A Continuing Pattern of Decline of the Sex Differential in Life Expectancy in Canada: Early 1970s – Late 1990s

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June 10, 2005

Paper prepared for the 25th International Population Conference of the International Union for the Scientific Study of Population (IUSSP) to be held in Tours, France, July 18-23, 2005.

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Abstract

For most of the 20th century the sex gap in life expectancy at birth in the industrialized countries has widened in favor of women. By the early 1980s a reversal in the long-term pattern of this differential had occurred in a large number of Western countries, where it reached a maximum and thereafter has followed a declining trend. In this study we investigate this phenomenon in Canada between 1971 and 2000. The pattern of change in this differential in Canada is similar to that of other high-income Western nations, including the United States, England and Wales, Australia, Sweden, Finland, Norway and Germany, among others. We decompose the sex difference in life expectancy at birth across four discrete time periods (1971, 1981, 1991 and 2000) to separate the contribution to the difference of ten cause-of-death components. We then look at the change in contribution of these ten components between sequential periods. Our results show that narrowing sex differences in life expectancy in Canada have resulted from larger than expected improvements in male death rates as compared to women during the 1980s and 1990s, principally with respect to heart disease, accidents and violence, and lung cancer. Change in the effects of these three components explains most of the decline in the size of the sex gap in life expectancy at birth during the interval of observation. A number of hypotheses are developed drawn largely from the literature concerning epidemiological transition and recent sociological works in the area of sex differences in mortality in post-industrial societies. Our results confirm the importance of sex differences in smoking prevalence in the past as a factor in the narrowing of the sex gap in longevity in recent years. It is shown however, that a significant portion of the reduction in the size of the sex differential in life expectation between 1981 and 2000 in Canada is also attributable to convergence in sex differences in mortality from accidents and violence, which have no direct relationship to smoking. It is proposed that narrowing differences in life expectancy at birth between men and women represents a new feature of the epidemiological profile of post-industrial societies in the midst of a "second demographic transition."

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INTRODUCTION

During the twentieth century mortality in the Western world and in Japan has declined to unprecedented levels (Coale, 2003; Preston, 1976; Tuljapurkar, Li and Boe, 2000; White, 2002; White and Preston, 1996; Wilmoth, 1998; Andreev, 2000; Riley, 2001). In this generalized context of improved survival, female life expectancy has surpassed that of males by an increasing margin (Madigan, 1957; Stolnitz, 1956; Enterline, 1961; El-Badry, 1969; Preston, 1976; Retherford, 1975; Waldron, 1976, 1986, 1993; Lopez, 1983; Vallin, 1983, 1993, 2002; Nathanson, 1984; Smith, 1993; Rogers, Hummer and Nam, 2000; Riley, 2001; Salomon and Murray, 2002; Luy, 2003; Meslé, 2004).[1] At present, life expectancy at birth in the industrialized countries ranges in the upper seventies for men and above 80 years for women (Van Hoorn and Broekman, 1999; Population Reference Bureau, 2004). Figures 1 and 2 illustrate the long-term trends in life expectancy at birth and the sex difference in this measure for Canada and Sweden, as two representative countries that have passed through the described historical trends in life expectancy.

---Insert Figure 1 here---

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[1] The historical record can shed further light on the magnitude of the sex gap in survival in earlier times. During the latter part of the 18th century, female life expectancy in European countries such as Sweden, France and England, exceeded male expectancy by a margin of about three years (Preston, Keyfitz and Schoen, 1972; Stolnitz, 1956). And during the mid to late 19th century, life expectancy for men and women and corresponding female-male difference tended to range as follows: England and Wales (1841: male 40.19, female 42.18, difference = 1.99); France (1817-31: male 38.33, female 40.83, difference = 2.50; Sweden (1816-40: male 39.50, female 43.56, difference = 4.06); Germany (1871-81: male 35.58, female 38.45, difference = 2.87) (Acsadi and Nemeskeri, 1970; Preston, Keyfitz and Schoen, 1972; United Nations Department of Economics and Social Affairs, 1973: 116).

Early in the 20th century the sex differential in longevity in these countries was between 2 and 3 years.[2] By 1950, it had changed to about 4.5 years in Canada, while in Sweden the differential did not pass the 3-year mark until the mid 1950s. By comparison, around this time in the United States the sex gap stood at almost six years (Smith, 1993: 83; Peron and Strohmenger, 1985: 121), and it varied between 2 and 7 years across other industrialized countries. Around 1960, some European countries had seen their sex differential in life expectancy reach 8 or 9 years (e.g., France and Finland) (Lopez, 1983: 86-87). By the early part of the 1980 the gap in longevity between men and women had peaked to about 7 years in Canada and to just over 6 years in Sweden.

---Insert Figure 2 here---

Table 1 looks at the situation for a larger set of high-income countries (including the three just examined) for the period between the early 1970s and the late 1990s (in a few cases to 2000 and 2001) in order to illustrate the generality of the phenomenon of narrowing sex differences in life expectancy, as well as the timing of occurrence of this relatively new trend across the countries. England and Wales led the way in the

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[2] The sharp drop in the sex differential in life expectancy in Canada around 1921 seems unusual. It may reflect problems with the estimated historical life expectancy figures (e.g., Quebec province not included between 1921 and 1925), or possibly the consequence of some event or condition in society that may have led to a temporary drop in the sex gap in life expectancy. In this connection, it is interesting to note that a similar situation has been documented for the United States, attributed to the greater female mortality during the influenza pandemic around this time in history (Smith, 1993: 83; Noymer and Garenne, 2000). Perhaps the Canadian case is reflective of this as well. The continuation of reduced differentials through the 1930s in Canada may signify differential mortality between men and women associated with the effects of the Great Depression.

phenomenon under investigation.[3] Between 1970 and 1980 the sex gap in life expectancy for this population had reduced by 0.31 of a year.

---Insert Table 1 here---

This tendency would later spread to a large number of countries in the 1980s and 1990s. The exceptional case of Japan, where the differential continues to expand in favor of women, is examined in a separate investigation. Here, we restrict our observations to Figure 3 in which the Japanese case is juxtaposed to that of Sweden's. As two of the longest-lived populations in the world, the two experiences with respect to the phenomenon in question are obviously very different. The case of Japan is indicative of the possibility that even with the highest levels of life expectancy in the world, the disparities in health between the sexes do not necessarily decrease.[4]

---Insert Figure 3 here---

STUDY OBJECTIVES

This investigation expands on recently published works in this area of mortality analysis (e.g., Trovato and Lalu, 1996a, 1996b, 1998; Pampel, 2002, 2003a; Waldron,

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[3] Actually, Lopez (1983: 10) showed that beside England and Wales, a few other countries had experienced a small decline (by about 0.10 of a year) in their sex differentials in life expectation during the interval between 1970-74 and 1975-78. In Fact, as shown in Table 1, the situation in Scotland parallels closely that of England and Wales.

[4] A brief overview of the Japanese case is presented by Meslé (2004).

1993; Nathanson, 1995). However, rather than examining an aggregate of countries, we look at the specific case of Canada and its continuing pattern of declining sex differences in life expectancy at birth over roughly a 30-year interval from 1971 to 2000.[5] Observed narrowing and widening of the sex difference in life expectancy must necessarily derive from temporal shifts in sex differences in mortality from major causes of death such as heart disease and cancer, which claim a large number of lives annually in the industrialized countries, along with cases associated with suicide, accidents and violence. Thus, we examine in detail the contribution of causes of death to the sex differential in life expectancy at birth during this period. Mortality rates vary significantly by age. Therefore we also examine the contribution of age to the explanation of change in the sex gap in life expectancy. Being a low mortality population, a large proportion of diseases and deaths in Canada would be concentrated in the older ages (Kannisto et al, 1994, Manton, 1982; Fries, 1980; White, 2002).

Our statistical analysis is motivated by three questions. First, what is the relative contribution of major cause-of-death categories to the sex differential in life expectancy at birth within and between periods in Canada? Secondly, what causes of death are responsible for the change in the sex difference in longevity across time periods to either widen or narrow this difference? Thirdly, what is the contribution of age to the change in the sex differences in life expectation? These questions are explored through a decomposition methodology that partitions observed female-male difference in life expectancy into the independent contributions of sex differences in mortality due to ten cause-of-death components.

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[5] These recently published works do not extend the period of observation beyond the early or mid 1990s.

In theoretical terms, we situate this analysis in the context of epidemiological transition theory and the recent sociological literature concerning gender role change and sex differences in mortality in post-industrial societies. An important feature of this literature considers sex differences in smoking as a key determinant of change in the sex differential in mortality and life expectancy. It is argued that narrowing sex differences in mortality represent a characteristic feature of post-modern societies in the midst of a "second demographic transition." Thus, the changing mortality differential between men and women cannot be viewed in isolation of sociocultural shifts in the Post-War years in advanced societies.

THEORETICAL FRAMEWORK
Epidemiological Transition and the Sex Differential in Life Expectancy

Notwithstanding the exceptional case of Japan, the tendency for a growing number of high-income nations to experience reduced sex differences in life expectancy over the past two decades can be viewed as an emerging feature of the epidemiological profile of post-industrial societies. The epidemiological transition theory explains the historical shift in mortality as countries experience modernization, from a period in history when infectious and parasitic diseases dominate as the leading killers, to a stage where chronic and degenerative ailments become the predominant causes of death (Omran, 1971). All societies in the Western world, including Japan, have passed through three stages, described by Omran (1971) as "the age of pestilence and famine," "the age of receding pandemics," and "the age of man made and degenerative diseases." An important proposition in this theory states that with modernization populations experience

widening sex differences in mortality, resulting in faster life expectancy gains for females. The larger improvements in survivorship for females that occur with the recession of pandemics (stage II) are especially beneficial to infants and children of both sexes, and to females in the adolescent and reproductive age periods. And during the transition from infectious to degenerative disease predominance (stage III) "women switch from a level of mortality in the reproductive years higher than that of men to a level more advantageous, such that the female 's higher relative risk of death disappears at about the level of 50 years life expectancy and becomes lower than that of males thereafter" (Omran, 1971: 525). Omran's theory remains an important framework for the study of disease and mortality change. However, this formulation is silent with specific reference to the phenomenon of interest to this investigation. It does not anticipate that after a prolonged period of widening sex differences in life expectancy, industrialized nations would experience declines in this measure.

Recent extensions of Omran's theory (Olshansky and Ault, 1986; Rogers and Hackenberg, 1987; Caselli, Meslé and Vallin, 2002; White, 2002; Salomon and Murray, 2002) point to the continued predominance of chronic and degenerative diseases in the most advanced countries. Olshansky and Ault (1986) proposed a fourth stage, the "age of delayed degenerative diseases," whereby a large proportion of deaths annually are caused by chronic and degenerative ailments, mainly concentrated in the older ages. In this stage, the segment of the population that experiences the most pronounced improvements in survival probabilities are the elderly, as mortality in the younger ages and in infancy has reached historic low levels. As well, survival probabilities among those with major

chronic diseases improve, and the average age at death rises accordingly. Taken together, these epidemiological features of advanced societies imply that sex differences in life expectancy obtain principally from sex differences in mortality among older adults, and that chronic and degenerative diseases would account for most of the discrepancy in life expectancy between men and women.

Rogers and Hackenberg (1987) add that risky behaviors and lifestyle underlie a large proportion of deaths in contemporary high-income countries. For instance, in Canada, during 1995 about 15,000 people lost their lives to lung cancer, a disease connected to tobacco use. In the United States, the number of such cases exceeded 149,000 (World Health Organization, 1998). It is also true that a large number of accidental deaths are linked to alcohol and other substances, and that suicide and homicide continue to be significant causes of premature death among young and middle-aged adults (Stack, 2000a, 2000b). These prevailing epidemiological trends in the advanced societies suggest the existence of a "hybristic" configuration of factors, whereby chronic diseases associated with aging and conditions related to poor life style and personal habits are mainly responsible for premature mortality (Rogers and Hackenberg, 1987; McGinnis and Foege, 1993; Caselli, Meslé and Vallin, 2002; Mokdad et al., 2004).

In tandem with these epidemiological developments, high-income countries during the Post-War years have also experienced major social demographic changes. The view has been expressed that such countries are actually in the midst of a "second demographic transition" (Van de Kaa, 1987, 1999, 2004; Lesthaeghe and Surkyn, 1988),

characterized by a pluralization of living arrangements among young adults and a

pervasive tendency to postpone marriage, a large percentage of couples living in

cohabiting unions, declining marriage rates, increased divorce probabilities, very high

contraceptive prevalence levels, sub-replacement fertility rates; increased proportion of

couples remaining childless; and an increasing tendency among couples for childbearing

outside of traditional marriage.[6] As part of this configuration of change, gender roles in

these societies have become more egalitarian (Davis, 1984; McDonald, 2000). Could it

be that part of the convergence in the sex differential in life expectancy noted recently in

some countries is linked to changes associated with the status of women in these

societies? In addressing this question, we restrict ourselves to two strands of theorizing,

based largely on the recent works of Pampel (2002, 2003a, 2003b) and Nathanson (1995),

though clearly the work of others are also relevant (e.g., Waldron, 1976, 1986, 1991a,

1991b, 1993; Veevers and Gee, 1986; Verbrugge, 1976). Pampel's research emphasizes

smoking diffusion as the mechanism underlying the recent reductions in death rates

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[6] It has also been suggested that these social demographic trends in postmodern society are supported by a cultural mindset among the young, characterized by a generalized mistrust toward established institutions and traditional sources of authority (Lesthaeghe and Surkyn, 1988; Van de Kaa, 1999, 2004). Although the second demographic transition perspective emphasizes shifts in societal value systems that give rise to change in demographic behavior, most notably related to family formation and procreation, it does also consider---albeit to a lesser degree---issues pertaining to mortality and international migration. Van de Kaa (1999), the scholar most closely associated with the concept of "second demographic transition," has explicitly incorporated in his discussions elements of mortality and longevity expectations in the context of postmodern societies. For instance, he writes, "…[A] shift in value orientation provides a perfect explanation for the many demographic changes since 1965…It is consistent with an individualistic life style in which people make their own choices about marriage or cohabitation, where they are free to have children in or outside marriage, to have them alone or with a partner, and where they can have them early or late in life. A lifestyle where it is understood that sex and marriage/union are no longer closely related, and that contraception is only interrupted to have a self-fulfilling conception. The value shift is also consistent with people adopting an optimal risk strategy to reduce the probability of premature illness and death. The idea of choosing a personal death in the case of terminal illness is also in line with this lifestyle. …" (p. 31). Clearly, Van de Kaa's conceptualization with respect to health and mortality in post-industrial contexts is not inconsistent with propositions expressed by social epidemiologists (e.g., Rogers and Hackenberg, 1987; Mokdad and colleagues, 2004) on the relevance of life style factors in determining health status in contemporary high-income countries.

between men and women, whereas Nathanson's explanation includes additional factors, of which change in the position of women in society is of particular importance.[7]

Smoking and the Sex Differential in Life Expectancy

In the context of widespread social change, women in the industrialized countries have moved away from unpaid work in the home and into the paid labor force. This has in general resulted in greater economic gain for women and their families (Repetti, Matthews and Waldron, 1989). However, as part of this transformation, women may also experience some less desirable consequences to their health. Aspects of their lifestyles may change; they may adopt some of the less positive features of the male gender role, and thereby acquire some of the mortality risks traditionally associated with men. To the extent that this is true, women would at some point begin to experience erosion in their advantage in longevity in relation to men (Nathanson, 1995). One detrimental behavior being increasingly adopted by women is cigarette smoking (Waldron, 1991a, 1991b, 1995, Lopez, Caselli and Valkonen, 1995; Pampel, 2002, 2001a, 2003a, 2003b).[8]

It has been postulated that the adoption of cigarettes by women may reflect in part a rejection of traditional norms for appropriate female behavior (Waldron, 1991b). In Nathanson's conceptual model, change in the position of women in society (in terms of

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[7] Explanations for the sex differential in mortality emphasize a wide range of factors, from biological and genetic differences between the sexes to structural and sociological causes underlying differential behaviors of men and women. A review of this vast literature is avoided here due to space limitations (for more extensive reviews see Luy (2003); Vallin (2002); Waldron (1976, 1995, 2000); Perls and Fretts (1998); Owen (2002)).

[8] In this connection it may also be argued that with the erosion of the traditional "breadwinner system"(Davis, 1984) the expansion of roles for women in society may result in some erosion of "protection" against certain types of risks, including those from accidents, homicide, and suicide (Durkheim, 1887[1951]; Stack and Danigelis, 1985).

division of labor, family status, political power) is viewed as a potential determinant of women's increased smoking prevalence, and this in turn is thought to translate into slower pace of life expectancy gains for women. Nathanson (1995) hypothesized that countries with relatively high levels of gender equality would have high levels of smoking prevalence among women, and that this in turn would result in slower gains in life expectancy at age 40 for women. Nathanson's cross-national analysis revealed that increased female labor force participation is inversely associated with change in female life expectancy at age 40; and in countries where female smoking prevalence in 1970 was relatively high, women's life expectancy gains between 1970 and 1988 were slower than in those countries characterized by low smoking prevalence. Thus, for example, Japan with very low female smoking rates showed the largest increases in female life expectancy between 1970 and 1988; and Denmark, with the highest smoking prevalence, had the slowest gain in female life expectancy during this period. However, according to Nathanson (1995), there results do not in themselves prove conclusively that greater levels of gender equity in society is associated with a slowdown in female life expectancy gains over time: "[N]either the data…presented nor the scenarios for the future…are consistent with the existence of a causal relationship between movement toward gender equality and women's mortality" (p. 154). A recent analysis of sex differences in accidental mortality across 18 high-income nations by Pampel (2001b) also failed to produce unequivocal support for the gender equity thesis.

In countries where the sex difference in life expectancy has narrowed, change in mortality from heart disease and lung cancer have contributed significantly to this

(Trovato and Lalu, 1996a, 1996b, 1998). These causes of death are known to be strongly

associated with tobacco use (Doll and Peto, 1981; McGinnis and Foege, 1993; Mokdad et

al., 2004; Peto et al., 1992, 2000; Ravenholt, 1990; Bartecchi et al., 1994; Waldron, 1976,

1986, 1995, 2000). It is estimated that smoking caused approximately 440,000 deaths in

the United States during 2004 (Bombard et al., 2004). In the European Union, the number

of male deaths from lung cancer in 2000 was close to 140,000 (Boyle et al., 2003). In

Canada, about 45,000 people died in 2002 of smoking related causes (Wister, 2005: 39).

The negative health effects of tobacco in a population are typically felt decades

after the onset of widespread smoking adoption (Hegmann et al., 1993; Lopez, 1995;

Nathanson, 1995; Pampel, 2002). In a study of 22 high-income countries between 1975

and 1995, Pampel (2002) tested this idea (i.e., smoking diffusion thesis) against the

gender equity thesis as possible explanations for the convergence in sex difference in

mortality rates. No support was found for the proposition that movement toward greater

levels of gender equity is a factor in this trend. Support was found for the idea that rising

levels of female smoking over the course of the latter part of the twentieth century, and

the consequent lagged increases in female lung cancer and other smoking related

mortality in the 1970s and thereafter, fully accounts for the recently observed narrowing

of the sex difference in mortality. Pampel (2002) concluded that all of the observed

narrowing in the sex gap in mortality between 1975 and 1995 noted across industrialized

countries has resulted from convergence in smoking prevalence between men and

women: "The results…do not suggest that cigarette smoking fully accounts for the sex

differential in mortality between males and females; rather, smoking fully explains the

recent narrowing of the sex differential" (p. 96). Thus, according to Pampel (2002), the female relative advantage in life expectancy has fallen recently because of the adoption of smoking by an increasing proportion of women over past decades and the consequent lagged effects on their survival probabilities.

It should be reiterated however, that in addition to smoking related diseases, in the industrialized countries accidents, violence, suicide, and cirrhosis of the liver also account for a large number of deaths annually (Peto et al., 1992; Mokdad et al., 2004; Pampel, 2001b; Chesnais, 1985, 2003). These causes of premature mortality have little direct association with smoking, and tend to be heavily concentrated among young adults, with death rates being considerably greater in men (Owen, 2002).[9] For instance, death rates from accidents and adverse effects exceed female rates by a ratio of 3 to1 or greater (Waldron, 1976, 1993, 1983; Verbrugge, 1976; Wingard, 1984; Nathanson, 1984; Perls and Frets, 1998).[10] Change in sex differences in mortality due to these causes may also account for narrowing sex differences in life expectancy.

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[9] This point is also acknowledged by Peto and associates (1992) in their extensive analysis of smoking related mortality in the industrialized world (see also Waldron, 1986).

[10] For example, according to the World Health Organization, in the United States during 1994, there were a total of 91,437 deaths linked to accidents and adverse effects. Of this total, over 60,000 deaths were males and almost 31,000 were females, accounting for a ratio of male to female deaths of about 2:1. In the same year, there were 31,142 suicides of which over 25,000 were males and close to 6,000 cases were females, for an approximate sex ratio of almost 6:1. The number of homicides was reported to have been 24,547 (19,342 males, and 5, 205 females, for a ratio of almost 4:1). In 1995, there were a total of 210,733 deaths in Canada, of which 8,820 occurred as a result of accidents and adverse effects, and the male to female ratio for this cause was almost 2:1. The corresponding ratios for suicide and homicide were about 4:1 and 2:1, respectively (World Health Organization, 1988).

HYPOTHESES

Our discussion of epidemiological transition theory and the recent sociological literature concerning sex differences in mortality, suggests the following hypotheses.

1. Being in the most advanced stage of epidemiological transition, Canada would experience a pattern of morbidity and mortality dominated by chronic/degenerative diseases. Therefore, change in heart disease and cancer mortality should account for a large part of narrowing sex differences in life expectancy between 1971 and 2000.

2. Based on the literature on the fourth stage of the epidemiological transition, we anticipate that most of the sex differential in life expectancy is attributable to change in death probabilities between men and women in the ages beyond 50.

3. In accordance with the notion that in post-industrial societies social pathologies account for a significant number of deaths annually, we expect that change in non-medical conditions, namely accidents and violence, and suicide, along with diseases such as cirrhosis of the liver (largely associated with alcohol abuse), would contribute significantly to the observed declines in the sex gap in life expectancy in Canada.

4. On the assumption that sex differences in smoking in the past underlie current sex differences in mortality, we expect that change in smoking prevalence in the past in men and women will correlate with current sex differences in life expectancy. A rise in female smoking prevalence in relation to men would result in a narrowing of the sex gap in life expectancy as a function of either increased mortality rates in women from smoking related causes (e.g., lung cancer), or from a slowdown in their mortality improvements over time.

DATA AND METHODS

Mortality and population data were obtained from the World Health Organization electronic database (www.who.org). Cause specific deaths rates by age (0, 1-4, 5-9, … 85+), sex and period were computed, and used to generate appropriate abridged life tables. The appropriate ICD codes for specific causes were grouped into the following ten cause components (see Appendix A1): (1) Heart Disease, (2) Other Diseases of the Circulatory System, (3) Lung Cancer, (4) Breast Cancer, (5) Prostate Cancer, (6) All Other Cancers, (7) Cirrhosis of the Liver, (8) Accidents and Violence (excluding Suicide), (9) Suicide, (10) All other causes of death. The female-male difference in life expectancy at birth was decomposed into the independent contributions of these ten cause components using multiple decrement life tables in conjunction with a decomposition method proposed by Das Gupta (1993) (refer to Appendix A2). To explain, let us consider the hypothetical case where only two causes of death wholly determine life expectancy in the population, and thus the expectation of life at birth is a function of two vector factors (i.e., the cause-specific probabilities of death for the two causes for ages 0 through to the last age in the life table). The expectation of life at birth for males and females can be expressed as:

$$e^0_{males} = \mathbf{F}(\mathbf{A}, \mathbf{B}),$$

$$e^0_{females} = \mathbf{F}(\mathbf{a}, \mathbf{b}),$$

where $\mathbf{A}$ is the vector of age specific probabilities of death from cause 1 for males, $\mathbf{B}$ is the vector of age specific probabilities of death from cause 2 for males, $\mathbf{a}$ is the vector of age specific probabilities of death from cause 1 for females, and $\mathbf{b}$ is the vector of age specific probabilities of death from cause 2 for females. The female-male difference in

expectation of life can then be decomposed into the contribution of the two cause components,

$$e^0_{females} - e^0_{males} = F(a, b) - F(A, B)$$

$$= [F(a, b) - F(A, b) + F(a, B) - F(A, B)]/2 \qquad \text{(cause 1)}$$

$$+ [F(a, b) - F(a, B) + F(A, b) - F(A, B)]/2 \qquad \text{(cause 2)}$$

The contribution of components to the sex gap in life expectancy can be either positive or negative. A positive contribution would imply that the effect of sex differences in mortality due to a given component serves to increase the female advantage in life expectation over males, while a negative sign would indicate the opposite effect.

ANALYSIS

Table 2 includes decomposition of period specific sex differences in life expectation at birth for Canada across four time periods, 1971, 1981, 1991, and 2000. This table also shows the corresponding change of the sex differential in survival between sequential periods and associated cause contributions. These results are shown in terms of actual years of life expectancy and also in terms of percentage distributions (the emphasis of the analysis is on years of life expectancy).[11] The first four columns in the tables list the contribution of given cause components to observed sex gaps in life expectancy within periods, whereas columns 5, 6 and 7 reflect change in cause

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[11] The use of percentages is to help in the interpretation of relative importance of given causes of death, recognizing that reliance on percentages in this case can be problematic because theoretically it is possible for one cause of death to contribute more than the actual difference being decomposed when the other causes contribute negatively.

contributions between sequential periods, to either widen or narrow the sex differential in life expectancy. Canada has seen its sex differential in life expectancy shrink from just over seven years in the early 1970s, to 5.347 years in 2000. After a long period of widening sex differences in life expectancy, the arrival of the 1980s saw a reversal of this long established pattern. Between 1981 and 1991, the female advantage over males in life expectation narrowed by 0.77 of a year; and a further drop of 1.21 years was recorded in the final decade of the 20th century.

In agreement with our first hypothesis, within each period examined, sex differences in heart disease mortality and other types of circulatory conditions (i.e., higher male than female death rates) account for a large portion of the observed sex differentials in life expectancy. Given the dominance of these causes of death in the industrialized countries, this is not unexpected.[12] Across periods, this cause component explains roughly between 41 and 27 per cent of the sex gaps. Viewed in terms of actual years of life expectancy, the contribution of heart disease has dropped over time, from 2.956 years in 1971, to 1.47 years in 2000. Thus, the impact of heart disease as a factor in the sex difference in life expectancy has diminished during this interval, though most notably since 1981 (compare the corresponding changes for this cause in columns 5, 6 and 7 of Table 2). This is indicative of the occurrence of appreciable reductions in the differential in mortality rates between men and women from heart disease, and therefore constitutes an important reason underlying the noted drop in the size of the sex gap in life expectancy in Canada since the early 1980s.

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[12] As an illustration, in 1995, deaths due to acute myocardial infarction and other ischemic heart diseases accounted for about 21 per cent of all deaths in Canada (World Health Organization, 1998).

---Insert Table 2 here---

Stated differently, male death rates are generally higher than those of females with respect to major causes of death, including heart disease, lung cancer, most other cancers, accidents, violence and suicide. Therefore, in the decomposition analysis, reduced contributions of a given cause component to the sex gap in life expectancy across periods must reflect varying degrees of convergence in male and female death rates from a given cause of death. In the Canadian context the described effect obtains from greater improvements in mortality by men in relation to women under the typical condition in which both sexes experience gains in survival probabilities. To illustrate this point, in Figure 4, the trend in the age standardized death rate for heart disease has been downward since 1971 in both men and women but the decline is clearly steeper for men. With the exception of lung cancer, this type of pattern is common to virtually all of the other cause components included in this figure, though clearly at varying degrees of effect. (The female death rate from "other" causes of death has been rising since 1981, but this is difficult to interpret given the heterogeneous composition of this cause category.) The case of lung cancer is strikingly different however, since the male and female graphs follow opposing directions of change: male death rates had essentially peaked by the early 1980s, and have been on the declining since the early 1990s, whereas those of females show a clear upward trend.

Returning to Table 2, beyond the large contribution of heart disease, sex differences in mortality from accidents and violence (excluding suicide) also explain a substantial portion of the sex differences in life expectancy. This cause of premature mortality contributed between roughly 11 and 20 per cent of the difference in life expectancy across periods (or approximately between 1.42 years in 1970, and 0.62 of a year in 2000). As is the case with heart disease, these trends indicate that Canadian men have managed to close some of their risk disadvantage in relation to women with respect to this cause of premature death (a point clearly confirmed by the corresponding age standardized death rates in Figure 4).

With reference to lung cancer, its pattern of contribution across periods also underlies substantial convergence in mortality rates between men and women. As indicated earlier this is especially evident since the early 1990s (refer to columns 6 and 7 of Table 2 and also Figure 4). The timing of this effect relates to the variability in the stage of the male and female smoking epidemics. The pattern of change in the male lung cancer death rate in Figure 5 is reflective of widespread smoking cessation in the 1960s, thereby accounting for the subsequent pattern of declining lung cancer mortality some two to three decades later, in the 1980s and 1990s. The female lung cancer epidemic however, has progressed unabated, largely as a function of a general pattern of rising prevalence of smoking in the Post-War years.

As would be expected, given their sex specificity, the contribution of breast cancer mortality to the life expectancy differential is consistently negative within periods,

whereas that of prostate cancer is consistently positive.[13] However, the change in the

contribution of these two components across time periods can be either positive or

negative in terms of their effects on the change in the sex gap in life expectancy. As listed

in columns 5, 6 and 7 of Table 2, breast cancer contributed to a narrowing of the

difference in longevity between 1971 and 1991, but helped widen the difference in the

interval between 1991 and 2000. This indicates that during this most recent period, there

have been some declines in breast cancer mortality among women. In the case of prostate

cancer, for the most part its change over time has been to widen the sex gap in life

expectancy, though during the last decade of the 20th century, there have been

improvements in this cause of death for men, and the effect has been to make a small

contribution to reduce the sex differential in life expectation. Concerning "other" cancers,

sex differences in death rates from this cause category have been diverging, to expand the

female advantage in life expectancy in relation to men, though clearly at a diminishing

degree of change across time (see columns 5-7 in Table 2). In other words, men continue

to experience higher mortality rates from "other" cancers, but time the male excess

mortality in relation to women has been getting smaller over time, though not sufficiently

so to produce a negative contribution to the sex difference in longevity.

 Although its contribution is relatively small, the effect of sex differences in

mortality from cirrhosis of the liver in the 1990s has been to diminish the gap in

expectation of life in Canada. Concerning suicide, its contribution has diminished since

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[13] Cancer of the breast and of the prostate are sex-specific (breast cancer afflicts predominantly women; prostate cancer is strictly a male disease). Improvement in survival probabilities from breast cancer would, all other things being equal, serve to widen the sex gap in life expectancy in favor of women, whereas

1981, when it accounted for roughly 0.43 of a year of the observed sex gap in life

expectancy. Thus, clearly some convergence in suicide risk has occurred recently

between men and women, translating into small contributions toward closing some of the

discrepancy in life expectancy between the sexes. (Figure 4 confirms the downward trend

in both male and female death rates, though at different degree of intensity). Finally, with

reference to "other" causes of death (residual component), the contribution of this cause

component has tended to decline over time.[14]

------Insert Figure 4 here---

Decomposition of the Interval 1981-2000

Table 3 looks at the contributions of cause components to the change in the

longevity gap between men and women across two time points, 1981 and 2000. This

roughly 20-year interval covers the change in the differential from the approximate point

at which it had reached a maximum and the most recent period of observation, thus its

current minimum.[15] During this period the sex gap in life expectancy in Canada narrowed

by almost two years (i.e., 1.982 years). As expected, given the earlier results, most of this

reduction in the female-male difference in longevity is attributable to declines in sex

differences in heart disease mortality (i.e., by 1.332 years---a 67 per cent contribution),

reductions in prostate cancer mortality, all other things equal, would help narrow the differential in life
expectancy.

[14] Ideally, this broad category of mortality would be disaggregated into its component parts for a more
complete analysis.

[15] One should distinguish between the "historical" maximum point of the differential, and the "maximum
point" of the data analyzed. The two many not be identical. However, as can be seen in Figure 2, these two
time points in Canada are quite close, as the historical peak point of the differential took place between
1976 and 1981.

and to a lesser degree to reduced differences in mortality from accidents and violence (26 per cent contribution) and lung cancer (18 per cent contribution), "other" circulatory conditions (5 per cent contribution), and cirrhosis of the liver (3 per cent contribution). The remaining cause components, namely breast cancer, prostate cancer, "other" cancers and the "residual" component, all show positive effects, to widen the gap in the average length of life in favor of females. For the most part these effects tend to be relatively minor (with the exception of "other" cancers, whose impact is about 12 per cent).

---Insert Table 3 here---

Age Effects

Period shifts in life expectation at birth are usually not equally attributable to change in all age groups in the life table (Keyfitz, 1968; Arriaga, 1984; Kannisto et al., 1994, Manton, 1982; Fries, 1980; Vaupel and Conudas Romo, 2003; Murthy, 2005); therefore, a further aspect of the decomposition analysis considers the contribution of mortality differences within age categories to the sex difference in life expectation at birth. Whereas the earlier decomposition focused on the contribution of causes of death, the factor of interest here is age.[16] The female-male difference in life expectancy at birth is decomposed into the contribution of five age vector factors: (1) age 0-14, (2) age 15-34, (3) age 35-54, (4) age 55-74, and (5) age 75+. Through this approach one is able to address the question: "How much of the observed female-male difference in life expectancy at birth within a given time period is attributable to sex difference in mortality

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[16] See Das Gupta (1993: 46-49) for a detailed presentation of the age decomposition procedure.

in given age categories?"[17] A related question is: "How much of the observed change between periods (i.e., narrowing) in life expectancy at birth is attributable to change in sex differences in mortality in given age categories?"

Table 4 displays the results of this decomposition across two periods, 1981 and 2000. The female advantage in average length of life increases with age, though at age 75 and over there is a notable drop in the magnitude of this effect as compared to age 55-74. This age category represents the largest contribution to the sex differential in life expectancy, accounting for 3.2 years of the difference in 1981, and for 2.17 years in 2000. Thus, over half (about 52 per cent) of the decline in the life expectancy gap between males and females across this period is attributable to declining sex differences in mortality in this age category alone.[18] The next largest contribution is associated with the age 35-54 (about 23 per cent contribution). The youngest age group (<15) shows a relatively minor contribution (about 9 per cent). However, about 20 and 23 per cent, respectively, of the sex differential in longevity is due to mortality change in the ages of 15-34 and 35-54. This means that while it is generally the case (as predicted earlier in the hypotheses section) that mortality dynamics in the older ages is largely responsible for most of the change in the sex gap in life expectancy in Canada, a nontrivial part of this is

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[17] A similar approach is would be to decompose sex differences in partial expectation of life (PEL) within broad age categories. PEL for the age interval 15 to 44 is the average number of years lived in the age interval 15 to 44 by those who survive to age 15, and it is clear that the maximum value of the expected number of years lived in this interval is 30 years (Trovato and Lalu, 1988). Decomposition of age specific PEL differences between females and males produced similar results to the age decompositions in Table 4.

[18] Further analysis revealed that the relatively large reductions in the sex differentials in life expectancy for 55-74 year olds in Canada between 1981 and 2000 are accounted mainly by reduced sex gaps in heart disease mortality in this age group. Change in sex mortality differences due to lung cancer and "other" circulatory diseases are also important for this age class (and also for other adults over the age of 35), though weaker in comparison to heart disease. The effect of accidents/violence is relatively minor in the ages below 15, though it is important in the population aged 15-34.

due to mortality convergence in young adult and middle aged men and women. Finally, it is also of interest to note that change in the sex mortality differential among the oldest segment of the Canadian population (i.e., age 75+) have actually served to expand by a small degree the female relative advantage in life expectancy (by about 5 per cent).

---Insert Table 4 here---

Additional insight into these differential patterns of age effects can be gained by an examination of sex differences in age specific death rates by cause of death. Figures 5 and 6 exhibit such information in connection with three principal causes of death, Heart Disease, Lung Cancer, and Accidents/Violence (excluding Suicide) for 1971, 1981, 1991 and 2000. A comparison of the graphs reveals the occurrence of larger mortality improvements in men as compared to women over time in the older ages beyond 50 in the cases of Heart Disease and Lung Cancer. In the case of Accidents and Violence, the pattern of mortality decline for men and women is not concentrated in the older ages. Rather, significant relative risk reductions between 1981 and 2000 are clearly evident for men in the young adult years between the ages of 15 and 34, and also in the prime adult ages of 35 to 64.

---Insert Figure 5 and 6 here---

Contribution of Smoking Related Mortality to the Sex Differential in Life Expectancy

As indicated earlier, in the industrialized countries the male smoking epidemic started earlier in the 20th century than it did for females. In recent decades across Western

societies smoking has become less popular; and many men have abandoned the habit;

however, the prevalence of smoking among women has declined less steeply, and in

some cases it continues to increase (Lopez, Caselli and Valkonen, 1995; Waldron, 1995;

Nathanson, 1995; Mackey and Eriksen, 2002). With regard to Canada, Wister (2005: 39)

has documented that since the late 1970s there has been an overall decline in smoking

prevalence in the population, down to 22 per cent in 2002, from the a level of 40 per cent

in the late 1970s. Notwithstanding this overall drop in smoking, among young adults---

especially women---cigarette consumption has actually been on the rise. Consequently, in

Canada (as in the case of many other high-income nations) male lung cancer death rates

have tended to level off and decline in the 1980s and 1990s, whereas for women

mortality from this disease has been rising (Canadian Cancer Society 2005,

http://www.cancer.ca/ccs/internet/standardpf/). It is therefore reasonable (as hypothesized

earlier) to assume that reductions in the sex difference in life expectancy since the early

1980s reflect shifts in past smoking behavior by men and women (Pampel, 2001a, 2002,

2003a). From the results of the decomposition analysis executed in this study it may be

concluded that change in sex differences in lung cancer and other types of mortality

associated with smoking, including heart disease, other circulatory conditions, and other

forms of cancer, are indeed key factors underlying the observed shifts in the size of the

sex differential in longevity in Canada. Notwithstanding this, however, the findings are

not consistent with the view that all of the observed narrowing in the life expectancy gap

between men and women in Canada occurring in the interval between 1981s and 2000 is

solely a function of convergence in male and female smoking related mortality, as the

combined contributions of accidents and violence and cirrhosis of the liver have also been substantial.

To further explore the association of past smoking trends for men and women with change in the sex differential in all-cause mortality, Figure 7 is included. It displays the lagged relationship between sex differences in smoking at t-20 years ago (i.e., the ratio of female to male smoking prevalence at t-20, where t = 1951, 1961, 1971, 1981) and sex differences in death rates at ages 40-44, 50-54, and 60-64 (measured as male/female death rate ratios at time t, where t = 1971, 1981, 1991, and 2000).[19] In general, the pattern or relationship between these variables reinforce the notion that sex differences in smoking prevalence in the past and current sex differences in all-cause mortality among adults between the ages of 40 and 64 are inversely associated: The greater the ratio of female to male smoking prevalence at t-20 years ago, the lower the male/female death rate ratio for these age groups at time t. Stated differently, as overall smoking prevalence for females goes up in relation to men, the relative risk of mortality for men at approximately twenty years later declines, presumably as a function of slowed mortality improvements in females due to increased smoking related morbidity (i.e., lung cancer and vascular diseases).

---Insert Figure 7 here--

DISCUSSION

In high-income countries in the Western world the sex differential in life expectancy at birth widened during most of the 20th century. However, by the early 1970s

this long established differential had started to narrow, first in England and Wales and in

Scotland; and then in the 1980s, in a large number of European countries as well as in

Canada, the United States, Australia, and New Zealand. Later, by the early part of the

1990s, a third set of nations in Europe had also experienced this phenomenon. The

present investigation looked at the situation in Canada across four discrete time periods

between 1971 and 2000. Following a number of propositions drawn from the literature in

the area of epidemiological transition theory, it was postulated that the sex gap in

longevity in Canada would be explained mainly by differences in chronic/degenerative

diseases in the older adult population. In accordance with expectation, the decomposition

analysis revealed that indeed a large portion of the change in the gap in life expectancy

between men and women over the interval 1981 to 2000 is accounted by change in sex

differences in heart disease mortality. It was also shown that convergence in lung cancer

death rates between men and women has played an important role as well (though to a

lesser degree than has heart disease). A large portion of the observed change in the sex

gap in longevity is attributed to the contribution of change in sex differences in mortality

in the older adult population between the ages of 55 and 74. A complementary hypothesis

emphasized the relevance of external types of mortality ("social pathologies") to the

changing sex differential in life expectancy. The empirical results confirmed the

importance of this cause component as a factor in the declining sex differential in life

expectancy at birth in Canada. A significant factor for this is the larger than expected

improvements in male death rates (as compared to women) in regard to heart disease,

lung cancer, and accidents and violence. On an annual basis these three causes combined

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[19] Smoking statistics for this part of the analysis are from Nicolaides-Bouman et al (1993). The age-specific death rate ratios were computed with data from World Health Organization.

account for almost 40 per cent of all the deaths in Canada; therefore, differential levels of improvements in these cause components would impact significantly on the size of the sex difference in life expectancy.

Some of the sociological literature has focused on the role of increased smoking prevalence in women as a factor in the declining sex differential in mortality and life expectancy in the industrialized countries (Nathanson, 1995; Waldron, 1993; Pampel, 2002, 2003a, 2003b). There appears to be strong basis for the proposition that increased smoking prevalence in women has contributed to the narrowing trend in this measure in Canada since the early stages of the 1980s. This effect is most obvious in the case of female lung cancer death rates, which have been on the ascendancy during the post-War yeas. For men, a large portion of the decline in mortality risk from heart disease and lung cancer can be attributed to widespread reductions in cigarette smoking by men, beginning around the early 1960s. The concomitant rise of smoking prevalence in women has led to increasing death rates in the female population from lung cancer and other smoking related diseases.

Therefore, changes in smoking behavior among men and women during the latter half of the twentieth century must explain a good portion of the observed change in the sex differential in life expectancy between 1981 and 2000 in Canada. However, as shown by the decomposition analysis, smoking couldn't account for all of the observed narrowing of the gap in life expectancy during this period, because beside the contributions of chronic conditions---of which many such diseases are smoking related---

a sizeable portion of the reduction in this differential is attributable to the combined contributions of convergence in male and female mortality from accidents and violence, which bear no direct relationship to tobacco use. This raises the question as to what sociological factors underlie the decline in this cause of death for men.

The reductions in risk from accidents and violence noted for men (and to a lesser extent also for women) can be attributed in part to behavioral changes promoted by the introduction of public health measures during the 1960s and thereafter. Among the many examples of this one may list mandatory seat belt legislation in the 1970s and more recently the inclusion of air bags in automobiles to diminish the incidence of serious injuries and death for persons involved in motor vehicle crashes. Perhaps also better built vehicles on the one hand, and laws aimed at reducing speeding on the road on the other, may have played a role in reducing the number of motor vehicle fatalities as well. The obligatory use of helmets for motorcyclists and cyclists can also be mentioned. Additionally there have been gradual improvements in the workplace, as a result of legislation coupled with educational programs, directed at improving occupational health and safety. Therefore it would seem reasonable to assume that declines in male accidental mortality in Canada during recent years are at least partly related to public health interventions and to the adoption and compliance of rules and regulations to reduce accidental injuries.[20] In the cases of suicide and homicide, it is known that male death rates exceed those of females by a wide margin. Criminologists have noted that homicide rates in Canada and the United States have been on the decline since the early 1990s

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[20] Additional information on public health interventions in the Canadian context may be found at the Canadian Public Health website: http://www.cpha.ca/english/policy/resolu/archive.htm

(Guimet, 2002; Blumstein, Rivara and Rosenfeld, 2000; South and Messner, 2000; La Free, 1999). Although there is some uncertainty as to the societal factors responsible for this trend, it would seem that in general people have been adopting less lethal means to resolve interpersonal conflicts and/or conditions in society have change as to reduce the likelihood of murder as compared to earlier periods in history. The role of public health campaigns and educational programs aimed at stopping violence and aggression in society should not be understated as exogenous factors for the decline in male and female death rates from this cause.[21] As for suicide, death rates in Canada rose for both men and women between the early 1950s and the early 1970s; however, after about 1974, female rates have been declining. The male suicide death rate continued to increase until about 1984, at which point it began to decline (Sakinofsky, 1998). The causes for these trends are of course multifaceted. Some of the drop in suicide can probably be attributed to the role of public health campaigns among other sociological factors (Pampel, 1996, 1998, 2001b; Stack, 2000a, 2000b).

Concerning the future course of the sex differential in longevity in high-income countries, it has been suggested that once the female smoking epidemic, currently

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[21] Explanations for the crime drop since the early 1990s have been offered in the criminological literature. These explanations cover a wide range of factors, including demographic shifts (a drop in the young adult population due to low fertility since the middle of the 1960s); change in incarceration policies to keep criminals in prison and to discourage crime; new police practices to increase surveillance in order to reduce potential criminal behavior; reduced economic stress in society (improved economic conditions in society lead to less crime); shifts in drug use and demand (decline in the demand for hard drugs such as crack cocaine, reduces the number of drug related homicides); reduction in family disorganization (i.e., stabilization of divorce rates and less incidence of intimate partner violence); education and welfare effects (the crime bust in the of the 1990s coincides with a significant rise in education and job opportunities for young graduates, and therefore criminal motivation is reduced by people having greater access to needed resources). Perhaps also important is the role of shifts in values and orientations in society, whereby violence is less tolerated today as compared to earlier periods in history (Blumstein, Rivara and Rosenfeld, 2000; South and Messner, 2000; La Free, 1999).

underway and at different points of development depending on the country, peaks and eventually subsides, smoking related mortality for females (currently on the rise) should stabilize and then drop, at which point the sex gap in survival would revert to the traditional pattern of expanding differences in favor of women (Pampel, 2002). Unfortunately, this proposition cannot be fully verified until more data become available in the course of the next several decades or beyond. An alternative perspective would see future trends in mortality and life expectancy among men and women as dependent not only on smoking differentials but also to a significant degree on change in sex differences in other life style habits and behaviors that also impact health in the long term (Waldron, 1995, 2000). To the extent that sex differences in cancer and cardiovascular disease mortality are dependent on additional factors beside tobacco use, improved health habits in men would translate into further male gains in survival probabilities, even in a context of widespread reductions in the prevalence of smoking among females. And given the importance of external causes of death as a factor in male mortality probabilities, additional improvements in risk from injuries and violence would also help close some of the male relative disadvantage in longevity.[22], [23]

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[22] Historical data on sex differences in life style and health behaviors would help uncover how past developments in the lives of men and women may relate to present sex differences in survival probabilities. But such data are difficult (if not impossible) to assemble. As has been argued in connection with smoking, it is not unlikely that the noted reductions in mortality differences between the sexes over recent decades are manifestations of behavioral patterns and changes among cohorts of men and women as they passed through their childhood, youth and young adulthood in past years. Unfortunately, the study of sex differences in health behaviors, as researched through cross-sectional sample surveys, can only provide a limited picture of the possible behavioral causes of currently observed sex gaps in mortality and life expectancy. On the other hand, the investigation of current sex differences in health behaviors based on representative sample surveys of young adults can provide useful insight into possible sex differences in morbidity and mortality in the future once these cohorts reach old age. Epidemiological cohort studies have shown that health status at baseline predicts health status and survival chances later in life, and that negative health behaviors during the life course, such as cigarette smoking, excessive alcohol consumption, poor diet and lack of exercise, are detrimental to one's health and life span (Peters et al., 2003; Fontaine et al., 2003). In such studies psychosocial factors have also been shown to be important in predicting health

status and mortality probabilities (House, Landis and Umberson, 1988; Wilkinson, 1996; Berkman and Syme, 1979; Brockmann and Klein, 2004; Rogers, Hummer and Nam, 2000; Idler and Kasl, 1992; Marmot et al., 1997; Eaker et al., 2004; Stansfeld et al., 2002).

[23] One may speculate about the possible closing of the sex differential in the future. Calculations by Fries (1980) and others (i.e., Olshansky, Carnes and Cassel, 1990) suggest that the average human life span is not likely to exceed about 86 years. Whether this is a realistic limit is of course debatable, and alternative scenarios have been presented in the literature (see for example, Manton, 1982; Wachter and Finch, 1997; Vaupel et al., 1998; special issue of Population, 2001; Carey and Tuljapurkar, 2003). If the upper limit to the average human life span were indeed in the vicinity of 86 years, the limit would not be expected to be identical for males and females. It can be reasonably assumed therefore, that while male and female life expectancies are bound to continue to increase (though it would seem at slower rates of gain as compared to earlier periods in the 20th century---see Appendix A3), and that the differential in longevity between the sexes will constrict further, a complete closing of this gap would seem unlikely.

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Table 1: Sex gaps in life expectancy at birth for selected countries, by timing of the start of the decline in the difference, early 1970s-late 1990s/early 2000

Country and timing of narrowing	F-M difference (years) by approximate period				Change across sequential periods		
	(1) Early 1970s	(2) Early 1980s	(3) Early 1990s	(4) Late 1990s/early 2000s	(2)-(1)	(3)-(2)	(4)-(3)
Early starters (early 1970s)							
England &Wales	6.30	6.00	5.66	4.76	-0.31	-0.34	-0.90
Scotland	6.47	6.15	5.74	5.27	-0.33	-0.40	-0.47
Early followers (late 1970s/early 1980s)							
Australia	6.77	7.17	6.14	5.64	0.40	-1.03	-0.50
Iceland	5.82	6.22	5.30	5.22	0.40	-0.92	-0.08
Canada	7.17	7.33	6.56	5.35	0.16	-0.77	-1.21
Finland	8.43	8.66	8.00	6.98	0.23	-0.66	-1.02
USA	7.50	7.70	7.07	5.39	0.20	-0.64	-1.68
Netherlands	5.89	6.86	6.26	5.14	0.97	-0.60	-1.12
Norway	6.30	6.93	6.34	5.58	0.63	-0.59	-0.75
Austria	7.07	7.18	6.60	5.82	0.11	-0.58	-0.78
Denmark	5.32	6.15	5.58	4.96	0.83	-0.57	-0.61
Northern Ireland	6.04	6.41	5.89	4.95	0.37	-0.52	-0.94
Sweden	5.40	6.16	5.68	4.92	0.76	-0.48	-0.76
W Germany	6.45	6.75	6.48		0.31	-0.28	
Germany			6.55	6.11			-0.43
New Zealand	6.06	6.18	6.03	4.98	0.12	-0.15	-1.05
Belgium	6.48	6.87	6.75	6.76	0.39	-0.12	0.01
Late followers (early 1990s)							
Italy	6.22	6.66	6.74	6.31	0.44	0.08	-0.43
Malta	4.09	4.45	4.58	4.29	0.37	0.12	-0.29
France	7.72	8.25	8.41	7.64	0.53	0.16	-0.77
Ireland	4.79	5.53	5.70	5.42	0.74	0.17	-0.28
Portugal	6.51	7.02	7.23	7.01	0.51	0.21	-0.22
Switzerland	6.15	6.78	7.04	5.79	0.63	0.27	-1.25
Greece	4.31	4.60	5.28	5.24	0.29	0.68	-0.04
Poland	7.05	8.28	9.14	8.29	1.24	0.86	-0.85
Spain	5.42	6.21	7.25	7.09	0.78	1.04	-0.16
Bulgaria	4.56	5.52	6.66	6.64	0.96	1.14	-0.02
Hungary	5.88	7.48	8.98	8.44	1.61	1.49	-0.54
Continued widening							
Japan					0.11	0.87	1.03

Source: Computations based on data from World Health Organization. www.who.org. Note: East and West Germany were reunited in 1990; therefore after this date the WHO reports mortality data for Germany as a whole.

Table 2: Decomposition of the female-male differential in life expectancy at birth (e0) by period and its change due to ten cause of death components; Canada, 1971 to 2000

	Period				Change across sequential periods		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	1971	1981	1991	2000	1971-1981	1981-1991	1991-2000
Female e0	76.649	79.244	80.999	82.216	2.595	1.755	1.217
Male e0	69.479	71.915	74.438	76.869	2.436	2.523	2.431
Female e0 – Male e0	7.170	7.329	6.561	5.347	0.159	-0.768	-1.214
Decomposition (years of life expectancy)							
Heart Disease	2.956	2.800	2.067	1.468	-0.156	-0.733	-0.599
Other Circulatory	.394	.403	.352	0.302	0.009	-0.051	-0.050
Lung Cancer	.681	.885	.838	0.527	0.204	-0.047	-0.311
Breast Cancer	-.493	-.535	-.596	-0.511	-0.042	-0.061	0.085
Prostate Cancer	.228	.286	.394	0.364	0.058	0.108	-0.030
Other Cancers	.344	.591	.742	0.838	0.247	0.151	0.096
Cirrhosis of Liver	.145	.188	.140	0.120	0.043	-0.048	-0.020
Accidents/Violence (-Suicide)	1.415	1.131	.770	0.615	-0.284	-0.361	-0.155
Suicide	.272	.394	.432	0.364	0.122	0.038	-0.068
Other Causes of Death	1.228	1.186	1.422	1.260	-0.042	0.236	-0.162
Total	7.170	7.329	6.561	5.347	0.159	-0.768	-1.214
Decomposition (per cent)							
Heart Disease	41.23	38.21	31.50	27.45	-3.02	-6.71	-4.05
Other Circulatory	5.50	5.50	5.37	5.65	0.00	-0.13	0.28
Lung Cancer	9.50	12.08	12.77	9.86	2.58	0.69	-2.92
Breast Cancer	-6.88	-7.30	-9.09	-9.56	-0.42	-1.79	-0.47
Prostate Cancer	3.18	3.90	6.00	6.81	0.72	2.10	0.80
Other Cancers	4.80	8.07	11.31	15.67	3.27	3.24	4.36
Cirrhosis of Liver	2.02	2.56	2.13	2.24	0.54	-0.43	0.11
Accidents/Violence (-suicide)	19.73	15.43	11.73	11.50	-4.30	-3.70	-0.23
Suicide	3.80	5.38	6.59	6.81	1.58	1.21	0.22
Other Causes of Death	17.12	16.17	21.69	23.56	-0.95	5.52	1.89
Total	100.00	100.00	100.00	100.00	0	0	0

Source: Authors' computations based on data from World Health Organization (2003) www.who.org

Table 3: Change in the contribution of cause-of-death components to the change in F-M difference in life expectancy at birth in Canada between 1981 and 2000.

Cause component	Contribution to the change in the F-M difference in life expectancy at birth	
	(years)	%
Heart Disease	-1.332	-67.20
Other Circulatory	-0.101	-5.10
Lung Cancer	-0.358	-18.06
Breast Cancer	0.024	1.21
Prostate Cancer	0.078	3.94
Other Cancers	0.247	12.46
Cirrhosis of Liver	-0.066	-3.43
Accidents/Violence (-suicide)	-0.516	-26.03
Suicide	-0.030	-1.51
Other Causes of Death	-0.074	-3.73
Total change	-1.982	100.00

Note: A negative value for a cause component denotes that the effect of change over time in sex differences in mortality due to that cause of death served to narrow the sex gap in life expectancy; a positive sign implies the opposite effect.

Table 4: Decomposition of the female-male difference in life expectancy at birth in Canada in terms of the contribution of mortality differences within age categories between 1981 and 2000

Age	Contribution in 1981 (years of life expectancy)	Contribution in 2000 (years of life expectancy)	Change 1981-2000	%
<15	0.310	0.128	-0.182	-9.18
15-34	0.902	0.499	-0.403	-20.33
35-54	1.091	0.639	-0.452	-22.81
55-74	3.210	2.172	-1.038	-52.37
75+	1.816	1.909	0.093	4.69
Total	7.329	5.347	-1.982	100.00
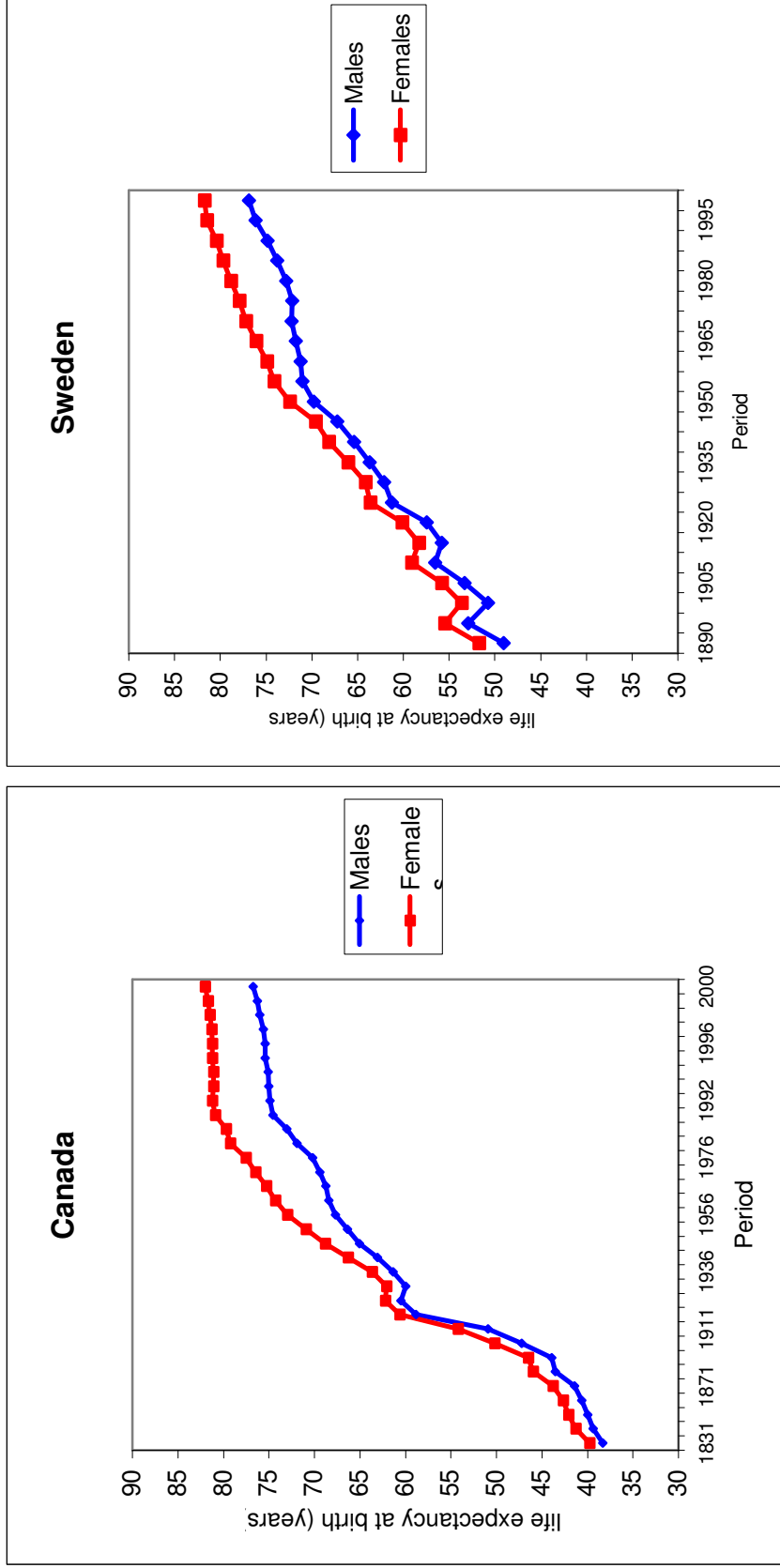
Figure 1: Historical trend in male and female life expectancy at birth in Canada and Sweden.

Sources: For Canada, Peron and Strohmenger (1985: 115); Belanger (2003: 17); Nagnur (1986). For Sweden, Statistics Sweden (2005); Statistics Sweden: http://www.scb.se/templates/tableOrChart____25831.asp; Berkley Mortality Data Base, http://www.mortality.org/.
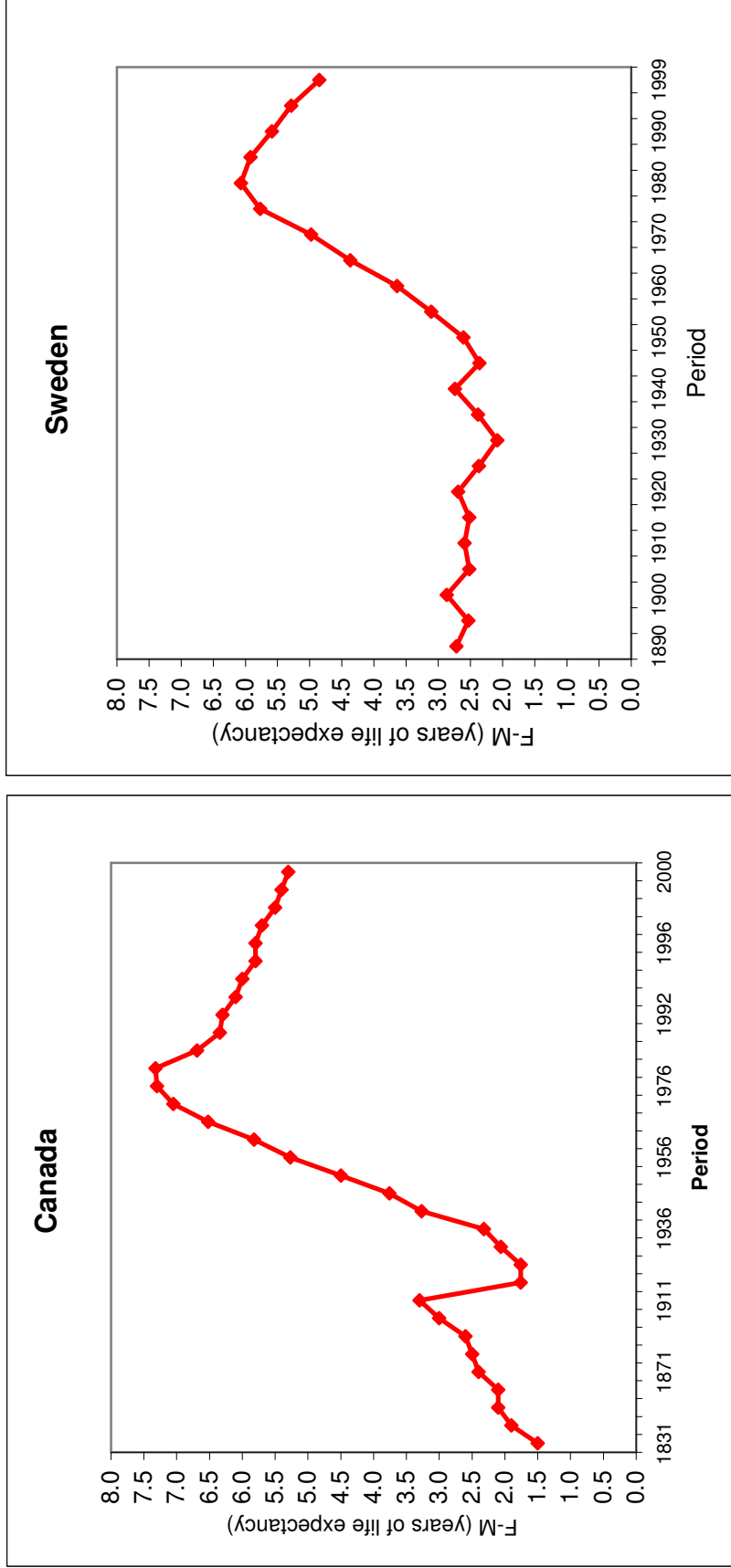
Figure 2: Historical trend in the female-male difference in life expectancy at birth in Canada and Sweden.
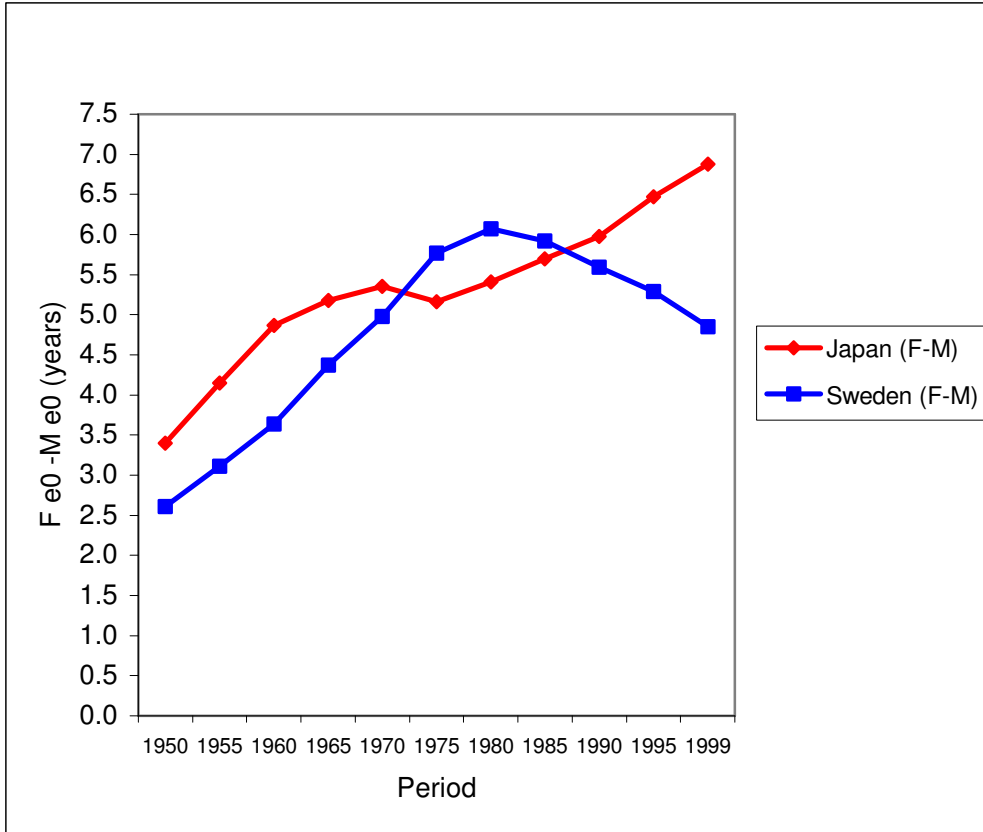
Figure 3: The differential pattern of change in the F-M gap in life expectancy at birth (e0) in Sweden and Japan, early 1950s to late 1990s.

Data sources:

Statistics Sweden: http://www.scb.se/templates/tableOrChart_____25831.asp; Berkley Mortality Data Base, http://www.mortality.org/. Japan Statistics and Information Department, Minister's Secretariat, Ministry of Health and Labour and Welfare: http://www.stat.go.jp/data/chouki/zuhyou/02-31-a.xls
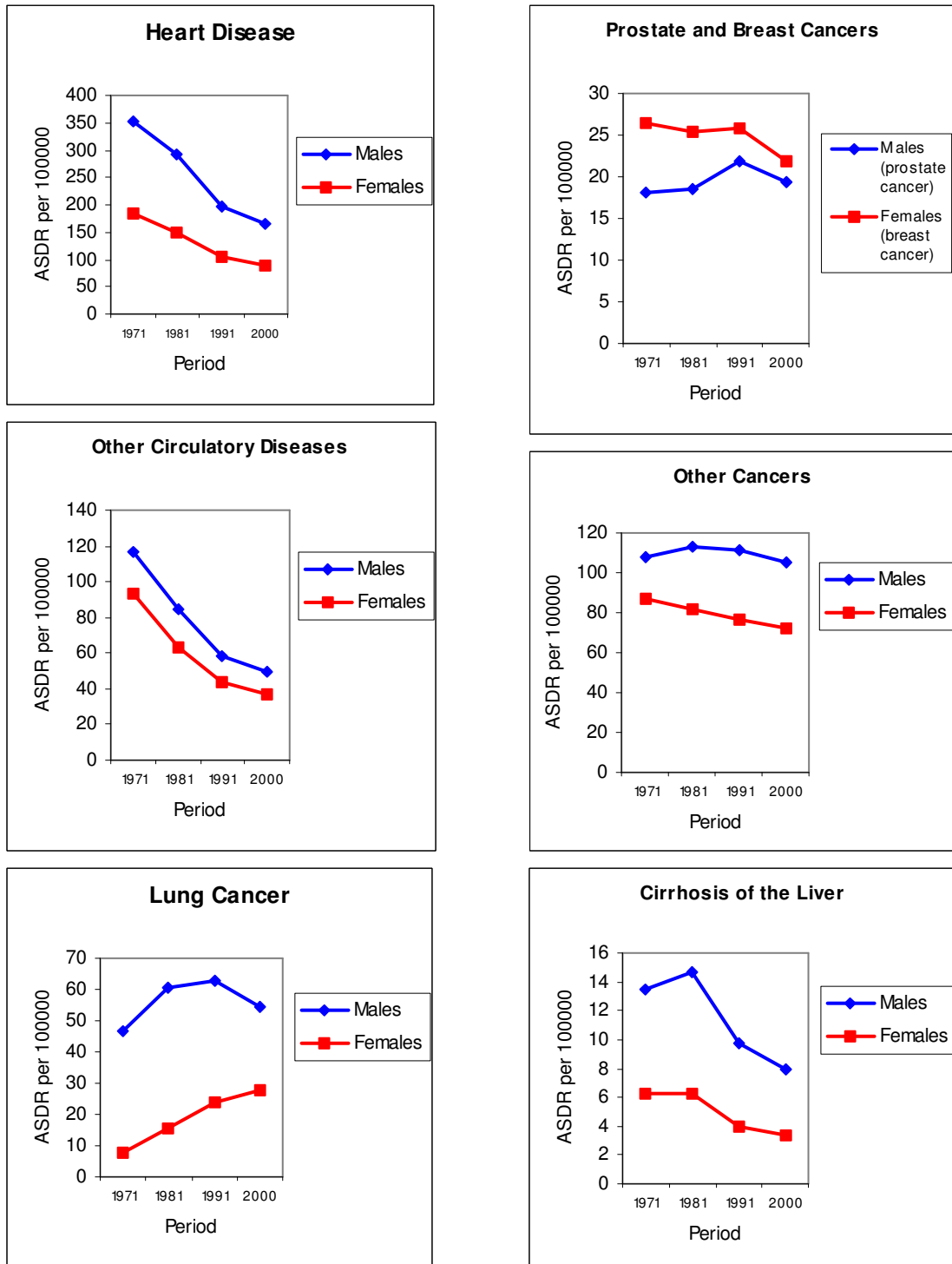
Figure 4: Age standardized death rates (per 100,000 population) (ASDRs) in Canada by sex, cause of death component, and total death rate, 1971 to 2000. Note: the standard population is the European standard million (World Health Organization, 1998).
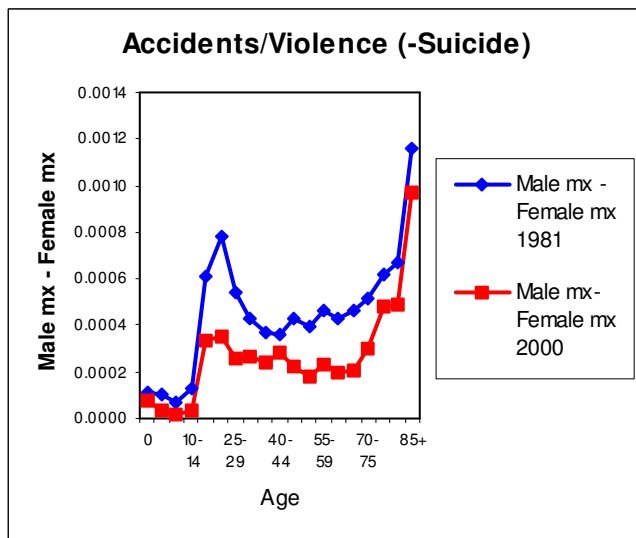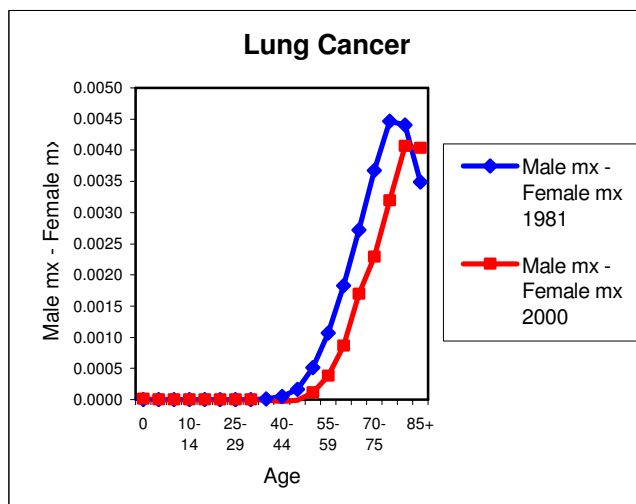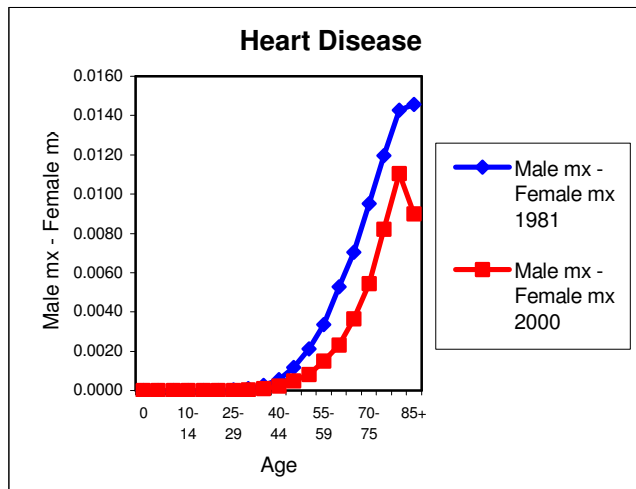
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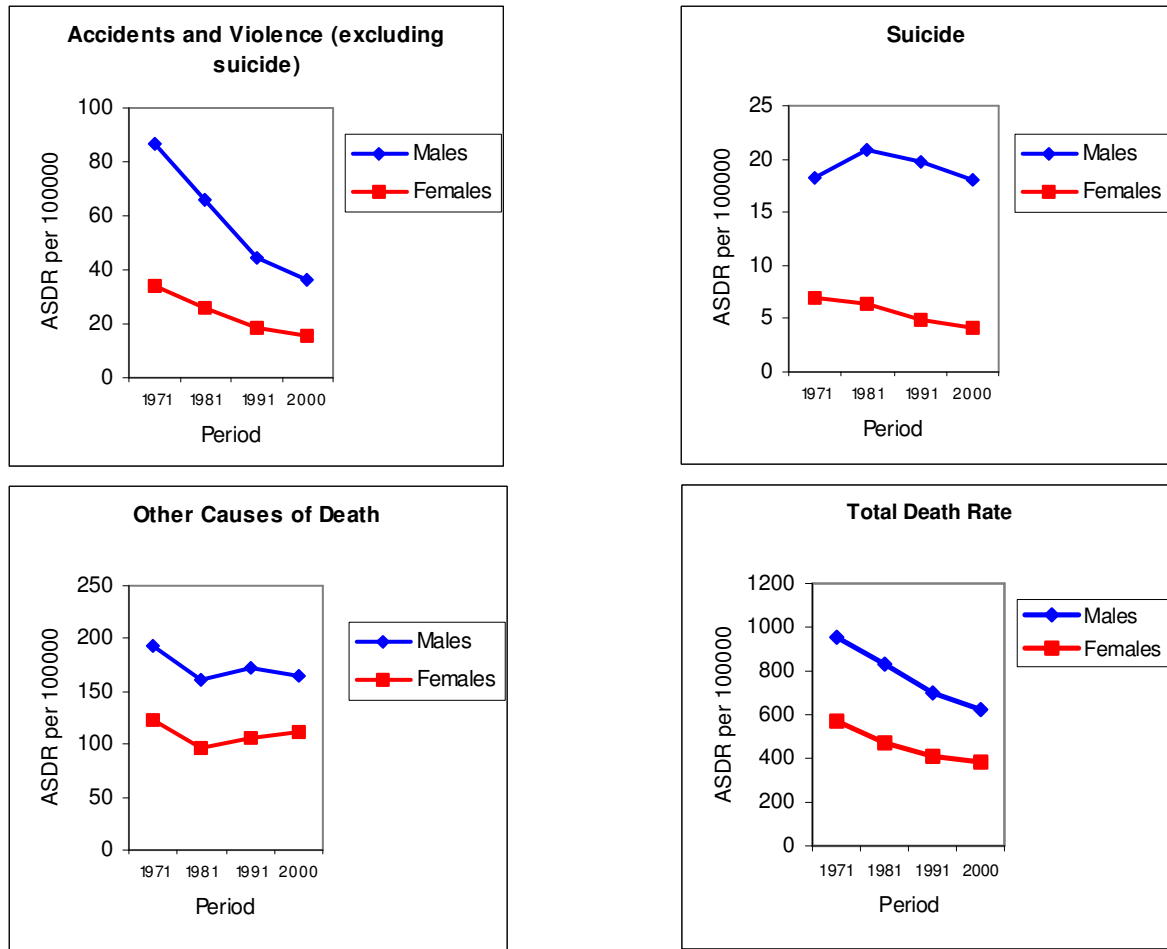
Figure 4 (continued): Age standardized death rates (per 100,000 population) (ASDRs) in Canada by sex, cause of death component, and total death rate, 1971 to 2000.
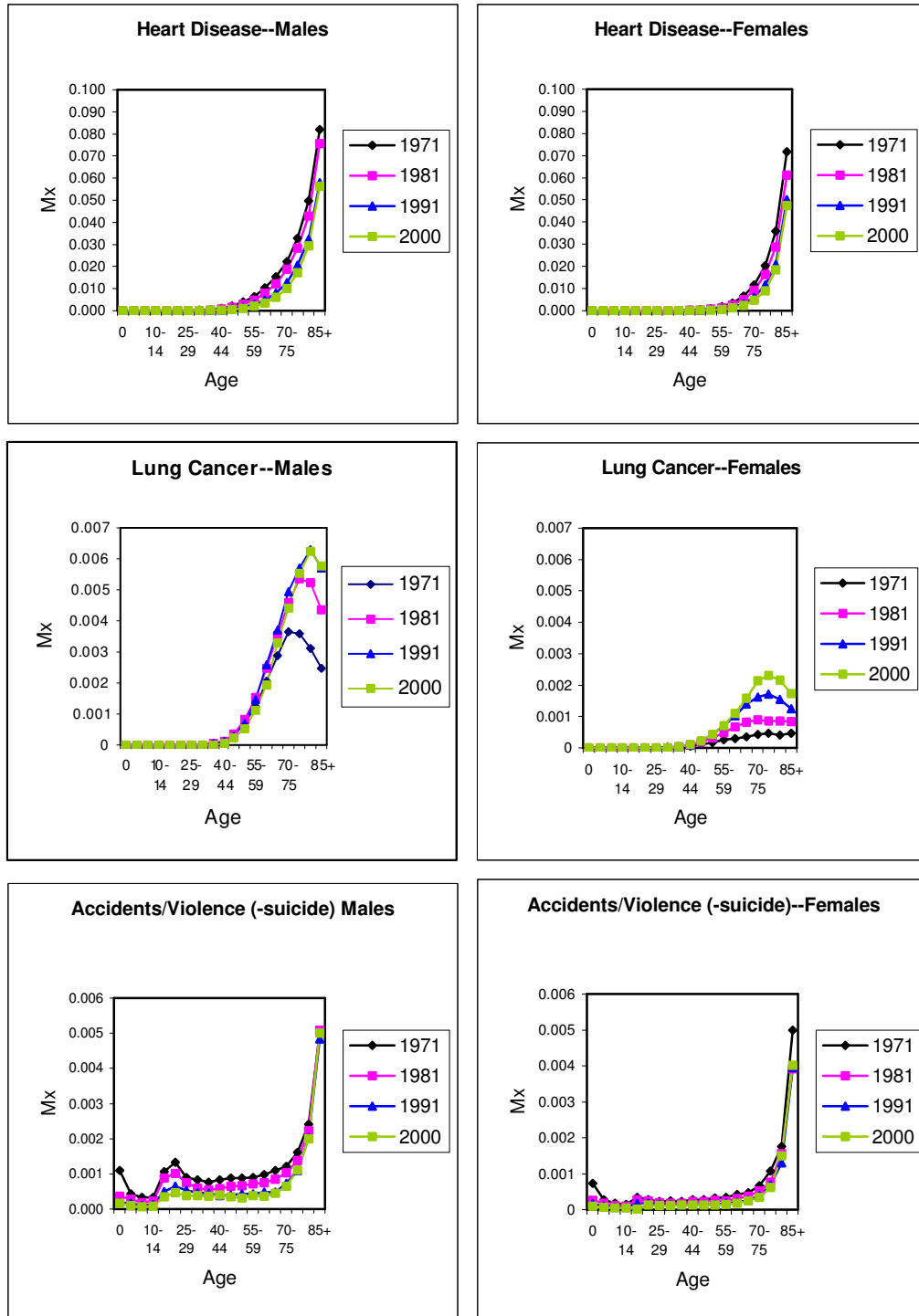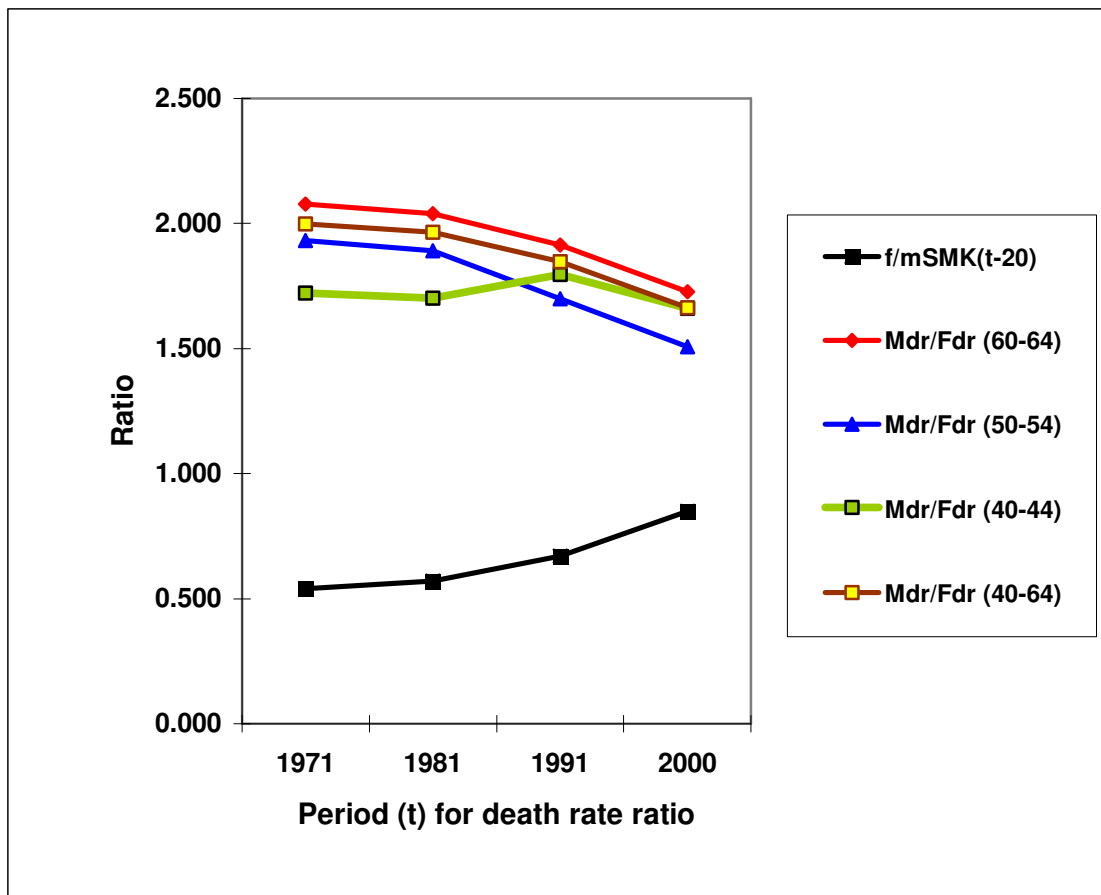
Figure 5: Age specific death rates for men and women in Canada for three cause-of-death components, 1971-2000.

Figure 6: Sex differences in age specific death rates in 1981 and 2000 for three cause-of-death components; Canada, 1981 and 2000.

Figure 7: Relationship between female/male smoking prevalence ratios lagged by 20 years (f/m SMK(t-20)), and male/female age-specific death rate ratios (Mdr/Fdr) for ages 40-44, 50-54, and 60-64, at time (t) in Canada. Where, (t) for the smoking variable is: 1951, 1961, 1971, 1981; and for the death rate ratio it is, 1971, 1981, 1991, and 2000.

Note: Smoking data are from Nicolaides-Bouman et al (1993); death rate ratios computed with data from the World Health Organization (see text).

Appendix A1: Causes of death and corresponding ICD codes

Cause of Death Category	ICD-8	ICD-9	ICD-10
1. Heart Disease	A81-A84	B25-B28	I20, I21, I22, I23-I25
2. Other Circulatory Diseases	A85-A88	B29-B30	I26-I51, I60-I69, I70, I71-I78, I80-I82, I83-I99
3. Lung Cancer	A51	B101	C33-C34
4. Breast Cancer	A54	B113	C50
5. Prostate Cancer	A57	B124	C61
6. Other Cancers (+ benign type)	A45-A48, A50, A52, A53, A55, A56, A58-A61	B08, B09, B100, B109, B110-B112, B114-B119, B120-B123, B125- B129, B13-B17	C00-C32, C53-C55, C67, C17, C23-C31, C37-C49, C51, C52, C56-C60, C62-C66, C68-C80, C97, C91-C95, C81-C90, C97, D00-D48
7. Cirrhosis of the Liver	A102	347	K70, K73-K74, K76
8. Accidents/Violence (excluding suicide)	AE138-AE146, AE148, AE150	BE470-BE53, BE55, BE56	V01-X59, Y40-Y86, Y88, X85-Y09, Y10-Y36, Y87, Y89
9. Suicide	AE147	BE54	X60-X84
10. Other causes of death	All else	All else	All else

Appendix A2: Decomposition Method

Assume life expectancy for males is totally determined by two causes of death. Define these as, *A* and *B*, where *A* = vector of age specific death rates from Heart Disease, and *B* = vector of age specific death rates for all "other" causes of death. The life expectancy for females is completely determined by the same two causes of death, defined as the vectors *a* and *b*. Thus,

$$\mathbf{F(A, B)} = e^0{}_{males} \tag{1}$$

$$\mathbf{F(a, b)} = e^0{}_{females} \tag{2}$$

We calculate two new life expectancies at birth, F(a, B) and F(A, b). Consider the four differences:

$$\mathbf{F(a, b) - F(A, b)} \tag{3}$$

$$\mathbf{F(a, B) - F(A, B)} \tag{4}$$

$$\mathbf{F(A, b) - F(A, B)} \tag{5}$$

$$\mathbf{F(a, b) - F(a, B)} \tag{6}$$

The differences (3) and (4) can be attributed to difference in Heart Disease rates for males and females since the other cause of death is held constant {as "**b**" in (3) and as "**B**" in (4)}. Similarly, the differences (5) and (6) can be attributed to the differences in "Other causes" of females and males. By adding (3), (4), (5), and (6) we get,

$$
\begin{aligned}
(3)+(4)+(5)+(6) &= \{\mathbf{F(a, b) - F(A, b)}\} + \{\mathbf{F(a, B) - F(A, B)}\} + \\
&\quad \{\mathbf{F(A, b) - F(A, B)}\} + \{\mathbf{F(a, b) - F(a, B)}\} \\
&= \mathbf{F(a, b) - F(A, B) + F(a, b) - F(A, B)} \\
&= 2\{\mathbf{F(a, b) - F(A, B)}\} \\
&= 2\{(e^0{}_{females} - e^0{}_{males})\} \tag{7}
\end{aligned}
$$

From equation (7) we can see that,

$$(e^0{}_{females} - e^0{}_{males}) = \frac{[\,\mathbf{F(a, b)} - \mathbf{F(A, b)} + \mathbf{F(a, B)} - \mathbf{F(A,B)}\,]}{2} +$$

$$\frac{[\,\mathbf{F(a, b)} - \mathbf{F(a, B)} + \mathbf{F(A, b)} - \mathbf{F(A, B)}\,]}{2}. \tag{8}$$

= Effect of Heart Disease + Effect of "Other"
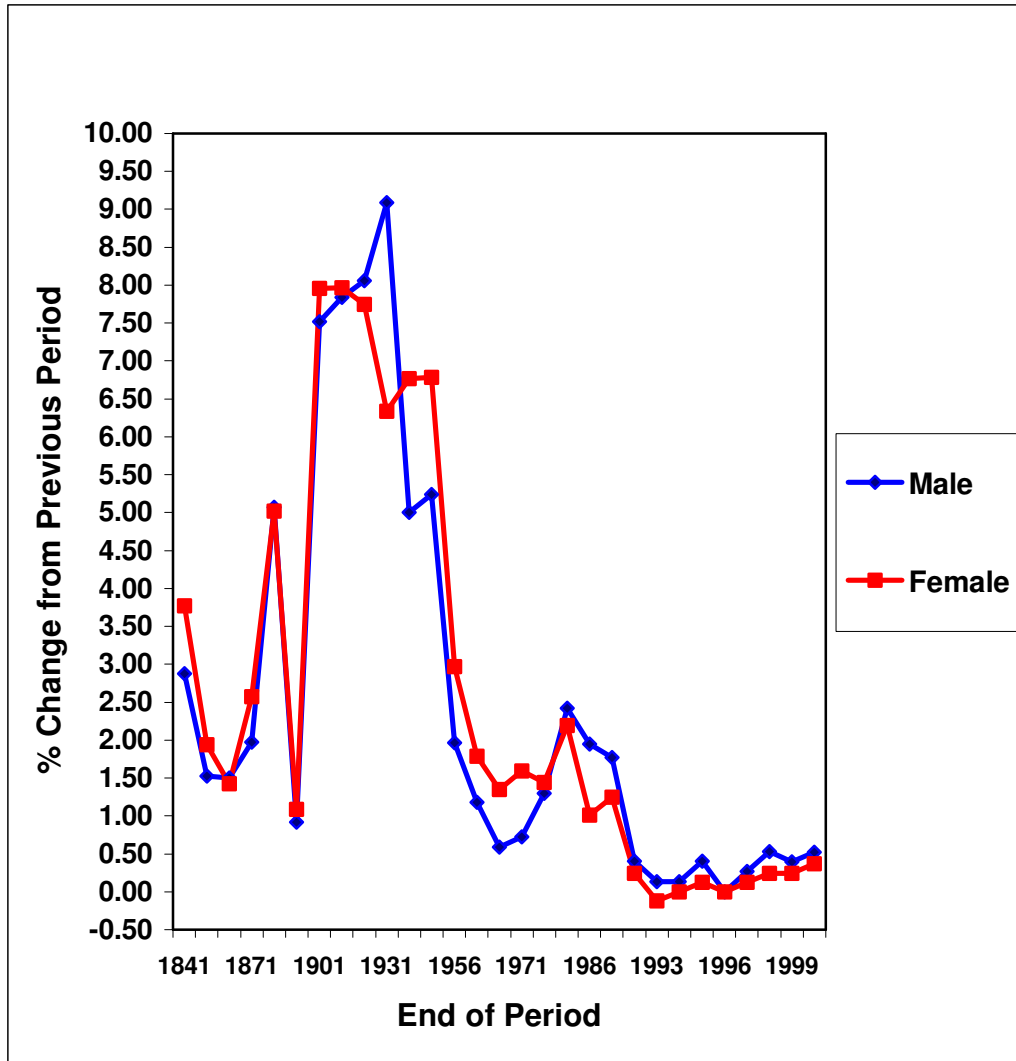
Appendix A3: Percentage change across sequential periods in male and female life expectancy at birth; Canada, 1841 to 2000