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The Narrowing Sex Differential in Mortality in Canada Since 1971

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Abstract

Around the turn of this century the expectation of life at birth for Canadian females was approximately two years above that of males. In 1921 men lived to an average age of 58.84, while females died on average at the age of 60.60. This difference rose steadily thereafter to about 7 years in 1971, at which point the gap began to contract. By 1991 the amount of convergence in this differential had reached half a year. We examine this phenomenon in Canada for the twenty-year interval between 1971 and 1991 from the point of view of the following questions: (1) What causes of death have contributed to the narrowing of the sex difference in longevity since 1971? (2) What is the relative contribution of different causes of death to the survival discrepancy within specified age categories? (3) How have cause-specific mortality differences changed over time in their impacts on the sex differential in survival? We use standardization and components analysis to address these questions.

Résumé

Au tournant du siècle, l'espérance de vie des Canadiennes à la naissance dépassait d'environ deux ans celle des Canadiens. En 1921, les hommes vivaient en moyenne 58,84 ans et les femmes 60,60 ans. L'écart allait ensuite se creuser progressivement jusqu'à 7 ans en 1971, pour diminuer ensuite et atteindre une demi-année en 1991. Nous avons examiné ce phénomène au Canada pour la période de 1971-1991 à la lumière des questions suivantes : 1) Quelles causes de décès ont contribué à réduire la différence de longévité selon le sexe depuis 1971? 2) Quelle est la contribution relative des différentes causes de décès à cet écart de survie dans les catégories d'âges étudiées? 3) Comment les différences de mortalité par cause ont-elles évolué au fil du temps et quels ont été leurs impacts sur la différentielle sexuelle en terme de survie? Nous avons utilisé des procédés de standardisation et d'analyse factorielle pour aborder ces questions.

Introduction

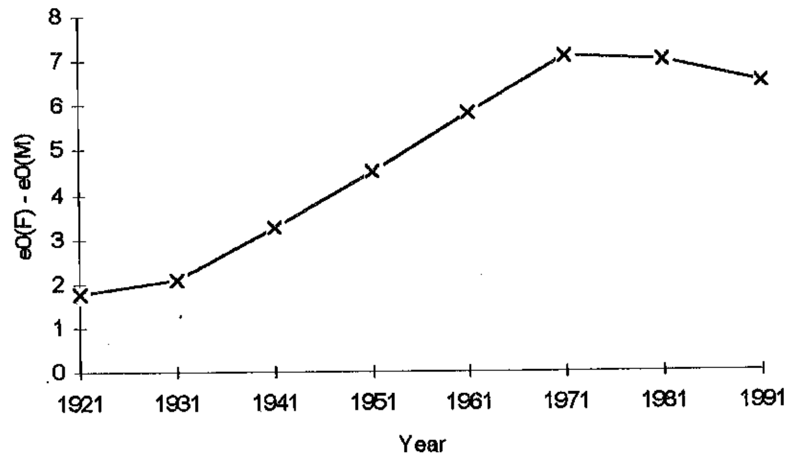
One of the most pervasive difference in humans is the longevity advantage of women over men (Madigan, 1957; Lopez and Ruzicka, 1983; Waldron, 1983, 1976; Gove, 1973; Retherford, 1975; Enterline, 1961; Nathanson, 1984; Wingard, 1984; Verbrugge, 1980, 1989, 1976; Gee and Veevers, 1983; Veevers and Gee, 1986). With few exceptions this phenomenon is universal and has persisted over historical time. Women in the industrialized countries enjoy an overall survival advantage anywhere from an average of three to seven years (Population Reference Bureau, 1993).[1] Recent evidence indicates that since the early part of the 1970s a number of societies have witnessed for the first time in their histories, a narrowing of this long-established trend.[2]

For example, in Canada, during the early stages of this century the discrepancy in life expectation was only about two years. In 1921 men lived on average 58.84 years, and females survived to the age of 60.60, for a difference of 1.76 years in favor of women. At the end of the three decades following 1921, the gap had widened to 4.5 years; and by 1961 women were enjoying an additional 5.8 years of life in relation to men. In 1971 this difference had reached its historical apex at 7.1, as in the subsequent years it would follow a declining trend. By 1981 the survival gap had narrowed to 7.0. Official figures for 1986 showed a further downturn to 6.69 years (Dumas, 1987; Peron and Strohmenger, 1985; Nagnur, 1986). The situation based on the latest Canadian life tables indicates a continuation of this pattern, such that in 1991 a baby boy could expect to live to the age of 74.19, and a baby girl would die 6.53 years later at the age of 80.72 (Statistics Canada, 1993).[3]

Few scholars had anticipated *a priori* the timing and the seeming persistence of this demographic development. Consequently, this phenomenon has not yet received much systematic attention. This trend is not unique to Canada, and represents an emerging feature of the industrialized world, raising the possibility that societies may be undergoing a new stage of epidemiological development.

In this study, we confine our observations to Canada and evaluate three questions: (1) What causes of death have contributed to the narrowing of the sex difference in life expectancy between 1971 and 1991? (2) What is the relative contribution of different causes of death to the survival discrepancy within specified age categories? (3) How have cause-specific mortality differences between the sexes changed over time in their impacts on the differential in life expectation? In our discussion section we assess the relevance of our empirical results to the substantive issues underlying this investigation, namely, the importance of bio-demographic and sociological factors for the onset of reversal in the sex gap in death probabilities.

Figure 1
Difference in e0 of Females and Males:
Canada 1921-1991



Data and Methods

Mortality data from Census and Vital Statistics classified by age (0, 1-4, 5-9,..,85+), sex, and cause of death are used in this study (Statistics Canada, 1973, 1983, 1993). For the purposes of this analysis, causes of death are grouped into six categories: (1) heart disease, (2) all cancers except that of lungs, (3) lung cancer, (4) other chronic diseases (diabetes, liver disease, cardiovascular and arteriosclerosis), (5) external causes of death (motor vehicle accidents, suicide, homicide, accidental falls, all other accidents, and undetermined causes), and (6) residual causes of death. The six causes of death will be referred to as C_1, C_2, C_3, ...,C_6. Infectious diseases were not considered separately because they account for only a small portion of the deaths in this period under consideration (they are included in the residual class C_6).

In this analysis, we apply direct standardization (using the population of Canada in 1971 as the standard to provide an overview of how Canadian men and women differ in terms of general and cause-specific mortality risk. We then develop a measure of change in the gender gap in age-specific death rates, which we refer to as the second-order difference of mortality rates. This measure if computed as follows:

$$\Delta^{t_1}_{m-f} = M^{t_1}_{asdr} - F^{t_1}_{asdr} \quad (1)$$

$$\Delta^{t_2}_{m-f} = M^{t_2}_{asdr} - F^{t_2}_{asdr} \quad (2)$$

$$\Delta(\Delta^{t_2-t_1}) = \Delta^{t_2}_{m-f} - \Delta^{t_1}_{m-f} \quad (3)$$

where $\Delta^{t_1}_{m-f}$ represents the difference in death rate between males and females at time point one; $\Delta^{t_2}_{m-f}$ corresponds to the same difference for the second period of observation, and $\Delta(\Delta^{t_2-t_1})$ indicates the second-order difference of rate differences (i.e., the difference of the differences).

Although age-specific death rates tend to decline over time for both sexes, men typically continue to have higher mortality probabilities than women. Therefore, a positive value of this index would indicate a widening of the gender gap as a function of male death rates having declined less over time than for those of females. On the other hand, if the value of this measure is negative, it would show a narrowing in the sex differential, but on such occasion convergence would result as a function of women's rates having declined less than those of men. Thus, if both $\Delta^{t_1}_{m-f}$ and $\Delta^{t_2}_{m-f}$ are positive, narrowing of the sex gap is indicated by a negative value of $\Delta(\Delta^{t_2-t_1})$.

We express the values of second-order differences as per 100,000 population. For example, under the conditions specified above, a value of -10.00 would indicate a declining sex difference in mortality over time by 10 deaths per 100,000 population, while a result of +10.00 would represent a corresponding widening of the differential by the same number of deaths. A value of zero would of course denote no change.

Another possible scenario would be if females were to have consistently higher death rates than males--as in the case of breast cancer: In this situation a positive second-order difference would reflect a narrowing of the sex gap of mortality as a result of females' death rates declining over time more than those of their male counterparts. A negative second-order difference, on the other hand, would indicate a divergence in the differential. This last possibility occurs so infrequently that it is encountered only in a few instances in our analysis. For this part of the analysis, we group deaths into six major age groups: 0-14, 15-34, 35-54, 55-74, 75-84, and 85+.

A third aspect of our analysis is to examine the partial years of life expectancy available to men and women within specified age categories, given their differential mortality levels by age and cause of death. From this information we can identify the causes of death responsible for varying length of life for men and women within different age groups.

Temporal changes in mortality are not uniform for all age groups (e.g., some age groups may change more than others and in different directions) hence age classes will vary in the extent of contribution to overall expectation of life (Arriaga, 1984). The causes of death which contribute to the death rate within a given age group will also tend to differ depending on the age category (e.g., for young adults, accidents and violence are leading killers, while for persons in the older age classes, chronic/degenerative conditions are more prevalent). In order to control for these sources of variation in our analysis, we constructed separate abridged life tables for the sexes for 1971 and 1991 (using conventional age groupings, 0, 1-4, 5-9, 85+). From these tables, we obtained the life expectancies and partial life expectations within broad age groups for men and women. The corresponding differences in life expectancies for the two points in time were subsequently decomposed into causes-of-death components.

The partial expectation of life at age x for the age interval x to $x+n$ is defined as the average number of years lived in the interval x to $x+n$ by those who reach age x, and may be expressed as follows with standard life table notation:

$$^{n}e_x = (T_x - T_{x+n})/l_x \qquad (4)$$

where T_x is the total number of person-years lived by those who reach age x ($= l_x$) between age x and the end of the life span. The partial life expectancy is not affected by mortality changes in other age groups and thus may be thought of as a measure summarizing the death rates in the selected age groups alone. It should be noted that $^{n}e_x$ has an upper limit of n which can be attained only when no one dies in the age interval x to $x+n$. For example, the partial expectation of life for age interval 15 to 44 ($^{30}e_{15}$) 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. From the definition of ${}^{n}e_x$ it can be easily seen that

$$e_0 = \sum \frac{l_x}{l_0} \, {}^{n}e_x \qquad (5)$$

Multiple decrement life tables were also computed to estimate the probability of persons dying from a given cause of death within each of the age intervals under consideration (Johnson and Johnson, 1980; Namboodiri and Suchindran, 1987; Keyfitz, 1968). To do this, cause-specific probabilities of death for each age group are calculated by applying the cause-of-death ratios to the probabilities of death in that age group from an ordinary life table. That is,

$$^{a}q_x = {}^{a}r_x \cdot q_x \qquad (6)$$

where q_x is the probability of dying in the age interval x to $x+1$ for those who are alive at age x; ${}^{a}r_x$ is the ratio of deaths due to cause a to the total number of deaths in the age group x to $x+1$; and ${}^{a}q_x$ is the probability of dying from cause a in the age interval x to $x+1$ for those who are alive at age x. These cause-specific probabilities of death are utilized as factors in the decomposition analysis of sex differences in expectation of life.

The decomposition technique deals with finding additive contributions to the difference between two rates that can be associated with compositional or rate factors (i.e., cause-specific death rates). We apply the approach of Das Gupta (1993, 1978), which is based on a generalized method first developed by Kitagawa (1955).

For the sake of explanation, let us consider only two causes of death in a multiple decrement life table. In this case, expectation of life at birth is a function of two vector factors, namely the cause-specific probabilities of death for the two causes of death for ages 0 through to the last age in the life table. The expectations of life at birth for males and females can be expressed in the following functional form:

$$e^{0} \text{ (males)} = F(A, B) \qquad (7)$$

$$e^{0} \text{ (females)} = F(a, b) \qquad (8)$$

where A is the vector of age specific probabilities of death from cause 1 for males, B is the vector of age specific probabilities of death from cause 2 for males, a is the vector of age specific probabilities of death from cause 1 for females, and b is the vector of age specific probabilities of death from cause

2 for females. The difference in expectation of life at birth between males and females is decomposed into two components in the following manner:

$$\begin{aligned} \text{Difference in } e_0 &= F(a, b) - F(A, B) \\ &= [\, F(a, b) - F(A, b) + F(a, B) - F(A, B)]/2 \\ &+ [\, F(a, b) - F(a, B) + F(A, b) - F(A, B)]/2 \qquad (9) \end{aligned}$$

The first and second components are attributable to the first and second causes of death, respectively. It is clear that the two components add up to the total gender difference in expectation of life at birth. The extension to more than two factors is straight-forward (even though the formulas are more complicated).

Change in Standardized and Age-sex Specific Death Rates

Table 1 concerns itself with overall death rates as well as age-sex specific mortality by cause for 1971, while Table 2 contains this information for 1991. Standardized rates per 100,000 population are also reported. With regard to the standardized measures, overall mortality has declined for Canadians; and the difference between the sexes have been narrowing. In 1971, the gender gap was 3.77 per 1000 in favor of females, and by 1991 it had been reduced to 2.82, representing a 25% reduction in the overall gender gap (absolute reduction is .95). When we examine death rates by cause, the overall picture remains similar: for the most part, the differentials have narrowed over time. The only exception to this pattern is in connection with cancer other than lung, where a divergence is noted, and it is primarily a result of women's larger mortality improvements in relation to men.

In the case of general mortality, the male rates always exceed those of females, irrespective of period or age category. In fact, in both time points, the age-sex-specific differences in death rates increase quite dramatically from the youngest to the older age classes. For example, during 1971, the youngest class represented a male excess mortality of 45.48 deaths per 100,000 population, while in the oldest age group males displayed a disadvantage of 3460.30 deaths per 100,000 population. A similar trend is evident in 1991, though it is important to emphasize that in comparison to the earlier period, overall death rates are considerably lower for both genders.

Table 1
Cause Specific Death Rates (per 100,000) by Age and Sex and the Difference (M-F) Between the Rates in 1971

Cause of Death		Age 0-14	15-34	35-54	55-74	75-84	85+	Standardized Death Rate#
All	Males	174.62	161.97	500.25	2756.06	9469.39	21097.00	9.46
	Females	129.14	64.92	277.22	1450.04	6217.19	17636.70	5.69
	Diff.	45.48	97.05	223.03	1306.02	3252.20	3460.30	3.77
C1	Males	0.61	5.03	172.84	1180.14	3910.00	8714.71	3.48
	Females	0.55	2.22	39.14	495.91	2618.54	7706.19	1.85
	Diff	0.06	2.81	133.70	684.23	1291.46	1008.52	1.63
C2	Males	7.97	10.66	67.70	454.35	1440.81	2292.65	1.31
	Females	6.22	9.44	107.11	405.29	949.97	1467.14	1.13
	Diff	1.75	1.22	-39.41	49.06	490.84	825.52	.18
C3	Males	...	0.35	28.69	219.05	341.11	265.78	.45
	Females	...	0.23	8.12	32.23	44.40	51.18	.07
	Diff	...	0.12	20.57	186.82	296.72	214.60	.38
C4	Males	0.90	3.92	48.07	319.15	1703.92	4607.67	1.26
	Females	0.91	3.57	32.28	239.93	1496.73	4722.92	1.06
	Diff	-0.01	0.35	15.79	79.22	207.19	-115.25	.20
C5	Males	39.79	125.07	111.91	130.38	217.95	575.63	1.03
	Females	22.47	34.37	40.92	55.40	141.03	545.91	.41
	Diff	17.32	90.70	70.99	74.98	76.92	29.72	.62
C6	Males	125.33	16.90	71.01	452.94	1855.61	4640.56	1.93
	Females	98.99	15.07	49.65	221.27	966.53	3143.37	1.17
	Diff	26.34	1.83	21.36	231.67	889.07	1497.20	.76

Notes:
... Means too few cases or non-existant number of cases
Standard population is Canada 1971
C_1 = heart disease, C_2 = all cancers except that of lung, C_3 = lung cancer, C_4 = other chronic diseases, C_5 = external causes of death, C_6 = residual causes of death

Table 2
Cause Specific Death Rates (per 100,000) by Age and Sex and the Difference (M-F) Between the Rates in 1991

Cause of Death		Age 0-14	15-34	35-54	55-74	75-84	85+	Standardized Death Rate#
All	Males	74.74	122.69	292.44	2044.57	7661.85	18025.61	6.86
	Females	59.48	44.79	165.39	1141.16	4543.29	13913.77	4.04
	Diff	15.26	77.90	127.05	903.41	3118.55	4111.84	2.82
C1	Males	1.30	3.69	63.28	635.99	2476.70	5864.09	1.95
	Females	1.15	1.68	15.43	276.51	1524.95	5089.45	1.06
	Diff	0.15	2.01	47.85	359.48	951.75	774.64	.89
C2	Males	3.81	8.78	54.60	480.39	1492.39	2605.88	1.31
	Females	2.88	8.49	71.91	381.05	912.33	1502.27	.99
	Diff	0.93	0.29	-17.31	99.34	580.05	1103.60	.32
C3	Males	...	0.39	24.38	293.28	591.86	578.18	.61
	Females	...	0.39	15.79	119.56	169.64	122.31	.24
	Diff	...	0.00	8.59	173.72	422.22	455.87	.37
C4	Males	0.41	2.64	19.44	183.02	925.74	2462.20	.67
	Females	0.40	1.89	13.91	119.96	688.42	2537.11	.51
	Diff	0.01	0.75	5.53	63.06	237.31	-74.92	.16
C5	Males	13.03	83.73	67.29	74.77	174.96	510.98	.63
	Females	8.32	21.42	21.45	33.14	105.19	385.21	.23
	Diff	4.71	62.31	45.84	41.63	69.77	125.77	.40
C6	Males	56.12	23.47	63.47	377.11	2000.20	6004.29	1.70
	Females	46.66	10.92	26.92	210.94	1142.75	4277.41	1.01
	Diff	9.46	12.55	36.55	166.17	857.45	1726.87	.69

Notes:
... Means too few cases or non-existent number of cases
\# Standard population is Canada 1971
C_1 = heart disease, C_2 = all cancers except that of lung, C_3 = lung cancer, C_4 = other chronic diseases, C_5 = external causes of death, C_6 = residual causes of death

Table 3 shows that over the twenty-year interval under observation, males have enjoyed greater degrees of reduction in their age-specific death rates (with the exception of the oldest age group, 85+). The largest narrowing in the sex gap of age specific death rates appears to have been made in the ages of 55-74 and 75-84 (-402.61 and -133.54 per 100,000 population, respectively). Also notable is the amount of convergence in middle-age (-95.98) and among 0-14 year olds (-30.22). The lowest improvements for men in comparison to women occurred among those aged 15-34 (-19.15).

Heart disease death rates for the ages beyond 0-14 declined over time for both men and women. Notwithstanding this trend, the male excess in mortality from this cause of death remains substantial, ranging from a disadvantage of only .06 and .15 per 100,000 in the age range between 0 and 14 in 1971 and 1991, respectively, to very large excesses of 1291.46 and 951.75 within the ages of 75-84 in both 1971 and 1991.

However, when one examines the changes in the male/female differentials across age categories, Table 3 indicates that over time men have made greater degrees of improvement in comparison to women. This can be seen by the negative values of the second-order differences, where although not in a linear fashion, the male gains become more significant with advancing age: Among 35-54 year olds, there was a narrowing in the sex differential of -85.85 per 100,000, and it was -324.75 among those aged 55-74, peaking at -339.71 for the 75-84 year olds; at age 85+ the change reduced to -233.89. From this evidence one may conclude that the sex differential in heart disease mortality has narrowed within virtually all age categories (with the exception of ages 0-14, where a very slight divergence is noticeable).

With the exception of 35-54 year olds, mortality from cancer excluding that of the lung appears to be consistently higher among Canadian men. The higher death rates for 35-54 year old women are most likely associated with their greater risk of succumbing to breast cancer during this stage of their lives and perhaps also to cancers of the reproductive system. It is interesting, however, that from the age of 35 and beyond, the corresponding second-order differences are positive, denoting that in comparison to men, women have made more progress in cutting down their mortality from this disease category.

Between 1971 and 1991, the large male disadvantage in risk due to lung cancer narrowed for those in the ages of 15 through to 74 and widened thereafter (Table 3). The second-order differences for this age range are rather small in comparison to the large positive changes for the advanced ages. In 1971 the male disadvantage varied from only .12 among 15-34 year olds, to 296.72 and 214.60 per 100,000 in the 75-84 and 85+ age groups, respectively. The data in Tables 1 and 2 show that death rates for men aged 35-54 declined over time (from 28.6 to 24.38), while those of females in this same age group almost doubled (from 8.12 to 15.79).

At subsequent ages both sexes experienced a rise in lung cancer mortality, but the change in this respect is more dramatic for women. Among Canadians aged 55-74, lung cancer mortality went up by only 34% for men, but rose by a startling 241% for women. For those aged 75-84, the situation is similar: men experienced an increase in risk by 73%, while the risk for females shot up by 282%. Finally, the mortality of women aged 85+ rose by 139%, and the odds for men went up by 118%. Given these patterns of change in lung cancer mortality, the increases in risk between 1971 and 1991 have materialized at a slower pace for males than females.

For the other chronic diseases category (C4), Tables 1, 2, and 3 show that over time both genders have enjoyed notable reductions in their mortality rates. But with the exception of the oldest age group, male rates consistently exceed those of females. In terms of second-order differences, however, there has been some convergence in the sex gap in mortality for persons aged 35-54 and 55-74. Within the remaining age categories the gap has actually widened, but more noticeably among those aged 75 and above.

Men tend to have higher death rates from accidents, violence and suicide by a considerable margin (two to three times the rates of females in 1971, and somewhat lower in 1991). The most vulnerable are persons in their twilight years. This is largely a reflection of increased risk of fatal accidents among the aged. Another possible component in this may be an increased tendency for older people to commit suicide. Notwithstanding the large male disadvantage in this cause, Table 3 indicates that men have made significant mortality improvements in comparison to females. In fact, with the exception of age 85+, all age-specific second-order differences are negative.

Male death rates from residual causes declined over time for those aged 0-14, 35-54, and 55-74, but increased among those aged 15-34, 75-84, and 85+ (see Tables 2 and 3). The situation for women is somewhat different in that only at age 85+ is there evidence of a rise in risk over time. However, male/female discrepancies in age-specific mortality actually narrowed in the age groups of 0-14, 55-74 and 75-84. Divergence occurred among those aged 15-34, 35-54, and 85+ (see Table 3).

Table 3
Male-Female Difference in Death Rates in 1971 and 1991
and its Change Over the Period

Cause of Death		Age 0-14	15-34	35-54	55-74	75-84	85+	Difference in ASDR
All	1971	45.48	97.05	223.03	1306.02	3252.20	3460.30	3.77
	1991	15.26	77.90	127.05	903.41	3118.55	4111.84	2.82
	Change	-30.22	-19.15	-95.98	-402.61	-133.64	651.54	-.95
C1	1971	0.06	2.81	133.70	684.23	1291.46	1008.52	1.63
	1991	0.15	2.01	47.85	359.48	951.75	774.64	.89
	Change	0.09	-0.80	-85.85	-324.75	-339.71	-233.89	-.74
C2	1971	1.75	1.22	-39.41	49.06	490.84	825.52	.18
	1991	0.93	0.29	-17.31	99.34	580.05	1103.60	.32
	Change	-0.82	-0.93	22.10	50.28	89.21	278.09	.14
C3	1971	...	0.12	20.57	186.82	296.72	214.60	.38
	1991	...	0.00	8.59	173.72	422.22	455.87	.37
	Change	...	-0.12	-11.98	-13.10	125.50	241.27	-..01
C4	1971	-0.01	0.35	15.79	79.22	207.19	-115.25	.20
	1991	0.01	0.75	5.53	63.06	237.31	-74.92	.16
	Change	0.02	0.40	-10.26	-16.16	30.13	40.34	-.04
C5	1971	17.32	90.70	70.99	74.98	76.92	29.72	.62
	1991	4.71	62.31	45.84	41.63	69.77	125.77	.40
	Change	-12.61	-28.39	-25.15	-33.35	-7.15	96.05	-.22
C6	1971	26.34	1.83	21.36	231.67	889.07	1497.20	.76
	1991	9.46	12.55	36.55	166.17	857.45	1726.87	.69
	Change	-16.88	10.72	15.19	-65.50	-31.62	229.68	-.07

Notes:
... Means too few cases or non-existent number of cases
C_1 = heart disease, C_2 = all cancers except that of lung, C_3 = lung cancer, C_4 = other chronic diseases, C_5 = external causes of death, C_6 = residual causes of death

To summarize this part of our investigation, the change in male/female death differences between 1971 and 1991 indicates that in the case of overall mortality, there emerged a clear pattern of reduced sex differentials. Men have been diminishing their disadvantage in comparison to women as a result of their larger mortality improvements. However, for some causes of death the sex gap in mortality has been widening to the detriment of males (for example, among 15-34 and 55-74 year olds, we saw a divergent trend in the case of residual causes of death; and among persons aged 35-54 and 85+, a similar pattern was noted in connection with cancer other than that of the lung; in the oldest age class, increased sex differences were observed in connection with lung cancer). Considerable reductions in the male/female differential were noted with regard to heart disease mortality, with the largest reduction occurring among those aged 75-84, followed closely by those in the age groups of 85+ and 55-74.

Decomposition Analysis

In this section of the study, we decompose the sex differential in life expectation in 1971 and 1991 from the point of view of the relative contribution of the six cause of death categories examined earlier. By comparing the results of decomposition across two time periods, we can observe the changing relevance of these causes of death on change in the sex gap in life expectancy. As was indicated earlier, the decomposition is executed first for all ages combined (Table 4) and then for specific broad age classes (Table 5).

In Table 4, the sex gap in overall life expectancy during 1971 was 7.087 years, and by 1991 it had been reduced to 6.523. What accounts mostly for the differential over the two periods are the effects of heart disease, external causes, and the residual category of mortality. The relative contributions of heart disease and external causes to the sex differential have been steadily declining over time while those of other causes have been increasing. Reductions in gender related risk of heart disease mortality account for 41.4% of the longevity gap in 1971, but contribute 31.4% in 1991. On the other hand, cancers, other than that of lung cancer and other chronic conditions, tend to account for an increasing portion of the gender difference in average length of life, and their relative importance tend to magnify over time. Also of interest is the trend for external causes, where its relative contribution to the differential actually declined from 24% in 1971 to 19% in 1991. This provides further confirmation that since the early seventies, males have been reducing their relative disadvantage in premature mortality from external causes of death. Across time, heart disease emerges as the most important cause of death in explaining period-specific sex differences in survival, while external and residual causes account for the next most important sources of the based survival differential, followed by lung cancer, other chronic conditions, and finally other cancers.

In 1971, if heart diseases alone differed between males and females while holding constant (i.e., standardizing) all other causes of death, the sex gap in life expectation would have been 2.937 (= 41.437% of 7.087) and the corresponding gap in 1991 would be 2.084 years (=31.401% of 6.523). Thus if we consider the net effects of heart disease, its impact on the temporal change in the sex differential in the length of life would be to reduce it by .889 years (=2.048 - 2.937). Similar calculations were done for each of the remaining causes of death: external causes were responsible for a reduction in the sex gap by .471 years; cancer, except that of the lung, raised the differential by .453, lung cancer by .156, other chronic conditions, by .041, and residual causes increased it by .144.

Table 4
Decomposition of Sex Difference in Expectation of Life at Birth by Cause of Death and Period

	1971	1991
e_0 for Males	76.421	80.937
e_0 for females	69.333	74.414
Difference	7.087	6.523
Decomposition		
C1	41.437	31.401
C2	1.082	8.129
C3	9.903	13.147
C4	4.739	5.787
C5	23.743	18.586
C6	19.095	22.951
Total	100.000	100.000

Note:
C_1 = heart disease, C_2 = all cancers except that of lungs,
C_3 = lung cancer, C_4 = other chronic diseases, C_5 = external causes of death, C_6 = residual causes of death

Table 5 displays decomposition of the sex difference in expected years of life lived within a given age interval in the presence of the influence of six cause-of-death categories. Beginning with age 0-14, we note that mortality is very low in this age group; and both sexes live out virtually all of the 15 years in the interval. The female advantage is negligible. The longevity differential changed from .084 of a year in favor of women in 1971 to only .023 in 1991, mostly as a result of changes in male/female differences in residual and external causes of death, respectively. Over time, external causes have been contributing less to this difference, while residual causes have been accounting for an increasing portion.

Between the ages of 15 and 35, the female advantage in terms of partial life expectancy reduces from .198 of a year in 1971 to .145 in 1991. Clearly, the most important source of the differential is male/female discrepancies in external causes of death, accounting for 93.5% in 1971, and 85.2% in 1991. Thus, as indicated earlier in our previous analysis, over time there has been a reduction in the male mortality disadvantage in this age class, and a large part of this change is the result of their somewhat greater success in lowering their risk from external cause of premature death.

Within the age category of 35-54, the slight female advantage in survival during 1971 declined over time. About 44% of the sex difference in longevity is due to the effects of gender discrepancies in external causes of death. Heart disease is also important, although its impact reduces from about 53% in 1971 to 31% in 1991. If we consider cancers other than that of lung, males would have had an advantage of .005 years (-18% of 0.301) in 1971 and only of .003 in 1991(-16% of 0.201). Male/female discrepancies in lung cancer and other chronic conditions account for relatively little of the sex gap in survival, but the fact that the relative contribution of lung cancer diminishes over time supports our earlier conclusion that female mortality from this cause has risen over the study period and at a more accelerated pace than that for males.

Sex differences in partial expectation of life are considerably larger in the older ages. Among 55-74 year olds in 1971, females had 1.791 additional years of life over men. In 1991 this difference changed to 1.222. Gender difference in heart disease is the major source of this differential, accounting for almost 56% in 1971 and 42% in 1991. Sex difference in lung cancer is also important in explaining this phenomenon, but to a lesser extent. What is particularly interesting is the increasing contribution of lung cancer to reducing the sex gap in longevity, indicating that it is becoming a more important cause of death in this regard. Male/female differences in other chronic conditions and in external causes are also important, but to a lesser degree than heart disease and lung cancer.

Table 5
Decomposition of Sex Difference in Expected number of Years Lived within Specified Age Groups by Cause of Death and Period

Age	Sex and Cause of Death	Year 1971	1991
0 - 14		*Expected number of years lived in the age interval*	
	Females	14.728	14.895
	Males	14.644	14.872
	Difference	.084	.023
		Decomposition of difference expressed as percentage	
	C1	.090	1.520
	C2	2.056	4.518
	C3	.000	.224
	C4	-.028	.327
	C5	23.443	16.723
	C6	74.438	76.688
	Total	100.000	100.000
15 - 34		*Expected number of years lived in the age interval*	
	Females	19.881	19.921
	Males	19.684	19.776
	Difference	.198	.145
		Decomposition of difference expressed as percentage	
	C1	1.623	1.668
	C2	2.292	2.045
	C3	.063	.068
	C4	.165	.349
	C5	93.528	85.174
	C6	2.330	10.695
	Total	100.000	100.000
35 - 54		*Expected number of years lived in the age interval*	
	Females	19.593	19.742
	Males	19.292	19.541
	Difference	.301	.201
		Decomposition of difference expressed as percentage	
	C1	52.795	31.304
	C2	-18.154	-16.117
	C3	7.232	4.085
	C4	6.390	3.211
	C5	44.010	44.125
	C6	7.728	33.393
	Total	100.000	100.000

Table cont'd.

Table 5 cont'd.

Age	Sex and Cause of Death	Year 1971	1991
55-74		*Expected number of years lived in the age interval*	
	Females	17.884	18.406
	Males	16.092	17.184
	Difference	1.791	1.222
		Decomposition of difference expressed as percentage	
	C1	55.690	42.070
	C2	1.182	9.379
	C3	14.323	18.944
	C4	6.131	6.798
	C5	6.601	5.719
	C6	16.073	17.090
	Total	100.000	100.000
75+		*Expected number of years lived in the age interval*	
	Females	10.638	12.686
	Males	8.449	9.644
	Difference	2.188	3.043
		Decomposition of difference expressed as percentage	
	C1	37.548	27.030
	C2	16.596	20.710
	C3	9.738	13.384
	C4	2.337	4.535
	C5	2.101	2.488
	C6	31.681	31.854
	Total	100.000	100.000

Note:
C_1 = heart disease, C_2 = all cancers except that of lung, C_3 = lung cancer, C_4 = other chronic diseases, C_5 = external causes of death, C_6 = residual causes of death

As demonstrated in Table 5, substantial sex discrepancies in survival are evident in the two oldest age categories, ranging from just under one year of partial life expectancy (for 85+ in 1971) to one and-a-half years (for 85+ in 1991). For 75-84 year olds the difference goes up from 1.002 in 1971 to 1.031 in 1991. At age 85+, however, the sex gap has been widening over time. Gender variation in heart disease and cancer (both types) explain most of the sex differential in life expectancy in these two age classes. Residual causes account for a considerable portion of the differences as well. Over time, lung cancer has increased its contribution to the sex differential in longevity. The oldest age category (85+) represents a case where the traditional pattern of sex differences in mortality, and hence life expectancy, still prevails. This is largely the result of men's higher death rates from heart disease and cancers, which over the years have tended to increase more rapidly in comparison to women.

Conclusions and Discussion

A non-negligible component of the observed changes in survival between 1971 and 1991 for Canadian men and women is related to men having made somewhat larger mortality improvements from heart disease and external causes of death (e.g., accidents, violence, suicide), both of which are known to be highly associated with behavioural orientations and pre-dispositions. This change is most pronounced after age 35 in the case of heart disease, and was observed across all age categories with respect to external conditions with the exception of age 85. It was also shown that the sex difference in lung cancer has narrowed in the age group 35-54; and this is also true in connection with other chronic conditions, and external causes of death. Among 15-34 year olds, some reduction of the sex differential was noted in conjunction with external causes of death.

This analysis of decreasing sex differentials in mortality between 1971 and 1991 in Canada should stimulate further thought surrounding the issue of future sex differences in longevity. Advanced nations of the world may be embarking on a new phase of epidemiological transition, where one of its distinguishing characteristics may be a continued reduction in the gender gap in survival. This phenomenon has implications for further refinement to theories of future mortality patterns in the industrialized world (e.g., Fries, 1980; Manton, 1982).

Some authors have proposed that the average human life span has an upper limit of around 86 years (e.g., Olshanky, Cassell and Carnes, 1990; Coale, 1992).[4] Under the postulates of this perspective, further life expectancy gains for women in the more advanced nations should evolve at slower rates of change than during earlier phases of epidemiological evolution, as they now close to this upper limit. For men, on the other hand, there is a wider margin for further improvement because their death probabilities continue to surpass those of females in virtually all age classes and for all major causes of death. Therefore, survival gains for men should continue to proceed at a more accelerated pace over the next century, until some point where the degree of convergence may ultimately approach a minimum. It seems unlikely that this limit would be zero, as there may be immutable biological bases for the female advantage in survival (Carnes and Olshansky, 1993; Olshansky and Carnes, 1994; Waldron, 1976).

Notwithstanding the role of biological factors, explanation and prediction of future sex differences in life expectancy must also rely heavily on the role of sociological factors. For the most part, the underlying bases for men's survival deficit, are grounded in the environment of the "male world" (i.e., riskier life styles and pre-dispositions associated with gender roles and social conventions, etc.). Thus, continuation of male mortality improvements will depend to a large extent on how the "male world" evolves over time.

The long-established sex differential in life expectancy in Canada will persist well into the next century. But if the recent trend in reduced gender differences in life expectancy is any indication of the future, the survival discrepancy should become increasingly smaller, not only as a function of a possible "ceiling" effect on the maximum attainable life expectation, and women's close proximity to it, but also as a result of improvement in male health behaviours on the one hand, and possibly continued erosion of female survival advantages from certain causes of death, particularly external conditions (accidents, suicide, violence) and also lung cancer. This situation is exacerbated by what appears to be a growing tendency among younger cohorts of women to adopt behaviours which have traditionally contributed to the male deficit in longevity (e.g., smoking).

Footnotes

1. See El-Badry (1969), Nadarajah (1983), and D'Souza and Chen (1980) for exceptions based on the experience of developing countries.

2. In the period between the early 1970s and the early 1990s, Trovato and Lalu (1996) report that 12 industrialized societies showed for the first time in their histories the beginning of convergence in their gender gaps in life expectancy at age zero. These countries are: Hong Kong, Iceland, Austria, United States, Scotland, United Kingdom, Canada, Australia, Finland, USSR, New Zealand, and Switzerland. The amount of narrowing ranges from 1.85 years (Hong Kong) to .02 of a year (Switzerland).

3. After completing this study, Statistics Canada published a Bulletin indicating that previously published life tables for 1986 and 1991 for the nation underestimated life expectancy because the base populations for the computation of death rates had not been adjusted (i.e., inflated) for census under-enumeration and for non-permanent residents. According to the revised figures, as reported in the *Daily* (June 2, 1995), the life expectations at age zero for Canadian men and women in 1986 and 1991 should be:

	1986		1991	
	Male	Female	Male	Female
e0	73.30	79.94	74.55	80.89
F-M	6.64		6.34	

If we take into consideration the revised estimates shown above and include them in our own computations, this would actually serve to increase the extent of convergence in the sex gap in life expectancy at age zero. With our data, between 1971 and 1991 the amount of convergence in the differential is -.57. If we incorporate the new 1991 figures for the sex gap (6.34), with our computed 1971 figures (7.01), the second-order difference would show a narrowing of -.76 (i.e., 6.34 -7.1= -.76). We substituted life expectancies for 1971 published in official vital statistics into our computations, and the amount of narrowing was -.53, which is very close to the reported figure of -.57. Thus, it seems unlikely that our substantive conclusions would change had we used revised population estimates in our analyses.

Not all demographers agree with this proposition. There are two main schools of thought on the issue of what may be the maximum attainable average life span for humans. The Compression of Morbidity and Mortality school contends that the limit is around the age of 85, and that it is highly unlikely that the average life span will move beyond this value due to the effects of senescence associated with the aging process (Fries, 1980; Olshansky, Carnes and Cassel, 1990). The Expansion of Survival theorists maintain that in the near future (e.g., in 25 to 50 years from now), biomedical improvements and therapies will raise the average human life span beyond the age of 85 and could reach levels in the vicinity of 100 years or more (Manton, 1982; Manton, Stallard and Tolley, 1991; Vaupel and Lundstrom, 1994; Kannisto et al., 1994).

References

Arriaga, E.E. 1984. Measuring and explaining the change in life expectancies. *Demography* 21(1):83-96.

Carnes, B. and S.J. Olshansky. 1994. Evolutionary perspectives on human senescence. *Population and Development Review* 19(4):793-806.

Coale, A.J. 1992. The possible future of mortality in Europe and North America. Paper presented at the annual meetings of the Population Association of America, St. Louis, Missouri.

Das Gupta, P. 1978. A general method of decomposing a difference between two rates into several components. *Demography* 15(1): 9-112.

Das Gupta, P. 1993. Standardization and decomposition of Rates: A user's manual. U.S. Department of Commerce, (Cat. No. P23-186) Washington, DC.

D'Souza, S. and L.C. Chen. 1980. Sex differentials in mortality in rural Bangladesh. *Population and Development Review* 6(2):257-270.

Dumas, J. 1987. Current demographic analysis. Report on the demographic situation in Canada 1986. Ottawa: Minister of Supply and Services Canada. (Catalogue 91-209 E).

El-Badry, M.A. 1969. Higher female than male mortality in some countries of South Asia: A digest. *Journal of the American Statistical Association* 64:1234-1244.

Enterline, P.E. 1961. Causes of death responsible for recent increases in sex mortality differentials in the United States. *Milbank Memorial Fund Quarterly* 39:312-328.

Fries, J.F. 1980. Aging, natural death, and compression of mortality. *The New England Journal of Medicine* 303:130-135.

Gee, E. 1986. The life course of Canadian women: Historical and demographic analysis. *Social Indicators Research* 18:263-283.

Gee, E.M. and J.E. Veevers. 1983. Accelerating differentials in mortality: An analysis of contributing factors. *Social Biology* 30(1):75-85.

Gove, W.R. 1973. Sex, marital status and mortality. *American Journal of Sociology* 79:45-67.

Johnson, N. and R.C. Johnson. 1980. *Survival Models and Data Analysis*. New York: John Wiley and Sons.

Kannisto,V.J., Lauritsen, A.R. Thatcher and J.W. Vaupel. 1994. Reductions in mortality at advanced ages: Several decades of evidence from advanced countries. *Population and Development Review* 20(4):793-810.

Keyfitz, N. 1968. *Introduction to the Mathematics of Population*. Massachusetts: Addison-Wesley.

Kitagawa, E.M. 1955. Components of a difference between two rates. *Journal of the American Statistical Association* 50(272):1168-1194.

Lopez , A.D. and L.T. Ruzicka. 1983. *Sex Differentials in Mortality: Trends, Determinants and Consequences*. Canberra, Australia: Department of Demography, Australian National University Printing Press.

Nadarajah, T. 1983. The transition from higher female to higher male mortality in Sri Lanka. *Population and Development Review* 6(2):257-270.

Madigan, F.C. 1957. Are sex mortality differentials biologically caused? *Milbank Memorial Fund Quarterly* 35(2):202-223.

Manton, K.G., E. Stallard and H.D. Tolley. 1991. Limits to human life expectancy: Evidence, prospects and implications. *Population and Development Review* 17(4):603-638.

Manton, K.G. 1982. Changing concepts of mobility and mortality in the elderly population. *Milbank Memorial Fund Quarterly/Health and Society 60*:183-244.

Nagnur, D. 1986. Longevity and historical life tables: 1921-1981 (Abridged), Canada and the Provinces. Ottawa: Minister of Supply and Services Canada (Catalogue 89-506).

Namboodiri, K. and C.M. Suchindran. 1987. *Life Table Techniques and Their Applications*. New York: Academic Press.

Nathanson, C.A. 1984. Sex difference in mortality. *Annual Review of Sociology* 10:191-213.

Olshansky, S.J. and A.B. Ault. 1986. The fourth stage of epidemiologic transition: The age of delayed degenerative diseases. *The Milbank Quarterly* 46(3):355-391.

Olshansky, S.J., B.A. Carnes and C. Cassel. 1990. In search of Methuselah: Estimating the upper limits to human longevity. *Science* 250:634-640.

Population Reference Bureau. 1993. World population data sheet for 1993. Washington, DC.

Peron, Y. and C. Strohmenger. 1985. Demographic and Health Indicators: Presentation and Interpretation. Ottawa: Minister of Supply and Services Canada (Catalogue 82-543 E).

Pollard, J.H. 1988. On the decomposition of changes in expectation of life and differentials in life expectancy. *Demography* 25(2):265-276.

Retherford, Robert D. 1975. The Changing Sex Differential in Mortality. Westport/London: Greenwood Press.

Statistics Canada. 1973. Causes of death, 1971. Ottawa: Minister of Industry, Science and Technology (Catalogue 84-208).

Statistics Canada. 1983. Causes of death, 1981. Ottawa: Minister of Industry, Science and Technology (Catalogue 84-208).

Statistics Canada. 1992. Age sex and marital status: The Nation. Ottawa: Supply and Services Canada (Cat. 93-310).

Statistics Canada. 1993. Causes of death, 1991. Ottawa: Minister of Industry, Science and Technology. Catalogue 84-208.

Statistics Canada. 1995. *The Daily*. June 2, 1995. Cat. 11-001E.

Trovato, F. and N.M. Lalu. 1996. Narrowing sex differentials in life expectancy in the industrialized world: Early 1970s to early 1990s. *Social Biology* (forthcoming).

Vaupel, J.W. and H. Lundstrom. 1994. The future of mortality at older ages in developed countries. Pp. 295-315 in Wolfgang Lutz (ed.), The Future Population of the World: What Can We Assume Today? London: Earthscan Publications.

Veevers, J.E. and E.M. Gee. 1986. Playing it safe: Accident mortality and gender roles. *Sociological Focus* 19(4) 349-360.

Verbrugge, L.M. 1980. Recent trends in sex mortality differentials in the United States. *Women and Health* 5(3):17-37.

Verbrugge, L.M. 1976. Sex differentials in morbidity and mortality in the United States. *Social Biology* 23(4): 275-296.

Verbrugge, L.M. 1989. The Twain meet: Empirical explanations of sex differences in health and mortality. *Journal of Health and Social Behavior* 30(3):282-304.

Waldron, I. 1983. The role of genetic and biological factors in sex differences in mortality. In A. D. Lopez and L.T. Ruzicka (eds.), Sex Differentials in Mortality: Trends, Determinants and Consequences. Canberra: Australia; Department of Demography, Australian National University Printing Press. Pp. 141-164.

Waldron, I. 1976. Why do women live longer than men? *Social Science and Medicine* 10:349-362.

Waldron, I. 1986. The contribution of smoking to sex differences in mortality. *Public Health Reports* 101(2):163-173.

Waldron, I. 1990. Effects of labor force participation on sex differences in mortality and morbidity. Paper presented at the meetings of the Population Association of America, Toronto, Canada.

Wingard, D.L. 1984. The sex differential in morbidity, mortality and life style. *Annual Review of Public Health* 5:433-458.

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