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Has Canadian Mortality Entered the Fourth Stage of the Epidemiologic Transition?

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Résumé
Selon la théorie de la transition épidémiologique, les maladies professionnelles et dégénératives constituent le troisième et dernier stade de l'évolution des régimes de mortalité et de morbidité. Mais on suggère maintenant qu'il existerait encore un quatrième stade, remarquablement différent du troisième. Le présent article tente d'effectuer la synthèse des diverses perspectives à cet égard et examine si la mortalité canadienne est parvenue à ce quatrième stade.

Abstract
According to the epidemiologic transition theory, the third and final stage of the evolution of mortality and morbidity patterns consists of degenerative and man-made diseases. It has been proposed that there is yet another stage of the epidemiologic transition, the fourth stage which is remarkably different from the third. This paper brings together the different perspectives of this new stage and examine whether or not Canadian mortality has entered the fourth stage.

Key Words — epidemiologic transition, fourth stage, hybristic stage, social pathologies

Introduction

The epidemiologic transition theory was first proposed by Omran (1971). The theory focuses on the complex changes in patterns of health and disease in a society and on their demographic, socioeconomic and biologic determinants and consequences. It proposed that disease patterns shift over time so that infectious and

parasitic diseases are gradually, but not totally, displaced by degenerative and man-made diseases as the leading causes of death (Omran, 1983). According to the theory, there are three major successive stages in the transition: the stage of pestilence and famine, the stage of receding pandemics and the stage of degenerative and man-made diseases. In progressing from one stage to another, mortality declines and life expectancy increases. The theory further proposes four models to account for the different variations in pattern, pace, determinants and consequences of population change in different societies (Omran, 1983). Developed societies have long since reached the third stage of their epidemiologic transition.

Recent literature, however, proposes that developed societies may have entered the fourth stage in their epidemiologic transition. This stage is described by Olshansky and Ault (1986) as "the age of delayed degenerative diseases" and by Rogers and Hackenberg (1987) as "the hybristic stage." Data from the United States were used to substantiate the new proposition. While Olshansky and Ault emphasize the distinctive patterns of old age mortality during this stage, Rogers and Hackenberg emphasize the behaviourial aspect of mortality as being the characteristic feature of this stage. This paper seeks to synthesize these two perspectives and, in the light of this synthesis, to examine whether Canadian mortality can be described as having entered the fourth stage of the epidemiologic transition.

The Fourth Stage

Olshansky and Ault include the following general characteristics in the fourth stage: "(1) rapidly declining death rates that are concentrated mostly at 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 are shifted progressively toward older ages; and (3) relatively rapid improvements in survival being concentrated among the population in advanced ages" (1986:360). They remark that the major characteristic that distinguishes the fourth stage from the third is the unexpected shift in the age pattern of mortality by degenerative causes for the population in advanced ages. In short, "in this fourth stage, the major

degenerative causes of death that prevailed during the third stage remain with us as the major killer, but the risks of dying from these diseases are distributed to older ages" (ibid., 361). They attribute the source of this change to a combination of factors including shift in the age structure toward older ages, advances in medical technology, health care programs for the elderly and reductions in risk factors at population level.

The description of the fourth stage by Rogers and Hackenberg (1987) is more substantive. They focus on the different propositions in Omran's theory, one of which is concerned with the existence of mortality differentials among several population subgroups. For example, it is proposed that the epidemiologic transition favours females over males, the young over the old and, in the United States, whites over non-whites. Another proposition of Omran's theory is that infectious diseases will decline but will not be entirely eradicated. Rogers and Hackenberg provide evidence from the United States data to show that these propositions have changed. They agree with Olshansky and Ault that the leading causes of death in this stage are still due to degenerative and man-made diseases, but disagree with them in identifying the source of this change. Rogers and Hackenberg argue that the major source of this change is the increasing influence of individual behaviours and new lifestyles on mortality. This influence may either be positive — such as in areas where measures of health promotion are effective — or negative — such as in areas where potentially destructive lifestyle practices are widespread. On the negative side, individual behaviours and destructive lifestyle practices include sexual orientations and social pathologies like accidents, suicides, homicides, excessive drinking and smoking. Even though Acquired Immunodeficiency Syndrome (AIDS) is an infectious disease, Rogers and Hackenberg consider it a disease belonging to the fourth stage because of its direct relation to an individual's behaviour and lifestyle. They argue that the root cause of these destructive lifestyle practices is "hybris" — an excessive self confidence, a belief that one cannot suffer and that one is invincible. Hence they refer to this fourth stage as the "hybristic stage."

These two formulations of the fourth stage are not exclusive of each other; rather, they reflect different aspects of this new stage of

mortality which is characterized by an interplay between the age-cause patterns of mortality, micro-level determinants such as individual behaviour and social lifestyles, and macro-level determinants such as health care and health promotion programs. Generally, advances in medical technology help delay death until very old ages. Health promotion programs, however, affect all ages, not necessarily the oldest ages. They help reduce preventable deaths and morbidity primarily through modifications of individual behaviours and lifestyles. However, certain causes of death are primarily determined by potentially destructive individual behaviours and lifestyles and are products of man-made environments.

Mortality Patterns in Canada

The major work on Canadian epidemiologic transition was done by Nagnur and Nagrodski (1987, 1990). They considered changes in mortality and in structures of causes of death over the past six decades. In analyzing overall mortality, they used quantitative measures such as crude death rates, age standardized rates, infant mortality rates, life expectancies, survival probabilities, entropy (H) and potential years of life lost (PYLL). In the cause of death analysis, they used multiple decrement and cause-deleted tables. From the cause deleted tables, they also computed H and PYLL values. The analyses of Nagnur and Nagrodski show without doubt that Canadian mortality had gone through the various stages of the epidemiologic transition and had already entered the third stage by the 1950s. They base their conclusions on the following quantitative evidences:

1. the decline in infant mortality by 90% between 1931 and 1981;
2. the increase in life expectancy of 12 years for males and 17 years for females over the period from 1931 to 1981;
3. the increase in the difference between male and female life expectancy over time;
4. the larger increase in the number of survivors after 1951 compared to before 1951;
5. the increase in rectangularization of the survival curve;

6. the change in the leading contributors to the PYLL from infectious diseases to cardiovascular diseases, neoplasms, and deaths due to accidents with progress in time; and
7. the change in cause of death structure from "diseases of underdevelopment" to "diseases of development."

The analysis of Canadian mortality by Nagnur and Nagrodski did not go beyond the third stage to investigate whether Canadian mortality had progressed beyond this stage especially during the last decade. This work therefore builds upon theirs and attempts to interpret recent changes in mortality and causes of death in the light of the proposed synthetic view of the fourth stage of the epidemiologic transition.

In order to answer the question regarding the status of the epidemiologic transition, age patterns of mortality and causes of death structures need to be analyzed. Different combinations of methods are available for doing so. The mortality indicators and method employed by Nagnur and Nagrodski (1990) for instance differ markedly from those employed by Olshansky and Ault (1986). In this paper, the fourth stage has been described as a synthesis of the two existing descriptions, one of which emphasizes mortality in the young and adult ages and the other which emphasizes mortality in the older ages. This modification requires that the age pattern of mortality at young and middle ages also be considered in addition to those at old ages. One convenient and effective tool for studying changes in young, middle and old age patterns of mortality simultaneously is the eight parameter model of Heligman and Pollard (1980). The Heligman-Pollard model relates the life table probability q_x of dying between age x and $x+1$, as a function of age, x, and several parameters. It is given by:

$$q_x = A^{(X+B)^C} + D^* e^{[-E(\ln(x/F))^2]} + \frac{GH^X}{(1+GH^X)}.$$

Where A, B...H are the parameters which have been interpreted as follows:

1) The first term containing the parameters A, B and C takes account of infant and child mortality. A shows the level of early life mortality

and is approximately equal to q_1. *B* and *C* measure the difference between q_0 and q_1 and the rate of mortality decline during childhood respectively.

2) The second term containing the parameters *D*, *E* and *F* takes account of the "accident hump" in younger adult ages. *D* measures the level of middle life mortality. *1/E* and *F* measure the dispersion and location respectively of this middle age mortality.
3) The final term consisting of *G* and *H* is the Gompertz law which accounts for senescent mortality; *G* measures the level while *H* measures the rate of increase of this old age mortality (Heligman and Pollard, 1980).

The shift in age patterns of mortality will be studied using survival curves and median ages at death. The cause of death structure will be studied using simple percentage distribution of deaths by cause and age-cause-specific death rates and results from cause-deleted life tables.

Changes in Canadian Mortality after 1950

Using Canadian mortality data over the period from 1950 to 1986, the program UNABR, found in the United Nations package for mortality analysis (MORTPAK), was used to fit the Heligman-Pollard model. The values obtained for the eight parameters are shown in Table 1 and diagramatically presented in Figures 1 through 8.

The levels of infant, middle and old age mortality are represented by parameters *A, D* and *G*, respectively. These parameters show that the level of male mortality has been higher than that of females throughout the period of study. In particular, the steady decline in *A* for both males and females reflects the remarkable improvement in infant mortality over the period. The values of *A* declined by about 73 per cent for males and about 77 per cent for females over the period from 1950 to 1982. There was hardly any change between 1980 and 1986.

The values of the parameter *C* show that the rate of decline of infant mortality has been higher for females than for males, but the gender gap has narrowed over the years. While the difference in *C* values between the genders was .017 in 1950-52, by 1975-77, it was

0.003 and by 1980-82, the value of *C* was slightly higher for males than for females. This lead by males continued in 1984-86.

The values of the parameter *D* suggest that middle age mortality has been higher for males than for females throughout the period under study. As Figure 4 shows, middle age mortality has distinct patterns for males and females. For males, *D* shows an increase between 1960 and 1977 and a steady decline afterwards. For females, *D* remains constant after 1975-77 after a decline from the 1970-72 value.

The reciprocal of the parameter *E (1/E)* suggests that the dispersion of the middle age mortality has been decreasing for both genders since 1955-77 — the rate, however, has been much faster for females than for males. The dispersion of middle age mortality had been decreasing for female until 1975-77, after which it started to increase.

The values of the parameter *F* support this observation. The age location of middle age mortality decreased from 31 years to being close to 19 years in the case of females, while it remained between 20 and 22 years in the case of males during the whole period. As a pair, both *E* and *F* were closer for males and females in 1980-82 than at any other time.

The parameter *G* suggests that the level of old age mortality decreased between 1970 and 1982 for males, and between 1970 and 1977 for females. The value of *G* in 1984-86 was close to the 1975-77 level in spite of the slight rise in 1980-82.

The parameter *H* shows decline in the rate of increase of old age mortality between 1955 and 1972 for both genders. However, over the period 1975-86, the results are different. While the male data show a steady increase, the female data show a sudden increase in 1975-77, then a decline again in 1980-82 and an increase afterward.

To summarize, this model has tried to capture the changes in age patterns of Canadian mortality by means of eight parameters. The first three parameters *A*, *B* and *C* show the rapid changes in infant and child mortality over the period under consideration and a reduction of gender differentials in mortality in the young ages. The parameters *D*, *E* and *F* suggest that while the level of middle age mortality remained higher for males than females, significant changes have taken place in

the dispersion and modal age of mortality for females in these ages. For females, both the parameters *1/E* and *F* declined steadily, revealing a convergence of female to the male pattern of mortality. Changes in the parameter *G* show that in spite of higher level, male old age mortality improved since the period 1970-72 as well as getting closer to female mortality. The values of the parameter *H* show a decline for both genders between 1955 and 1970 and then an increase in 1975-77. Could this mean a turning point in old age mortality? At this point it is too early to be certain. Further analysis on the distribution of death and cause of death pattern over this period (1955-77) can shed more light on this question.

TABLE 1. PARAMETERS A-H OF THE HELIGMAN-POLLARD MODEL. CANADA, 1950-1986.

	A	B	C	D	E	F	G	H
				Males				
1950-52	.00318	.00583	.11569	.00093	12.07944	20.76715	.00010	1.09172
1955-57	.00258	.00855	.11781	.00105	9.33575	21.10088	.00007	1.09828
1960-62	.00185	.00332	.10151	.00103	12.95449	20.74798	.00007	1.09747
1965-67	.00156	.00257	.09384	.00125	14.54547	20.79159	.00007	1.09700
1970-72	.00135	.00373	.09250	.00138	14.97508	20.14720	.00008	1.09587
1975-77	.00116	.00849	.09668	.00154	15.60067	20.22898	.00007	1.09594
1980-82	.00086	.00788	.09089	.00126	10.99839	20.50557	.00005	1.09956
1984-86	.00083	.04018	.12398	.00106	7.02510	21.28386	.00004	1.10269
				Females				
1950-52	.00295	.01700	.13257	.00055	1.49104	31.26065	.00004	1.10296
1955-57	.00239	.02562	.13960	.00028	2.05222	24.06221	.00003	1.10367
1960-62	.00172	.01443	.12386	.00023	7.97672	20.60241	.00003	1.10127
1965-67	.00127	.00468	.09913	.00022	16.98088	19.22877	.00004	1.09874
1970-72	.00115	.00823	.09977	.00029	20.41382	18.41685	.00004	1.09515
1975-77	.00104	.01199	.09970	.00025	50.40921	18.97041	.00002	1.10716
1980-82	.00069	.01000	.09064	.00025	12.18700	18.83396	.00003	1.09814
1984-86	.00067	.03250	.11110	.00024	9.29774	18.73027	.00002	1.10061

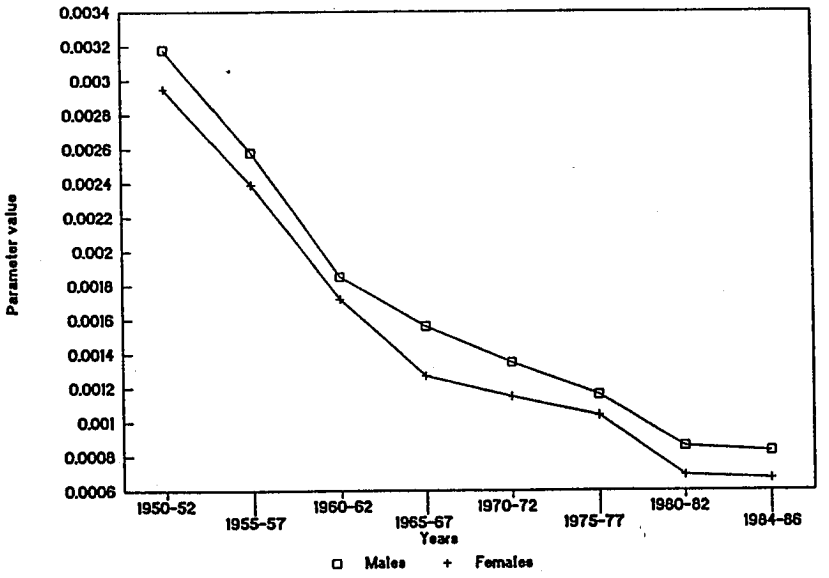

FIGURE 1. HELIGMAN-POLLARD PARAMETER A

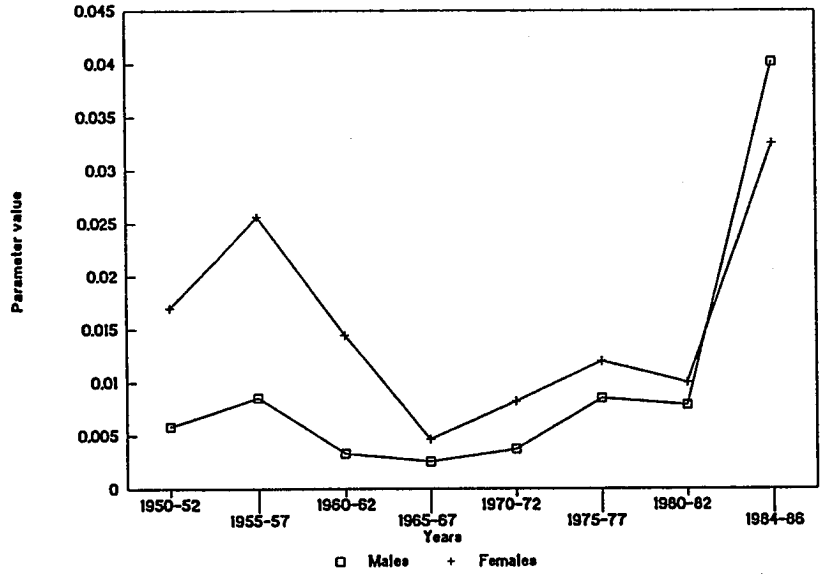

FIGURE 2. HELIGMAN-POLLARD PARAMETER B

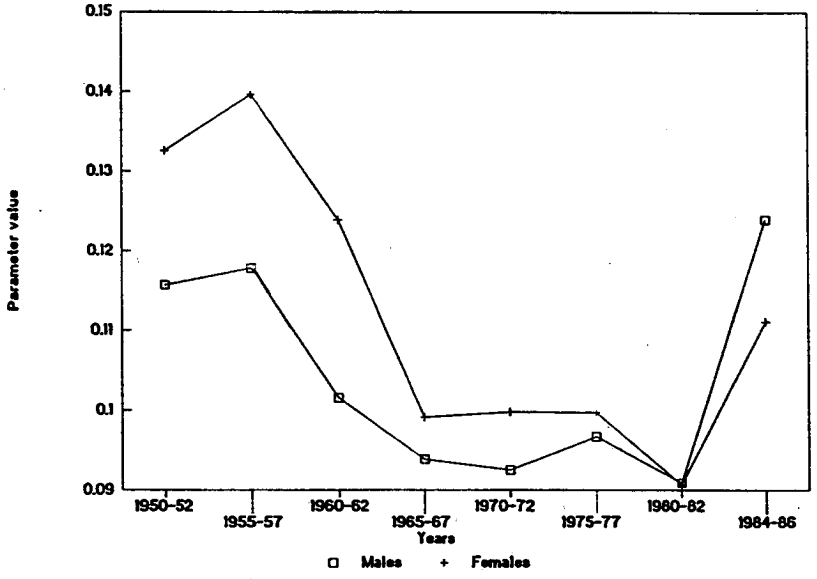

FIGURE 3. HELIGMAN-POLLARD PARAMETER C

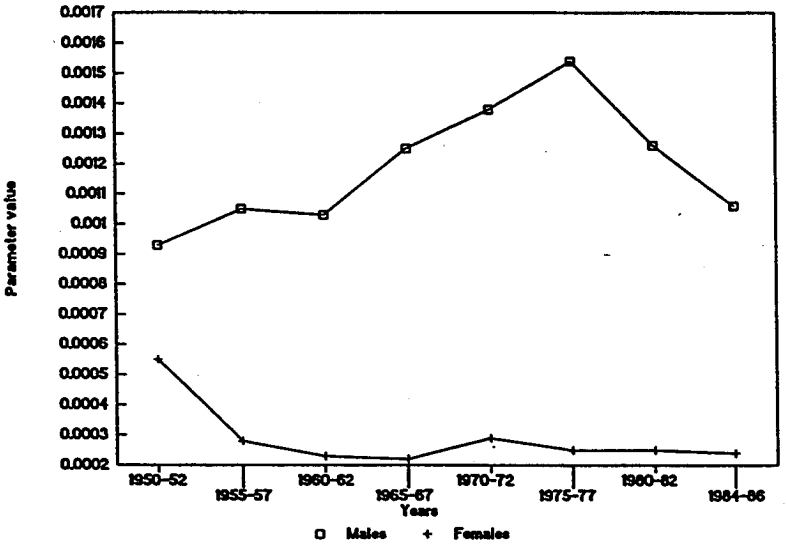

FIGURE 4. HELIGMAN-POLLARD PARAMETER D

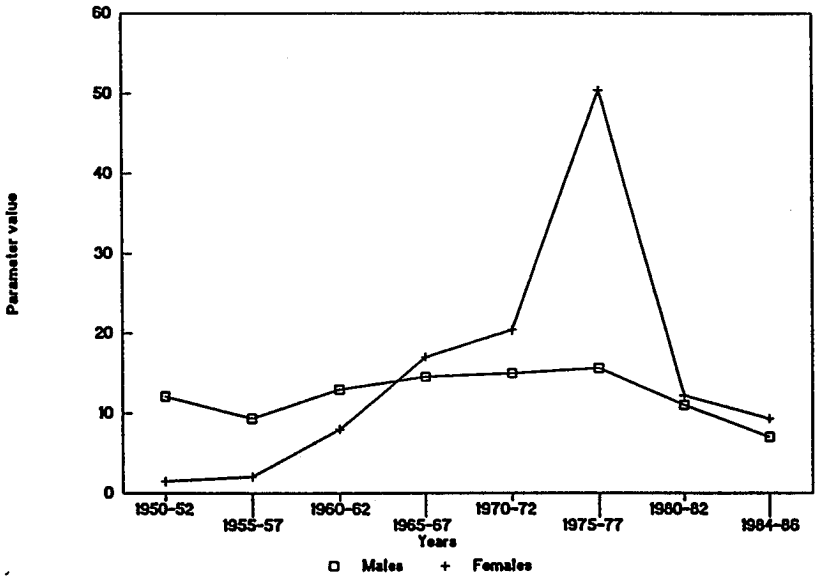

FIGURE 5. HELIGMAN-POLLARD PARAMETER E

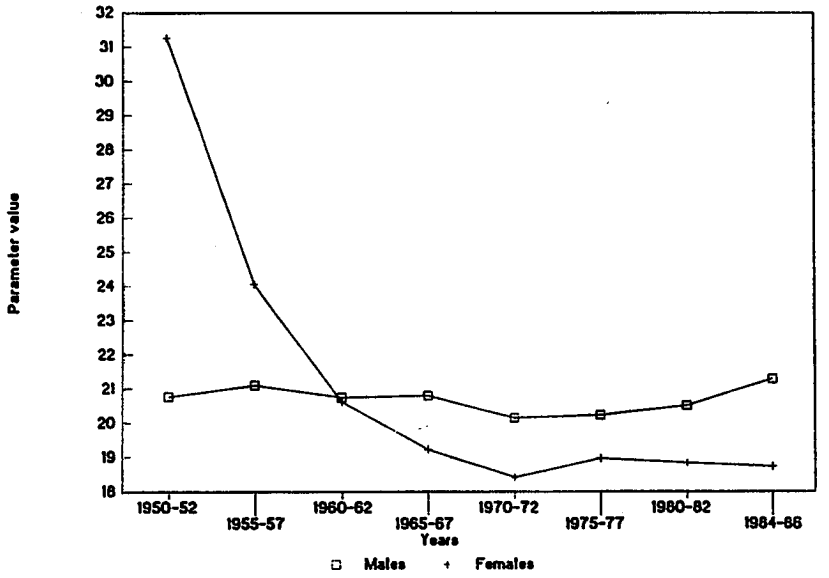

FIGURE 6. HELIGMAN-POLLARD PARAMETER F

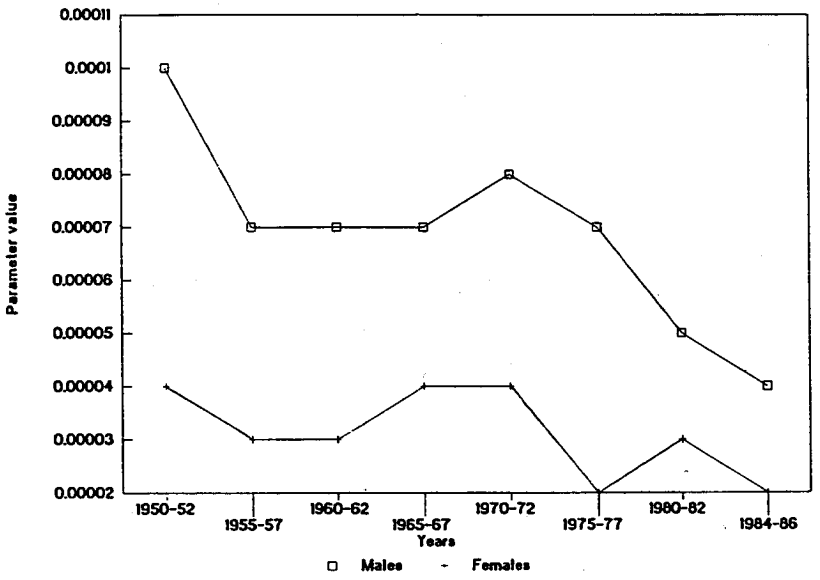

FIGURE 7. HELIGMAN-POLLARD PARAMETER G

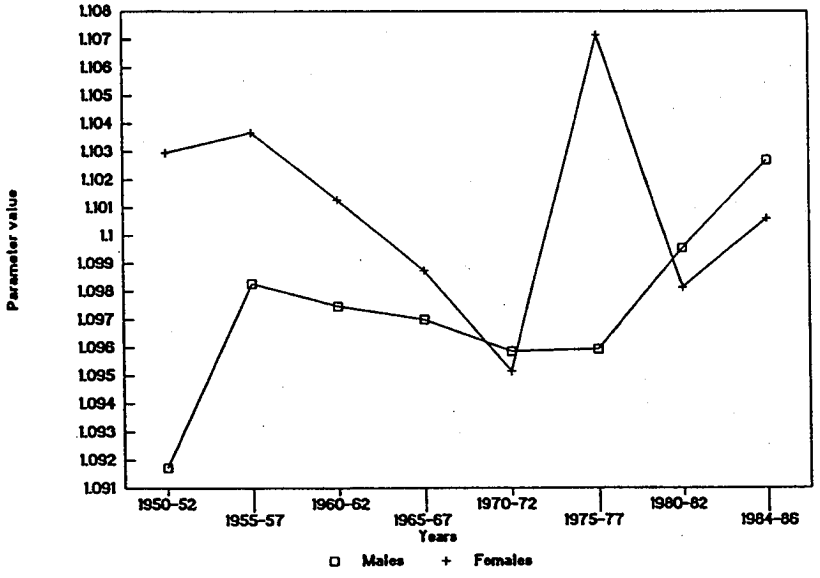

FIGURE 8. HELIGMAN-POLLARD PARAMETER H

Old Age Mortality

The changes in mortality of ages 65 years and over are reflected in the changes in life expectancy at advanced ages. These changes have been plotted on Figures 9 and 10 for males and females, respectively. For males, the gain in life expectancy increased since 1961-66, reaching a maximum in 1976-81. However, since 1981-86, the gain has fallen considerably. For females, the gains were substantial throughout the period prior to 1981. The gains had been increasing since 1956-61 to achieve a peak in 1966-71. This peak, however, was not as well defined as it was for males. More accurately, one could describe the period of high peak gains as extending from 1966 to 1981; a marked drop in gain occurred only after 1981. Further, as revealed by Figure 10, the gains for females consistently decreased with increasing age in each period; this age pattern for males emerged only after 1971.

Distribution of Deaths

Distribution of deaths can be studied using graphical presentation of survival curves (Figures 11 and 12) in conjunction with the concept of rectangularization and median ages at death (Figure 13). As the figures show, the survival curves became more flattened or rectangular over the period from 1951 to 1986, and the curves were moving in the direction of the advanced ages. Comparing this rectangularization to earlier periods, Nagnur (1986) observed that the increase in rectangularization was more pronounced during the period from 1951 to 1981 than in earlier decades. The median ages at death for males showed a very slow increase prior to 1966 and a somewhat rapid increase after that. The highest increase occurred over the period 1976-81. In the case of females, median ages at death exceeded those for males over the whole period 1951-86, and the rate of increase was uniform.

Distribution of Causes of Death

Over the period from 1951 to 1986, cardiovascular diseases (CVD) and neoplasms (NEO) or cancers have maintained their ranks as the leading and the second leading causes of death, respectively, for both

males and females in Canada. Figures 14 and 15 show the percentage distribution of these two causes of death for both males and females.

Cardiovascular diseases (encompassing both heart diseases and cerebrovascular diseases) have been declining in Canada since the 1960s. Figure 14 shows that the percentage of deaths due to cardiovascular diseases have been decreasing since 1961 for males and since 1971 for females. The age standardized mortality rates (ASMR) for heart diseases fell by 27 per cent between 1977 and 1987, compared to a fall of 18 per cent between 1967 and 1977. Cerebrovascular diseases fell more steeply by 34 per cent from 1977 to 1987, compared to 24 per cent from 1967 to 1977 (Brancker, 1990). The percentage of deaths due to neoplasms increased throughout the period of study for both genders, and a rapid increase occurred over the period 1971 to 1981. Figure 15 shows that female deaths due to neoplasms exceeded male deaths until quite recently. By 1985, the male percentages had almost equalled the female ones.

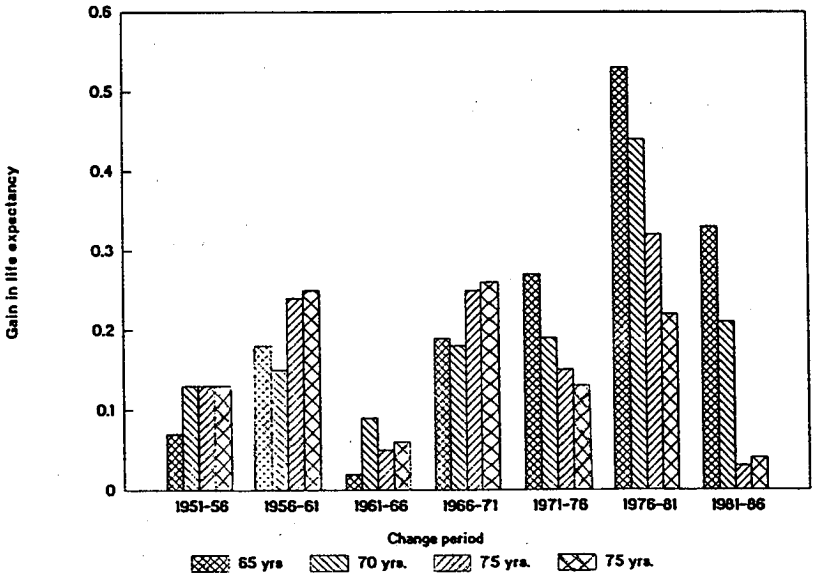

FIGURE 9. CHANGES IN OLD AGE LIFE EXPECTANCIES. CANADIAN MALES, 1951-1986

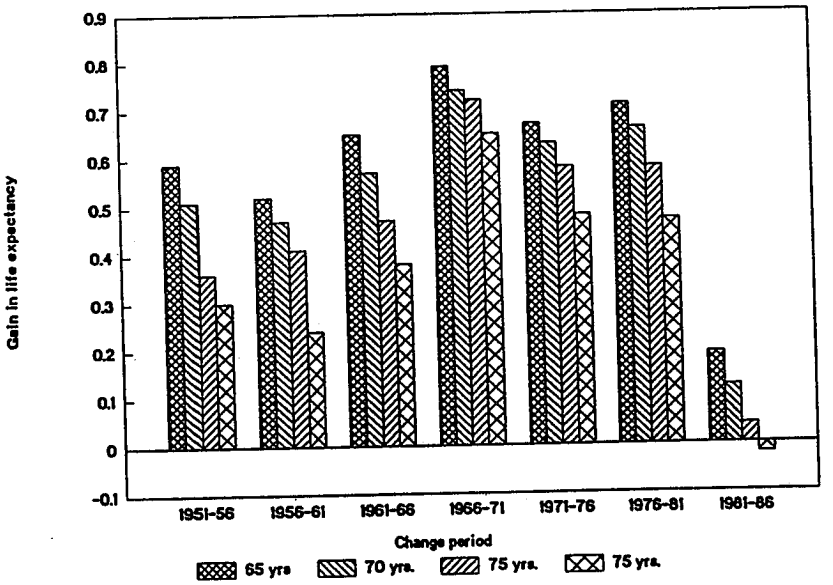

FIGURE 10. CHANGES IN OLD AGE LIFE EXPECTATIONS. CANADIAN FEMALES, 1951-1986

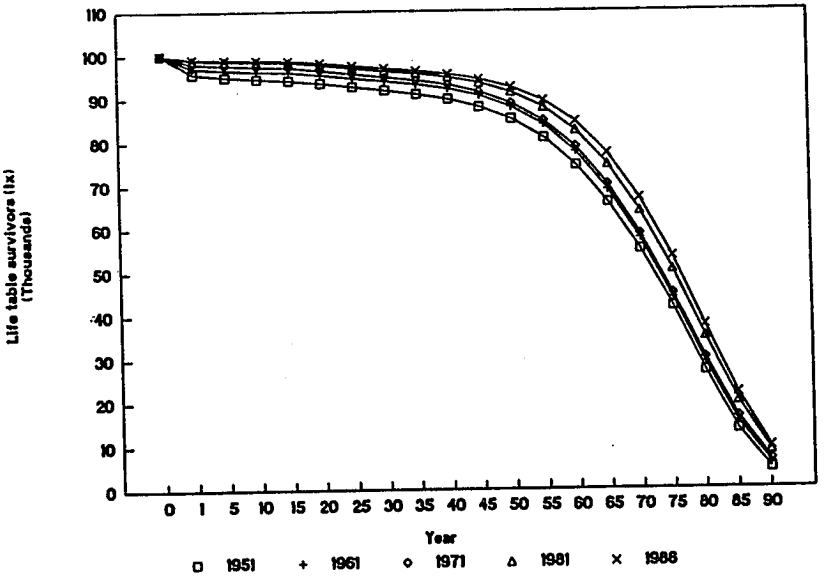

FIGURE 11. SURVIVAL CURVES. CANADIAN MALES, 1951-1986

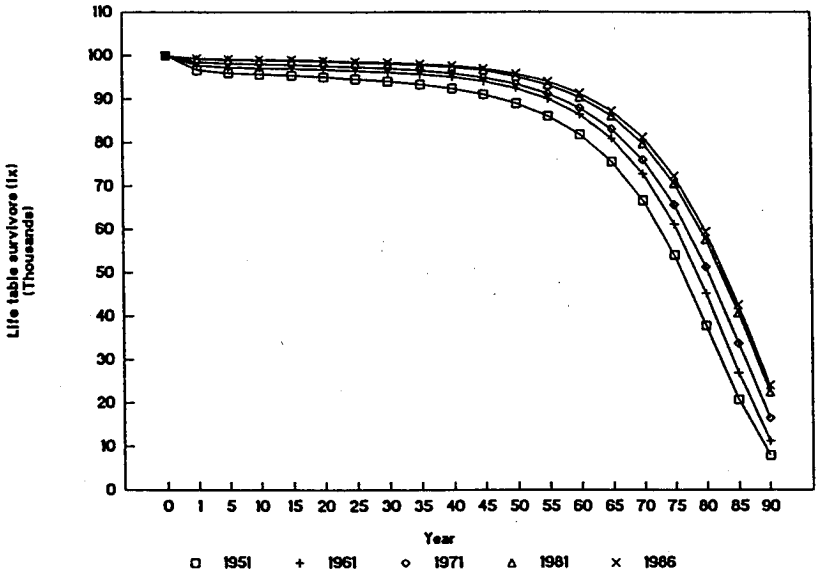

FIGURE 12. SURVIVAL CURVES. CANADIAN FEMALES, 1951-1986

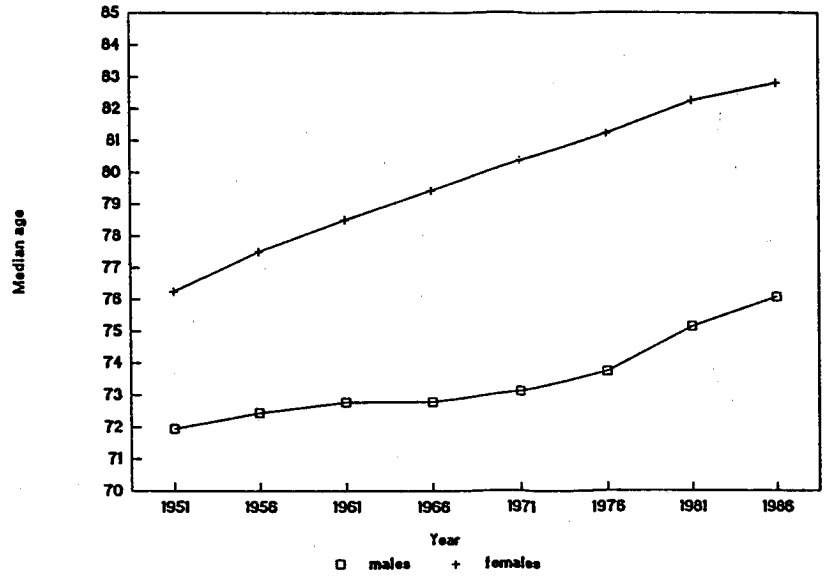

FIGURE 13. MEDIAN AGES AT DEATH. CANADA, 1951-1986

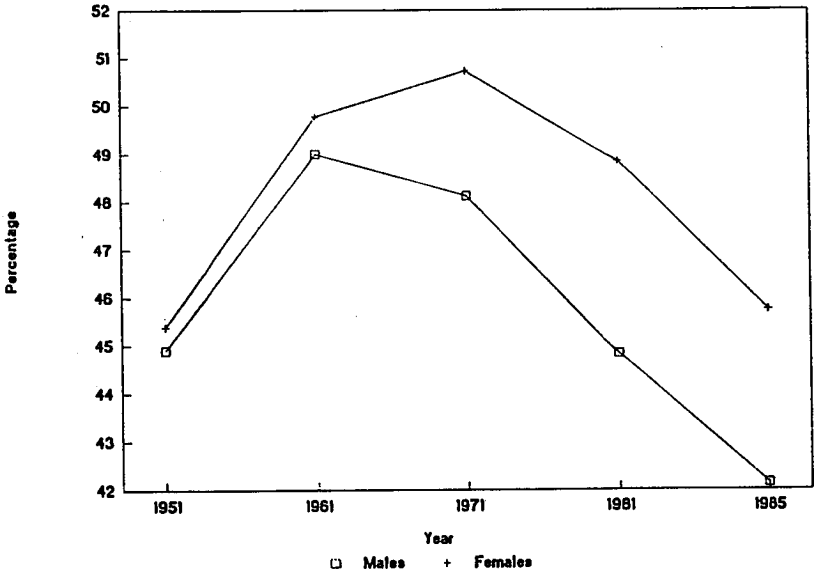

FIGURE 14. PERCENTAGE DISTRIBUTION OF DEATH FOR CVD. CANADA, 1951-1985

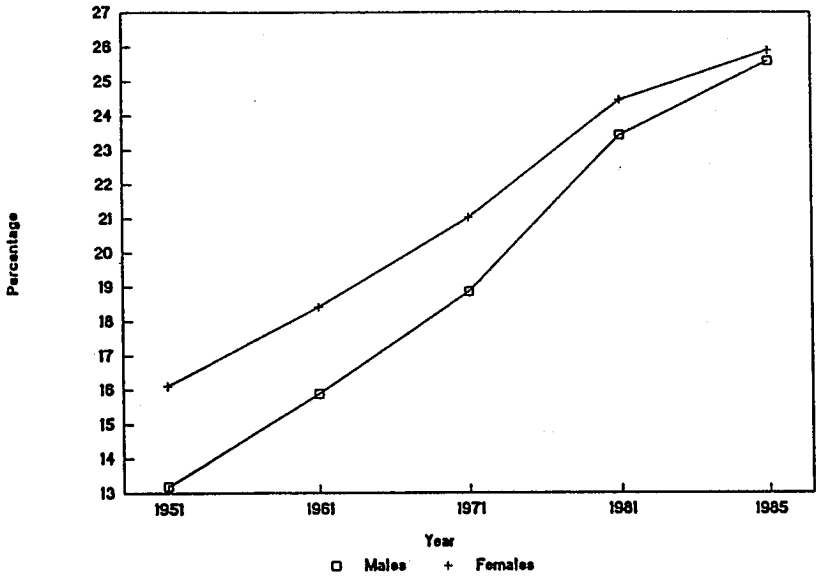

FIGURE 15. PERCENTAGE DISTRIBUTION OF DEATH FOR NEO. CANADA, 1951-1986

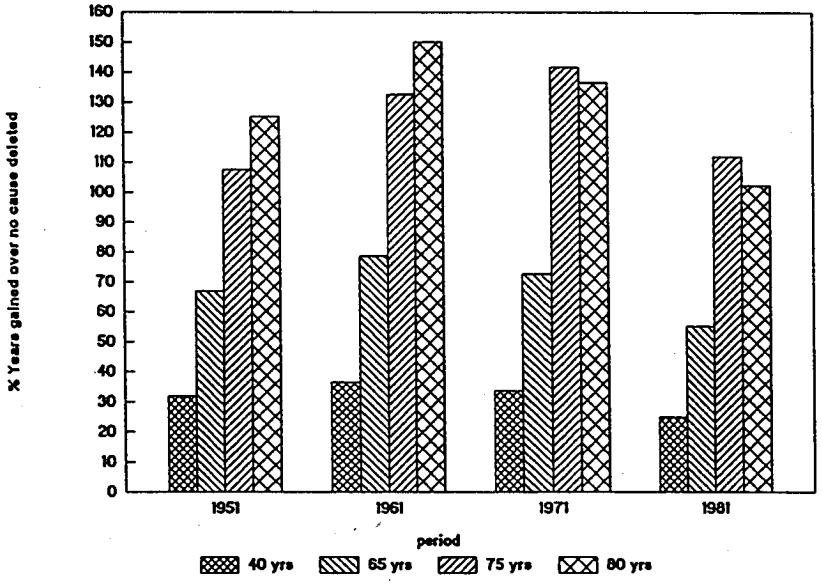

FIGURE 16. % YEARS OF LIFE EXPECTANCY GAINED IF CVD WERE ELIMINATED (MALES)

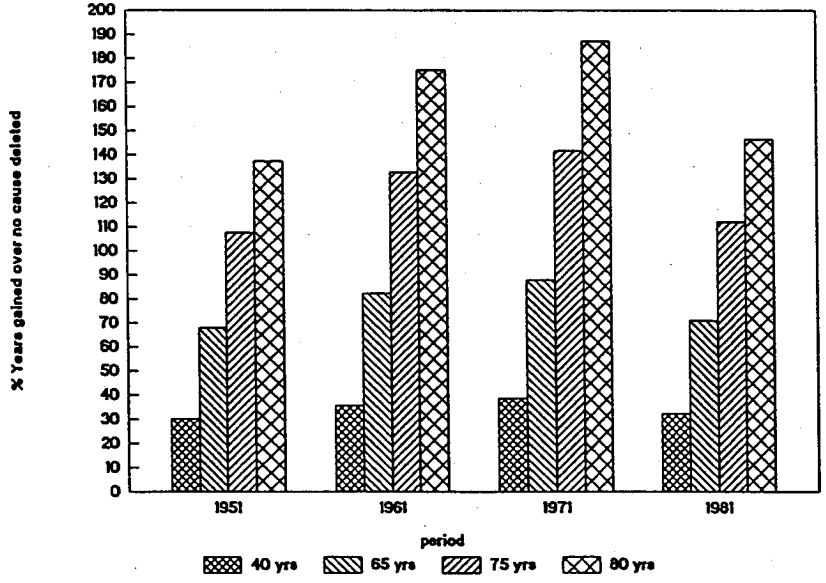

FIGURE 17. % YEARS OF LIFE EXPECTANCY GAINED IF CVD WERE ELIMINATED (FEMALES)

Age Structure of Causes of Death

The importance of different causes of deaths at specific ages can be directly inferred from cause-deleted life tables. These tables have been constructed by Nagnur and Nagrodski (1987). They show what the increase in life expectancy would be at specific ages if certain causes were to be eliminated. Concentrating on the higher ages of 40, 65, 75 and 80, these life tables show that the leading causes of death at these ages are: cardiovascular diseases, neoplasms, certain degenerative diseases and accidents. Considering only cardiovascular diseases and neoplasms, the percentage gains in life expectancy are extracted from these life tables and are represented in Figures 16 to 19.

Figure 16 shows that for cardiovascular diseases, the male gains in life expectancy started declining mostly after 1961. The percentage gains shown in Figure 17 for females reflect the same temporal trend even though the pattern of gains by ages differs markedly from that of males. The percentage gains for both genders with the elimination of CVD show a shift in importance of CVD towards higher ages and a subsequent decline. The third stage of the epidemiologic transition theory had not anticipated this shift nor the decline in deaths in a leading degenerative disease.

As far as neoplasms are concerned, Figures 18 and 19 show the percentage gains for males and females, respectively. These figures reveal quite consistently the growing importance of neoplasms over both age and time. The percentage gains from 1971 to 1981 are far higher compared to the gains between 1961 and 1971. This could be interpreted as the "unexpected shift" that Olshansky and Ault (1986) describe as being the characteristic feature of the fourth stage.

Trends in Social Pathologies

During the fourth stage, deaths become increasingly influenced by individual behaviours and new lifestyles (Rogers and Hackenberg, 1987). Deaths due to social pathologies such as excess drinking, smoking, accidents and other risky behaviours would reflect such an influence, which could be either positive or negative in terms of its contribution to mortality reduction.

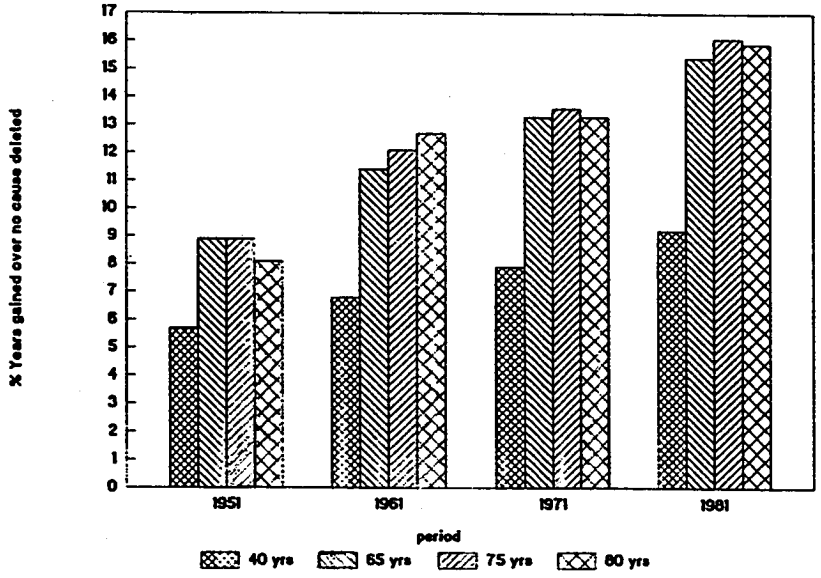

FIGURE 18. % YEARS OF LIFE EXPECTANCY GAINED IF NEO WERE ELIMINATED (MALES)

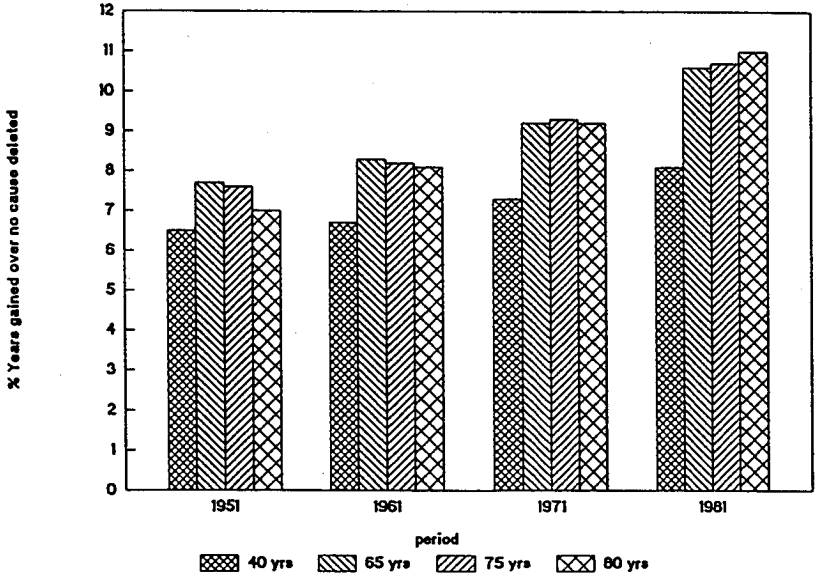

FIGURE 19. % YEARS OF LIFE EXPECTANCY GAINED IF NEO WERE ELIMINATED (FEMALES)

From 1951 to 1986, the age standardized mortality rates for accidents have decreased for both males and females. No appreciable change occurred from 1951 to 1971. However, from 1971 to 1986, the rates decreased by 44 per cent for males; and 39 per cent for females (Riley and Paddon, 1989). Of deaths by accidents, motor vehicle traffic accidents account for more than half. Lung cancer is directly linked to detrimental lifestyles such as cigarette smoking. Steep increases in lung cancer have been observed since the 1950s. Adjusted rates for men reached a peak in 1984, and the first slight decrease was reported in 1985. For women, however, lung cancer death rates are still rising steeply, particularly in ages 65 and above (Statistics Canada, 1986).

Another outcome of risky behaviour with negative influence on death rates is the Acquired Immunodeficiency Syndrome (AIDS), which is also strongly related to a person's behaviour and lifestyle except in the case where it is acquired through blood transfusion. According to Rogers and Hackenberg, AIDS in the United States exemplifies the hybristic stage when unnecessary risks are taken on the belief of invincibility. In Canada, the number of AIDS cases reported have increased from one case in 1979 to 628 cases in 1987; approximately 46 per cent of the AIDS cases fall in the age group 30-39 (Laboratory Centre for Disease Control, 1988).

Discussion

By the 1950s, life expectancy in Canada had risen to 66.33 years for males and 70.83 years for females; thus Canadian mortality had already entered the third stage of its epidemiologic transition. The leading causes of death in 1950 were: accidents for ages 1 to 44, cancer followed by CVD for ages 45-64, and CVD followed by cancer for ages 65 and over. This ranking of the causes of death remained the same over the period from 1950 to 1986 (Statistics Canada, 1986; Nagnur, 1986). This unchanged pattern of causes satisfies the first criterion for recognizing the onset of the fourth stage, assuming that the onset of this stage occurred sometime during the later part of the period 1950 to 1986. During this period, cancer mortality was shifting toward the older ages. This shift is more remarkable during the period from 1971 to 1981. Thus the second criterion of the fourth stage —

namely that a shift would occur in the distribution of deaths even if the pattern of causes of death remains the same — is satisfied.

The third criterion for recognizing the onset of the fourth stage is that there is a rapid improvement in mortality concentrated in old ages. While old age mortality has been improving throughout the period, rapid improvement can be observed over only after 1971. The fourth criterion is a rapid decline in deaths due to social pathologies, mainly as a result of the enforcement of health laws and implementation of health promotion programs. In Canada, the rapid decline of deaths due to motor vehicle accidents in the 1970s has been attributed to improvement in driving skills, enforcement of law against drinking and driving, use of seat belts and improvement in highway engineering (Riley and Paddon, 1989).

The fifth criterion is the rise in deaths related to individual behaviour and lifestyle. There are indications - such as AIDS and smoking - that the future of Canadian mortality will depend a great deal on individual behaviour and lifestyle. With the exception of this fifth criterion, all other features of the fourth stage seem to have taken place during the period from 1971 to 1981. One can possibly narrow down this period of transition to 1976-81 in the case of males. The transition, however, has been more gradual in the case of females and covers the entire period 1971-81. The transition of Canadian mortality to this new stage was complete after 1981.

Conclusion

The purpose of this paper was to answer the question whether Canadian mortality has entered the fourth stage in its epidemiologic transition. The paper started with a synthetic view of the two descriptions of the fourth stage, and, as a first step to answering the question, the Heligman and Pollard model was used to capture the sectional changes in age patterns of mortality by means of eight parameters. These parameters gave the first clue that significant changes had taken place over the period from 1971 to 1981. Further analysis on general mortality and cause of death structure confirmed this point. Further analysis of the pattern of changes in Canadian mortality showed that the transition into this new stage took place over the period 1976-81 for males and over the period 1971-1981 for

females, and by the 1980s, the new stage became more firmly established.

This study has several implications, but first there must be a recognition and awareness — especially among public health officials — that a new era in Canadian mortality has set in. Mortality declines in this stage will depend primarily upon prevention strategies, health promotion, and changes in individual behaviour and lifestyles. Responsibility for doing so, however, does not rest solely on an individual or an institution. As emphasized by Rogers and Hackenberg (1987), it is a collective responsibility that must take into account the long and complex chain of individual and societal interactions. Many behaviours and lifestyles are not developed in a vacuum, but are shaped and reinforced through political, social and economic forces. Health law and the media will play an important role in the reduction of morbidity and mortality during this new era.

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