constant in the last twenty years of the period and is situated around 48%. Finally, other respiratory diseases doubled their weight from 5% to 10% between 1958 and 1999.

4. Did a gradual shift towards older ages of mortality by chronic diseases take place? (Olshansky and Ault, 1986)

Olshansky and Ault's last hypothesis consisted in a postponement of age at death by chronic diseases. According to Olshansky and Ault, this delay would neither be caused by a reduction of chronic diseases' incidence, nor by a deferment of age at which chronic diseases develop. According to them, this shift of age at death towards older ages, if it takes place, would be due to a prolonging of survival with chronic diseases; in other words to an expansion of morbidity.

To test this research question, two indicators will be used in order to bring to light the validity of this premise. The mean age at death by chronic diseases will be the first one, calculated from standardized rates by age so that the aging of population bias is eliminated. We will also use the standardized number of deaths in order to generate our second indicator, the distribution of deaths by chronic diseases according to age.

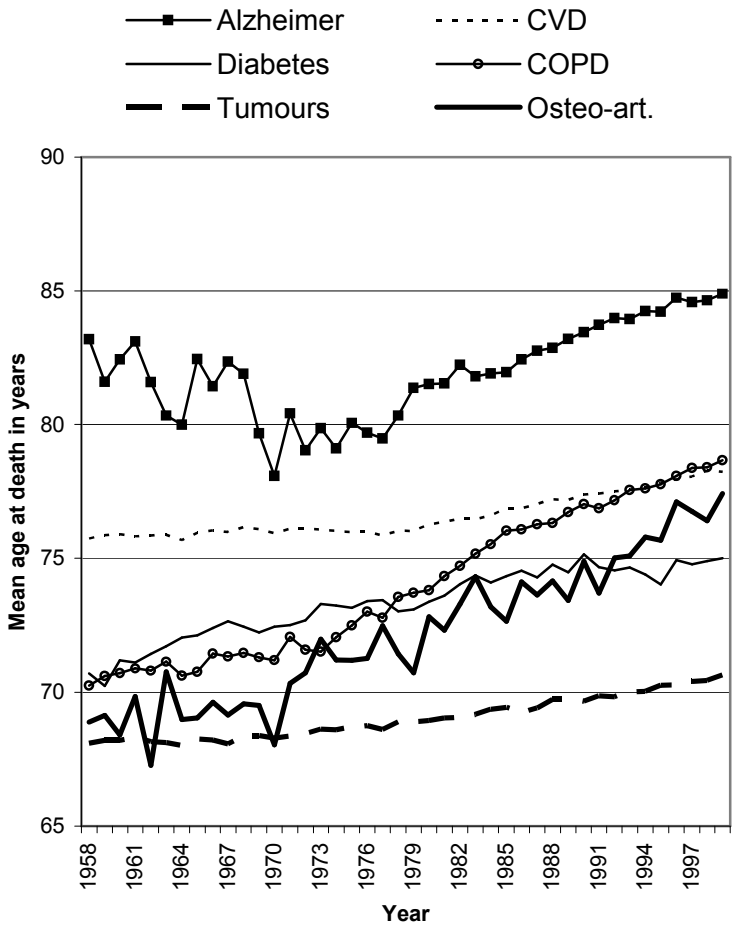
Mean age at death by chronic diseases

We notice, on figure 8, that the mean age at death did indeed increase fairly steadily for all chronic causes of death. Alzheimer's disease clearly stands out with an age at death far higher than any other cause of death throughout the entire period, even though the general trend was a declining slope in the first twenty years. In 1999, the mean age at death from Alzheimer's disease came close to 85 years.

Moreover, the most striking and continuous growth of age at death belongs undoubtedly to chronic obstructive pulmonary diseases (COPD). Between the beginning and the end of the interval, their age at death increased by 8.5 years, growing from 70.2 to 78.7 years.

Cardiovascular diseases were preceded only by COPD for second highest mean age at death, although their mean age at death only increased by 2.5 years in 42 years.

Figure 8. Mean age at death by chronic diseases, both sexes, Canada, 1958-1999 (calculated from age-specific standardized rates)



Sources: Same as figure 4.

Even though the evolution of the mean age at death from osteo-articular diseases has been quite irregular, it grew significantly and, at 77.5 years in 1999, it stands about average compared to the other chronic diseases. In addition, the mean age at death from diabetes stands at 75 years at the end of the period, which ranks that disease second to last. The growth of its mean age at death between 1958 and 1999 was about average at 4.3 years.

Finally, the mean age at death by tumours trails at the bottom throughout the entire time interval. The mean age at death for an individual suffering from cancer only grew from 68.1 to 70.6 years from 1958 to 1999.

Another interesting fact that we come across while studying the mean age at death for all chronic causes of death gathered is that it only grew 1.2 years between 1958 and 1999, which seems remarkably low. In addition, we notice that the delay of age at death by chronic diseases started its ascent only in the early 1980s. The reason why the mean age at death from all causes of death struggles to increase is because the growths of the means ages at death from CVD and from tumours, which count for 85% to 95% of all chronic deaths between 1958 and 1999, were the least impressive.

Distribution of deaths by chronic diseases according to age

We have distributed deaths into three large age groups: 0-64 years, 65-84 years and 85 years and over. There were no major disruptions in the proportions of standardized deaths by age by cardiovascular diseases, although there was a delay visible especially among people aged 85 years and over (not illustrated).

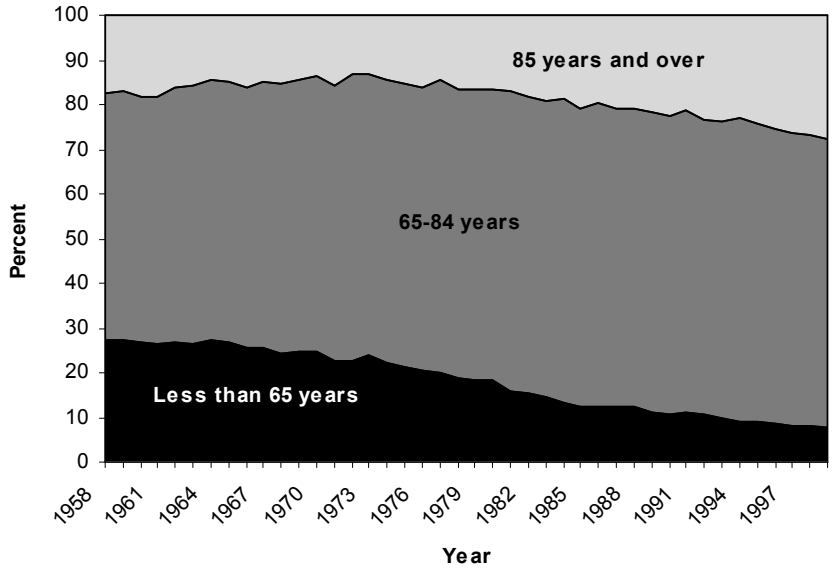
The age-specific portrayal of Canadians dying from a malignant tumour is surprisingly invariable (not illustrated). The weight of deaths from people aged 65 years and less have had the most notable change with a decrease of 7%. Moreover, the Canadian population aged 85 years and over has as much chance in 1958 of dying from cancer as in 1999. This fact gives rise to a less persuasive transition of cancer deaths toward older ages.

As illustrated by figure 9, deaths by chronic obstructive pulmonary diseases are characterized by a switch of proportions between people aged less than 65 years and those aged 85 years and more during the interval. Therefore, the 85+ age group supplanted the 0-64 age group as the second age category causing the most deaths by COPD.

Contrary to tumours, MCV and COPD, the age distribution of deaths by diabetes was characterized by a decrease in the importance of the age group 65-84 years, in addition to the reduction observed amongst the people aged less than 65 years. As a result, the age group 85+

collected the totality of losses by the younger age groups, which augmented their proportion from 10% in 1958 to 23% in 1999 of deaths by diabetes.

Figure 9. Standardized age distribution of deaths by chronic obstructive pulmonary diseases, Canada, 1958-1999



Sources: Same as figure 4.

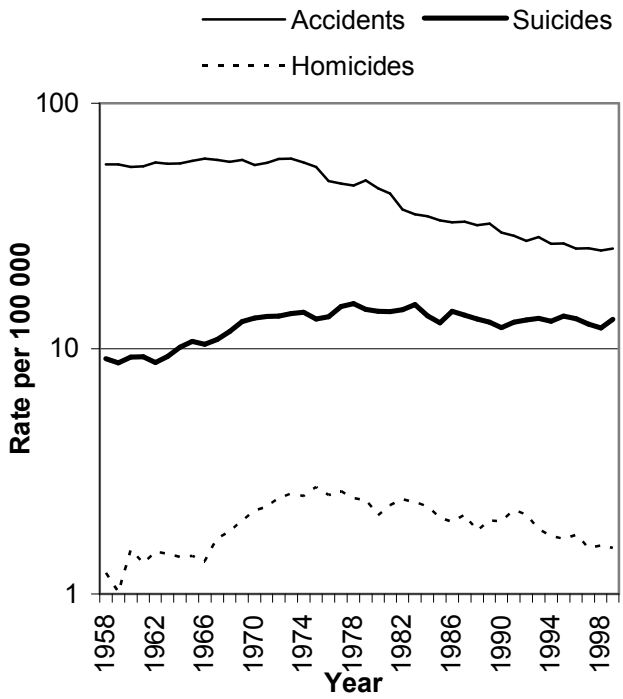
The analysis of age distributions of deaths ends with the most inconsistent chronic causes of death, Alzheimer's disease and osteo-articular, muscle and conjunctive tissue diseases. The postponement of deaths to older ages has indeed occurred for deaths due to Alzheimer's disease. Like diabetes, the age group 85+ was the only one that gained deaths from Alzheimer's between 1958 and 1999. Besides, Alzheimer's disease is the only chronic affection where most deaths occur after 85 years old. As for diseases of the osteo-articular system, we noticed that the weight of the age group 85+ more than doubled (from 16% to 34%) and that the proportion of the younger age group (0-64) tumbled from 30% to 16%.

5. Have we observed a decline of mortality by social pathologies? (Rogers and Hackenberg, 1987)

In addition to Olshansky and Ault (1986), Rogers and Hackenberg (1987) also suggested a fourth stage of the epidemiologic transition. We will now examine one of their two hypotheses (the second one being too difficult to measure), stating that there is a decrease of mortality by social pathologies during the fourth stage. We had previously defined that deaths from social pathologies were actually deaths by accidents, suicides and homicides.

Figure 10 illustrated the evolution of standardized mortality rates for these three social pathologies. We observe that accidental deaths clearly lead as the main cause of death from social pathologies throughout the entire period. All the same, mortality due to accidents started decreasing rapidly in the early 1970s and, in the 1990s, it was still declining, but at a slower rate. In 1999, accidental mortality only represented half of that observed in 1973, where it was at its highest.

Figure 10. Standardized mortality rates by accidents, suicides and homicides, Canada, 1958-1999



Sources: Same as figure 4.

Mortality by suicide slightly increased over the entire interval. The growth of mortality by suicide proved to be more impressive during the first half of the period. Therefore, we cannot claim there was a reduction in mortality by suicide between 1958 and 1999. The pronounced decrease of mortality by accidents, combined with suicide rates that have been nearly unchanged since the 1980s, brings together the two curves. In 1958, the Canadian population had six times more risks of dying from an accident than from a suicide, but in 1999 the same ratio had dropped to two.

As for homicides, they are the least frequent social pathology during the whole period. Like mortality by accidents and by suicide, homicides have seen their standardized mortality increase as well in the 1970s. After reaching their culminating point at 2.6 deaths per 100 000 in 1977, mortality by homicide decline slowly, in opposition to accidental deaths. At the end of the century, the standardized mortality rate by homicide finds itself back at the same level as it was at the end of the 1960s.

6. Was the impact of AIDS on mortality significant? Did a resurgence of infectious diseases like cholera, diphtheria and dengue take place? (Omran, 1998)

In 1998, Omran also proposed a fourth stage, added to his three initial stages. It is characterized, among other things, by the emergence of new infectious diseases and by the reappearance of former infectious diseases. Although this fourth stage described by Omran was aimed mostly at developing countries, he also mentioned that developed countries should keep an eye on the evolution of AIDS, cholera, diphtheria and dengue. We will examine the impact of these four diseases in Canada since 1958.

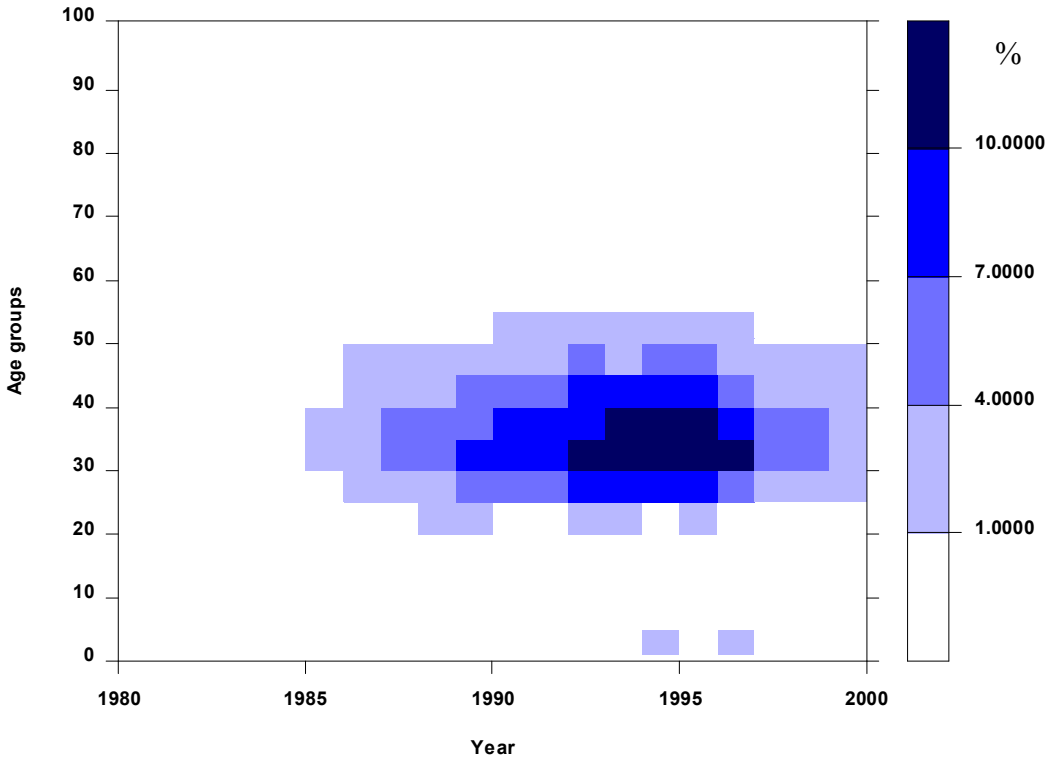
First of all, we can assert that Canada was certainly not one of the countries pointed by Omran for experiencing the revival of cholera, diphtheria and dengue. In fact, the last death attributable to cholera that occurred in Canada goes back to 1959; two Canadians died from dengue between 1958 and 1999; and diphtheria caused a total of 95 deaths during the same period.

On another hand, the surfacing of AIDS, whose first death occurred in 1983, had a small repercussion on the overall mortality in Canada. The effect of the onset of AIDS on women's mortality was not very significant, as the mortality rate by AIDS among females never reach 2 per 100 000. However, the impact of AIDS on male mortality was not unimportant. After rising to 11 deaths per 100 000 in 1995, men's mortality rates by AIDS started declining astoundingly and, in 1999, their mortality rate was a fifth of what it was in 1995.

AIDS did not affect all age groups in the same way. We have illustrated by a Lexis surface for each age group, the proportions of deaths due to AIDS within the totality of deaths. Unlike most other causes of death, the mortality due to AIDS is at its lowest among people aged 60 and over. Individuals less than 20 years old are equally not affected. However, the impact of

AIDS on adult mortality (20-49 years) is more severe, causing up to 16% of the total number of deaths amongst the age group 30-34 years in 1995 (20% for men). But at the end of the century, the importance of AIDS as a cause of death among people aged 25-44 years was fading.

Figure 11. Proportion of deaths attributable to AIDS according to the age group, both sexes, Canada, 1980-1999



Sources: Statistique Canada, Catalogues 84-206 (1980-1986), 84-204 (1980-1986), 82-003S (1987-1989), 82-003S15 (1989-1990), 82-003S11 (1990), 84-208 (1991-1993), 84-211 (1991-1992), 84-210-XPB (1993-1995), 84-208-XPB (1994-1995), 84-209-XPB (1995-1999), 84F0210XPB (1996-1997), 84F0208 (1996-1999), 84F0211XPB (1998-1999).

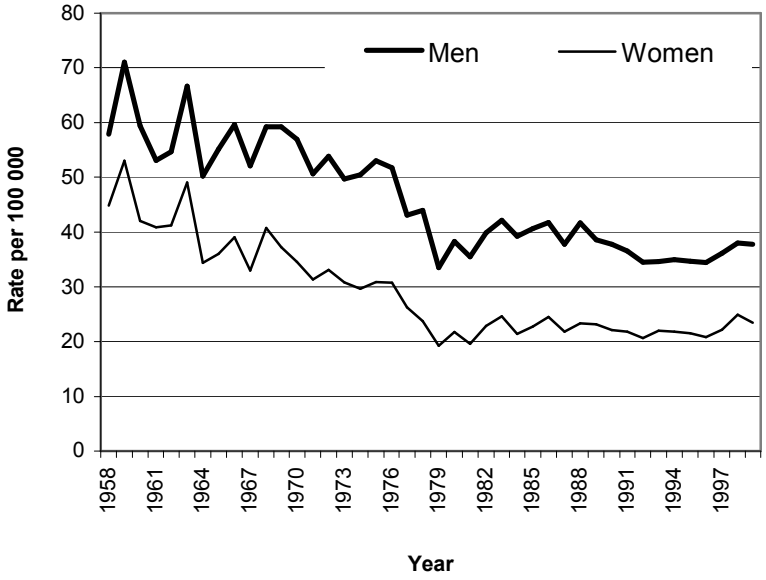
7. Could mortality due to pneumonia and influenza have increased? (Olshansky and al. 1998)

In their suggestion of a fifth stage of the epidemiologic transition, Olshansky et al. (1998) maintain that population aging increases mortality due to pneumonia and influenza. We will analyze this hypothesis by means of the standardized mortality rate by pneumonia and influenza according to the sex since 1958.

We see, on figure 12, that the standardized rate follows the same trend for both sexes, the only difference being the higher mortality of men compared to women. We also observed that,

especially during the first half of the period, mortality was subject to abrupt variations due to the epidemic nature of influenza and pneumonia. But the general trend was a decline of mortality until the end of the 1970s. During the last twenty years, mortality fluctuated between 34 and 42 per 100 000 for men, and between 19 and 25 per 100 000 for women. Mortality by pneumonia and influenza almost stabilized in the 1990s.

Figure 12. Standardized mortality rates by pneumonia and influenza according to sex, Canada, 1958-1999



Sources: Same as figure 4.

DISCUSSION

In conclusion, the breaking down of the epidemiologic transition into dissociable stages is hardly applicable to Canada since the 1950s. Many researchers have given their outlook on the matter, and some of their premises were refuted, others confirmed. Here is a review of the results found.

1. **Was mortality's decline concentrated mostly in advanced ages and did the decline occur at nearly the same pace for males and females? (Olshansky and Ault, 1986)**

Continued…

- *Yes*, older age groups (65 years and over) have gradually contributed more

and more to the decline of Canadian mortality since 1958.

- *No*, the decline of mortality between 1958 and 1999 did not occur at the same pace for women and for men.

2. Did the pattern of mortality by cause stabilized (Olshansky and Ault, 1986)?

- *No*, standardized mortality rates did not evolve the same way among different causes. Moreover, the study of the distribution of causes of death shows that the domination of CVD shaded off and gave way to malignant tumours.

3. Did specific changes occur within chronic disease groups?

- *Yes,* and the major modification turned out to be the transfer of predominance from digestive system tumours to respiratory system tumours.

4. Did a gradual shift towards older ages of mortality by chronic diseases take place? (Olshansky and Ault, 1986)

- *Yes*, particularly for chronic obstructive pulmonary diseases and for diseases of the osteo-articular, muscular and conjunctive tissue system. However, the postponement towards older ages of deaths from cancer proves to be not significant.

5. Have we observed a decline of mortality by social pathologies? (Rogers and Hackenberg, 1987)

- *Yes*, especially since the middle of the 1970s.

6. Was the impact of AIDS on mortality significant? Did a resurgence of infectious diseases like cholera, diphtheria and dengue take place? (Omran, 1998)

- *No*, the impact of AIDS on mortality only lasted a few years and was limited to men aged 20-49 years old.
- *No*, there was no resurgence of infectious diseases like cholera, diphtheria and dengue.

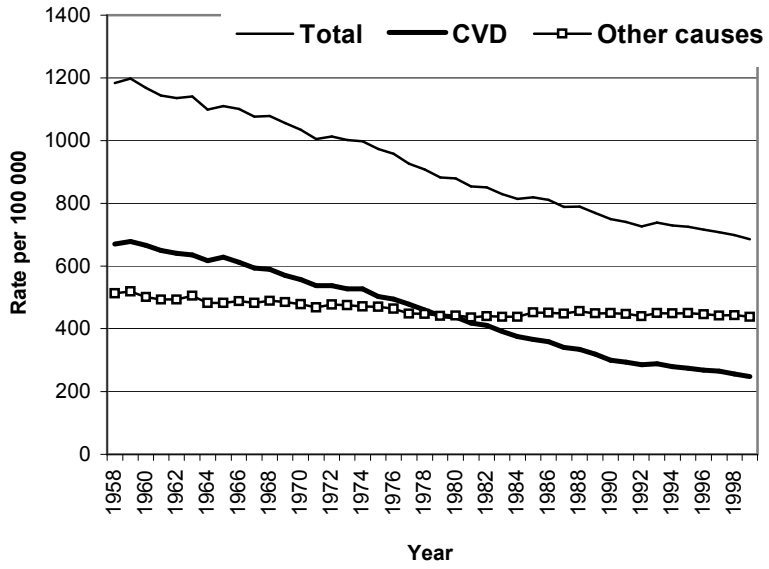
7. Could mortality due to pneumonia and influenza have increased? (Olshansky and al. 1998)

- *No*. Mortality due to pneumonia and influenza decreased between 1958 and 1980, and then stabilized until the end of the century.

In addition, Robine (2001) as well as Meslé and Vallin (2002) studied the theory of the epidemiologic transition, but their observations were not examined in this research paper. It would have been interesting to look at Robine's redefinition of the third stage, called the "age of the conquest of the extent of life". According to him, deaths are indeed postponed to older ages, but this fact does not imply a reduction of the dispersion of life spans. As for Meslé and Vallin (2002), they suggest that a "sanitary transition" comprised of two stages is taking place. They identify the second stage as the "cardiovascular revolution", which is portrayed by a continuation of improvement in survival that is mostly imputable to the decline of cardiovascular diseases. This hypothesis by Meslé and Vallin is easily observable for Canada, as we can see on figure 13. The prolongation of mortality's decrease between 1958 and 1999 was almost entirely due to the decline of mortality by cardiovascular diseases.

Although Meslé and Vallin's broader redefinition of a sanitary transition (including a cardiovascular revolution as the second stage) seems the most adequate proposition, the switch from their first to their second stage is not explicated, nor is the slowing down of the decrease of mortality in the middle of the 20th century. Moreover, even though the reduction of mortality by cardiovascular diseases has been the defining moment of these last thirty years, this trend alone cannot justify the progress into the second stage since the various stages are suppose to describe the evolution of all causes of death.

Figure 13. Standardized mortality rates for all deaths, for deaths by cardiovascular diseases, and for deaths by all other causes, Canada, 1958-1999



Sources: Same as figure 4.

Conclusion

We conclude, first of all, that the evolution of mortality and of the pattern of causes of death in Canada do not genuinely fit the theory of the epidemiologic transition and, secondly, that the fragmentation of the theory of the epidemiologic transition into distinctive stages delimited in time proves to be inappropriate, at least since the middle of the latest century. Rather, the epidemiologic transition of the last fifty years should be perceived as a continuum of the third stage during which mortality keeps on decreasing and during which chronic diseases are largely predominant. More precisely, the decline of mortality increasingly profits the elderly; the proportion of deaths by malignant tumours gets higher at the same time as that by cardiovascular diseases diminishes; the importance of deaths by diseases of the respiratory system, like lung, bronchial tubes and windpipe cancer as well as chronic obstructive pulmonary diseases, is growing as a result of tobacco consumption; at last, infectious and parasitic diseases subsist, although their potential threat is modest thus far.

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