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Sex Mortality Differentials in the United States: The Role of Cohort Smoking Patterns*

Samuel H. Preston
Haidong Wang

Population Studies Center
University of Pennsylvania
Philadelphia, Pa. 19104

* Samuel H. Preston, Population Studies Center, University of Pennsylvania, 3718 Locust Walk, Philadelphia, PA 19104; Email: spreston@sas.upenn.edu. Haidong Wang, Population Studies Center, University of Pennsylvania, 3718 Locust Walk, Philadelphia, PA 19104; Email: haidong@sas.upenn.edu. This project was supported by National Institute of Aging grant P30 AG12836 and by the Boettner Center for Pensions and Retirement Security at the University of Pennsylvania. We are grateful to Donna Hoyert from the National Center for Health Statistics and to David M. Burns of the University of California, San Diego for supplying certain of the data on which this study is based. We appreciate the comments and suggestions of John Bongaarts, Douglas Ewbank, Hans-Peter Kohler, and editors and reviewers for this journal.

Abstract:

This paper demonstrates that, over the period 1948-2003, sex differentials in mortality in the age range 50-84 widened and then narrowed on a cohort rather than on a period basis. The cohort with the maximum excess of male mortality was born shortly after the turn of the century. Three separate data sources suggest that the turnaround in sex mortality differentials is consistent with sex differences in cigarette smoking by cohort. An age/period/cohort model reveals a highly significant effect of smoking histories on men's and women's mortality. Combined with recent changes in smoking patterns, the model suggests that sex differences in mortality will narrow dramatically in coming decades.

Life expectancy for females in the United States has exceeded that of males whenever the mortality of the sexes has been compared (e.g., U.S. National Center for Health Statistics, 2004). However, longevity differences in recent years have been narrowing. Female life expectancy at birth exceeded that of males by 7.7-7.8 years from 1972 to 1979 but by 2003 the difference had declined to only 5.3 years (U.S. National Center for Health Statistics, 2004, 2005). The change in trend of sex mortality differences has created major uncertainties for extrapolative mortality projections that are used to predict the fiscal burdens of an aging population (Wilmoth, 2005).

Narrowing sex differentials in mortality have also been observed in most but not all European countries (e.g., Gjonca, et al., 2005). The most commonly invoked explanation of reduced differentials is the different histories of cigarette smoking for men and women (Gjonca, et al., 2005; Janssen, et al., 2005; Pampel, 2002; Valkonen and van Poppel, 1997). In all countries where data exist, women's uptake of smoking has lagged behind that of men (Pampel, 2002). Cigarette smoking was also implicated in earlier years when sex differentials were widening rather than narrowing (Preston, 1970; Retherford, 1975). Smoking patterns are an obvious place to look for an explanation of sex mortality differences because the health risks are high and long-lasting; large fractions of the population have engaged in the habit; and smoking patterns have differed between the sexes (Waldron, 1986). While the health risks of cigarette smoking have been observed in large epidemiologic studies for a half century, more recent studies using better research designs and more careful measurement have raised the estimated relative risk of death from current and past smoking (Rogers et al. 2005; Taylor et al., 2002; Thun et al., 1998).

In this paper, we demonstrate that changes in sex mortality differentials in the United States have been structured on a cohort rather than a period basis, a feature that has previously escaped attention. Furthermore, we show that the cohort imprint is closely related to a cohort's history of cigarette smoking. Rather than attempting to extrapolate from epidemiologic studies to the national level, as previous studies have done, we achieve these results through a difference-of-differences design that directly reveals the impact of smoking on mortality. The different smoking histories of women and men provide a telling vantage point from which to view the havoc that smoking has wrought on national mortality patterns.

Data

For each sex, we reconstruct age-specific death rates from ages 50-54 to 80-84 for every fifth calendar year from 1948 to 2003. Using five-year age groups every fifth calendar year enables us to identify uniquely birth cohorts as they pass through life. Numerators of death rates were drawn from official vital statistics sources; denominators were drawn from U.S. Census sources.[1]

Sex Differences in Rates of Mortality Change

We begin by presenting the rates of mortality change for males and females separately. These changes reflect a myriad of factors, among which improvements in medical technology have probably played the most important role during the period under review (Cutler, 2004; Tunstall-Pedoe, et al., 2000). These improvements were deployed and diffused on a period-specific basis, probably accounting for the fact that

demographers have noted a preponderance of period-specific influences on adult mortality during the period (Kannisto, 1994; National Research Council, 2000:149).

Table 1 shows the proportionate rates of change in male mortality during five-year time intervals. Rates of decline slower than the median value of -.0658 are shaded. Clearly, the period 1948-68 was one of relatively slow improvement while the period since 1968 has shown persistently faster improvements at all ages except 80-84. Table 2 presents comparable data for women. The pattern is again organized primarily by rows (periods), but the periodicity is somewhat different. Like men's mortality, women's improved relatively quickly from 1968 to 1978. Unlike men's, however, women's mortality improvement was unusually slow between 1978 and 1993 and rapid during 1948-58.

When male and female rates of change are compared, a radically different pattern emerges. Table 3 presents the difference between rates of mortality change for males and females. When male mortality is rising relative to female (i.e., the difference between the rates of change for males and females is positive), the value is shaded. Clearly, the sex difference in rates of mortality change is organized diagonally. Above the diagonal line that is drawn on Table 3, all values are positive: male mortality is increasing relative to female within a five-year age-time bloc. Below the diagonal line, on the other hand, 38 of the 42 values are negative.

Thus, the pattern of change in sex difference is tightly structured on a cohort basis. Relative to females, mortality was growing worse for males through the cohort aged 40-44 in 1948. This cohort was born between 1903 and 1908. Sex differences in mortality began to narrow between this cohort and the cohort born in 1908-13, and they continued

to narrow from one cohort to the next all the way through the cohort born in 1948-53. Taking a difference-of-differences approach removes the influence of period-specific factors that are common to both sexes and permits a striking cohort pattern to become visible.

Can smoking patterns account for the change in direction of sex mortality differentials across these cohorts? Three sources of information, independent of one another, can help answer this question. The first national sample survey of smoking behavior was conducted by the U.S. Census Bureau for the National Cancer Institute in 1955 (Haenszel et al., 1956). A question was asked about the age at which someone had become a "regular cigarette smoker" and results were tabulated by birth cohort. No allowance was made for differential mortality by smoking status. Table 4 shows the percent who reported that they had become regular cigarette smokers by age 35. Both male and female smoking prevalence continued to increase through cohorts born in the 1920's, but the sex difference in smoking behavior peaked at 44-45% among the cohorts born in the 1890's and 1900's.

A careful and detailed reconstruction of smoking histories was made by Burns et al. (1998a). They employed a total of 15 National Health Interview Surveys conducted between 1965 and 1991 to estimate cohort smoking histories. The reliability of estimates is increased by virtue of the multiple observations available on the same cohort. The authors used estimates of differential mortality by smoking status to translate current reports by the living into past behavior by the living and dead.[2] David Burns supplied us with updated, unpublished estimates using the same methodology. These incorporated data from three additional National Health Interview Surveys through 2001.

We have converted these data into an estimate of the average number of years spent as a current smoker before the age of 40. This value is derived by summing across ages between 0 and 39 the proportion of cohort members who were estimated to be current cigarette smokers. Table 4 shows that this series has the same general conformation as that drawn from the 1955 survey. The peak difference between the prevalence of smoking among women and men occurs in the 1895-99 and 1900-04 cohorts (see also Figure 1). This latter cohort overlaps with the 1903-08 cohort in which sex mortality differentials peak.

Lung cancer death rates are often used as a proxy for cigarette smoking prevalence because such a high fraction of deaths from lung cancer are attributable to smoking (Pampel, 2002; Peto, et al., 1994). We have reconstructed lung cancer death rates for the same ages and periods shown in Table 3.[3] Table 5 presents the difference between male and female lung cancer death rates for these groups.[4] In four out of seven age groups, the sex difference in lung cancer death rates peaks in the cohort born 1903-08, the same cohort identified earlier as having the highest sex mortality differential for all causes combined. In two other age groups, the peak is displaced by only five years from this cohort.

Thus, three independent tests support the plausibility of cigarette smoking patterns as the source of the widening and then contraction of sex mortality differentials. It is reasonable to ask whether lung cancer is <u>solely</u> responsible for the diagonalized pattern of change in sex mortality differentials shown in Table 3. That would be surprising in view of the fact that lung cancer accounts for only about 14-28% of the excess deaths from smoking in the United States, depending on the study (Thun et al,

1998: 328). To investigate this possibility, we have subtracted lung cancer death rates from all-cause mortality and repeated the tabulation shown in Table 3. The result (not shown) is little altered: 33 of 35 observations above the diagonal remain positive, and 35 of 42 below the line remain negative. When lung cancer deaths are removed from Table 3, the difference between the mean values of observations above and below the diagonal declines only from .0815 to .0680. Clearly, other causes of death must also be implicated in this structure.

Age/Period/Cohort Analysis of Mortality Trends

Cohort influences on mortality have been recognized since the pioneering work of Kermack, McKendrick, and McKinlay (1934). Most of the successful studies, like theirs, used graphical methods to demonstrate that age patterns of mortality by cohort were very different from those arranged by period and to argue that the cohort patterns reflected genuine and persistent influences embedded in cohorts.

Less successful have been statistical efforts to disentangle age, period, and cohort effects in an accounting framework using dummy variables. Because each variable is a linear combination of the other two variables, some restriction must be imposed in order that the effects of ages, periods, and cohorts be identified. These restrictions are often arbitrary and results can be highly sensitive to the restriction employed because of the correlation among variables (e.g., Mason and Smith, 1985). When non-linear terms for cohort and period are introduced along with a common linear drift term, the typical result across countries is that the linear drift term explains the great majority of variation in all-cause mortality (Janssen and Kunst, 2005).

In our case, it is not necessary to study cohort effects by employing a set of dummy variables to represent cohort membership because we have a hypothesis about cohort influences: that a cohort's smoking history affects its level of mortality. We will represent that history by using the variable introduced earlier, the mean number of years that members of a cohort smoked cigarettes before age 40. The value of this variable differs between men and women in the same cohort, reflecting their different smoking histories. While the variable is an indicator of only one of the two relevant dimensions of smoking, duration and intensity, it should be noted that all relevant studies of lung cancer mortality have concluded that the proportionate impact of duration is far greater than that of intensity (e.g., Knoke, 2004).

We model age and period effects through a series of dummy variables. Our model includes both men and women but we allow for well-known sex differences in the level and age pattern of mortality through a set of age/sex interaction dummies. We also allow for sex differences in the effect of smoking by constructing a sex/smoking interactive variable.

We model the mortality process using negative binomial regression. We initially used Poisson regression but the hypothesis that the data were Poisson-distributed was decisively rejected: the amount of dispersion in outcomes was significantly underestimated by the Poisson model. Our model is

$$D_{ijks} = \exp\{\ln N_{ijks} + B_i X_i + B_j X_j + B_c C_{ks} + B_s X_s + B_{is} X_{is} + V_{ijks}\}$$

where

D_{ijks} = Number of deaths in age group i , period j , cohort k, sex s,

N_{ijks} = Number of person-years of exposure at age i , period j, cohort k, sex s,

X_i = Dummy variable signifying membership in age group i ,

X_j = Dummy variable signifying observation pertained to period j,

X_s = Dummy variable signifying observation applied to sex s,

C_{ks} = Average number of years spent as current smoker prior to age 40 by members of cohort k, sex s,

X_{is} = Interactive dummy variable indicating observation pertained both to age i and sex s,

V_{ijks} = Error term whose exponential is gamma distributed,

B_i , B_j , B_c , B_s , B_{is} , B_{ks} = Coefficients indicating estimated effect of variable on mortality.

Coefficients of this model are estimated using STATA and are presented in the Appendix. The coefficient of the cohort/sex smoking variable is .0230, with a standard error of .0022 ($p<.001$). The coefficient implies that a cohort's death rates will rise by 2.33% for every 1-year increase in average smoking duration by a cohort. The sex/smoking interaction term has a significant ($p<.001$) coefficient of -.0100, indicating that a particular level of smoking prevalence in a cohort has a smaller proportionate effect on women's mortality than on men's, perhaps because women smokers on average consume fewer cigarettes per day, inhale less frequently, and smoke cigarettes lower in tar content (Thun, et al., 1998: 311-15).

The ratio of the female-to-male relative risks is .0130/.0230 = 0.57. This ratio is roughly consistent with sex disparities in the risk from smoking recorded in large epidemiologic studies. The largest such study, the American Cancer Society Cancer Prevention Study I conducted between 1959 and 1972, found a ratio of the mortality of current smokers to never-smokers at ages 40-84 of 1.91 for white males and 1.46 for white females, implying that the excess risk for females was 0.51 of that for males (Burns et al., 1998b: 232, 292). The later Cancer Prevention Study II estimated the ratio to be 2.3

for males and 1.9 for females between 1982 and 1988, suggesting that the relative risks from smoking had risen for both sexes and faster for women (Thun, et al., 1998). The mean of the excess risks from these two studies, which span the 1970s midpoint of our own study, is 0.68 for women and 1.10 for men. The sex ratio of mean excess risk in these studies is thus 0.62, close to our estimate of 0.57.

The regression results, combined with the smoking data shown in Table 4, enable us to address the question of how much variability smoking has introduced into sex mortality differentials. Figure 2 shows for men and women the estimated percentage excess in mortality rates by cohort that is attributable to smoking. The impact is clearly higher among men than women, both because more men have smoked and because smoking increased mortality more for men than for women. The estimated smoking-induced elevation of 51% in mortality rates for the male cohort born 1910-14 may seem implausibly high. But it should be remembered that smoking has increased men's mortality risks by a factor of 1.7-3.5 (depending on the study) and that the proportion of this cohort who were current smokers at any one time reached 77% (Burns et al, 1998a).

Among women, the impact of smoking has been smaller. Nevertheless, the rise in smoking prevalence between the cohorts of 1885-89 and the peak cohort of 1940-44 is estimated to have increased women's mortality by 13.4%.

Consistent with earlier data and discussion, the sex differential in the estimated impact of smoking peaks in the cohorts born around the turn of the century. Our estimates suggest that smoking raised the sex ratio of death rates for the cohort born 1900-04 by 41%. For the cohort born 1945-49, the estimated impact is only 18%. Thus, changes in smoking patterns account for a reduction of 23% in the sex differential in mortality across

these birth cohorts. The hypothesis that smoking is responsible for the change in pattern of sex mortality differentials is strongly supported by this analysis.

Figure 3 presents the estimated changes in "period effects" on mortality (i.e., first differences in the exponentiated period coefficients in the Appendix). When smoking is controlled, as in our basic model, the declines in mortality tend to grow smaller over time. However, when smoking is not controlled, the series is essentially trendless, with a reduction in mortality averaging approximately 4% during each 5-year period. The implication is that the upsurge in smoking shortly after World War II has partially obscured the major reductions in mortality that would otherwise have been occurring during that period, while the recession in smoking during the last two decades has exaggerated the improvements. The net effect of smoking is over the entire period is to have reduced the amount of decline. Controlling smoking histories, mortality levels are reduced by 56% during this period. In the absence of smoking, the estimated period decline in mortality would have been only 48%. Since most descriptive accounts of mortality decline during this period omit the obstructive role of smoking, they provide an overly pessimistic view of the period-specific progress that has been made in extending longevity.

We have demonstrated that a cohort's smoking history prior to age 40 has a powerful impact on its subsequent mortality. To some extent, its power reflects a positive correlation in smoking propensities across the life cycle, including smoking beyond age 40. But it also reflects the enduring impact of smoking behavior at an early age on health and mortality at later ages. Recent studies that more carefully measure smoking histories find larger impacts of smoking at younger ages than did earlier studies. For example,

using follow-up data from Cancer Prevention Study II, Taylor et al. (2002) find that former smokers aged 60-69 at baseline who had quit smoking 11-15 years earlier had a risk of death relative to lifetime non-smokers of 1.75 (males) and 1.59 (females) during the period 1982-96, i.e., an average of 20 years after they stopped smoking.

There may also be period-specific influences on smoking behavior that would not be reflected in our cohort smoking coefficients. One possibility is that the U.S. Surgeon General's first report describing the dangers of smoking (Department of Health, Education, and Welfare, 1964), and a subsequent national anti-smoking advertising campaign during 1967-70, may have produced a reduction in smoking propensities across all cohorts (Burns, et al., 1998a: 30; Tolley, et al., 1991: 85-86). If so, these changes would be reflected in period coefficients. Our period coefficients do show an unusually rapid reduction in mortality between 1968 and 1973, although a rapid diffusion of anti-hypertensive drugs has also been identified as an important factor in mortality during this period (Sytkowski, et al., 1996). Whatever period-specific influences on smoking behavior are present, they clearly do not erase the statistical impact of a cohort's early smoking behavior on its subsequent mortality.

Impending Smoking-Related Changes in Future Mortality

Just as mortality improvements at older ages in the past half century have been inhibited by increases in smoking, so should mortality declines in the future be accelerated by reductions in smoking. Even with no subsequent changes in smoking behavior, current age-specific smoking behavior implies that members of future cohorts reaching age 50 will have accumulated fewer years of smoking than cohorts who are currently in this age range. To illustrate this effect, we have created a synthetic cohort

whose smoking prevalence is the same at each age as the prevalence recorded at that age in 2000. Cumulating these values to age 40 gives an expectation of 8.40 years as a smoker for men and of 7.58 years for women. Substituting these values for the actual cohort-specific values in 2003 indicates how much improvement in mortality can be expected simply if current behavior continues.

Table 6 shows the result of this exercise in the form of probabilities of survival from age 50 to age 85. Note first that our age/period/cohort model comes close to replicating the actual survival probability in the official U.S. life table for 2003. Substituting the smoking values calculated for the synthetic cohort for those values actually observed in 2003 suggests that male mortality will benefit enormously from reductions in smoking that have already occurred. The male survival probability is estimated to increase from .307 to .377, or by 23%. The expected improvement for females is much lower at only 2%. The main reason for this disparity is that current female smoking patterns do not differ radically from those of the past, whereas male smoking patterns have shown large reductions. As a result, it is extremely likely that sex mortality differentials will continue to narrow. Pampel (2005) reaches a similar conclusion for the United States and other countries by projecting forward period changes in smoking behavior.

What if smoking were eliminated altogether? Table 6 shows that another large improvement in mortality could be expected. Both sexes would share in this improvement, but the survival enhancement once again would be larger for men. The combined effect of these reductions in smoking on sex differentials in mortality would be enormous. Currently, women have a 54% higher probability of surviving from age 50 to

age 85 than men, whether estimated from the official U.S. life table or from our model. With no smoking by either sex, our model suggests that the differential would be only 15%.

Thus, there is considerable potential for major mortality reductions from a recession in smoking. Large reductions for males seem not only possible but very likely based upon changes in smoking behavior that have already occurred. It is likely that these reductions will affect mortality in a manner that is organized by birth cohort. National mortality projections, all major versions of which are currently based upon extrapolations of period trends in mortality, would be well advised to take account of these powerful cohort effects.

Footnotes:

1. The numbers of deaths by age and sex are obtained from *Vital Statistics of the United States* for calendar year 1948, 1953, 1958, 1963, 1968, 1973 and 1978. Death rates from 1983 to 1998 are obtained on-line from the website of National Center for Health Statistics, Center for Disease Control and Prevention. Unpublished death data for 2003 were supplied by the National Center for Health Statistics. The population at risk by age and sex between 1948 and 1978 is obtained from U.S. Census Bureau, Current Population Reports, Series P-25, No. 311, No. 314, No. 519, No. 870, and Series P-20, No. 441. Population estimates in 2003 are taken from the website of the U.S. Census Bureau.

2. Estimates were not available in this source for black cohorts born before 1900. We accounted for blacks in the three earliest national cohorts by fitting a linear trend line to the relationship between national smoking prevalence and white smoking prevalence for cohorts born 1900-04 to 1950-54. This line was extrapolated backwards in time and actual white cohort values were used to predict national prevalence. The disparity between white values and national values was always very small.

3. The numbers of deaths from malignant neoplasm of trachea, bronchus and lung are drawn from the same sources as deaths from all causes combined (see footnote 1). For 1948, we combine two categories from the published data, "cancer of trachea" and "cancer of bronchus and lung"; for data between 1952 and 1963, we combine code 162 (malignant neoplasm of respiratory system of trachea, and of bronchus and lung specified

as primary) and code 163 (malignant neoplasm of lung and bronchus, unspecified as primary or secondary). Between 1968 and 1978, data are coded according to the Eight Revision, International Classification of Diseases, where malignant neoplasm of trachea, bronchus, and lung is code 162. Between 1983 and 1998, the Ninth Revision is used, wherein malignant neoplasm of trachea, bronchus, and lung is also coded 162. 2003 data employ the Tenth Revision in which malignant neoplasm of trachea, bronchus, and lung is coded as C33-C34.

4: The sex difference in death rates is preferred to the ratio for this comparison because the difference should be linearly related to the difference in smoking prevalence between the sexes, assuming a linear relation between smoking and mortality for each sex.

Appendix: STATA output of the model

Covariates	Coefficients	Standard Error	z	P>z
Age Groups				
50-54(Ref.)				
55-59	0.4297	0.0122	35.13	0.000
60-64	0.8674	0.0126	68.99	0.000
65-69	1.2756	0.0129	98.51	0.000
70-74	1.6908	0.0134	126.24	0.000
75-79	2.1012	0.0139	150.96	0.000
80-84	2.5357	0.0146	174.05	0.000
Periods				
1948(Ref.)				
1953	-0.1265	0.0196	-6.45	0.000
1958	-0.2118	0.0188	-11.25	0.000
1963	-0.2360	0.0185	-12.78	0.000
1968	-0.2652	0.0183	-14.46	0.000
1973	-0.3583	0.0183	-19.53	0.000
1978	-0.4890	0.0188	-26.04	0.000
1983	-0.5802	0.0191	-30.32	0.000
1988	-0.6296	0.0194	-32.45	0.000
1993	-0.6997	0.0196	-35.78	0.000
1998	-0.7650	0.0196	-39.12	0.000
2003	-0.8231	0.0194	-42.51	0.000
Number of year as current smoker prior to age 40	0.0230	0.0022	10.45	0.000
Female	-0.3297	0.0370	-8.90	0.000
Interactions:				
Female*Age 55-59	-0.0061	0.0174	-0.35	0.727
Female*Age 60-64	-0.0032	0.0178	-0.18	0.856
Female*Age 65-69	0.0166	0.0183	0.91	0.365
Female*Age 70-74	0.0686	0.0189	3.63	0.000
Female*Age 75-79	0.1424	0.0197	7.24	0.000
Female*Age 80-84	0.2265	0.0206	11.00	0.000
Female* Number of year as current smoker prior to age 40	-0.0100	0.0025	-4.05	0.000
Constant	-4.5574	0.0362	-125.77	0.000

References:

Burns, D.M., L. Lee, L.Z. Shen, E. Gilpin, H. D. Tolley, J. Vaughn, and T.G.Shanks. 1998a."Cigarette smoking behavior in the United States." Pp. 13-112 in Changes in cigarette-related disease risks and their implication for prevention and control, edited by D.M. Burns, L. Garfinkel , and J. Samet . Smoking and Tobacco Control Monograph No. 8. Bethesda, MD: Cancer Control & Population Sciences, National Cancer Institute, U.S. National Institutes of Health.

Burns, David M., Thomas G. Shanks, Won Choi, Michael J. Thun, Clark W. Heath, and Lawrence Garfinkel, 1998b. "The American Cancer Society Cancer Prevention Study I: 12-Year Followup of 1 Million Men and Women" Pp. 113-304 in Changes in cigarette-related disease risks and their implication for prevention and control, edited by D.M.Burns, L.Garfinkel, and J. Samet. Smoking and Tobacco Control Monograph No. 8. Bethesda, MD: Cancer Control & Population Sciences, National Cancer Institute, U.S. National Institutes of Health.

Cutler, David. 2004. Your Money or Your Life. Oxford. Oxford University Press.

Department of Health, Education, and Welfare. 1964. Smoking and Health: Report of the Advisory Committee to the Surgeon General of the Public Health Service PHS Publication No. 1103. Rockville, Md. U.S. Department of Health, Education, and Welfare, Public Health Service.

Department of Health and Human Services, 1989. Reducing the Health Consequences of Smoking: 25 Years of Progress. A Report of the Surgeon General Rockville, Md. U.S. Department of Health and Human Services.

Doll, R., R. Peto, K. Wheatley, R. Gray, and I. Sutherland. 1994. "Mortality in Relation to Smoking: 40 year's Observation on Male British Doctors." British Medical Journal 309: 901-911.

Gjonca, A., C. Tomassini, B. Toson, and S. Smallwood. 2005. "Sex Differences in Mortality, A Comparison of the United Kingdom and Other Developed Countries." Health Statistics Quarterly 26:6-16.

Haenszel, W., M.B. Shimkin, and H.P. Miller. 1956. Tobacco Smoking Patterns in the United States. Washington, DC: United States Government Printing Office.

Janssen, F. and A.E. Kunst. 2005. "Cohort Patterns in Mortality Trends Among the Elderly in Seven European Countries, 1950-99." International Journal of Epidemiology. Vol. 34: 1149-1159.

Kannisto, V. 1994. Development of Oldest-Old Mortality, 1950-1990: Evidence from 28 Developed Countries. Odense, Denmark. University of Odense Press.

Kermack, W.O., A.G. McKendrick, and P.L. McKinlay, 1934. "Death Rates in Great Britain and Sweden: Some Regularities and Their Significance" The Lancet March 31:698-703.

Knoke, James D., Thomas G. Shanks, Jerry W. Vaughn, Michael J. Thun, and David M. Burns, 2004. "Lung Cancer Mortality is Related to Age in Addition to Duration and Intensity of Cigarette Smoking: An Analysis of CPS-I Data" Cancer Epidemiology Biomarkers and Prevention Vol. 13: 949-957.

Mason, William M. and Herbert L. Smith. 1984. "Age-Period-Cohort Analysis and the Study of Deaths from Pulmonary Tuberculosis" pp. 151-227 in William M. Mason and Stephen E. Fienberg, eds. Cohort Analysis in Social Research: Beyond the Identification Problem New York. Springer-Verlag.

National Center for Health Satistics, 2004. United States Life Tables, 2002 (National Vital Statistics Reports, Vol. 53, No. 6). Hyattsville, MD: National Center for Health Statistics, Center for Disease Control and Prevention.

National Center for Health Statistics, 2005. Deaths: Preliminary Data for 2003 (National Vital Statistics Reports, Vol.53, No. 15). Hyattsville, MD: National Center for Health Statistics, Center for Disease Control and Prevention.

National Research Council, Panel on Population Projections, 2000. Beyond Six Billion Washington, D.C. National Academies Press.

Olshansky, S. Jay, Douglas J. Passaro, Ronald C. Hershow, Jennifer Layden, Bruce A. Carnes, Jacob Brody, Leonard Hayflick, Robert N. Butler, David B. Allison, and David S. Ludwig, 2005. "A Potential Decline in Life Expectancy in the United States in the 21st Century" New England Journal of Medicine Vol. 352(11): 1138-45.

Pampel, Fred. C. 2002, "Cigarette Use and the Narrowing Sex Differential in Mortality." Population and Development Review 28: 77-104.

Pampel, Fred. 2005. "Forecasting Sex Differences in Mortality in High Income Nations: The Contribution of Smoking" Demographic Research Vol. 13: 455-484.

Peto, R., A.D. Lopez, J. Boreham, M. Thun, and C. Heath, Jr. 1994. Mortality from Smoking in Developed Countries 1950-2000: Indirect Estimates from National Vital Statistics Oxford. Oxford University Press.

Preston, Samuel H. 1970. Older Male Mortality and Cigarette Smoking: A Demographic Analysis. Institute of International Studies. University of California, Berkeley.

Retherford, Robert D. 1975. The Changing Sex Differential in Mortality Westport, Conn. Greenwood Press.

Rogers, Richard G., Robert A. Hummer, Patrick M. Krueger, and Fred C. Pampel, 2005. "Mortality Attributable to Cigarette Smoking in the United States" Population and Development Review Vol. 31: 259-92.

Sytkowski, Pamela A., Ralph B. D'Agostino, Albert J. Belanger, and William B. Kannel, 1996. "Secular Trends in Long-term Sustained Hypertension, Long-term Treatment, and Cardiovascular Mortality: The Framingham Heart Study 1950 to 1990" Circulation Vol 93: 697-703.

Taylor, Donald H., Vic Hasselblad, Jane Henley, Michael J. Thun, and Frank A. Sloan, 2002. "Benefits of Smoking Cessation for Longevity"
American Journal of Public Health Vol. 92: 990-996.

Thun, Michael J., Cathy Day-Lally, Dena G. Myers, Eugenia E. Calle, W. Dana Flanders, Bao-Ping Zhu, Mohan M. Namboodiri, and Clark W. Heath, 1998. "Trends in Tobacco Smoking and Mortality from Cigarette Use in Cancer Prevention Studies I (1959 through 1965) and II (1982 through 1988)". Pp. 305-382 in Changes in cigarette-related disease risks and their implication for prevention and control, edited by D.M. Burns, L. Garfinkel, and J. Samet. Smoking and Tobacco Control Monograph No. 8. Bethesda, MD: Cancer Control & Population Sciences, National Cancer Institute, U.S. National Institutes of Health.

Tolley, H.D., L. Crane, and N. Shipley. 1991. "Smoking Prevalence and Lung Cancer Death Rates" pp. 73-144 in National Cancer Institute, Stategies to Control Tobacco Use in the United States: A Blueprint for Public Health Action in the 1990's. Betheda. National Institutes of Health Publication 92-3316.

Tunstall-Pedoe, Hugh, Diego Vanuzzo, Michael Hobbs, Markku Mahonen, Zygimantas Cepaitis, Kari Kuulasmaa, and Ulrich Keil, 2000. "Estimation of Contribution of Changes in Coronary Care to Improving Survival, Event Rates, and Coronary Heart Disease Mortality across the WHO MONICA Project Populations." The Lancet. Vol. 355: 688-700.

Valkonen, T. and F. von Poppel. 1997. "The Contribution of Smoking to Sex Differences in Life Expectancy: Four Nordic Countries and the Netherlands, 1970-1989" European Journal of Public Health Vol. 7: 302-310.

Waldron, Ingrid. 1986. "The Contribution of Smoking to Sex Differences in Mortality." Public Health Reports 101: 163-173.

Wilmoth, John R. 2005. "Some Methodological Issues in Mortality Projection, Based on an Analysis of the U.S. Social Security System" Genus Vol. XLI(1): 179-211.

Table 1: Rates of Mortality Change by Age and Period: United States Males, 1948-2003 *

Period	Age Interval						
	50-54	55-59	60-64	65-69	70-74	75-79	80-84
1953-1948	-0.0715	-0.0606	-0.0232	-0.0005	-0.0338	-0.0625	0.0353
1958-1953	-0.0456	-0.0520	-0.0176	0.0091	-0.0052	-0.0131	-0.0195
1963-1958	-0.0071	0.0314	0.0010	0.0576	0.0421	0.0047	-0.0176
1968-1963	-0.0061	0.0064	0.0338	-0.0276	0.0645	0.0048	-0.0658
1973-1968	-0.0961	-0.0698	-0.0758	-0.0735	-0.0888	0.0184	0.0137
1978-1973	-0.1107	-0.1624	-0.1054	-0.1257	-0.1074	-0.0848	-0.0525
1983-1978	-0.1154	-0.0672	-0.1225	-0.0693	-0.0676	-0.0980	-0.0620
1988-1983	-0.0856	-0.0827	-0.0534	-0.0646	-0.0589	-0.0518	-0.0213
1993-1988	-0.0865	-0.1005	-0.0940	-0.0745	-0.1032	-0.0833	-0.0631
1998-1993	-0.1242	-0.1262	-0.1171	-0.1063	-0.0691	-0.0833	-0.0692
2003-1998	0.0339	-0.0610	-0.0926	-0.1067	-0.1064	-0.0704	-0.0850

$$* \frac{M_i(t+5) - M_i(t)}{M_i(t)},$$

where M_i = death rate for males in age interval i , year t.

Source: U.S. National Center for Health Statistics, U.S. Department of Vital Statistics, and U.S. Bureau of the Census.

Table 2: Rates of Mortality Change by Age and Period: United States Females, 1948-2003 *

Period	Age Interval						
	50-54	55-59	60-64	65-69	70-74	75-79	80-84
1953-1948	-0.0937	-0.1235	-0.1123	-0.0771	-0.0964	-0.1028	-0.0277
1958-1953	-0.1172	-0.0931	-0.0663	-0.0621	-0.0770	-0.0584	-0.0231
1963-1958	-0.0313	-0.0265	-0.0258	-0.0240	-0.0424	-0.0580	-0.0392
1968-1963	-0.0091	-0.0115	-0.0443	-0.0311	-0.0249	-0.0624	-0.0924
1973-1968	-0.0769	-0.0398	-0.0715	-0.1381	-0.0940	-0.0269	-0.0844
1978-1973	-0.1059	-0.1299	-0.0579	-0.1139	-0.1365	-0.1173	-0.1000
1983-1978	-0.0793	-0.0471	-0.0686	-0.0065	-0.0451	-0.1382	-0.0841
1988-1983	-0.0611	-0.0293	-0.0183	-0.0120	-0.0174	-0.0719	-0.0219
1993-1988	-0.0836	-0.0693	-0.0501	-0.0366	-0.0420	-0.0413	-0.0601
1998-1993	-0.0859	-0.0845	-0.0667	-0.0448	-0.0214	-0.0324	-0.0130
2003-1998	0.0045	-0.0506	-0.0579	-0.0635	-0.0588	-0.0199	-0.0335

* $\dfrac{F_i(t+5) - F_i(t)}{F_i(t)}$,

where F_i = death rate for females in age interval i , year t.

Source: U.S. National Center for Health Statistics, U.S. Department of Vital Statistics, and U.S. Bureau of the Census.

Table 3. Sex Differences in Rates of Mortality Change by Age and Period: United States, 1948-2003*

Period	Age Interval						
	50-54	55-59	60-64	65-69	70-74	75-79	80-84
1953-1948	0.0221	0.0629	0.0891	0.0765	0.0625	0.0404	0.0630
1958-1953	0.0716	0.0410	0.0487	0.0712	0.0718	0.0452	0.0036
1963-1958	0.0243	0.0579	0.0269	0.0816	0.0844	0.0627	0.0216
1968-1963	0.0029	0.0179	0.0781	0.0035	0.0894	0.0672	0.0265
1973-1968	-0.0192	-0.0299	-0.0043	0.0646	0.0052	0.0453	0.0981
1978-1973	-0.0048	-0.0325	-0.0475	-0.0118	0.0291	0.0324	0.0475
1983-1978	-0.0361	-0.0201	-0.0540	-0.0628	-0.0224	0.0402	0.0220
1988-1983	-0.0245	-0.0534	-0.0350	-0.0526	-0.0415	-0.0339	0.0006
1993-1988	-0.0029	-0.0312	-0.0438	-0.0378	-0.0612	-0.0419	-0.0030
1998-1993	-0.0383	-0.0418	-0.0504	-0.0615	-0.0478	-0.0509	-0.0562
2003-1998	0.0294	-0.0104	-0.0347	-0.0431	-0.0476	-0.0505	-0.0515

* $\frac{M_i(t+5) - M_i(t)}{M_i(t)} - \frac{F_i(t+5) - F_i(t)}{F_i(t)}$,

where M_i = death rate for males in age interval i , year t.

F_i = death rate for females in age interval i , year t.

Source: U.S. National Center for Health Statistics, U.S. Department of Vital Statistics, and U.S. Bureau of the Census.

Table 4. Two Estimates of the Prevalence of Smoking within Birth Cohorts

Cohort Born	1955 Survey: Cumulative % Who Had Became Regular Cigarette Smoker by age 35[A]			National Health Interview Survey Data Since 1964: Estimated Number of Years Spent as Current Smoker Before Age 40 Per Member of Cohort [B]		
	Males	Females	Difference	Males	Females	Difference
1885-89	28.1*	1.7*	26.4*	11.6	0.8	10.7
1890-94				12.9	1.4	11.5
1895-99	51.6	6.1	45.1	15.8	2.4	13.5
1900-04				16.6	3.2	13.4
1905-09	62.7	18.5	44.2	17.5	5.3	12.3
1910-14				17.9	7.5	10.4
1915-19	67.3	33.8	33.5	17.8	8.9	9.0
1920-24				17.7	9.3	8.3
1925-29	68.4	42.0	28.4	17.3	10.1	7.2
1930-34				16.4	10.3	6.1
1935-39				15.1	10.5	4.7
1940-44				14.4	10.5	4.0
1945-49				12.5	9.2	3.3
1950-54				10.7	8.5	2.3

Notes: *Born before 1890.

A. Source: Haenszel, et al. 1956:56.
B. Source: Burns, et al. 1991; updated estimates supplied by David M. Burns, June 29, 2005.

Table 5. Differences in Lung Cancer Death Rates Between Men and Women (Deaths per 100,000 Population)

Year	Age Interval						
	50-54	55-59	60-64	65-69	70-74	75-79	80-84
1948	33.7	56.0	67.4	64.3	53.9	43.8	34.5
1953	48.3	80.6	106.4	109.8	94.3	78.7	62.1
1958	56.0	92.5	142.0	163.9	145.5	116.1	88.7
1963	58.7	105.7	161.7	219.4	215.9	182.1	137.3
1968	64.1	117.6	191.7	248.1	306.2	261.5	187.4
1973	63.2	116.4	192.4	270.1	331.5	344.2	282.6
1978	63.1	110.5	188.9	263.9	361.0	396.3	382.7
1983	51.2	101.0	161.9	247.3	338.6	404.8	411.0
1988	44.4	90.5	156.6	225.7	307.9	381.5	421.1
1993	31.9	72.2	132.9	204.6	257.7	320.2	385.9
1998	21.2	50.6	91.4	154.6	229.5	273.0	311.9
2003	18.4	38.0	65.6	114.4	173.4	233.8	262.5

Sources: U.S. National Center for Health Statistics, U.S. Department of Vital Statistics, U.S. Bureau of the Census.

Table 6. Estimated Changes in Probabilities of Surviving from Age 50 to Age 80 if Smoking were Reduced or Eliminated

	Probability of Surviving from age 50 to 80	
	Males	Females
U.S. Life table of 2003*	.464	.630
Age/Period/Cohort Model		
2003 Predictions with actual smoking histories	.477	.638
2003 Predictions with 2000 current smoking behavior	.538	.646
2003 predictions with no smoking	.600	.674

* Source: National Center for Health Statistics, 2005

Figure 1. Average Number of Years Spent as Cigarette Smoker Prior to Age 40 among Men and Women in Different Birth Cohorts

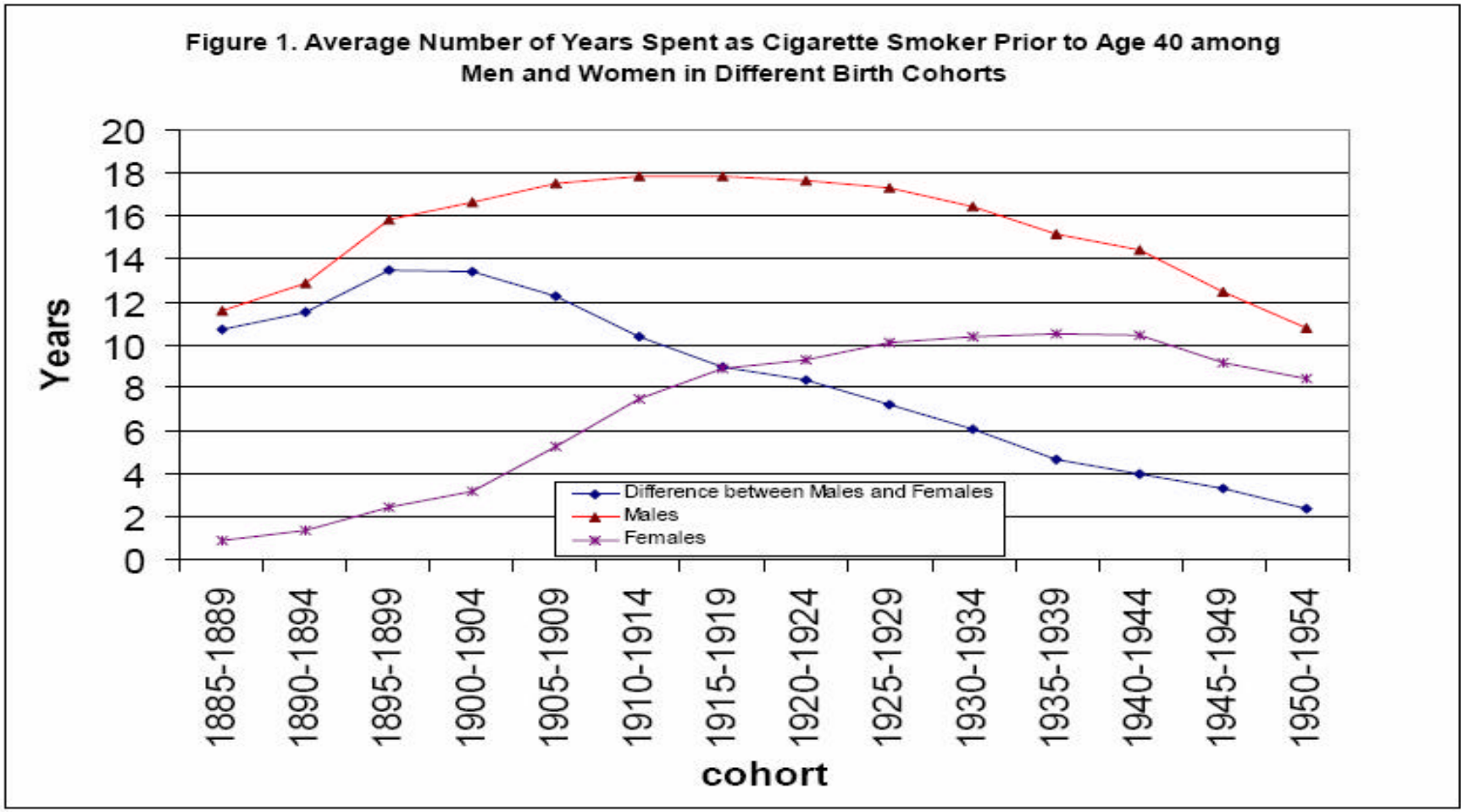
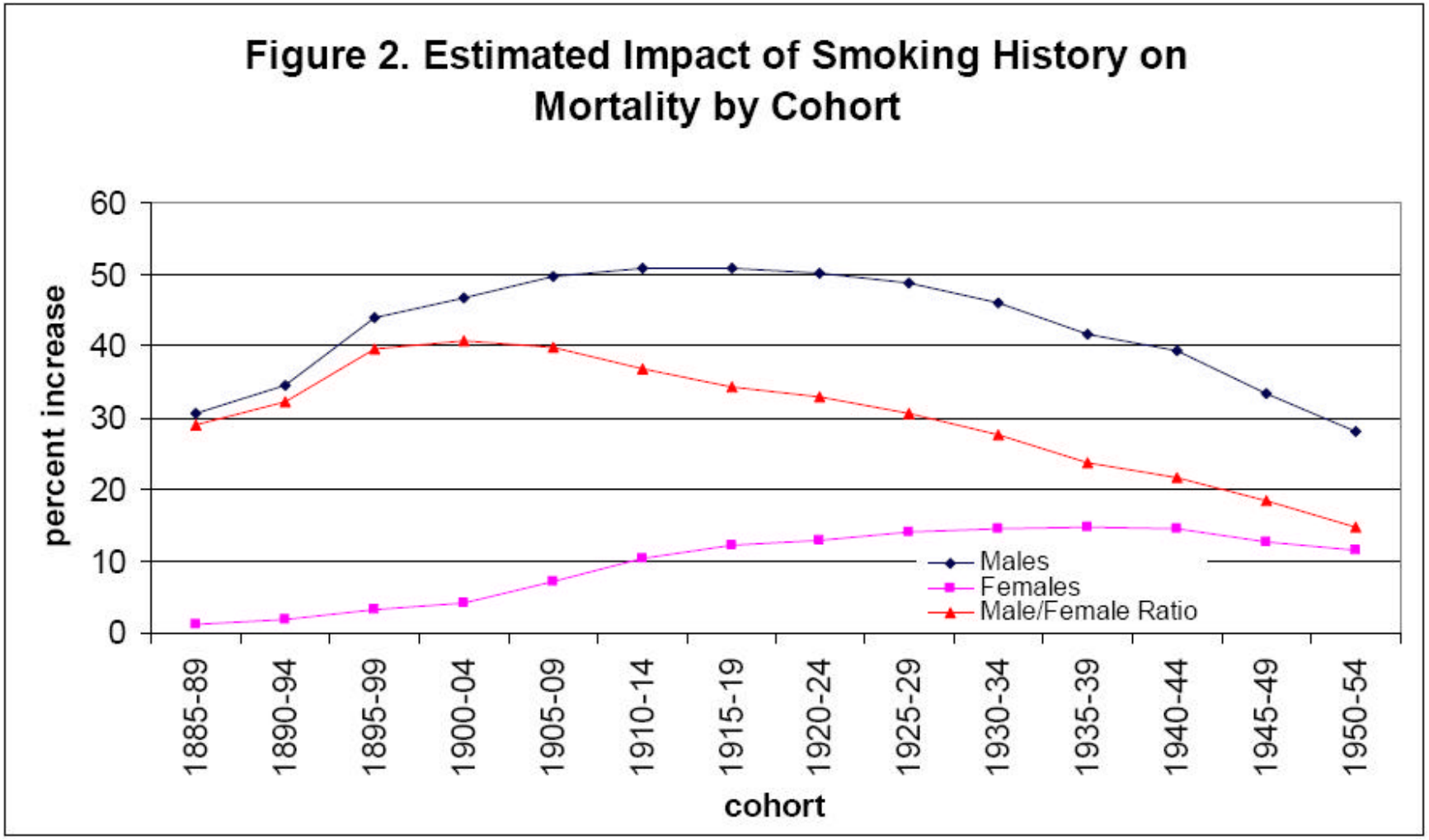


Figure 2. Estimated Impact of Smoking History on Mortality by Cohort



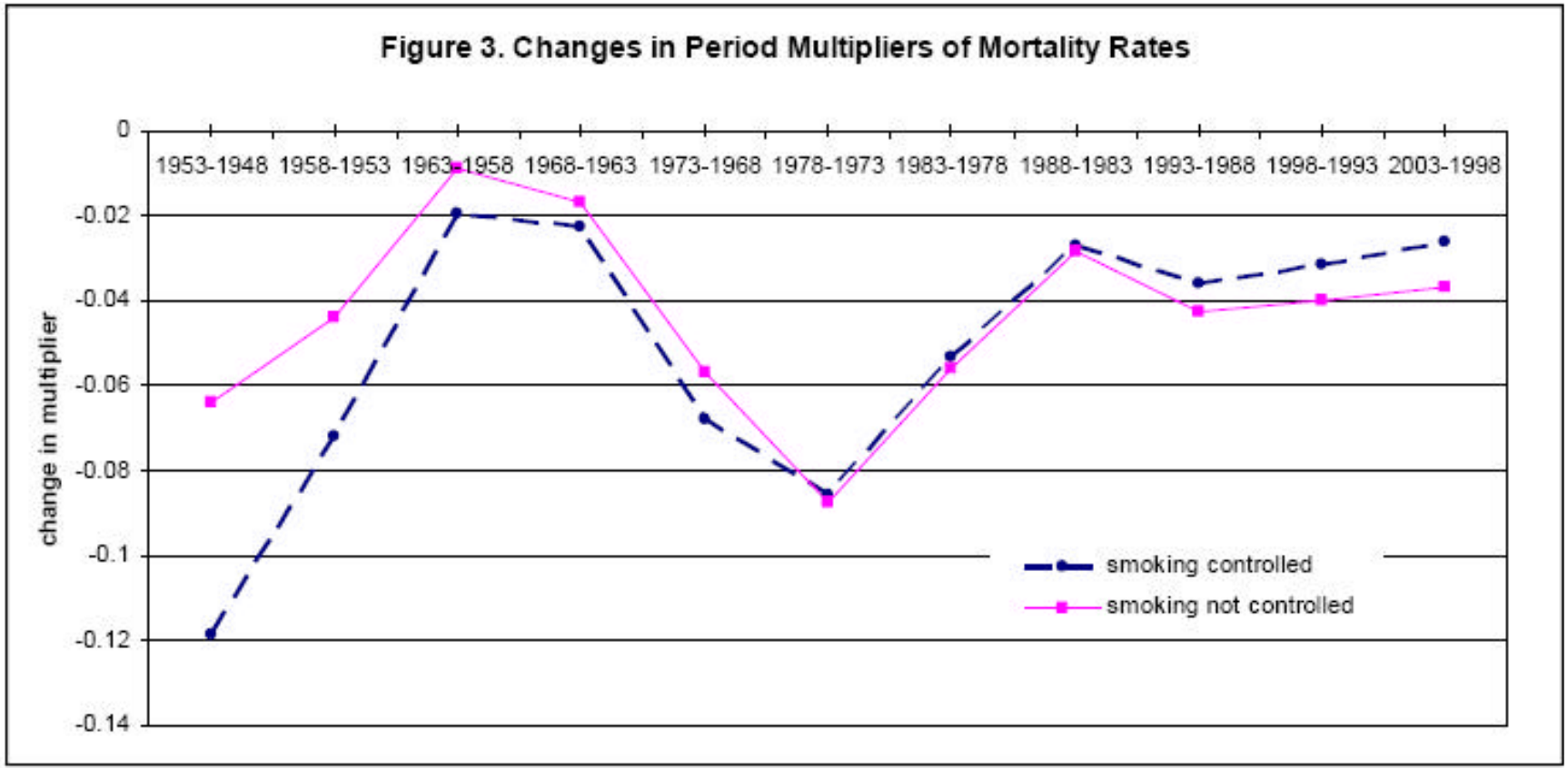


Figure 3. Changes in Period Multipliers of Mortality Rates
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
-0.14
change in multiplier
1953-1948
1958-1953
1963-1958
1968-1963
1973-1968
1978-1973
1983-1978
1988-1983
1993-1988
1998-1993
2003-1998
smoking controlled
smoking not controlled