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Global Mortality Improvement Experience and Projection Techniques

JUNE 2011

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Reinsurance Section
Financial Reporting Section
Product Development Section
Committee on Life Insurance Research

Society of Actuaries

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Section 1: Background

This report is intended to serve as an aid in the discussion of best practices in the development of a view regarding future expectations for rates of insured and annuitant mortality improvement. To that end, the report first reviews historical rates of improvement for both the general population and the insured population from a global perspective. It then provides an overview of current techniques for modeling and projecting future rates of mortality improvement. In order to provide a broad perspective on the topic, this report reviews the work of both the actuarial profession as well as other disciplines, including demographers, economists, statisticians and members of the medical profession.

As a first step in developing the report, the Research Team created a detailed database of research papers, industry publications and other sources of information related to mortality improvement experience and modeling approaches. Appendix A provides detailed citations for data sources identified as part of this project work.

Information is presented in three major areas — global trends in mortality improvement (Section 3), detailed information regarding mortality improvement for both the insured and general populations in the United States ("US"), Canada and the United Kingdom ("UK") (Section 4), and finally, biometric theories regarding future rates of mortality improvement as well as mortality improvement modeling and projection techniques in common use (Section 5). Section 6 outlines a current view regarding future rates of mortality improvement over the medium term (10-20 years) for individual life and annuity insureds based on information reviewed as part of this project work.

General Approach for Developing Mortality Improvement Results

Note that this report was developed with the intent of providing information regarding general trends over time. To that end, the reader should be aware of the following information as he/she reviews the data presented. Because information is drawn from multiple sources with varying formats, the following general approaches were adopted for combining and compiling data.

1. *Mortality Improvement Calculation*.

   For purposes of this report, mortality improvement experience is presented as an average annual rate over a specified period of time. Specifically, the mortality improvement for an individual age x between time t and time t+k is calculated as follows:

$$\text{Avg Ann Improv}_x^{t \text{ to } t+k} = 1 - (q_x^{t+k}/q_x^{t})^{\wedge(1/k)}$$

2. *Age Groupings*.

Some sources of information do provide data by individual age while others do not. Therefore, for purposes of making comparisons in experience data across various sources, a common age set of groupings was determined as follows: 0-1, 1-4, 5-9, 10-14, 15-19, 20-24, 25-34, 35-54, 55-64, 65-75, 75-84 and 85+. For data sources where available mortality data included death counts and amounts, exposures by count and amount, and central death rates or mortality rates, data was combined into the various groupings defined above. For other sources, including some of the insured data, only the final mortality rates are available in the level of detail required. In these cases, we have presented results for individual representative ages, typically ages 30-95. ***Care should be taken in applying insured data mortality improvement results directly. For this reason, in developing a medium term view of future levels of improvement, we have focused on population mortality as the basis for our estimates.***

3. *Experience Periods*.

An attempt was made to align the time periods over which mortality improvements are measured for the general and insured population data presented in order to allow for comparison. It should be noted that for making comparisons of insured, annuitant and pension data, the time periods over which improvements in mortality are measured do not precisely overlap and therefore there is some distortion introduced in these comparisons.

Also, most academic and technical sources measure mortality improvements over long periods of time (40-50 years or more), however consistent data over this length of time is generally not available for the insured populations. For this reason, we have focused on the period from 1965 to the present and, wherever possible, we have broken down results into the following sub-periods: 1965-1980, 1980-2000, and from 2000 to the most recent year available.

Finally, in cases where an experience study covers multiple years, we have used the midpoint of the period as the reference point for measuring mortality improvement levels.

4. *Estimating Overall Improvement Levels*.

Except in cases where there was insufficient information, we have included a “total” or “all ages” mortality improvement statistic for population and insured data.

5. *Primary Data Sources for Mortality Improvement Measurement*.

In order to facilitate the comparison of population data across both geographic regions and demographic groups, much of the general population information presented utilizes the Human Mortality Database (“HMD”) maintained by the Center for Demographic Studies at the University of California at Berkeley. In cases where alternate data sources within a local country are available, we have noted those sources and any material variations from HMD results.

For insured data, wherever possible, we have measured mortality improvements by comparison to the basic experience tables developed by various actuarial organizations worldwide from periodic mortality experience studies. Basic experience tables have been supplemented by population sources for age bands where actual experience is less credible and have been smoothed and graduated.

We note that at this time insured data is difficult to interpret due to "noise" in the results. The two main sources of noise arise from shifts in the mix of companies participating in industry studies over time and from changes in the underwriting and risk classification structure over time. Keeping this in mind, we do present what data is available for purposes of beginning a discussion regarding future assumptions. Finally, detailed information is focused on the US, Canada and the UK where relatively consistent long-term data is available.

6. *Mortality Experience Basis for Insured and Annuitant Data*.

All data for individually underwritten ordinary life insurance is included in the mortality improvement measurements without regard to policy size or other data breaks. Also, in most cases, we present mortality improvement results on an amount basis (rather than a number of policies basis). This decision was made for two reasons. First, in practice, mortality improvement assumptions are applied directly to base insured mortality which is typically developed on an amount basis. Second, in the US and Canada, it is more difficult to obtain historical mortality experience data on a number of policies basis.

For the UK mortality investigations, mortality experience by amount is currently collected for the immediate annuitant and life office pensioner lines. For all other investigations, data is only available based on the number of policies. The Continuous Mortality Investigation ("CMI"), the Institute of Actuaries group that publishes regular studies of UK insured and pension mortality experience, is currently moving to a seriatim data collection basis and they expect that future reports will include mortality results on both a number of policies and amount basis.

Section 2:Executive Summary

Over the last century, general population mortality has improved significantly, and this trend appears likely to continue at least over the near term. As a result, over the next several decades, mortality improvements are expected to continue to have a material impact on the financial viability of national social programs worldwide as well as on the financial results of insurance programs, including pension plans and annuities.

This document is intended to contribute to the discussion of best practices in developing future assumptions regarding mortality improvement. Toward that end, we first provide a review of trends in mortality improvement from both a population and insured perspective. We also review some of the key considerations in developing a view regarding future mortality improvement experience and its relationship to the past. These key considerations include the future impact of medical advances, lifestyle decisions (e.g., smoking habits, drinking habits, exercise, and diet), socioeconomic status, geography, race, the growth in rates of obesity among both adults and children in many developed countries, and future mortality improvement expectations at older ages.

For life insurance in particular, where less consistent long-term data is available, insurers will also need to form an opinion regarding differences, if any, between anticipated experience for the insured and the general population. Any direct examination of changes in mortality for the life insured population in particular, will necessarily require a view regarding what portion of insured mortality improvement has resulted from changes in the target market, distribution methods or underwriting processes of a particular company and the industry as a whole. This includes the implementation of more refined risk assessment and segmentation procedures (e.g., introduction of preferred risk classes, more extensive blood testing or collecting attending physician statements through the underwriting process).

Mortality Improvement Experience

Population Data

From 1900 to 1950, major improvements in mortality were seen in developed countries, with the largest improvements exhibited at ages under 35. This is largely attributed to the expanded focus on public health initiatives that led to the introduction of wide-scale immunization programs, penicillin and sulfate drugs, and other disease eradication methods. Since 1950, both in the US and across the globe, increases in life expectancy have continued but at a slower pace, with the most recent data from the World Health Organization (“WHO”) indicating that male and female life expectancies at birth are nearing 80 and 85 respectively for many developed nations.

Results By Age Group

A useful tool in the analysis of changes in life expectancy at birth over time is to examine changes in mortality rates over specific phases of the human lifespan — infancy, childhood, young adulthood, middle age, retirement and old age. Focusing on the US, UK, Canada and Australia, where data is available over similar periods, there are several overall trends of note (Table 2).

- *Infants* (improvement in the rate of mortality between ages 0 and 1): Rates of improvement for infant mortality have slowed significantly over the most recent period in all four countries, from highs of between 3 and 5 percent per year between 1940 and 1980 to rates generally under 2 percent during 2000-2007.

- *Children* (improvement in the rate of mortality between ages 1 and 20): Large mortality improvements were exhibited for child mortality during the period 1940-1960 (between 3 and 8 percent per year with the highest levels seen in the UK) as children and young adults benefited from the impact of stronger public health initiatives. Improvements also appear to have picked up between 1980 and 2000, possibly due to a decrease in the number of deaths due to accident or injury.

- *Young Adults* (improvement in the rate of mortality between ages 20 and 35): Rates of mortality improvement for young adults are also driven by lower rates of accident and injury as well as public health initiatives and medical advances in the treatment of bacterial and viral illnesses. With a few exception of males in Australia where for whom there was a notable increase in improvement (approximately 5 percent per year) during the period 2000-2007, levels of improvement for young adults have leveled off or declined since the period 1940 to 1960.

- *Middle Ages* (improvement in the rate of mortality between the ages of 35 and 65): Mortality between ages 35-65 has shown moderate but steady levels of improvement since 1960 (generally between 0.5 and 3 percent per year).

- *Retirement Ages* (improvement in the rate of mortality between the ages of 65 and 85): Mortality between ages 65 and 85 has exhibited lower levels of improvement, with the largest increases occurring between 2000 and 2007 (between 1 and 2 percent per year).

- *Old Age* (improvement in the rate of mortality between the ages of 85 and 100): Mortality for individuals between ages 85 and 100 has exhibited little or no improvement and even some deterioration. This observation has led some demographers and academicians to theorize that in the future, mortality improvements are more likely to be focused at the older ages where fewer strides have been made to date. And there is possible evidence for an increasing trend in the data for the most recent period.

Results By Gender

In the US, male improvements outpaced female improvements at all ages over the 20 year period from 1980 to 2000. In Canada, male improvements also outpaced female improvements at most ages. However, during the most recent experience period examined, 2000-2007, the pattern of gender differences is less clear for both countries. For the UK, Australia, Hungary, and Canada where experience data is available over most of the 30 to 40 year period between 1972 and 2009, males generally demonstrated greater levels of mortality improvement than females, with the exception of a few age groups between 20 and 44. In all cases, gender variations in improvement levels are small or nonexistent for ages 85 and older (Appendix E, Chart E-7). As a result, both the September 2010 CIA Report recommending mortality improvement levels for individual life insurance and annuity products and the most recent US Social Security Administration Technical Panel report assume that differences in mortality improvement levels by gender will continue to taper off over the next few decades.

Results By Geographic Region

There are variations in mortality improvement experience by geographic region in the US, Canada and the UK , with the lowest levels of improvement generally seen in the more rural and lower income areas of the countries. These differences are generally small for the periods examined.

Results By Socioeconomic Status

Several studies provide data to support the view that socioeconomic factors such as wealth, income level, attained level of education, and marital status have an impact on mortality and mortality improvement experience. The wealthier, better educated and married populations exhibit lower levels of mortality and also appear to have experienced higher levels of mortality improvement. As an example, a 2008 study funded by the American Cancer Society and the CDC covering experience years 1993-2001 indicated that rates of mortality improvement for those with a college education or higher were double those of the overall population.

Life Insured and Annuitant Data

Much of the insured information presented in this report, including the comparisons made to population and insured data across countries, is focused on ultimate mortality over the past few decades. This is intended to remove most of the impact of changes in underwriting and risk classification over time and provide a better view of the changes in mortality levels that are likely attributable to pure improvements in the underlying population results. However, results in the ultimate period can still be impacted by differences in the mix and number of companies included in the data at later durations. Results for life insureds in the select period are also examined. As one might expect, patterns are more difficult to discern. Available data is also presented for individual and group annuity experience. There are fewer annuitant experience studies to draw from, however there is also less noise in the measurement of results as these products are generally not underwritten.

US

For life insureds in the US, focusing on the period between 1978 and 2006, the pattern of mortality improvement by age and gender is similar for the insured population in the ultimate period and the general population. Ultimate data indicates that since the late 1970s, with the exception of the oldest ages, improvement levels for male insureds have been the same or lower than the general population on a number of policies basis. On an amount basis, male insured improvements have been slightly greater than the general population at ages 45 and older. Over the same period, female insureds have also exhibited results similar to general population data both on a number of policies and on an amount basis. For insureds in the ultimate period, male improvements appear to have outpaced female improvements at ages 55 and older.

Examining life insurance data during the select period, there is evidence to suggest greater levels of mortality improvement for nonsmokers than smokers, however the difference in results for smokers and nonsmokers is unclear at issue ages under 65. Possibly smoking impacts are greater for older issue ages because these individuals have likely been smoking for a longer period of time. In the ultimate period, data by smoker status is less credible as reliable splits by smoker status were not available until the early 1990s. However, limited ultimate data available does indicate stronger mortality improvements for nonsmokers.

Between 1963 and 2002, at attained ages over 65, individual annuitants exhibited greater levels of mortality improvement than the population in general with differences widening at increased attained ages.

Similarly, during the period 1951 and 1994, group annuitants exhibited greater levels of mortality improvement than the population in general, however differences appear to be declining with increased attained age for group annuitants.

Canada

In Canada, examining the period between 1989 and 2007, mortality improvement levels for life insureds were consistently greater than levels for the general population both on a number of policies basis and on an amount basis. The only exception to this appears to be insured males under 45 years of age and females under 25 years of age. In a trend similar to the US, male improvements have outpaced female improvements at ages 45 and over.

UK

For UK insureds, the mortality experience base that includes policies with various levels of underwriting from situations where medical data was collected, to situations where minimal medical information was collected, to policies issued on a guaranteed acceptance basis. Therefore, one might expect the differences between population and insured mortality to be less significant in the UK. And

over the 20 year period from 1980 to 2000, the levels of mortality improvement by age for UK permanent assureds and the UK general population are quite similar.

For UK immediate annuitants, rates of mortality improvement were relatively low between 1955 and 1980. However, healthier increases occurred both between 1980 and 1992 and between 1992 and 2000 for all but the oldest ages.

Mortality Improvement Projection Techniques

To date, insured mortality improvement scales have generally been developed through the extrapolation of past trends in population mortality combined with the application of professional judgment. As Li, Hardy and Tan point out in their 2010 paper, "Developing Mortality Improvement Formulas: The Canadian Insured Lives Case Study", these scales have generally been developed with little consideration for uncertainty regarding the relationship of the future to the past.

However, the academic community has made significant strides in the application of modeling and projection techniques for population and insured mortality and mortality improvements. These projection techniques generally fall into one of the following basic categories.

- *Predictive modeling*. A predictive model begins with the identification of a group of factors (predictors) that are likely to influence future results for a given value being estimated, e.g., mortality, mortality improvement or other items of interest. Focusing on life insurance mortality improvement as an example, many of the variables available for traditional experience analysis work (e.g., age, gender, product type, smoker status, risk classification) would be included in a predictive modeling exercise. Through a selected mathematical process, the impact of each of these factors is quantified and a model is developed that estimates future values based on expected levels of the predictors. The technique also defines a confidence interval for the estimated values under various conditions (for example, future mortality improvement levels within a specified range).

  For shorter term projections, there have been multiple and extensive applications of predictive modeling (including Generalized Linear Models (GLM) and Projection Pursuit Regression (PPR)) in the property casualty insurance industry for pricing, underwriting and claims management purposes.

- *Extrapolative projection techniques*. This general category includes the methods used by actuaries, economists and demographers in setting future mortality and mortality improvement assumptions based on the projection of past results.

  Gompertz and Weibull are well-known extrapolative models for mortality projection due to their relative simplicity. The most well-known extrapolative method today, the Lee-Carter model, has been used extensively on a global basis, and is one of the methods employed by the Social

Security Administration in the US and the Continuous Mortality Investigation in the UK for modeling future levels of mortality and mortality improvement.

- *Relational or targeting methods*. The basic approach for relational methods is to develop a function F that relates current mortality for a population under study to mortality for a reference population or other target level. The development of the function F is typically dependent on testing the fit of the relationship between the population being modeled and the reference population.

  Reference populations could be low mortality countries such as Sweden and Japan or other populations. A targeting method might involve assuming that future mortality improvements trend from their current levels to a long-term target assumption such as 2 to 2.5 percent per decade.

- *Cause-of-death specific models*. It has been common practice to apply either extrapolative or relational models to project all-cause insured or population mortality experience. However, it has also been argued that future all-cause mortality experience can be better predicted if trends in mortality by specific cause of death and future likely changes are understood. In theory, any of the models that we have reviewed could be applied to the mortality experience for specified cause-of-death groupings and then combined across all the groupings to produce aggregate assumptions. Under this approach, limiting the number of major groupings by cause of death has been important in maintaining a sufficient level of credibility.

- *Disease-based models*. A limitation of both all-cause and cause-specific mortality models is that data is restricted to information about the death itself and, therefore, there is no consideration of the potential impact of the timing and development of underlying disease that may have led to the death, including the impact of co-morbidities. Therefore, it has been suggested that superior estimates of future mortality may be produced by considering differences in the progression of disease as well as potential interactions between different existing morbidities. However, disease-based models are quite complex, typically involving multi-state transitional probabilities that require detailed, longitudinal data regarding the treatment and progression of various diseases for their estimation. This is often only possible through the use of patient health databases such as those that are available in countries with long-term universal health care programs such as the UK.

All of these approaches have both benefits and shortcomings. Extrapolative techniques tend to rely heavily on past experience to model the future. However, they may also involve less judgment in the model development process. Relational or targeting methods suffer from a heavy reliance on judgment, both in the selection of the target level or reference population as well as in the determination of the period and pattern over which targets are reached. Cause of death models provide greater insight into the potential causes of historical mortality and mortality improvement shifts. However the methods employed in the aggregation of the individual cause results to an all-cause mortality assumption have been called into question in some cases. Finally, disease-based models provide for the most detailed analysis of past results and their potential impact on the future; however

the level of complexity required both in the data needed to support assumptions and in the actual model development process have limited their use to date.

Further information regarding the projection techniques outlined in this report can be found in studies listed in Appendix A. In addition, public use software exists for some techniques including the Lee-Carter model. Also, the CMI publishes a Microsoft Excel add-in that provides for the fitting and projections of the Lee-Carter model.

Based on our review of potential approaches for projecting mortality and mortality improvements for the insured population, and bearing in mind the current insured and annuitant data limitations as compared to population sources, we believe the following steps may prove the most useful in the context of the current environment in developing future mortality improvement assumptions.

1. *Creation of a Detailed Database*. Compile and continually refresh a detailed database of information regarding the historical impact on mortality of specific lifestyle trends and behaviors, past and recent medical advances, and demographic/societal changes from both insurance industry and other outside sources. This data will allow for more informed monitoring and analysis of the impact of changes in these areas on current and future projections.

   A partial list of potential items that are expected to impact future mortality improvement levels includes the following:

   - Medical advances — Track new advances in health care that are expected to impact mortality improvements (newly introduced diagnostic tests, treatments, cures). Consider not just the potential reduction in mortality but also the population that will be impacted and the period of time over which the reduction is expected to emerge.
   - Lifestyle changes — Track levels of smoking (number of new smokers and rates of quitting in adulthood), alcohol intake, and differences in exercise and diet.
   - Changes in levels of disease incidence including emerging new diseases — Track new diseases and disease types as well as growth or decline in current disease diagnoses.
   - Access to medical care — Follow the development of the health care reform initiative in order to gauge its potential impact on future mortality and mortality improvement levels.

2. *Develop a Baseline Projection*. Select a rigorous and tested projection methodology, preferably one that provides a reasonable fit to recent historical experience. Utilize historical experience to develop a baseline projection of future results.

3. *Apply Profession Judgment Based Using Data Collected*. Modify the initial results from application of the projection technique selected in 2. to past experience by applying actuarial and other expert judgment regarding future expectations as to changes in the factors discussed in 1.

This approach allows for the application of a rigorous modeling methodology in developing a baseline projection, while retaining the element of professional judgment that forms the basis of current approaches to extrapolating assumptions for the insured population.

View Regarding Future Mortality Improvements for the US Individual Insured and Annuitant Populations (2011-2025)

As the information contained in this report indicates, there is no clear agreement regarding the overall level or pattern of future mortality improvement by age either for general population or insured data. However, using available information from general population sources and Society of Actuaries experience studies over time, we have developed a medium term (10-15 years) view regarding best estimate assumptions for the US general population, the US individual life insured population, and the US individual annuitant population.

In our view, population mortality data currently provides the most appropriate basis for developing an estimate of future mortality improvement for both the general and insured populations. This is because it represents the richest source of data in terms of the length of time over which experience is available, and just as importantly, it provides for greater consistency in the underlying population studied over time. We have focused the development of a future general population assumption on the period 1980-2007 as this provided nearly 30 years of data but is focused on more recent trends.

Our best estimate assumption for general population mortality improvement over the medium-term varies by age group and gender with median annual improvement levels of 1.5 percent for males and 1 percent for females.

In examining potential modifications of the population results for the life insured population, we note that, as discussed earlier, growing evidence supports the assertion that mortality and mortality improvement experience varies by socioeconomic status, whether this is measured in terms of level of education achieved, wealth, or income. And since the insurance-buying population tends to be focused at the higher education and income levels, we do make a distinction between insureds and the general population with regard to future mortality improvement expectations. Based on data from the 2008 American Cancer Society/CDC study discussed in greater detail in Section 5, we estimate that individuals in higher socioeconomic groups (identified by level of education achieved) will experience mortality improvements between 0.5% and 1% per year greater than the general population.

Also, for life insureds, we examined data from the most recent SOA study of individual life mortality experience and focus on results for policy durations 26 and later (in order to limit the impact of underwriting shifts), there appears to be emerging evidence for a difference in improvement levels between smokers and non smokers. For the 21 common companies submitting data over the 5-year period 2002-2007, focusing on the male data where there is greater credibility, results show mortality improvements for male smokers have been about 50% of the levels seen for male nonsmokers. And

at durations 16 to 20 where underwriting effects have largely worn off, the differences appear to increase with attained age.

As an additional consideration regarding smoking impacts on future results, we recognize that aggregate general population mortality has benefited from declines in the percentage of smokers over time. And since we are basing our view regarding future life insured improvements on the general population results, we must assume that at least a portion of the difference in smoker and non smoker insured experience has been accounted for our general population assumption.

Life Insureds

With these considerations in mind, for the individual life insurance population, we suggest a moderately higher assumption for improvement levels for insured nonsmokers than the general population (an additional 0.5% over general population levels at attained ages between 25 and 84). We then suggest using unadjusted population level mortality improvement levels for smokers. At the older ages, where improvement levels are much lower, we take the approach of maintaining the same average relationship between smokers and nonsmokers as at younger ages. This implies nonsmoker improvement levels approximately 33% higher than smokers for ages 85 and older.

For nonsmokers, this modification to general population estimates is intended to include both the socioeconomic impact and any additional health impact due to nonsmoking status. For smokers, we make the assumption that any socioeconomic benefit will be less significant or perhaps nullified by the negative impact of smoking on health.

Individual Payout Annuitants

For attained ages 65 and older for males and attained ages 75 and older for females, individual annuitants appear to have exhibited rates of improvement between 0.25% and 1.0% higher than those of the general population for the period 1973-2002 (see Chart 33). This may be due to socioeconomic status differences, self-selection effects, or both. For ages below 65, where results are less credible, general population mortality improvements exceeded annuitant mortality improvements. Based on this information, we have included a moderate additional 0.25% improvement over general population levels for individual annuitants at attained ages 75 and older and no adjustment at ages below 75.

The best estimate views regarding mortality improvement assumptions for the US general population, US individual life insureds, and US individual annuitants are presented in the table below. More detail regarding their development is provided in Section 6.

US Population, Life Insured and Individual Annuitant
Annual Mortality Improvement Best Estimates, 2011-2025

	General Population		*Ind Life Insureds Non Smokers*		*Ind Life Insureds Smokers*		*Individual Annuitants*	
Attained Age	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
25-34	1.50%	1.00%	2.00%	1.50%	1.50%	1.00%		
35-44	1.00%	0.50%	1.50%	1.00%	1.00%	0.50%		
45-54	1.00%	0.50%	1.50%	1.00%	1.00%	0.50%		
55-64	1.50%	1.00%	2.00%	1.50%	1.50%	1.00%	1.50%	1.00%
65-74	1.50%	1.00%	2.00%	1.50%	1.50%	1.00%	1.50%	1.00%
75-84	1.50%	1.00%	2.00%	1.50%	1.50%	1.00%	1.75%	1.25%
85-89	1.00%	0.75%	1.33%	1.00%	1.00%	0.75%	1.25%	1.00%
90-94	0.67%	0.50%	0.89%	0.67%	0.67%	0.50%	0.92%	0.75%
95-99	0.30%	0.25%	0.40%	0.33%	0.30%	0.25%	0.55%	0.50%
100+	0.20%	0.20%	0.27%	0.27%	0.20%	0.20%	0.20%	0.20%

Section 3: Global Mortality Improvement Trends

Part 1: General Population — Mortality Improvement Trends

From a global perspective, over the last century, we have seen major improvements in rates of mortality and resulting increases in life expectancy at birth for both highly industrialized as well as developing nations. Increases in male and female life expectancy at birth across North America, Europe, Australia and Asia averaged approximately 0.8 percent per year between 1900 and 1950, more recently dropping to levels around 0.3 percent per year (Charts 1 and 2).

Chart 1: Average Annual Rates of Increase in Life Expectancy
Population Life Expectancy at Birth, Males

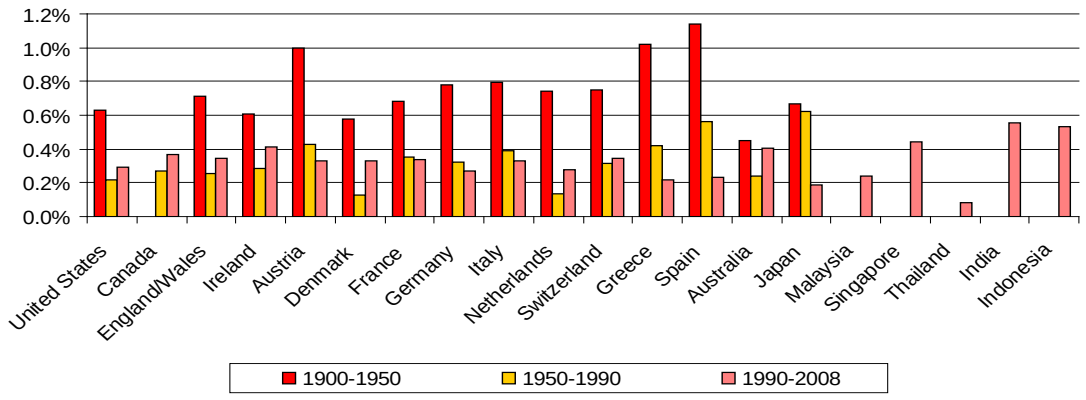
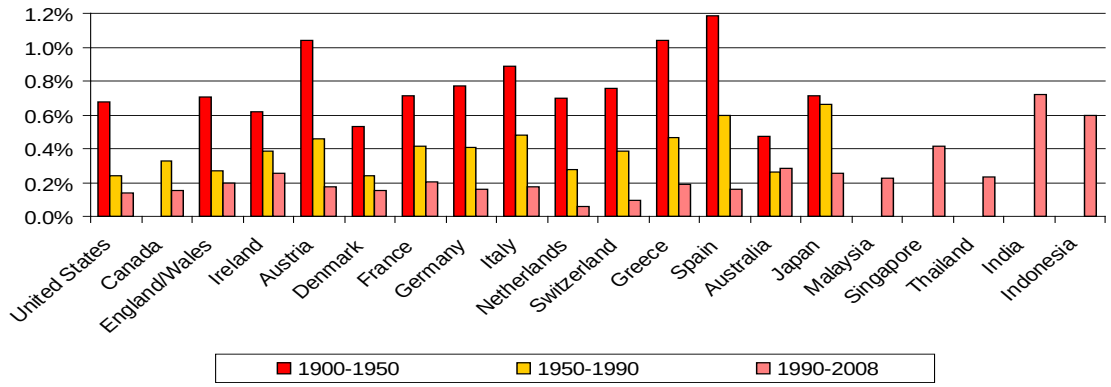


Chart 2: Average Annual Rates of Increase in Life Expectancy
Population Life Expectancy at Birth, Females



Source: World Health Organization Reports

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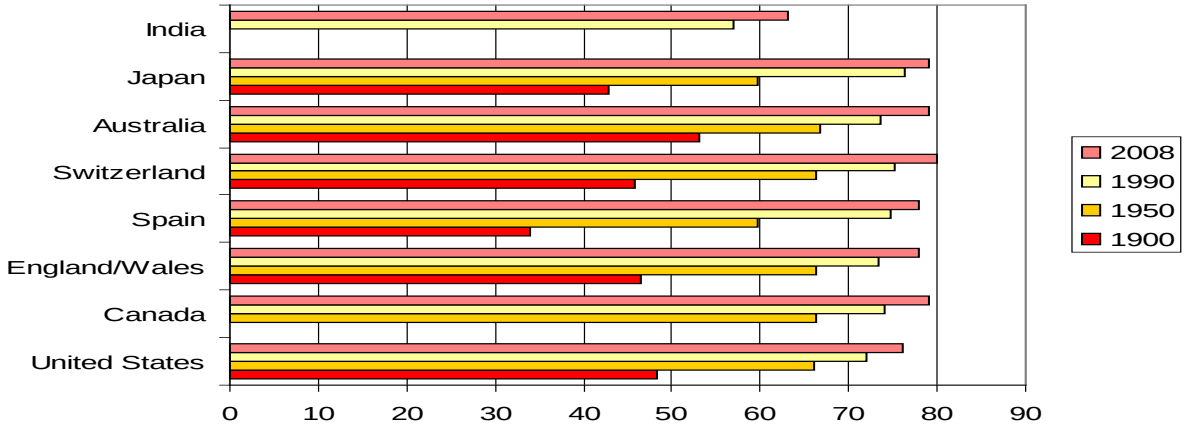
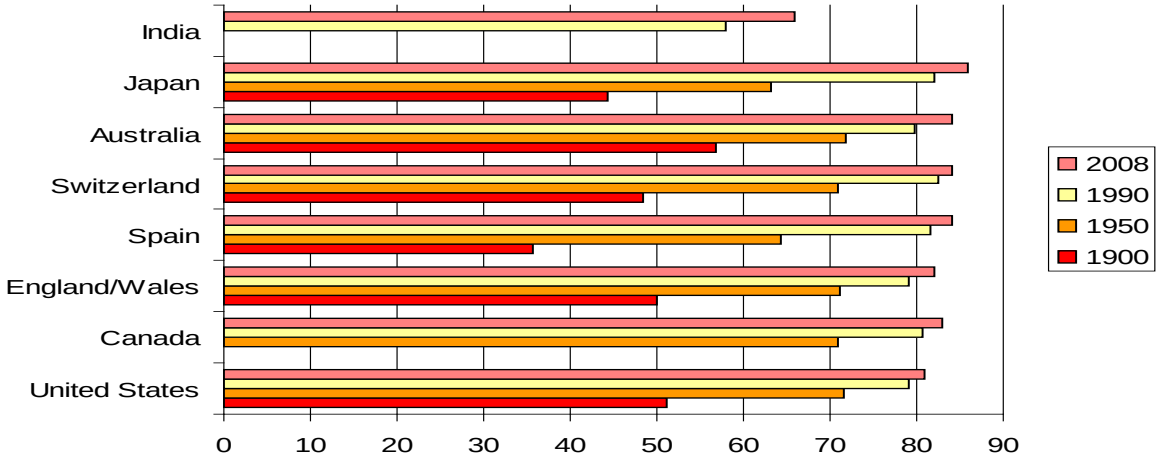
During the early to middle 20th century, major strides were made in improving mortality rates, mostly due to an expanded focus on public health initiatives that led to the introduction of wide-scale immunization programs, penicillin and sulfate drugs, and other disease eradication methods. Since 1950, both in the US and across the globe, increases in life expectancy have continued but at a slower pace. Recent data from the World Health Organization ("WHO") indicates that male and female life expectancies at birth are nearing 80 and 85 respectively for many developed nations. (Chart 3)

Chart 3: Population Life Expectancy at Birth by Country *

Males



Females



Source: US Census Bureau Estimates from Various Databases, American Journal of Clinical Nutrition, Changes in Life Expectancy 1900-1990, published 1992 and World Health Organization, Statistics 2010

***Note: Issues with data inaccuracy have been recently reported for Japan. Therefore, life expectancy estimates should be viewed with caution.**

Although the difference in life expectancy at birth between countries has been decreasing over time, material differences remain between the most developed and least developed nations. (Table 1)

Table 1: Population Life Expectancy at Birth (2008)

World Health Organization Life Expectancy by Country

Japan	82.6
Hong Kong	82.2
Iceland	81.8
Switzerland	81.7
Australia	81.2
United States	78.2 (Rank = 38)
Zimbabwe	43.5
Lesotho	42.6
Sierra Leon	42.6
Zambia	42.3
Mozambique	42.1

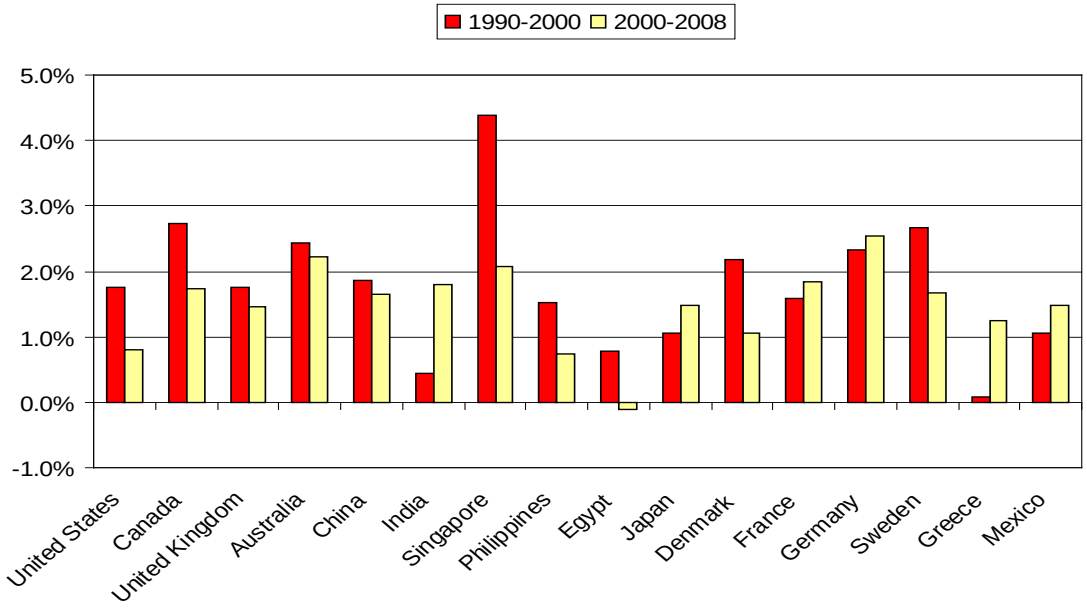
Source: World Health Organization Reports

Focusing on the adult population, Chart 4 presents average annual improvements in adult mortality rates as determined by the WHO. Here adult mortality is defined as the probability of dying between the ages of 15 and 60, i.e., ${}_{45}q_{15}$.

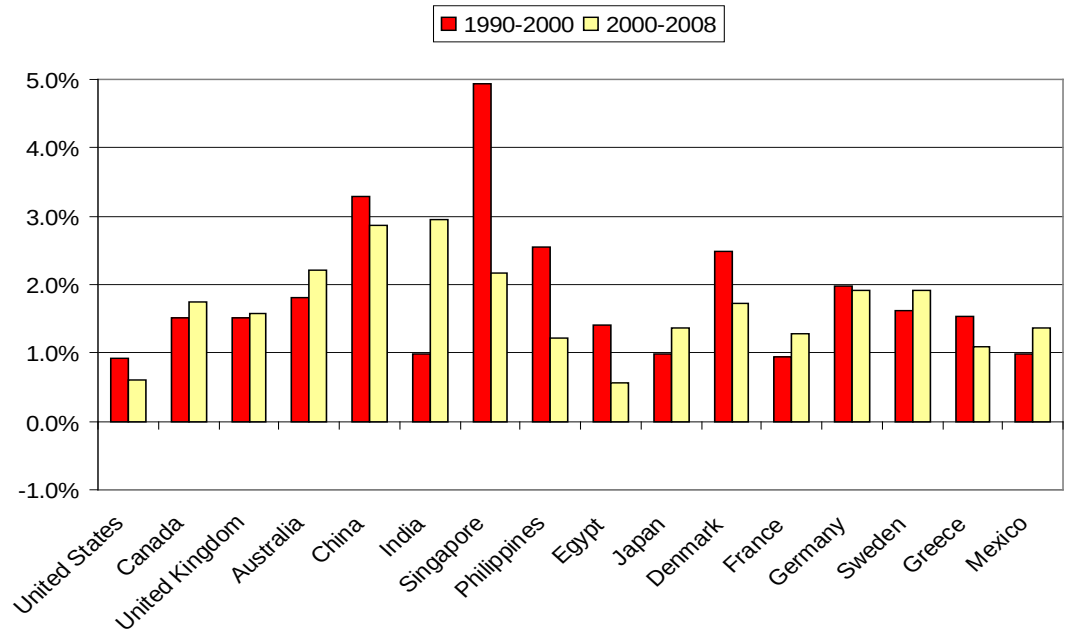
Note that for some countries, including India, Japan, Mexico, and France, improvements in mortality were more significant in recent years (2000-2008) for both males and females, while for other countries, such as the US, China, Singapore and the Philippines, improvements were more significant during the 1990s and have come down from that level in recent years. This highlights the importance of examining the details of experience for a specific region individually in setting expected future mortality improvement assumptions.

Chart 4: Average Annual Improvement in Adult Mortality Rates, 1990-2008

Males



Females



Source: World Health Organization, Statistics 2010

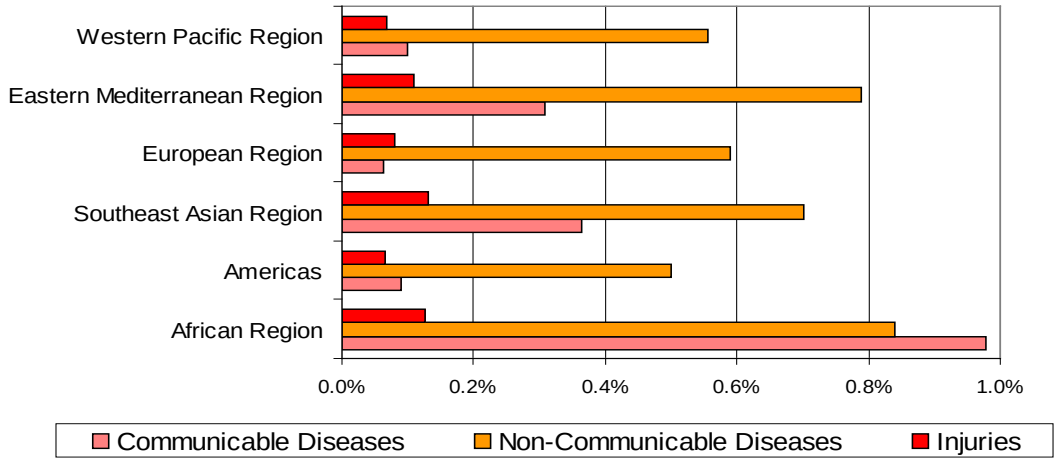
Sources of Variation in Mortality Improvement Results by Geographic Region

A valuable resource for comparison of both mortality and morbidity data across the globe is the WHO World Health Statistics series. These reports are published every two to three years and provide recent statistics regarding infant and child mortality rates, adult mortality rates, cause-specific mortality and morbidity data, and risk factors related to various diseases.

The WHO defines and tracks a group of factors that have historically influenced improvements in rates of mortality across the globe. These factors include the following:

- *Levels of Malnutrition*. This is an important indicator for improvement in infant and child mortality rates.
- *Child Health Interventions*. This includes increases in availability and success of immunization programs for measles and hepatitis B, efforts to prevent spread of HIV from mother to child, and micronutrient supplementation.
- *Maternal Mortality*. The rate of death during childbirth is a major factor impacting improvements in rates of death among young women and along with infant mortality represents one of the largest factors influencing differences in life expectancy, mortality, and mortality improvement experience between high and low income countries.
- *HIV Prevention Efforts*. Efforts to prevent the transmission of HIV as well as the development of effective antivirals that significantly slow the progression of the disease have contributed to improvements in mortality over the past few decades for both developed and developing countries.
- *Rates of Mortality for Non-communicable Diseases*. This category of disease includes conditions such as cancer, heart disease, chronic respiratory disease, diabetes and other non-viral/non bacterial morbidities. In more developed countries with lower mortality levels overall, rates of mortality due to non-communicable disease tend to be higher than rates of mortality due to communicable disease or injury. (Chart 5). In the near term, rates of mortality would be expected to improve more rapidly in developing countries where improved health, sanitation and education efforts have begun to lower rates of mortality due to communicable disease. Rates of improvement in mortality related to non-communicable disease have tended to be more moderate.

Chart 5: Age Adjusted Rates of Mortality by Global Region and Disease Type, 2004



Source: WHO Statistics 2010

- *Tobacco Use*. Higher income and more developed countries have seen greater success in reducing rates of tobacco use and therefore reducing rates of mortality due to lung cancer, heart disease and other tobacco-related illnesses. In the US, the portion of the population age 18 and older that smokes has declined over time, from 42 percent in 1965 to 21 percent in 2007. This has impacted US general population improvements exhibited in adult mortality over the past several decades as evidenced by a corresponding but lagged decline in lung and other respiratory cancer death rates.

- *Access to Health Care.* This is an issue in both developed countries and under-developed countries and accounts for the impact on mortality related to the availability of skilled healthcare workers in lower income countries as well as the impact of access to pharmaceuticals and advanced medical technology in higher income countries.

Mortality Improvement Trends in Developed Countries

A useful tool in the analysis of changes in life expectancy at birth over time is to examine changes in mortality rates over specific phases of the human lifespan — infancy, childhood, young adulthood, middle age, retirement and old age. Focusing on the US, UK, Canada and Australia, where data is available over similar periods, there are several overall trends of note (Table 2).

- *Infants* (improvement in the rate of mortality between ages 0 and 1): Rates of improvement for infant mortality have slowed significantly over the most recent period in all four countries, from highs of between 3 and 5 percent per year between 1940 and 1980 to rates generally under 2 percent during 2000-2007.

- *Children* (improvement in the rate of mortality between ages 1 and 20): Large mortality improvements were exhibited for child mortality during the period 1940-1960 (between 3 and 8 percent per year with the highest levels seen in the UK) as children and young adults benefited from the impact of stronger public health initiatives. Improvements also appear to have picked up between 1980 and 2000, possibly due to a decrease in the number of deaths due to accident or injury.

- *Young Adults* (improvement in the rate of mortality between ages 20 and 35): Rates of mortality improvement for young adults are also driven by lower rates of accident and injury as well as public health initiatives and medical advances in the treatment of bacterial and viral illnesses. With a few exception of males in Australia where for whom there was a notable increase in improvement (approximately 5 percent per year) during the period 2000-2007, levels of improvement for young adults have leveled off or declined since the period 1940 to 1960.

- *Middle Ages* (improvement in the rate of mortality between the ages of 35 and 65): Mortality between ages 35-65 has shown moderate but steady levels of improvement since 1960 (generally between 0.5 and 3 percent per year).

- *Retirement Ages* (improvement in the rate of mortality between the ages of 65 and 85): Mortality between ages 65 and 85 has exhibited lower levels of improvement, with the largest increases occurring between 2000 and 2007 (between 1 and 2 percent per year).

- *Old Age* (improvement in the rate of mortality between the ages of 85 and 100): Mortality for individuals between ages 85 and 100 has exhibited little or no improvement and even some deterioration. This observation has led some demographers and academicians to theorize that in the future, mortality improvements are more likely to be focused at the older ages where fewer strides have been made to date. And there is possible evidence for an increasing trend in the data for the most recent period.

Table 2: Improvements in Population Mortality by Country
Average Annual Improvement in Rates of Mortality Between Indicated Ages ($_tq_x$)
Human Mortality Database, 1940-2007

Males

	Ages					
	0-1	1-20	20-35	35-65	65-85	85-100
US						
1940-1960	3.2%	3.4%	2.6%	0.8%	0.3%	0.02%
1960-1980	3.7%	1.1%	-0.3%	1.1%	0.3%	0.04%
1980-2000	2.9%	2.5%	1.7%	1.5%	0.7%	-0.01%
2000-2007	0.8%	1.6%	-0.7%	1.0%	1.5%	0.2%
Canada						
1940-1960	4.0%	4.0%	2.3%	0.4%	0.3%	0.03%
1960-1980	4.7%	1.6%	0.3%	0.9%	0.3%	0.05%
1980-2000	3.6%	4.0%	2.3%	2.2%	0.8%	0.00%
2000-2007	0.2%	2.0%	1.2%	1.8%	1.7%	0.2%
UK						
1940-1960	4.7%	6.8%	6.2%	1.5%	0.3%	0.02%
1960-1980	3.1%	1.5%	1.1%	0.7%	0.2%	0.02%
1980-2000	4.0%	2.8%	-0.2%	2.2%	0.9%	0.03%
2000-2007	1.5%	1.9%	1.6%	1.9%	1.8%	0.2%

	Ages					
	0-1	1-20	20-35	35-65	65-85	85-100
Australia						
1940-1960	3.3%	3.6%	1.9%	0.6%	0.1%	-0.06%
1960-1980	3.1%	1.4%	0.7%	1.0%	0.3%	0.04%
1980-2000	3.7%	3.2%	0.7%	3.0%	1.2%	0.02%
2000-2007	2.8%	5.1%	4.9%	1.8%	1.7%	0.2%

Females

	Ages					
	0-1	1-20	20-35	35-65	65-85	85-100
US						
1940-1960	3.4%	4.7%	4.8%	2.0%	0.8%	0.04%
1960-1980	3.4%	1.7%	1.4%	1.2%	1.0%	0.12%
1980-2000	2.8%	2.2%	1.0%	0.9%	0.5%	-0.01%
2000-2007	0.7%	1.6%	-0.4%	1.1%	1.4%	0.3%
Canada						
1940-1960	4.1%	5.5%	5.8%	2.0%	0.7%	0.04%
1960-1980	4.6%	2.2%	1.6%	1.3%	1.1%	0.1%
1980-2000	3.5%	3.1%	2.4%	1.6%	0.9%	0.02%
2000-2007	-0.6%	2.0%	1.8%	1.4%	1.4%	0.2%
UK						
1940-1960	4.6%	8.3%	7.7%	2.5%	0.8%	0.04%
1960-1980	2.9%	1.8%	1.5%	0.6%	0.6%	0.05%
1980-2000	3.9%	2.9%	1.8%	1.8%	0.9%	0.07%
2000-2007	1.3%	0.4%	1.3%	1.8%	1.6%	0.2%

	Ages					
	0-1	1-20	20-35	35-65	65-85	85-100
Australia						
1940-1960	3.2%	4.2%	4.7%	1.4%	0.4%	-0.03%
1960-1980	3.1%	2.6%	1.6%	1.6%	0.9%	0.09%
1980-2000	3.5%	2.6%	1.0%	2.3%	1.4%	0.06%
2000-2007	1.8%	4.0%	3.1%	1.7%	1.6%	0.2%

Patterns of Mortality Improvement

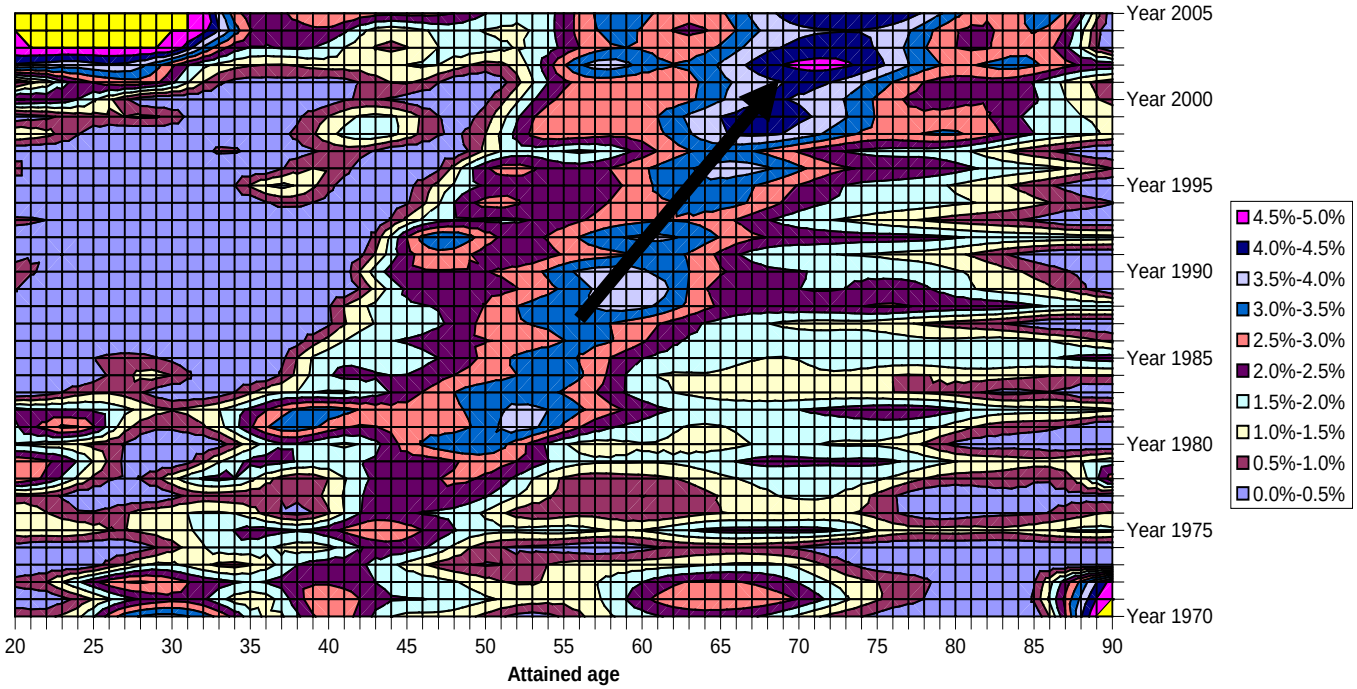
A common and useful tool for studying patterns of mortality improvement by age and gender over time is the heat map. Typically, these heat maps are color coded such that higher levels of mortality improvement are indicated by brighter colors and lower levels of improvement are indicated by cooler colors. This allows for easier identification of patterns and trends across large datasets.

Two broad patterns of mortality improvement are commonly discussed in the literature:

1. *Cohort Patterns* (or, "Cohort Effects") — This pattern is characterized by higher levels of mortality improvement occurring for a specific generation than for the generations born before or after. This phenomenon is identified by differences in levels of improvement that can be seen along the diagonal of the heat map. Chart 6 provides a good example of this pattern as seen in the UK population. Note that the generation born between 1925 and 1945 has demonstrated higher rates of improvement during the period shown than other generations (black arrow).

2. *Period Patterns* — This pattern is characterized by strong or stable levels of mortality improvement that occur over an extended period of time and across a broad range of ages. Note that for the US population to date, period patterns have been more predominant than cohort patterns. However, there is some evidence for emerging cohort patterns.

Chart 6: Annual Rates of Mortality Improvement from 1970 to 2005: UK Population, England and Wales, Males and Females Combined



Source: UK Population Data, ONS

Some of the reasons cited for the UK cohort effect include:

- Differences in diet for pre- and post-war Britain – Although food rationing continued through the end of World War II, consumption of fresh vegetables, bread, milk, potatoes and fish was higher in the post war years.

- Extended period of relative freedom from large-scale conflict - Children born during the period 1925-1945 were unlikely to have served in any major war in their lifetime and therefore war-related deaths would have been much lower than in previous or later generations.

- Differences in smoking habits – This is also considered a potential explanation of differences in mortality improvement experience for those born between 1925 and 1945. During the period after World War II, the health consequences of cigarette smoking first began to be seriously studied, leading to declines in smoking prevalence. As an example, a 2002 study by Evandrou and Falkingham estimated that 45 percent of men born between 1916 and 1920 that had smoked cigarettes at some point in their lives were still smoking at age 60 while only 25 percent of men born between 1931 and 1935 were still smoking by age 60.

Part 2: Insured Population — Comparisons to the General Population

Over the past several decades, strong improvements in mortality have also been documented for the insured population. While some insured data is available outside the US, UK and Canada, detailed information is relatively limited both in the number of explanatory factors available for study as well as the number of experience years over which mortality improvements can be measured. Therefore, the remainder of this report focuses primarily on experience for these three countries.

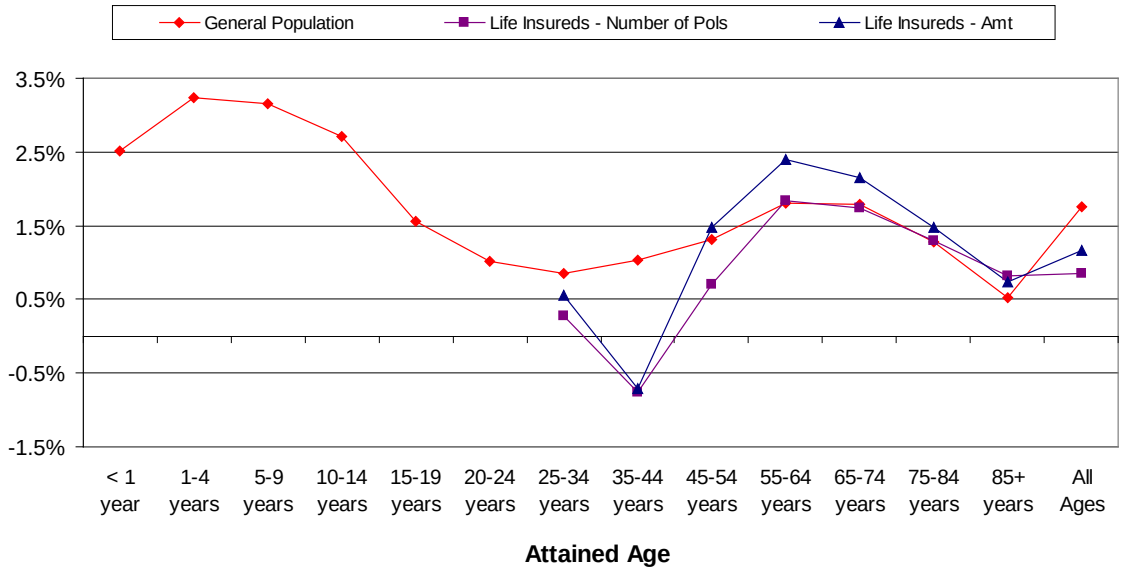
As discussed earlier, in the US, the pattern and level of improvement by age are similar between insureds and the general population. Ultimate data indicates that since the late 1970s, with the exception of the oldest ages, improvement levels for male insureds have been slightly lower than the general population on a lives or number of policies basis. On an amount basis, male insured improvements have been slightly greater than the general population at ages 45 and older. Over the same period, female insureds have also exhibited results similar to general population data both on a number of policies and on an amount basis. Also, for these insureds, male improvements appear to have outpaced female improvements at ages 55 and older. (Chart 7)

We again note the difficulty in interpretation of results for the ultimate period due to the smaller number (and varying mix) of companies underlying data at the later policy durations. We have therefore relied more heavily on general population based results in constructing a view regarding medium term future mortality improvements for insureds.

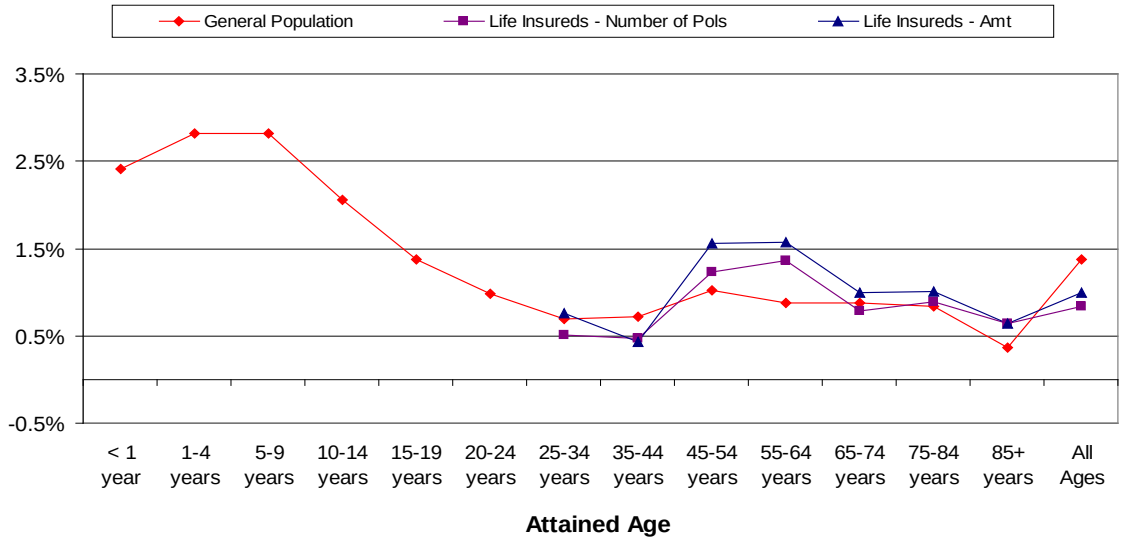
Note that the marked decline in mortality improvement for male insureds ages 35-44 is generally attributed to the impact of the AIDs epidemic during the 1980s and early 1990s.

Chart 7: US Average Annual Rates of Mortality Improvement
Life Insureds vs. General Population, 1978-2006, Ultimate Mortality
By Gender and Attained Age Group

Males



Females

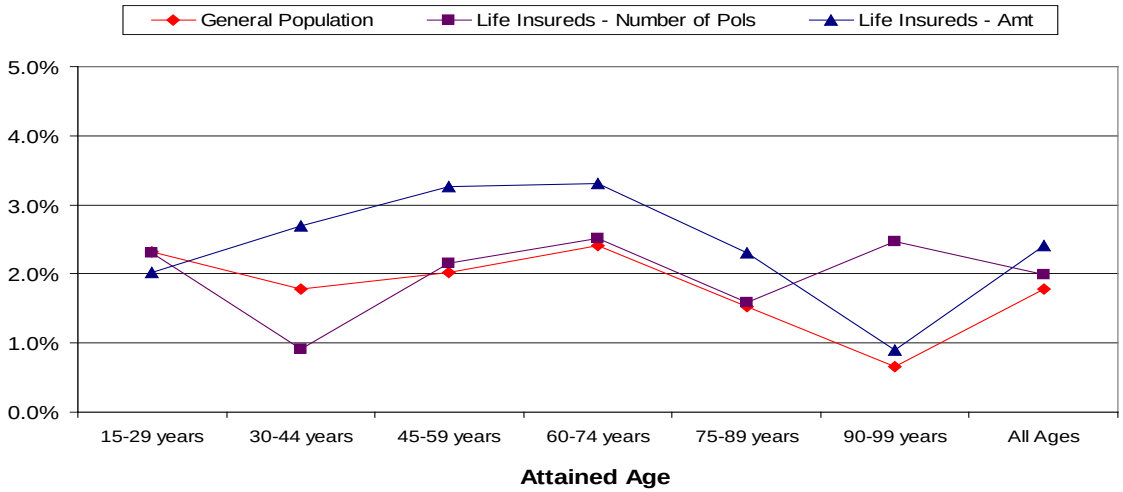


Source: HMD, Table Manager, and SOA Individual Life Experience Study, 2005-2007

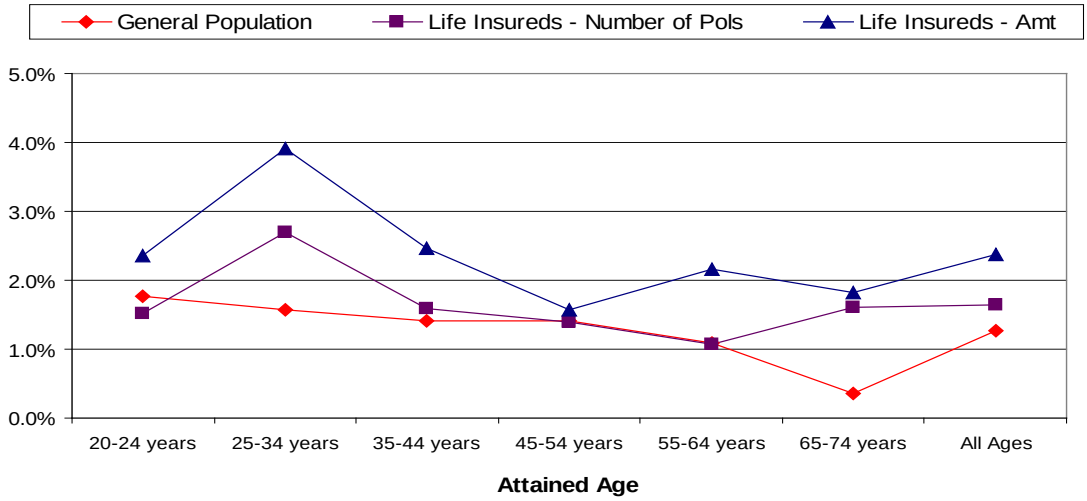
In Canada, for the period between 1989 and 2007, ultimate mortality improvement levels for life insureds were consistently greater than for the general population both on a number of policies basis and on an amount basis. The only exception to this appears to be insured males under 45 years of age and insureds females under 25 years of age. (Chart 8)

Chart 8: Canadian Average Annual Rates of Mortality Improvement
Life Insureds vs. General Population, 1989-2007, Ultimate Mortality
By Gender and Attained Age Group

Males



Female

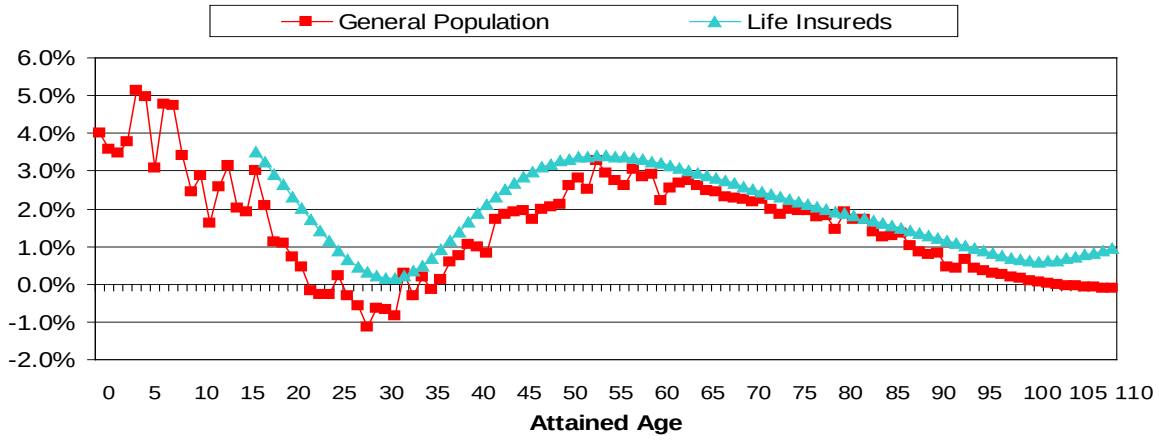


Source: HMD, Table Manager and CIA Individual Life Experience Studies

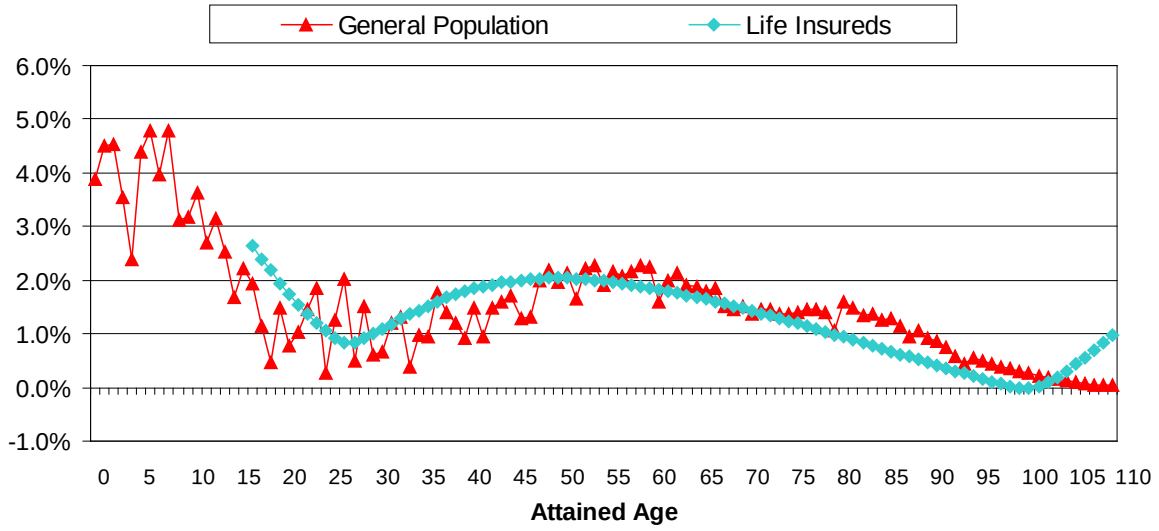
For UK companies, life insured data includes policies written under a simpler underwriting process than data in the US and Canada. Therefore, one might expect the differences between population and insured mortality to be less significant in the UK. And for the 20 year period from 1980 to 2000, the levels of mortality improvement by age for UK permanent assureds and the UK general population are quite similar. (Chart 9) In addition, select periods are shorter (2 years and 5 years are typically used) and therefore this report focuses on ultimate mortality for the UK.

Chart 9: UK Average Annual Rates of Mortality Improvement
Permanent Assureds vs. General Population, 1980-2000, Ultimate Mortality
By Gender and Attained Age

Males



Females



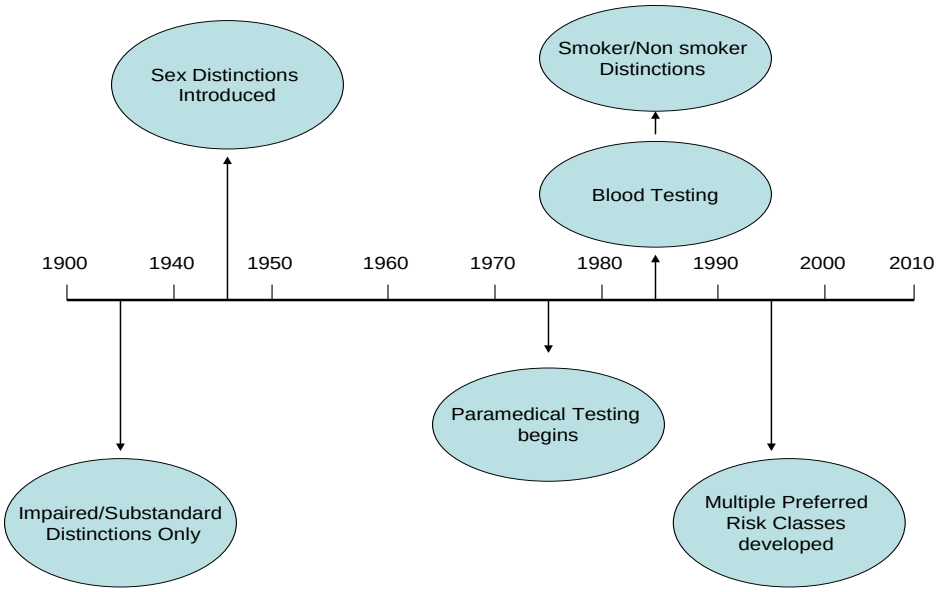
Source: HMD, Continuous Mortality Investigation Reports

Note: Life insured results based on mortality by number of policies (see *Background* section for discussion).

Before moving to a more detailed discussion of population and insured mortality improvement experience across the US, UK and Canada, it is important to stress the potentially large impact that changes in the underwriting process over time have had on life insured results. Care needs to be taken in interpreting and utilizing past trends to project future rates of insured improvement,

particularly during the policy select period. Chart 10 below lays out the timeline of major underwriting and risk classification changes in the US over the past century. The major developments in Canada closely parallel those in the US, in some cases with a lag time.

Chart 10: Development of Underwriting and Risk Classification Techniques in the US



In addition to changes in underwriting tools and methodology, shifts in lifestyle and other factors have also impacted past experience. The impact of these shifts may or may not be appropriate to incorporate in projections of future expectations.

Based on the studies, presentations and papers reviewed for this project, we have compiled the following list of factors that we believe should be considered in setting an assumption for insured mortality improvement to be used in pricing, valuation or strategic planning work, including consideration of both the timing and estimated impact.

- Introduction of new underwriting approaches across different product generations — Examples include extensive blood and urine testing introduced for HIV detection, cocaine use, hepatitis, liver enzymes and HDL cholesterol in the 1980s.
- Expansion or modification of the standard insurance risk classification definitions — Examples include smoker/nonsmoker distinctions as well as more refined preferred classes in the 1980s and 1990s respectively.

- Changes in products offered, target populations, and distribution channels – Since the 1960s, the insurance market has undergone considerable change, along with the products and distribution methods employed by the industry to serve the market.
- Changes in lifestyle for the target population — Examples include reductions in the prevalence of smoking and an increased focus on healthy habits (exercise and diet changes).
- Socioeconomic status of the target population — For example, the insured population generally represents a higher socioeconomic status than the population as a whole.
- Lapse and potential antiselection of insureds during different periods.
- Basis for the industry experience studies underlying the historical analysis of mortality improvements — Over time, industry studies have included different groups of participating companies with varying product offerings, target markets and distribution channels. This can further distort mortality improvement rates calculated from this data.
- Potential for future shifts in any or all of these areas, including new products with additional or different risk classifications, new target markets, the introduction of new underwriting tools including genetic testing, and positive or negative lifestyle changes including increased obesity and/or the continued shift toward healthier diets.

All of the above issues need to be considered carefully when reviewing and projecting the results of insured mortality improvements over time.

Section 4: Mortality Improvement Trends for the US, Canada, and the UK

This section of the report focuses on mortality improvements in the US, UK and Canada as those countries have richer sources of both population and insured data. Population-based data is also available for parts of continental Europe, Australia and Asia; however, the number of experience years and the number of explanatory variables available are fewer. Some information for these regions is provided in Appendix E of this report.

Part 1: Mortality Improvement Trends in the US

A) General Population Mortality Improvement Trends

There are four primary sources of general population mortality improvement data in the US. The first is the National Center for Health Statistics ("NCHS") Compressed Mortality File ("CMF") available for download from the CDC Wonder website (www.wonder.cdc.gov), the second is the US National Vital Statistics System ("NVSS"), the third is the Social Security Administration ("SSA"), and the fourth is the HMD (www.mortality.org). Details regarding accessing these and other sources of mortality and mortality improvement data are provided in Appendix A to this report.

Table 3 and Chart 11 below examine mortality improvements from 1979 through 2007 based on population data downloaded from the HMD. The start year was selected to coincide with the first year that more detailed splits by geographic region, cause of death, and race were available from the NCHS via the CDC Wonder online database.

Consistent with other sources of population mortality improvement data for the US, we note the following trends.

- *Gender Differences*. Male improvement outpaced female improvement by an average of about 0.5 percent between 1979 and 2000; however, during more recent years, 2000-2007, the differences have narrowed. (Chart 11).
- *Variations by Age Group*. Over the period 1979-2000, mortality improvements were lowest at the oldest ages (85 and older). However, during the most recent period, improvements have increased at older ages and generally decreased for younger age groups (between 20 and 54). Mortality experience for ages between 20 and 34 has deteriorated in the most recent period.

Table 3: US Average Annual Rates of Mortality Improvement
Human Mortality Database 1979-2007
By Gender and Age Group

Males				Females			
			Full Period				*Full Period*
Age Group	**1979-2000**	**2000-2007**	**1979-2007**	**Age Group**	**1979-2000**	**2000-2007**	**1979-2007**
< 1 year	3.0%	0.8%	2.4%	< 1 year	2.8%	0.7%	2.3%
1-4 years	3.2%	2.0%	2.9%	1-4 years	3.2%	1.7%	2.8%
5-9 years	3.5%	2.3%	3.2%	5-9 years	2.7%	2.2%	2.6%
10-14 years	2.3%	2.8%	2.4%	10-14 years	1.7%	2.1%	1.8%
15-19 years	2.0%	0.9%	1.8%	15-19 years	1.4%	1.4%	1.4%
20-24 years	1.8%	-0.8%	1.1%	20-24 years	1.4%	-0.5%	0.9%
25-34 years	1.6%	-0.7%	1.0%	25-34 years	0.8%	-0.3%	0.6%
35-44 years	0.9%	1.4%	1.0%	35-44 years	0.7%	0.7%	0.7%
45-54 years	1.6%	0.2%	1.3%	45-54 years	1.2%	-0.2%	0.9%
55-64 years	1.8%	1.5%	1.7%	55-64 years	0.8%	1.9%	1.1%
65-74 years	1.5%	2.5%	1.8%	65-74 years	0.5%	2.0%	0.9%
75-84 years	0.9%	2.3%	1.3%	75-84 years	0.5%	1.8%	0.8%
85+ years	0.1%	1.8%	0.5%	85+ years	0.0%	1.3%	0.3%
Average	1.8%	1.3%	1.7%	Average	1.4%	1.1%	1.3%

Chart 11a: US Average Annual Rates of Mortality Improvement
Human Mortality Database
1979-2000

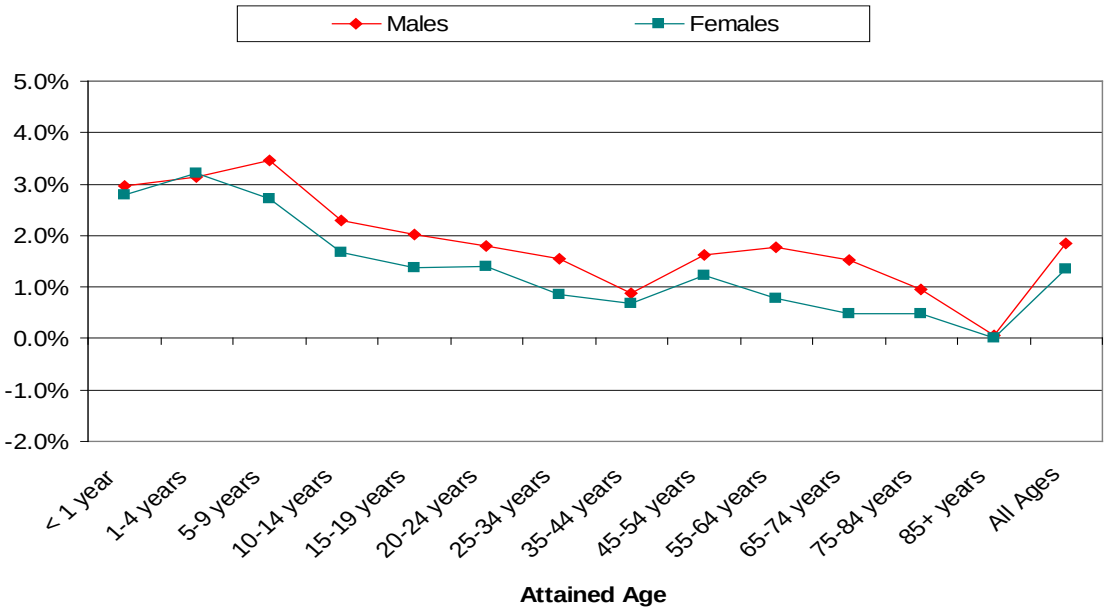


Chart 11b: US Average Annual Rates of Mortality Improvement
Human Mortality Database
2000-2007

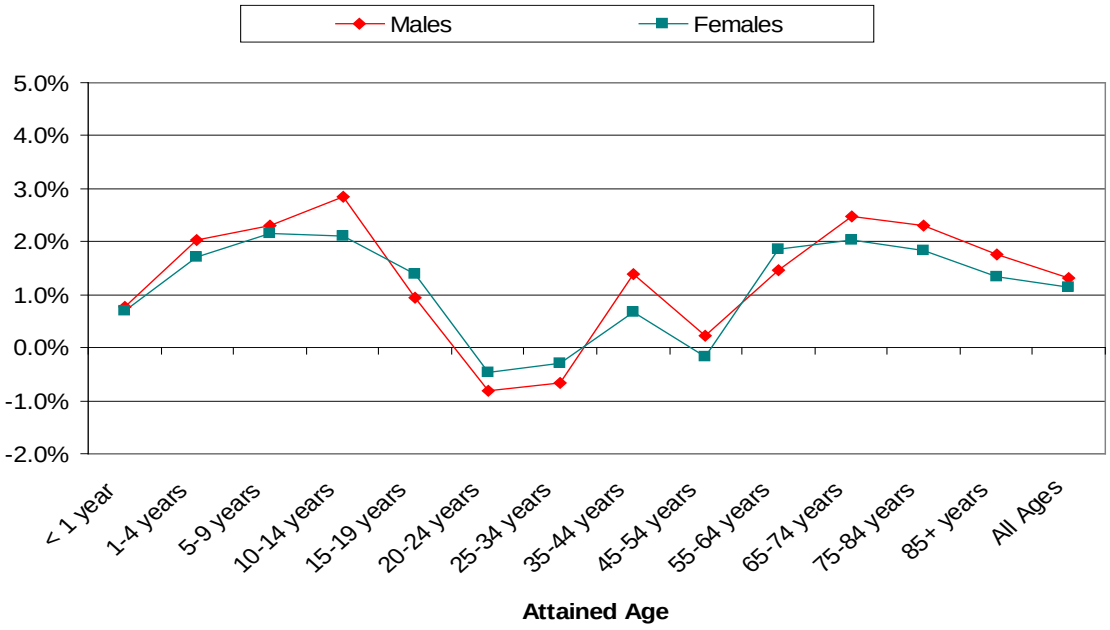
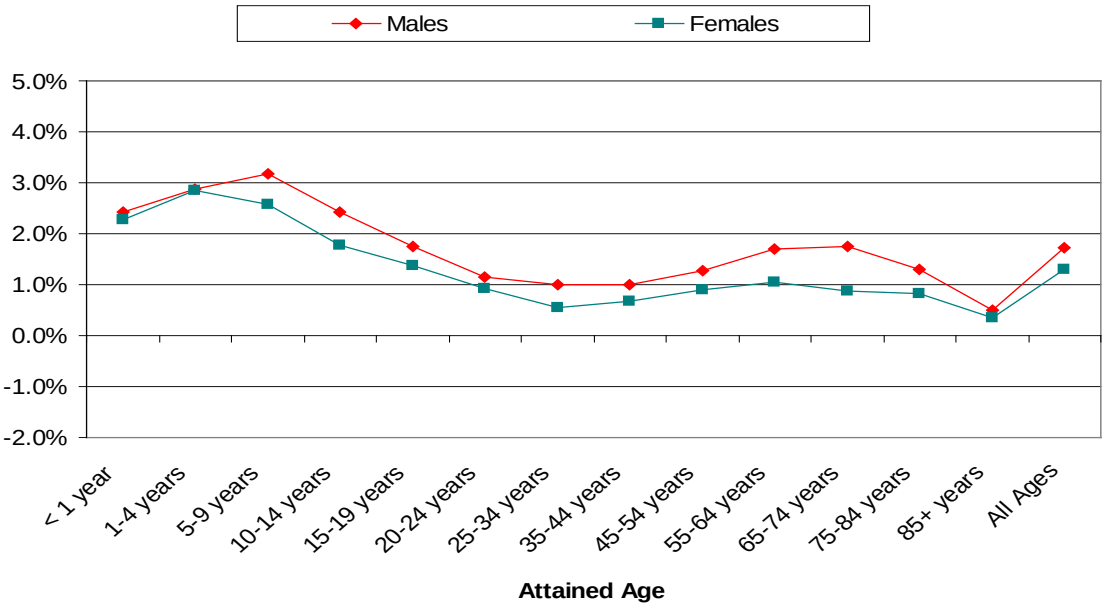


Chart 11c: US Average Annual Rates of Mortality Improvement
Human Mortality Database
1979-2007



The CMF is a US mortality and population database spanning the years 1968-2006 that contains information by gender, age, race, state, county, level of urbanization, and cause of death. The CMF is created and maintained by the US Department of Health and Human Services ("US DHHS"), Centers for Disease Control and Prevention ("CDC"), and the NCHS and is accessible online at the CDC Wonder website (www.wonder.cdc.gov).

Table 4 breaks down overall US mortality improvement trends by age, gender and geographic region using CMF data. Based on this information, it appears that over the past 27 years, for ages 35 and over, the largest improvements in mortality were seen in the northeast and west. For both males and females, the largest variations in experience between regions were seen at ages between 20 and 34, with differences of approximately 1 percent between the lowest improvement and highest improvement regions. However, as in the case of Canada and the UK, the data does not indicate large overall differences by region. This might be expected in more developed countries where socioeconomic differences by region are smaller and therefore less material to mortality results.

Table 4: US Average Annual Rates of Mortality Improvement
Compressed Mortality File 1979-2006
By Gender, Age Group and Geographic Region

Males

Age Group	Northeast	Midwest	South	West
< 1 year	2.7%	2.2%	2.3%	2.8%
1-4 years	3.1%	3.1%	2.8%	3.5%
5-9 years	3.6%	3.1%	3.1%	3.2%
10-14 years	2.7%	2.4%	2.7%	2.7%
15-19 years	2.1%	1.8%	1.3%	2.0%
20-24 years	1.2%	1.5%	0.6%	1.7%
25-34 years	1.1%	0.8%	0.8%	1.6%
35-44 years	1.1%	0.7%	0.8%	0.9%
45-54 years	1.7%	1.3%	1.2%	1.2%
55-64 years	2.1%	1.8%	1.7%	1.8%
65-74 years	2.1%	1.8%	1.5%	1.8%
75-84 years	1.4%	1.1%	1.0%	1.3%
85+ years	0.8%	0.6%	0.8%	0.9%

Females

Age Group	Northeast	Midwest	South	West
< 1 year	2.7%	2.1%	2.2%	2.5%
1-4 years	3.1%	2.7%	2.7%	3.0%
5-9 years	3.4%	2.6%	2.4%	2.8%
10-14 years	2.7%	2.0%	2.2%	1.5%
15-19 years	1.5%	1.5%	1.1%	1.6%
20-24 years	1.2%	1.1%	0.5%	1.4%
25-34 years	0.8%	0.5%	0.2%	1.3%
35-44 years	0.9%	0.5%	0.2%	0.8%
45-54 years	1.4%	1.0%	0.7%	1.1%
55-64 years	1.5%	1.0%	0.8%	1.2%
65-74 years	1.2%	0.7%	0.5%	0.8%
75-84 years	1.0%	0.6%	0.5%	0.7%
85+ years	0.4%	0.2%	0.3%	0.4%

Impact of Differences in Methodology and Data Sources

The NVSS, the second source of US population mortality data, provides information on mortality results by age, gender, cause of death and race for the US that is published regularly in the US Life Table Reports.

The US Life Table methodology for determining mortality for the older age population (ages 66 to100) was revised beginning with the 2005 life tables. First, Medicare data was used to supplement vital statistics and census data beginning at age 66 rather than age 85, as was done from 1997 through 2004. Second, the smoothing and extrapolation of the probabilities of death for ages 66 and over utilized a nonlinear least squares model rather than the linear model of the rate of change of the probabilities of death for ages 85 and over that had been employed in past years. This new methodology is believed to provide a better estimate of mortality at older ages where age misrepresentation can have a greater impact on results. Age misreporting is expected to be more limited in Medicare data due to the requirement to present a birth certificate to begin receiving benefits.

The CDC Wonder Compressed Mortality File and the HMD continue to utilize standard death certificate information for determining mortality experience at all ages.

As an example of the impact of differences in methodology on results for the same experience period, Table 5 compares rates of mortality improvement by age group and gender for the period 1990-2006 using the HMD results and results published in the National Vital Statistics Reports (US Life Tables). Note that the HMD data indicates larger improvements at ages 75 and over and ages 4 and under. This example, applied to US general population experience, highlights the larger issue of the complexity of working with various data sources both within a given region and across the globe.

Table 5: US Average Annual Rates of Mortality Improvement
HMD vs. US Life Tables
Experience Period: 1990-2006
By Gender and Age Group

Male

Age Group	US Life Tables	HMD	Difference
< 1 year	2.1%	2.3%	0.2%
1-4 years	3.1%	3.3%	0.2%
5-9 years	3.1%	3.1%	0.0%
10-14 years	3.1%	3.0%	-0.1%
15-19 years	2.0%	2.0%	0.0%
20-24 years	0.7%	0.7%	0.0%
25-34 years	2.0%	2.0%	0.1%
35-44 years	1.7%	1.6%	0.0%
45-54 years	0.8%	0.8%	0.0%
55-64 years	1.8%	1.8%	0.0%
65-74 years	1.9%	2.0%	0.0%
75-84 years	1.4%	1.6%	0.2%
85+ years	0.3%	0.7%	0.4%
All Ages	1.8%	1.9%	0.1%

Female

Age Group	US Life Tables	HMD	Difference
< 1 year	1.8%	2.0%	0.2%
1-4 years	2.6%	2.7%	0.2%
5-9 years	2.5%	2.6%	0.1%
10-14 years	2.6%	2.5%	-0.1%
15-19 years	1.3%	1.5%	0.1%
20-24 years	0.3%	0.3%	0.0%
25-34 years	0.8%	0.8%	0.0%
35-44 years	-0.1%	-0.1%	0.0%
45-54 years	0.5%	0.5%	0.0%
55-64 years	1.3%	1.3%	0.0%
65-74 years	0.9%	1.1%	0.2%
75-84 years	0.5%	0.8%	0.3%
85+ years	0.0%	0.3%	0.3%
All Ages	1.2%	1.3%	0.1%

B) Life Insured Mortality Improvement Trends

Much of the discussion of life insured mortality improvement experience included in this report focuses on ultimate mortality for the insured population. This is because changes in ultimate mortality should contain less distortion due to shifts in underwriting and risk classification techniques that have occurred over time.

As discussed in Section 1, life insured mortality improvements presented in this report are based on the change in rates of mortality by amount of insurance for life insureds and on amount of income for annuitants unless otherwise indicated. All data for the US insured population is based on Society of Actuaries mortality studies of individual standard ordinary life insurance conducted over time. For details regarding specific data referenced, please see Appendix A of this report. It should be noted again that differences in the number and type of insurers participating in the SOA experience studies over time has also affected the results shown.

Table 6 shows rates of ultimate mortality improvement by gender and attained age for US life insureds for the period 1967 through 2006. If the lengths of the select periods chosen were correct, then the impact of underwriting should be minimal for this data.

For life insureds in the US, focusing on the period between 1978 and 2006, the pattern of mortality improvement by age and gender is similar for the insured population in the ultimate period and the general population. Ultimate data indicates that since the late 1970s, with the exception of the oldest ages, improvement levels for male insureds have been slightly lower than the general population on a lives or number of policies basis. On an amount basis, male insured improvements have been slightly greater than the general population at ages 45 and older. Over the same period, female insureds have also exhibited results similar to general population data both on a number of policies and on an amount basis.

For life insureds in the ultimate period in the US, we note the following general trends over the periods examined.

- Between 1967 and 2006, average annual rates of improvement for all ages combined were 1.5% for males and 1.3% for females. (Table 6)
- For the period 1967 to 2006, there was more variation in rates of improvement by age group for males, with improvements at younger ages under 0.5% and improvements for middle and retirement ages between 1.0% and 2.5%. (Chart 12a)
- Between 1978 and 2006, in comparison to population data where male rates of improvement were greater than females at all ages, in the ultimate period male insured mortality improvements were greater than female improvements only for ages 55 and older. (Chart 12b)

Table 6: US Average Annual Rates of Mortality Improvement
Life Insureds, Experience Period: 1967-2006, Ultimate Mortality Only

Male

Attained Age	1967-1978	1978-2006	*Full Period* 1967-2006
30	0.3%	0.5%	0.4%
35	1.6%	-0.3%	0.3%
40	3.1%	-0.7%	0.4%
45	3.0%	0.0%	0.9%
50	2.9%	1.3%	1.8%
55	2.9%	2.1%	2.3%
60	2.9%	2.4%	2.5%
65	2.6%	2.4%	2.4%
70	2.1%	2.2%	2.1%
75	1.9%	1.8%	1.8%
80	1.7%	1.5%	1.5%
85	1.4%	1.1%	1.2%
90	1.0%	0.7%	0.8%
95	0.4%	1.4%	1.1%
All Ages	2.1%	1.2%	1.5%

Female

Attained Age	1967-1978	1978-2006	*Full Period* 1967-2006
30	1.6%	0.9%	1.1%
35	1.6%	0.5%	0.8%
40	1.9%	0.4%	0.8%
45	1.3%	1.2%	1.2%
50	1.5%	1.6%	1.5%
55	1.3%	1.7%	1.6%
60	1.4%	1.5%	1.5%
65	1.1%	1.2%	1.2%
70	1.7%	1.0%	1.2%
75	3.1%	1.0%	1.6%
80	2.6%	1.0%	1.5%
85	2.0%	0.9%	1.2%
90	1.9%	0.6%	1.0%
95	1.7%	1.0%	1.2%
All Ages	1.8%	1.1%	1.3%

Source: SOA Table Manager, SOA Studies of Individual Life Mortality Experience

Note: Life insured results based on mortality by amount (see *Background* section for discussion)

Chart 12a: US Average Annual Rates of Mortality Improvement
Life Insureds, Experience Period: 1967-2006, Ultimate Mortality Only

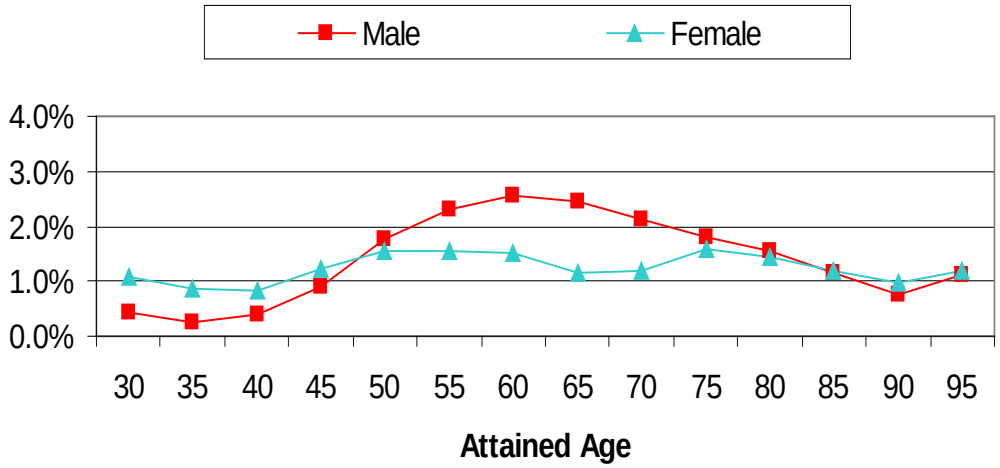
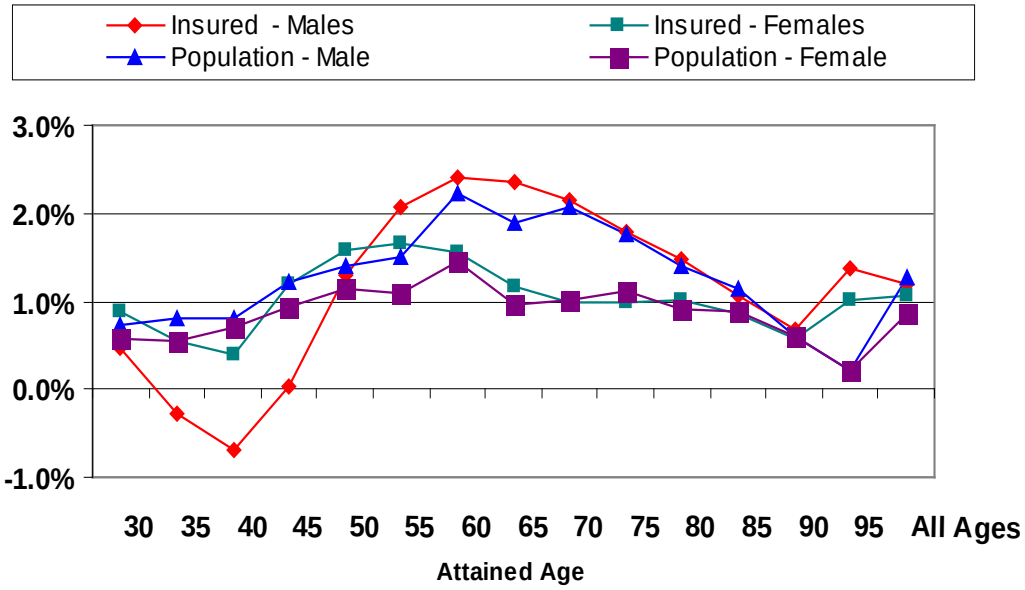


Chart 12b: US Average Annual Rates of Mortality Improvement
Life Insured Ultimate vs. General Population, Experience Period: 1978-2006



Source: HMD, SOA Table Manager, SOA Studies of Individual Life Mortality Experience

Note: Life insured results based on mortality by amount (see *Background* section for discussion)

Table 7 presents US life insured select mortality improvement experience for the first 15 policy years for the period between 1967 and 2004 by issue age. The impact of changes in underwriting and risk classification shifts over time has had a material impact on these results, possibly overshadowing any changes resulting from general secular mortality shifts.

As expected, patterns of mortality improvement are not as clear for insureds in the select period (Table 7). However, there are a few items of note regarding mortality improvements during the select period:

- For the period 1967-2004, male improvements consistently fell between 2.5 and 4.5 percent at all issues ages and durations. For females, improvement levels varied more widely, from apparent deterioration in duration 2 for issue age 55 to average annual improvements near 5 percent in duration 1 for issue ages 35 and 55.
- For the full period 1967-2004, with the exception of issue age 35, mortality improvements for females were generally lower than for males after policy year 1, in line with results by gender for the general population and for life insureds in the ultimate period.

Table 7: US Average Annual Rates of Mortality Improvement
Life Insureds, Experience Period: 1967-2004, Select Mortality
By Gender, Issue Age and Policy Year

Age 35

Male

Policy Year	1967-1978	1978-2004	1967-2004
1	2.4%	3.1%	2.9%
2	2.5%	4.5%	4.0%
3	1.6%	3.6%	3.1%
4	1.8%	3.7%	3.2%
5	2.1%	4.1%	3.6%
6-10	2.6%	3.3%	3.1%
11-15	3.0%	2.4%	2.6%

Female

Policy Year	1967-1978	1978-2004	1967-2004
1	5.4%	4.7%	4.9%
2	5.4%	3.3%	3.9%
3	4.9%	3.3%	3.8%
4	4.0%	4.0%	4.0%
5	3.5%	4.6%	4.3%
6-10	2.4%	3.3%	3.0%
11-15	1.7%	2.5%	2.3%

Age 45

Male

Policy Year	1967-1978	1978-2004	1967-2004
1	3.7%	3.9%	3.8%
2	3.1%	4.6%	4.2%
3	2.5%	3.6%	3.3%
4	2.6%	3.9%	3.6%
5	2.7%	4.4%	3.9%
6-10	3.4%	3.9%	3.8%
11-15	3.5%	3.2%	3.3%

Female

Policy Year	1967-1978	1978-2004	1967-2004
1	1.5%	5.4%	4.4%
2	1.5%	4.8%	3.9%
3	1.9%	3.4%	3.0%
4	2.0%	1.7%	1.8%
5	1.9%	2.3%	2.2%
6-10	1.4%	4.0%	3.3%
11-15	1.4%	2.8%	2.4%

Age 55

Male

Policy Year	1967-1978	1978-2004	1967-2004
1	2.6%	3.6%	3.3%
2	4.1%	4.0%	4.0%
3	4.6%	3.6%	3.8%
4	4.4%	2.1%	2.7%
5	4.1%	2.7%	3.1%
6-10	3.2%	4.0%	3.8%
11-15	2.9%	3.2%	3.1%

Female

Policy Year	1967-1978	1978-2004	1967-2004
1	3.3%	5.5%	4.9%
2	3.8%	-1.7%	-0.2%
3	3.7%	2.0%	2.5%
4	3.2%	0.3%	1.1%
5	2.3%	1.1%	1.4%
6-10	0.2%	3.1%	2.3%
11-15	2.0%	2.2%	2.1%

Age 65

Male

Policy Year	1967-1978	1978-2004	1967-2004
1	5.0%	4.5%	4.6%
2	5.0%	3.2%	3.7%
3	3.7%	3.2%	3.3%
4	3.0%	3.4%	3.3%
5	2.7%	3.9%	3.6%
6-10	1.8%	3.3%	2.9%
11-15	3.3%	2.3%	2.6%

Female

Policy Year	1967-1978	1978-2004	1967-2004
1	3.2%	5.1%	4.6%
2	4.9%	2.4%	3.1%
3	5.1%	0.4%	1.7%
4	4.8%	1.0%	2.0%
5	4.5%	1.6%	2.4%
6-10	3.5%	1.6%	2.1%
11-15	4.8%	0.7%	1.8%

Source: SOA Table Manager, SOA Studies of Individual Life Mortality Experience

Beginning in the early 1990s, mortality data became available separately for smokers and nonsmokers. However, credible data with a smoker/nonsmoker distinction is mostly focused in the early policy durations; therefore we begin by examining results by smoker status over the period 1993-2004 for select mortality (Table 8).

There are a few key considerations in reviewing this information. First, the experience period 1993-2004 included not only the smoker and nonsmoker distinctions but also the proliferation of new preferred risk classes. So the nonsmoker data in particular includes a combination of results for various risk classes from super preferred through standard nonsmokers. Second, it should be noted that the smoker data tends to have lower credibility due to the smaller proportion of smokers in the life insured population than the population in general. Third, the experience period itself is relatively short. Therefore, there is likely to be some distortion in pure smoker/nonsmoker results. Finally, changes in the definition of smokers over time, is also likely distorting results to some extent.

Some general observations regarding the results by smoker status in the select period:

- Clearly the influence of underwriting and risk classification changes over time is impacting the mortality improvement results presented below. In addition, the period 1993 to 2004 is relatively short for measurement of improvements.

- There is some evidence to suggest greater levels of mortality improvement for nonsmokers than smokers in the select period for older issue ages (see issue age 65 results). Possibly smoking impacts are greater for issue older ages because these individuals have likely been smoking for a longer period of time.

- There is also some evidence for a relatively uniform difference in the level of mortality improvement between smokers and nonsmokers after policy year 3 for issue age 65. (Chart 13)

- The difference in results for smokers and nonsmokers is unclear at issue ages under 65.

Table 8: US Average Annual Rates of Mortality Improvement
Life Insureds, Experience Period: 1993-2004
By Gender, Issue Age, Policy Year and Smoker Status

Age 35

Male

Policy Year	Non Smoker	Smoker
1	1.1%	10.4%
2	6.3%	3.2%
3	3.8%	3.4%
4	3.9%	5.9%
5	5.3%	7.2%
6-10	2.7%	3.8%

Female

Policy Year	Non Smoker	Smoker
1	4.8%	-2.8%
2	2.4%	8.3%
3	3.3%	6.5%
4	5.8%	0.1%
5	6.8%	0.5%
6-10	2.5%	-3.3%

Age 45

Male

Policy Year	Non Smoker	Smoker
1	3.6%	2.6%
2	5.9%	1.0%
3	2.5%	4.1%
4	3.7%	2.6%
5	5.3%	3.6%
6-10	6.8%	2.2%

Female

Policy Year	Non Smoker	Smoker
1	7.2%	3.6%
2	7.5%	5.4%
3	5.5%	0.2%
4	0.4%	3.0%
5	1.5%	4.5%
6-10	5.6%	4.1%

Age 55

Male

Policy Year	Non Smoker	Smoker
1	3.4%	7.3%
2	5.3%	5.5%
3	5.3%	3.4%
4	1.7%	-1.0%
5	2.7%	-0.1%
6-10	7.1%	3.7%

Female

Policy Year	Non Smoker	Smoker
1	11.4%	9.6%
2	-5.0%	3.6%
3	3.9%	8.5%
4	-0.9%	3.5%
5	-0.1%	4.6%
6-10	3.5%	7.3%

Age 65

Male

Policy Year	Non Smoker	Smoker
1	7.1%	3.4%
2	4.0%	3.2%
3	3.7%	4.0%
4	4.6%	2.7%
5	6.4%	4.2%
6-10	5.9%	0.3%

Female

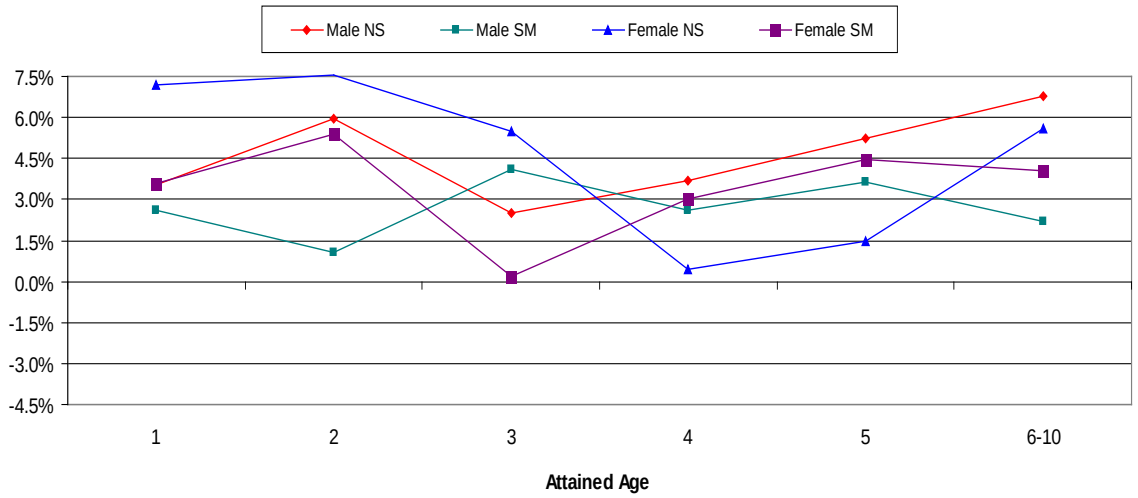
Policy Year	Non Smoker	Smoker
1	10.0%	5.7%
2	5.0%	5.2%
3	0.5%	4.3%
4	2.1%	-1.6%
5	2.7%	-0.7%
6-10	3.6%	1.3%

Source: SOA Table Manager, SOA Studies of Individual Life Mortality Experience

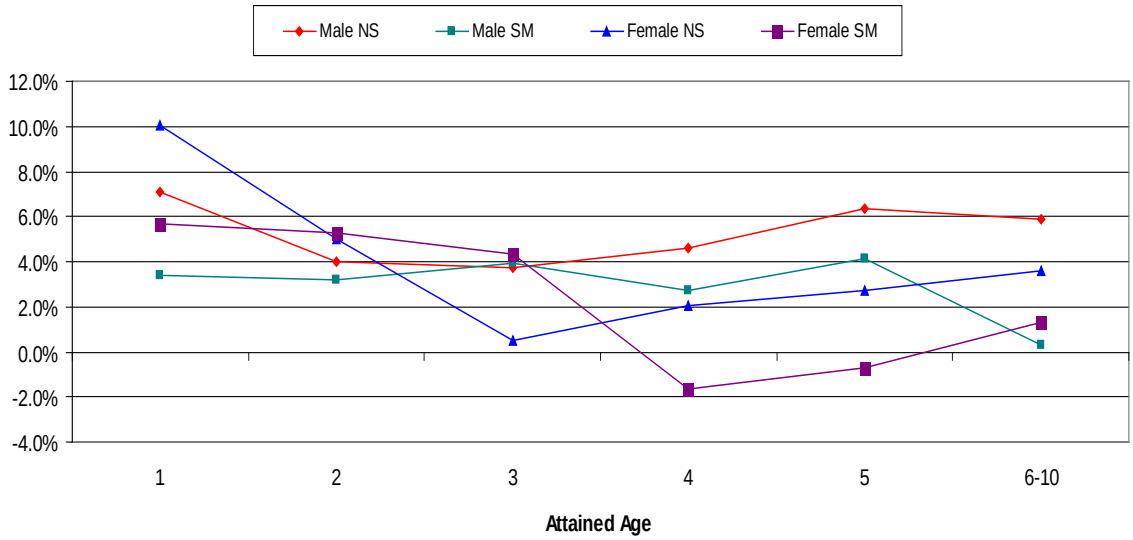
Chart 13 indicates the level of mortality improvement between 1993 and 2004 for the first 10 policy years for both males and females at issue ages 45 and 65.

Chart 13: US Average Annual Rates of Mortality Improvement
Life Insureds, Experience Period: 1993-2004
By Gender, Issue Age, Policy Year and Smoker Status
Select Mortality

Age 45



Age 65



Although only small amounts of data are available, information from recent SOA studies also provides some evidence for a difference in improvement levels between smokers and nonsmokers. For the 21 common companies submitting data over the 5-year period 2002-2007, only the male data has sufficient credibility in the ultimate durations for an analysis by smoker status. With these caveats, data shows that for males, overall mortality improvements for smokers have been about 50% of the levels seen for nonsmokers. And at durations 16-20 where there is less distortion due to underwriting impact than during the earlier portion of the select period, the differences appear to increase with increasing attained age.

C) Annuitant Mortality Improvement Trends

Based on SOA studies of individual immediate annuity and settlement option policyholder experience between 1963 and 1973, for males the largest rates of mortality improvement were seen at the youngest and oldest attained ages (Table 9). Interestingly, the opposite trend is exhibited during 1973-2002. For females, with the exception of the oldest ages, greater levels of mortality improvement were experienced during the earlier period than in more recent years. Males showed stronger improvements in the later period at most ages. This is an example of potential issues with extrapolation of future mortality improvements from the recent past.

Table 9: US Average Annual Rates of Mortality Improvement
Individual Annuitants, Experience Period: 1963-2002
By Gender and Attained Age Group
All Policy Years Combined (Annual Income)

Male			Female		
Age Group	**1963-1973**	**1973-2002**	**Age Group**	**1963-1973**	**1973-2002**
55-64 years	2.6%	0.8%	55-64 years	3.0%	-0.2%
65-74 years	1.0%	1.9%	65-74 years	0.8%	0.8%
75-84 years	0.7%	2.0%	75-84 years	1.7%	1.5%
85-94 years	1.1%	1.5%	85-94 years	1.9%	1.5%
95-100 years	2.9%	0.6%	95-100 years	0.4%	0.9%

Source: SOA Individual Annuitant Mortality Studies, SOA Table Manager.

For group annuitants, mortality improvements were measured using results of SOA studies of mortality experience for the periods 1951-1983 and 1983-1994. Similar to individual annuitants, females generally exhibited higher levels of improvement during the earlier period while males generally showed stronger improvements during the later period (ages 65 to 94). (Table 10)

A summary of group annuity mortality experience results for the period 1997-2002 is available in Microsoft Excel format on the SOA website. However, for several of the age breaks presented in Table 10, this data implies a deterioration in mortality between 1994 and the midpoint of the study experience period (2000) that does not correspond to general population results. Until this can be further reviewed and confirmed, it was decided to exclude this period from the current report.

Also, group annuitant experience for ages under 55 is relatively sparse and was therefore removed for purposes of this report.

Table 10: US Average Annual Rates of Mortality Improvement
Group Annuitants, Experience Period: 1951-1994
By Gender and Age Group (Number of Policies)

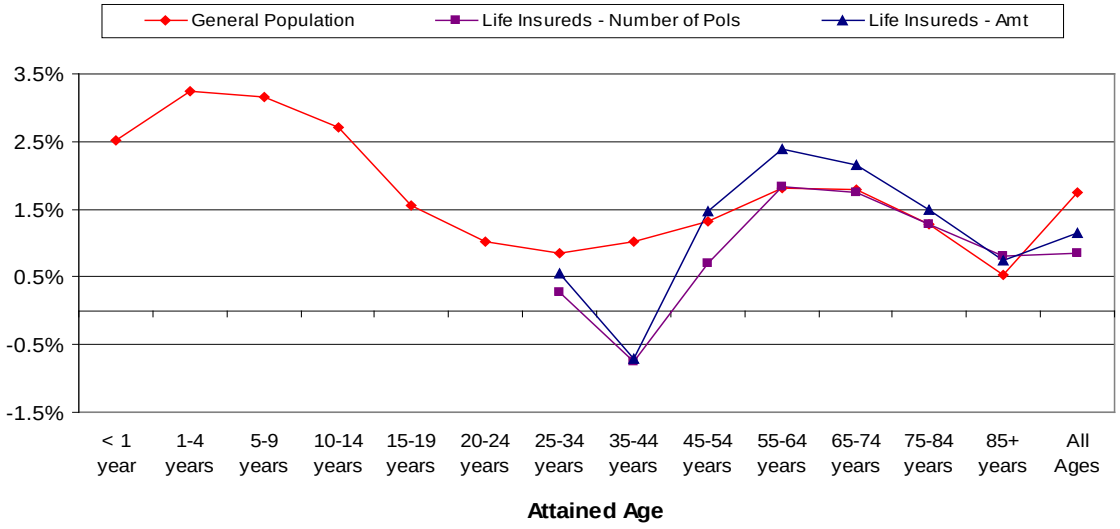
Male			Female		
Age Group	**1951-1983**	**1983-1994**	**Age Group**	**1951-1983**	**1983-1994**
55-64 years	1.6%	1.5%	55-64 years	1.9%	-0.1%
65-74 years	1.1%	1.6%	65-74 years	1.9%	-0.6%
75-84 years	0.9%	1.9%	75-84 years	1.7%	1.1%
85-94 years	0.6%	1.1%	85-94 years	1.2%	-0.1%
95-99 years	0.4%	0.1%	95-99 years	0.8%	0.4%

Source: SOA Group Annuitant Mortality Studies and Table Manager.

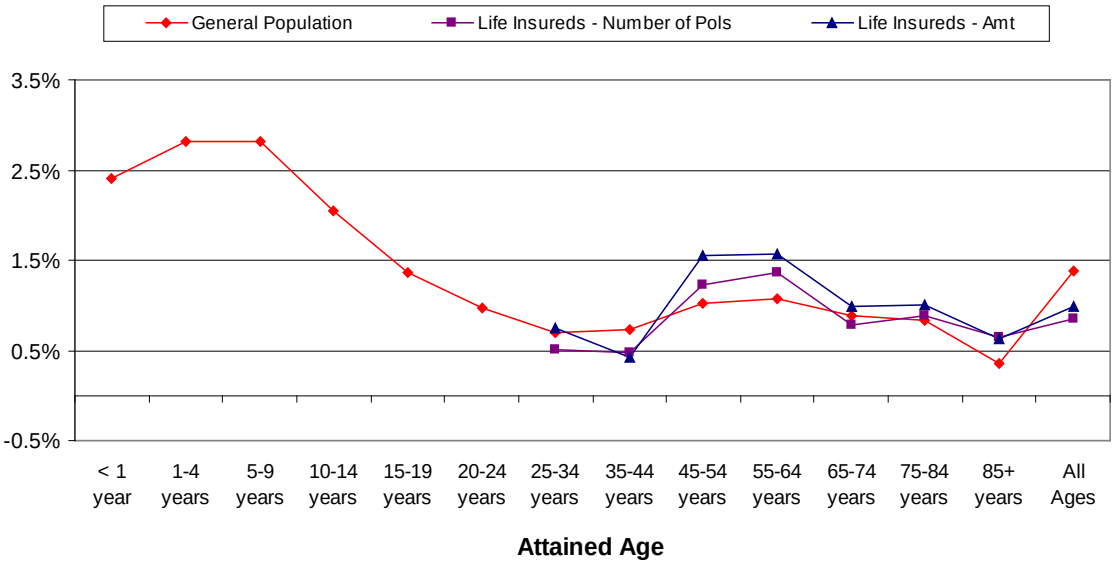
Comparing the mortality improvement experience in the US for the general population with the insured population, with the exception of the oldest ages, life insureds exhibited slightly higher levels of improvement in mortality for ages 45 and over during the period 1978-2006 than the population in general on an amount basis and similar or slightly lower levels of improvement on a number of policies basis. (Chart 14)

Chart 14: US Average Annual Rates of Mortality Improvement
Life Insured versus General Population Data, 1978-2006
By Gender and Attained Age Group, Ultimate Mortality Only

Males



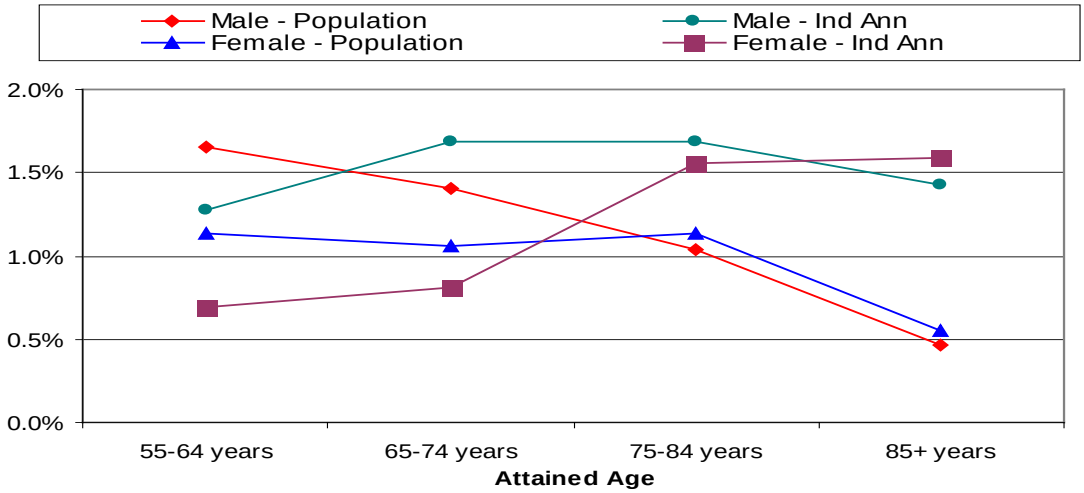
Females



Source: HMD, SOA Individual Life Insurance Mortality Studies and Table Manager

Between 1963 and 2002, beginning around age 65, individual annuitants exhibited greater levels of mortality improvement than the population in general (Chart 15a) with differences widening with increased attained age.

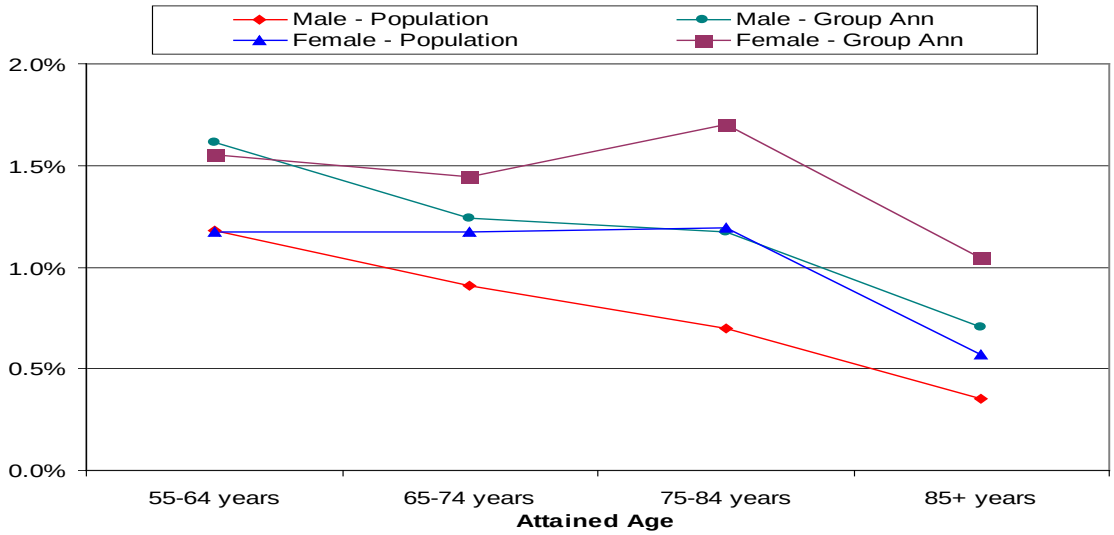
Chart 15a: US Average Annual Rates of Mortality Improvement
General Population and Individual Annuitants, 1963-2002
By Gender and Attained Age Group



Source: HMD, SOA Individual Annuitant Mortality Studies and Table Manager.

Similarly, during the period 1951 and 1994, group annuitants exhibited greater levels of mortality improvement than the population in general (Chart 15b), however differences appear to be declining with increased attained age for group annuitants and increasing with increased attained age for individual annuitants.

Chart 15b: US Average Annual Rates of Mortality Improvement
General Population and Group Annuitants, 1951-1994
By Gender and Attained Age Group



Source: HMD, SOA Group Annuitant Mortality Studies and Table Manager.

Part 2: Mortality Improvement Trends in Canada

A) General Population Mortality Improvements (Canada)

The primary source of general population mortality improvement data for Canada is Statistics Canada, which is required by law to provide statistics for the whole of Canada and each of its provinces.

Statistics Canada provides national data relating to the Canadian population, resources, economy, society, and culture, including the Canada Life Tables. The life tables are available for experience years 1990 through 2007 on a periodic basis; however, the most recent data available for free download through CANSIM covered the period 2000-2002. Splits of population mortality results are available by age, gender, race and cause of death. CANSIM is an electronic database service provided by Statistics Canada that is updated daily for new information.

A secondary source for Canadian population data is the HMD which includes mortality data for Canada covering the entire period from 1921 through 2007. Data is available by attained age and gender. In order to maintain consistency of data sources and methodology for comparison across regions, general population data for this report is generally drawn from the HMD.

Items of note from Canadian data:

- The greatest overall improvements during the timeframes examined occurred between 1972 and 1985 for males and between 1985 and 2000 for females with the largest average annual improvements occurring at ages under 20. (Table 11 and Chart 16)
- For the period 1985 to 2000, general population improvements were greater for males than females for ages 5 and over and improvements were smallest at the oldest ages (Table 11 and Chart 16).
- During 1972-1985 and 2000-2007, males do not demonstrate consistently greater improvement levels than females. The relationship varies by age. (Table 11 and Chart 16).
- Mortality improvement levels vary by geographic region for each age group, however there is no region that shows consistently higher levels of improvement across all age groups. (Table 12)

Table 11: Canadian Average Annual Rates of Population Mortality Improvement
Human Mortality Database
Experience Period: 1972-2007
By Gender and Age Group

Male

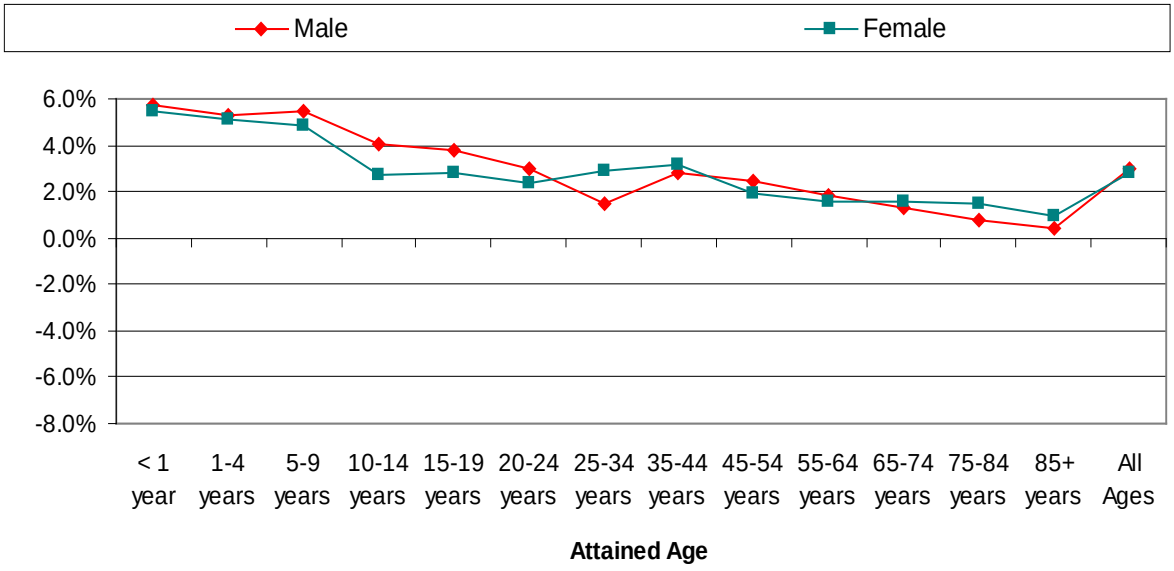
Age Group	1972-1985	1985-2000	2000-2007	1972-2007
< 1 year	5.7%	2.9%	0.2%	3.4%
1-4 years	5.8%	3.9%	2.8%	4.6%
5-9 years	4.9%	2.7%	-2.4%	3.5%
10-14 years	3.2%	2.8%	2.6%	3.0%
15-19 years	3.4%	2.3%	1.3%	2.7%
20-24 years	2.8%	2.2%	0.4%	2.4%
25-34 years	2.0%	2.1%	1.2%	2.0%
35-44 years	2.4%	1.5%	2.0%	1.8%
45-54 years	1.5%	2.2%	0.7%	1.9%
55-64 years	1.6%	2.1%	1.0%	1.9%
65-74 years	1.0%	2.3%	3.0%	1.8%
75-84 years	0.5%	1.9%	3.4%	1.4%
85+ years	0.3%	1.1%	2.1%	0.8%
All Ages	2.7%	2.3%	1.4%	2.4%

Female

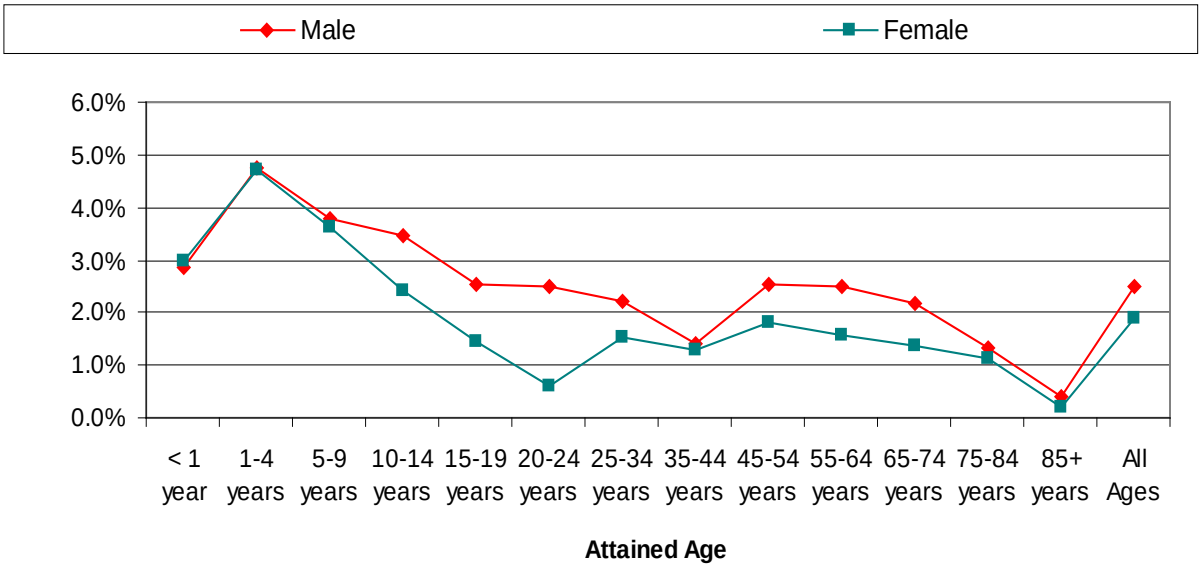
Age Group	1972-1985	1985-2000	2000-2007	1972-2007
< 1 year	5.4%	3.0%	-0.6%	3.2%
1-4 years	4.6%	5.6%	3.7%	4.9%
5-9 years	2.5%	5.5%	-6.5%	2.1%
10-14 years	-0.9%	4.5%	2.4%	2.1%
15-19 years	1.7%	1.9%	3.8%	2.2%
20-24 years	1.4%	1.4%	0.9%	1.3%
25-34 years	3.7%	0.8%	2.8%	2.3%
35-44 years	2.6%	1.5%	3.1%	2.2%
45-54 years	1.6%	1.6%	1.1%	1.5%
55-64 years	1.9%	1.6%	1.1%	1.6%
65-74 years	1.6%	1.5%	1.2%	1.5%
75-84 years	1.0%	1.1%	2.4%	1.3%
85+ years	1.0%	0.4%	2.1%	1.0%
All Ages	2.1%	2.3%	1.3%	2.1%

Chart 16: Canadian Average Annual Rates of Population Mortality Improvement
Human Mortality Database, Experience Period: 1972-2007
By Gender and Age Group

1972-1985



1985-2000



2000-2007

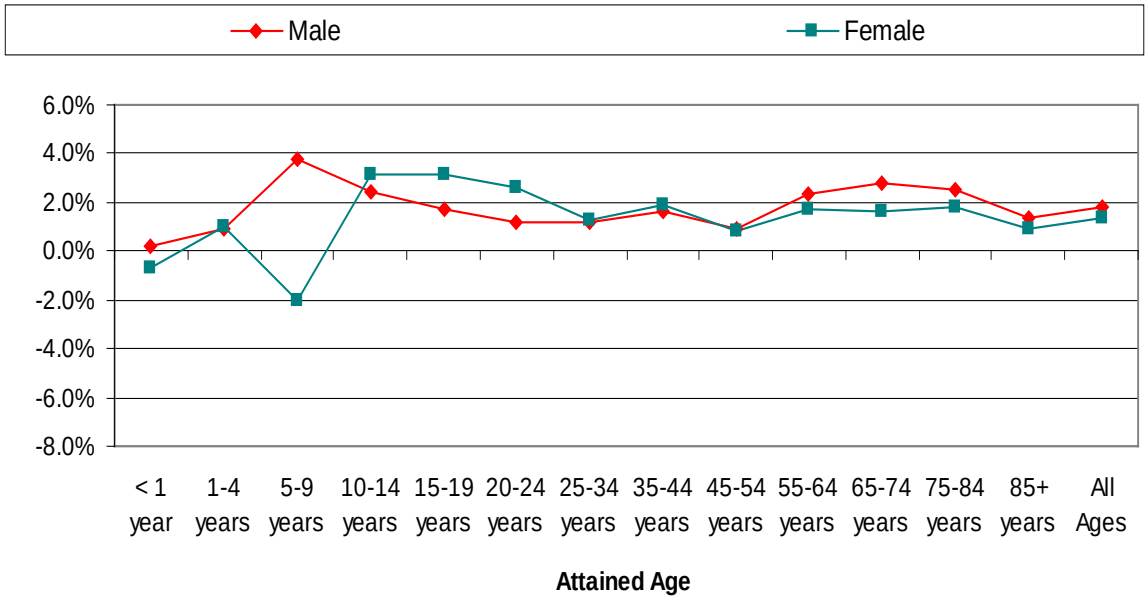


Table 12: Canadian Average Annual Rates of Population Mortality Improvement
Statistics Canada, Experience Period: 1991-2007
By Gender, Age Group and Geographic Region

Males

Age Group	Canada	Newfoundland	Prince Edward Island	Nova Scotia	New Brunswick
< 1 year	1.4%	1.9%	-1.1%	4.4%	-0.5%
1-4 years	4.2%	*	-1.8%	10.6%	-1.1%
5-9 years	4.2%	2.5%	*	*	8.3%
10-14 years	2.5%	*	*	*	4.2%
15-19 years	2.5%	0.8%	6.3%	2.2%	-0.6%
20-24 years	2.5%	0.6%	14.2%	1.2%	-1.7%
25-29 years	2.5%	*	4.2%	1.2%	2.0%
30-34 years	3.0%	3.3%	1.1%	1.4%	3.1%
35-39 years	1.8%	-1.1%	-4.4%	2.5%	1.0%
40-44 years	1.7%	1.2%	5.5%	1.1%	0.4%
45-49 years	1.7%	2.1%	3.0%	1.0%	3.2%
50-54 years	1.7%	0.3%	2.7%	1.2%	1.1%
55-59 years	2.2%	2.0%	0.3%	1.8%	1.9%
60-64 years	2.6%	2.0%	1.7%	2.4%	1.8%
65-69 years	2.6%	1.3%	1.9%	2.8%	3.0%
70-74 years	2.3%	2.1%	5.1%	1.3%	1.3%
75-79 years	2.2%	1.2%	2.7%	1.9%	2.1%
80-84 years	1.8%	0.7%	3.0%	1.6%	1.8%
85-89 years	1.4%	0.8%	-0.6%	1.4%	1.0%
90 years and over	0.4%	-1.8%	1.7%	-1.1%	-1.3%

Age Group	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	British Columbia
< 1 year	1.9%	1.0%	-1.3%	4.0%	0.8%	3.0%
1-4 years	2.5%	2.5%	6.6%	3.1%	*	6.6%
5-9 years	4.2%	4.2%	2.5%	2.5%	*	*
10-14 years	6.6%	4.2%	-4.4%	*	2.5%	6.6%
15-19 years	4.2%	2.1%	2.2%	0.9%	4.7%	4.2%
20-24 years	3.3%	1.6%	1.5%	1.5%	1.0%	3.1%
25-29 years	3.0%	2.2%	*	2.1%	2.7%	2.3%
30-34 years	3.4%	3.3%	*	-1.0%	1.1%	3.9%
35-39 years	1.8%	3.1%	0.4%	-2.8%	0.8%	1.5%
40-44 years	2.6%	1.5%	-1.0%	0.6%	0.7%	1.6%
45-49 years	2.6%	1.7%	0.4%	-0.6%	1.8%	1.1%
50-54 years	2.6%	1.6%	2.2%	1.3%	1.2%	0.8%
55-59 years	2.8%	2.2%	1.5%	1.5%	2.1%	1.4%
60-64 years	3.3%	2.7%	1.3%	0.9%	2.8%	2.0%
65-69 years	2.9%	2.8%	1.0%	2.0%	2.2%	2.2%
70-74 years	2.8%	2.3%	1.5%	1.2%	2.1%	2.4%
75-79 years	2.6%	2.3%	1.7%	1.3%	1.4%	2.1%
80-84 years	2.1%	1.9%	0.7%	1.3%	1.7%	2.0%
85-89 years	1.5%	1.6%	1.3%	1.4%	0.9%	1.3%
90 years and	0.3%	0.7%	0.6%	-0.5%	0.8%	0.5%

Females

Age Group	Canada	Newfoundland	Prince Edward Island	Nova Scotia	New Brunswick
< 1 year	1.3%	-1.6%	6.1%	2.2%	5.4%
1-4 years	2.5%	6.6%	1.4%	*	2.5%
5-9 years	4.2%	*	*	-4.4%	4.2%
10-14 years	4.2%	4.2%	*	*	-2.6%
15-19 years	1.8%	*	-4.4%	4.2%	*
20-24 years	1.8%	*	4.2%	-1.4%	*
25-29 years	1.8%	1.8%	4.2%	3.1%	4.2%
30-34 years	1.4%	*	6.6%	*	-2.6%
35-39 years	1.8%	4.2%	6.8%	*	1.1%
40-44 years	1.6%	-0.6%	-0.7%	1.4%	0.5%
45-49 years	0.7%	*	-4.7%	-0.3%	*
50-54 years	1.3%	-1.7%	2.5%	*	1.8%
55-59 years	1.6%	0.6%	1.1%	1.9%	1.9%
60-64 years	1.6%	1.2%	2.0%	1.5%	2.3%
65-69 years	1.6%	1.1%	3.6%	1.0%	1.1%
70-74 years	1.3%	1.1%	-0.2%	1.0%	0.7%
75-79 years	1.5%	1.3%	1.7%	1.1%	0.3%
80-84 years	1.2%	0.8%	*	1.0%	0.8%
85-89 years	0.9%	1.1%	1.5%	0.1%	0.1%
90 years and over	0.4%	-0.8%	0.8%	-0.2%	0.7%

Age Group	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	British Columbia
< 1 year	1.7%	1.3%	-0.1%	0.4%	0.4%	3.0%
1-4 years	4.2%	2.5%	1.4%	-1.8%	6.6%	4.2%
5-9 years	4.2%	4.2%	*	*	*	4.2%
10-14 years	*	*	2.5%	-4.4%	6.6%	4.2%
15-19 years	2.5%	2.5%	2.5%	*	6.6%	1.8%
20-24 years	4.2%	2.5%	-4.4%	*	*	1.8%
25-29 years	3.1%	1.8%	1.1%	3.4%	*	1.4%
30-34 years	1.4%	1.4%	-3.0%	2.2%	*	*
35-39 years	3.6%	1.0%	-1.8%	-1.8%	1.6%	2.2%
40-44 years	2.7%	1.1%	0.5%	1.1%	0.5%	0.6%
45-49 years	0.6%	1.4%	-0.9%	1.3%	1.0%	1.1%
50-54 years	1.1%	1.3%	0.6%	0.4%	1.4%	2.1%
55-59 years	1.5%	2.4%	-0.4%	-0.1%	0.6%	1.2%
60-64 years	1.9%	2.0%	1.0%	1.0%	0.7%	1.1%
65-69 years	1.9%	1.7%	1.6%	0.6%	1.4%	1.2%
70-74 years	1.5%	1.6%	0.7%	-0.4%	0.6%	1.6%
75-79 years	1.4%	1.8%	1.2%	0.8%	1.7%	1.8%
80-84 years	1.2%	1.4%	1.4%	0.4%	1.1%	1.2%
85-89 years	0.8%	1.0%	1.0%	0.2%	0.7%	0.9%
90 years and	0.4%	0.6%	0.2%	0.0%	0.4%	0.5%

*Insufficient data credibility to present results

B) Insured Mortality Improvements (Canada)

As with the US insured population data discussed above, mortality improvements presented in this section are based on mortality rates by amount of insurance rather than policy count unless otherwise indicated.

All data presented here is based on Canadian Institute of Actuaries (“CIA”) mortality studies of individual standard ordinary life insurance conducted over time. For details regarding specific reports referenced, please see Appendix A of this report. We note again that differences in the number and type of insurers participating in the underlying experience studies over time does affect the life insured data and therefore care should be taken in using this information.

In Canada, since the early 1970s, overall average improvements in ultimate insured mortality have been slightly lower for women across both earlier and later periods. Specifically, over the period 1972-2007, female improvements have been lower than male improvements between attained ages 40 and 75 while female improvements were greater than those of males for attained ages over 80. (Table 13 and Chart 17) Finally, as in the US, over the full period 1972-2007, improvements were smallest at the highest attained ages.

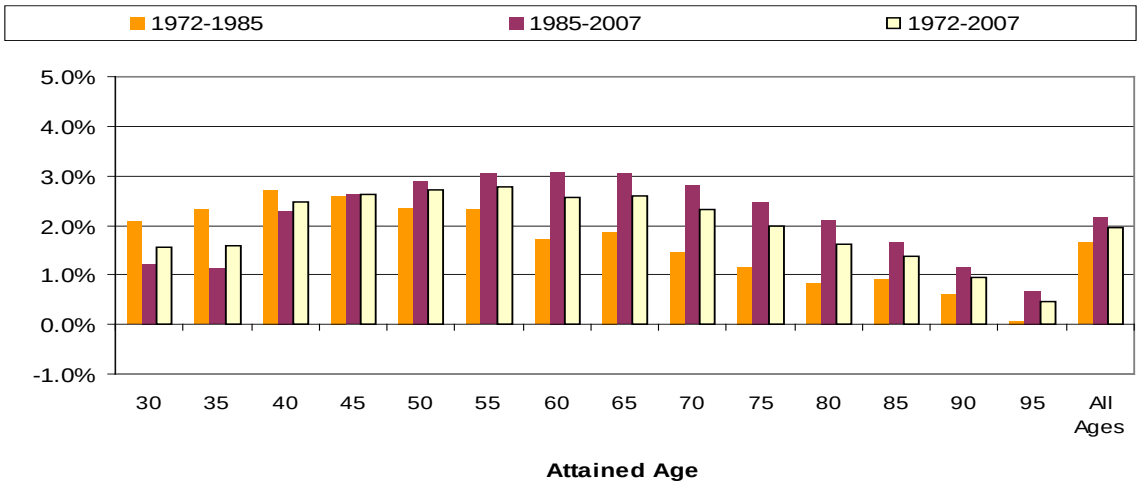
Table 13: Canadian Average Annual Rates of Mortality Improvement
Life Insureds, Experience Period: 1972-2007
By Gender, Attained Age
Ultimate Mortality Only

Male				Female			
Attained Age	**1972-1985**	**1985-2007**	**1972-2007**	**Attained Age**	**1972-1985**	**1985-2007**	**1972-2007**
30	2.1%	1.2%	1.5%	30	2.2%	3.4%	3.0%
35	2.3%	1.1%	1.6%	35	1.1%	3.5%	2.6%
40	2.7%	2.3%	2.5%	40	1.7%	2.6%	2.2%
45	2.6%	2.6%	2.6%	45	1.8%	2.3%	2.1%
50	2.4%	2.9%	2.7%	50	1.6%	2.4%	2.1%
55	2.3%	3.0%	2.8%	55	0.4%	1.5%	1.1%
60	1.7%	3.1%	2.6%	60	1.2%	1.8%	1.6%
65	1.8%	3.1%	2.6%	65	0.7%	1.9%	1.5%
70	1.5%	2.8%	2.3%	70	0.1%	2.6%	1.7%
75	1.1%	2.5%	2.0%	75	0.6%	2.3%	1.7%
80	0.8%	2.1%	1.6%	80	1.3%	2.0%	1.7%
85	0.9%	1.6%	1.4%	85	1.8%	1.4%	1.6%
90	0.6%	1.2%	0.9%	90	1.7%	1.1%	1.3%
95	0.1%	0.7%	0.5%	95	1.0%	0.9%	0.9%
All Ages	1.6%	2.2%	2.0%	All Ages	1.2%	2.1%	1.8%

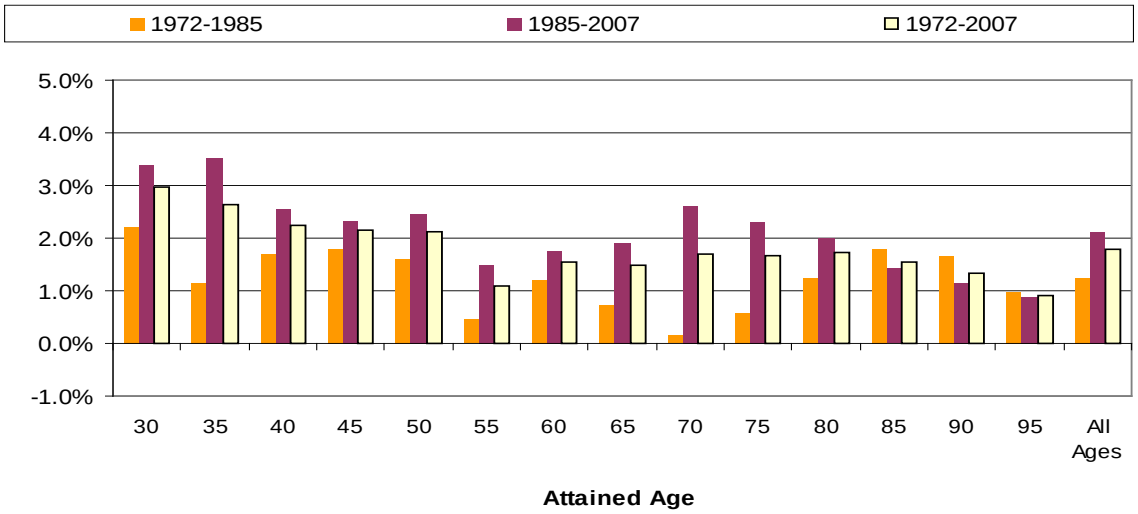
Source: CIA Studies of Individual Life Insurance Mortality Experience, Table Manager

Chart 17: Canadian Average Annual Rates of Mortality Improvement
Life Insureds, Experience Period: 1972-2007
By Gender, Attained Age, Ultimate Mortality Only

Males



Females



Source: CIA Studies of Individual Life Insurance Mortality Experience, Table Manager

As in the US, the impact of changes in underwriting and risk classification can lead to distortion in results for insurance data during the select period. Select data is presented by issue age and policy year for the period between 1972 and 1989. During this time mortality improvement levels were greatest in the first policy year than other policy years examined, possibly representing an estimate for the impact of changes in underwriting and risk selection/classification on antiselection over this period. Improvement levels also show a pattern of deterioration with increasing issue age over 45 for both males and females. This pattern is not apparent in the US data. (Table 14)

Table 14: Canadian Average Annual Rates of Mortality Improvement
Life Insureds, Experience Period: 1972-1989
By Gender, Issue Age and Policy Year, Select Mortality

Male

Age 35		Age 45		Age 55		Age 65	
Policy Year		**Policy Year**		**Policy Year**		**Policy Year**	
1	3.1%	1	5.6%	1	5.0%	1	3.7%
2	2.7%	2	4.5%	2	3.6%	2	2.3%
3	2.9%	3	4.1%	3	3.1%	3	2.0%
4	3.2%	4	3.7%	4	2.7%	4	1.9%
5	3.4%	5	3.4%	5	2.4%	5	1.7%
10	3.1%	10	2.6%	10	1.6%	10	0.2%
15	2.3%	15	1.6%	15	0.9%	15	-0.2%

Female

Age 35		Age 45		Age 55		Age 65	
Policy Year		**Policy Year**		**Policy Year**		**Policy Year**	
1	4.0%	1	4.4%	1	1.9%	1	1.9%
2	2.8%	2	3.1%	2	0.2%	2	-0.2%
3	2.6%	3	2.9%	3	-0.2%	3	-1.1%
4	2.4%	4	2.7%	4	-0.3%	4	-1.7%
5	2.3%	5	2.7%	5	0.0%	5	-1.9%
10	1.8%	10	1.2%	10	1.0%	10	-0.4%
15	1.8%	15	1.3%	15	-0.6%	15	-0.8%

Source: CIA Studies of Individual Life Insurance Mortality Experience, Table Manager

In Canada, sufficient detail was not available from the most recent CIA reports and accompanying tables to examine mortality improvements simultaneously for issue age, policy year and smoker status. In addition, there is less credible data with reliable splits by smoker status during the ultimate period, with a large category of experience with smoker status "unclassified".

With those caveats, we do present estimated average annual improvements in ultimate mortality between 1989 and 2007 for attained ages 40 and older by smoker status in Table 15. Bearing in mind the data limitations, we note that mortality improvement for non smokers is generally greater than for smokers across both genders and different age groups. Differences also appear more pronounced for females than for males.

Table 15: Canadian Average Annual Rates of Mortality Improvement
Life Insureds, Experience Period: 1989-2007
By Gender, Attained Age Group, and Smoker Status

Non Smokers

Male		Female	
Age Group	**1989-2007**	**Age Group**	**1989-2007**
40-49 years	3.9%	40-49 years	3.7%
50-59 years	3.2%	50-59 years	3.2%
60-69 years	3.7%	60-69 years	3.0%
70-99 years	3.4%	70-99 years	2.6%

Smokers

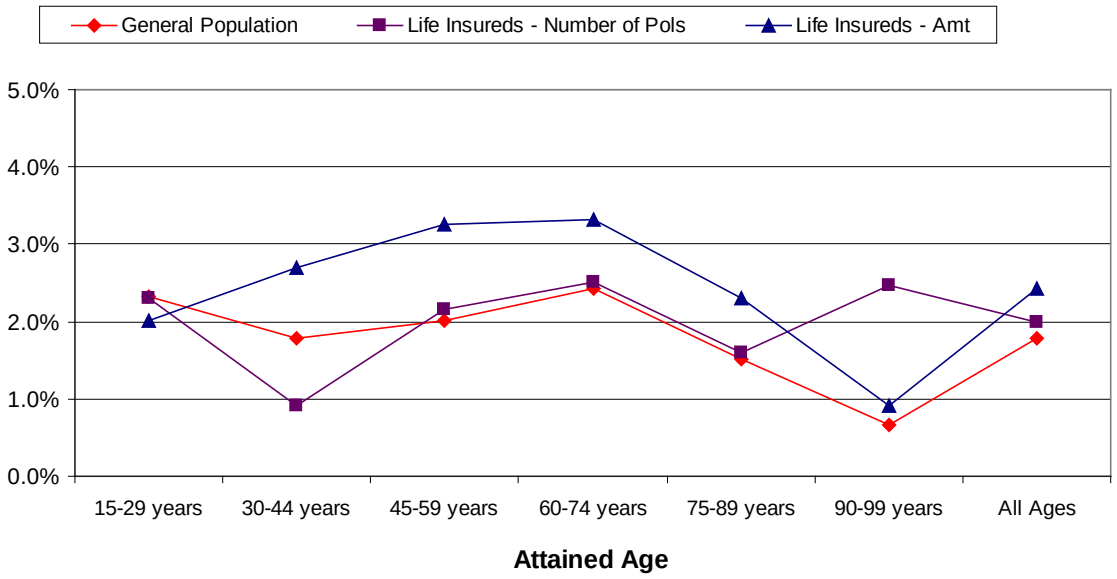
Male		Female	
Age Group	**1989-2007**	**Age Group**	**1989-2007**
40-49 years	3.5%	40-49 years	2.3%
50-59 years	3.4%	50-59 years	1.3%
60-69 years	3.6%	60-69 years	0.8%
70-99 years	1.8%	70-99 years	1.4%

Source: CIA Studies of Individual Life Insurance Mortality Experience, Table Manager

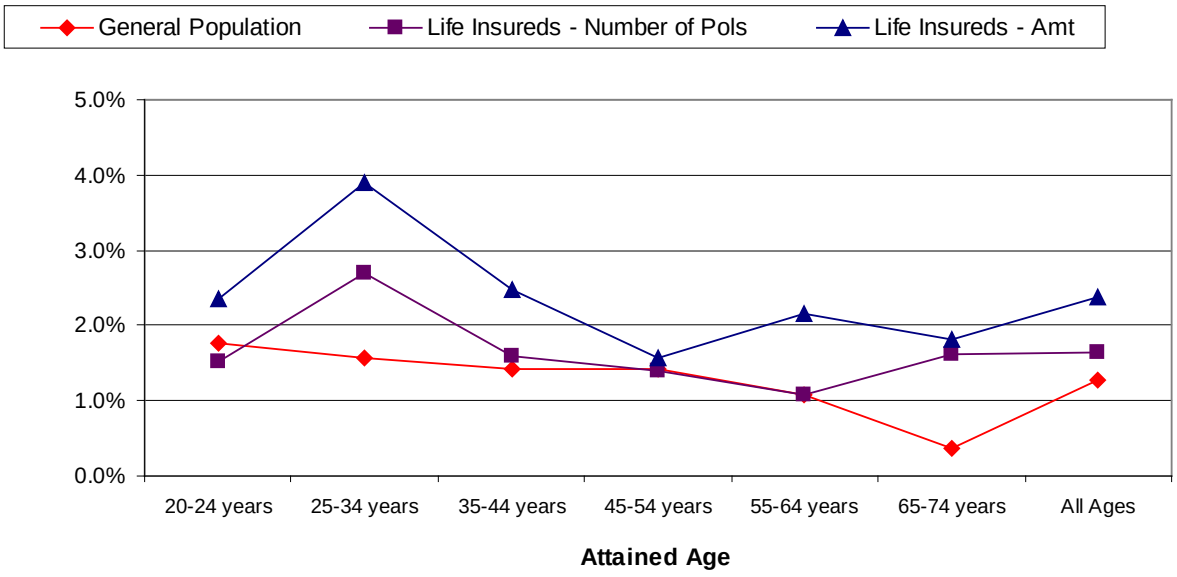
In Canada, for the period between 1989 and 2007, mortality improvement levels for life insureds were greater than those for the general population both on a number of policies basis and on an amount basis at most ages. (Chart 18)

Chart 18: Canadian Average Annual Rates of Mortality Improvement
Life Insured versus General Population Data, 1989-2007
By Gender and Attained Age Group
Ultimate Mortality Only

Males



Females



Source: HMD, CIA Studies of Individual Life Insurance Mortality Experience, Table Manager

Part 3: Mortality Improvement Trends in the UK

A) General Population Mortality Improvements (UK)

Interim life tables are produced annually by the Office of National Statistics ("ONS") for the United Kingdom and its constituent countries. These tables provide statistics on period life expectancy by age and sex. Each interim life table is based on the population estimates, births and deaths data for a period of three consecutive years, and then graduated life tables are prepared every ten years based on the collection of census data. The interim life tables are currently available for experience years 1980 through 2006 on a periodic basis.

Alternatively, the HMD covers the period 1922 through 2009 by attained age and gender.

Consistent with US and Canadian population data, UK population results show the greatest levels of mortality improvement coming at the youngest ages (ages under 10). Also, there is materially increased improvement indicated in the most recent time period at ages 65 and above. (Table 16 and Chart 19) Finally, in the UK, there is no clear pattern of greater improvement for males or females.

Table 16: UK Average Annual Rates of Population Mortality Improvement
Human Mortality Database
Experience Period: 1968-2009
By Gender and Age Group

Male

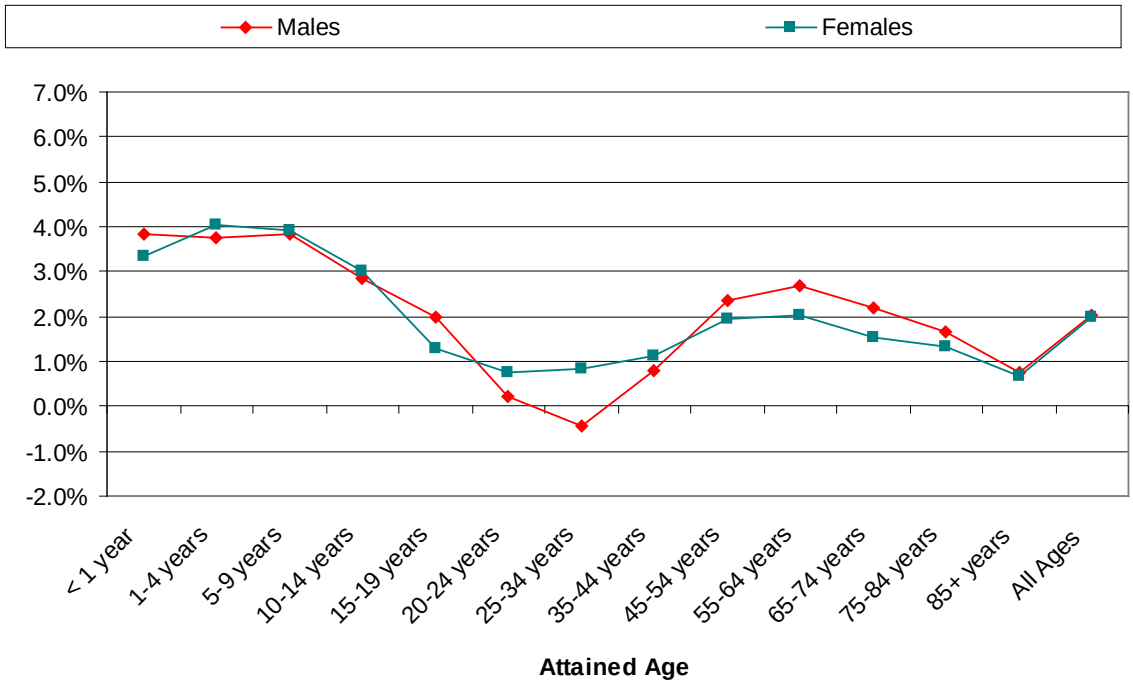
Age Group	1968-1981	1981-2000	2000-2009	1981-2009
< 1 year	4.0%	3.8%	1.8%	3.2%
1-4 years	3.8%	3.8%	4.2%	3.9%
5-9 years	3.6%	3.9%	3.3%	3.7%
10-14 years	2.4%	2.9%	3.9%	3.2%
15-19 years	0.5%	2.0%	2.5%	2.1%
20-24 years	0.6%	0.2%	3.5%	1.3%
25-34 years	0.5%	-0.5%	1.6%	0.2%
35-44 years	1.6%	0.8%	-0.1%	0.5%
45-54 years	1.1%	2.4%	1.5%	2.1%
55-64 years	1.1%	2.7%	2.6%	2.7%
65-74 years	1.2%	2.2%	3.6%	2.6%
75-84 years	0.7%	1.7%	2.8%	2.0%
85+ years	0.6%	0.8%	1.7%	1.1%
All Ages	1.7%	2.0%	2.5%	2.2%

Female

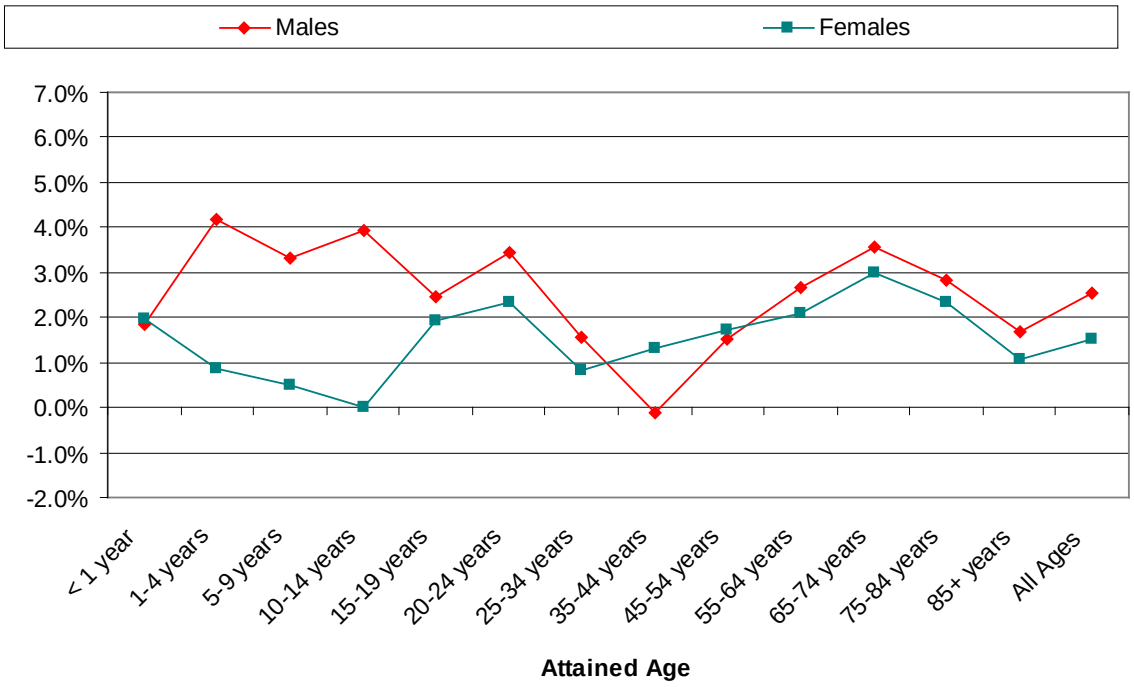
Age Group	1968-1981	1981-2000	2000-2009	1981-2009
< 1 year	4.0%	3.4%	2.0%	2.9%
1-4 years	3.9%	4.0%	0.9%	3.0%
5-9 years	3.2%	3.9%	0.5%	2.8%
10-14 years	2.3%	3.0%	0.0%	2.1%
15-19 years	1.0%	1.3%	1.9%	1.5%
20-24 years	1.1%	0.7%	2.4%	1.3%
25-34 years	1.8%	0.8%	0.8%	0.8%
35-44 years	2.0%	1.1%	1.3%	1.2%
45-54 years	1.0%	2.0%	1.7%	1.9%
55-64 years	0.6%	2.0%	2.1%	2.0%
65-74 years	1.2%	1.5%	3.0%	2.0%
75-84 years	1.3%	1.3%	2.3%	1.7%
85+ years	0.8%	0.7%	1.1%	0.8%
All Ages	1.8%	2.0%	1.5%	1.8%

Chart 19: UK Average Annual Rates of Population Mortality Improvement
Human Mortality Database
Experience Period: 1981-2009
By Gender and Age Group

1981-2000



2000-2009



Similar to results in the US and Canada, levels of mortality improvement don't vary by a large degree across geographic regions of the UK; however there are some larger variations by region for specific age groups. (Table 17)

Table 17: UK Average Annual Rates of Population Mortality Improvement
ONS Data
Experience Period: 1981-2006
By Gender, Age Group and Geographic Region

Males

Age Group	England and Wales	Great Britain	Scotland	Northern Ireland	UK (Total)
< 1 year	3.3%	3.3%	3.6%	3.8%	3.3%
1-4 years	3.0%	3.1%	4.0%	2.4%	3.1%
5-9 years	3.9%	3.8%	2.3%	4.6%	3.8%
10-14 years	2.9%	2.9%	3.1%	2.5%	2.9%
15-19 years	2.8%	2.6%	0.9%	1.1%	2.6%
20-24 years	0.9%	0.9%	0.6%	0.7%	0.9%
25-34 years	0.0%	-0.1%	-0.9%	0.8%	0.0%
35-44 years	0.9%	0.9%	1.0%	1.4%	0.9%
45-54 years	2.1%	2.1%	1.8%	2.2%	2.1%
55-64 years	2.9%	2.8%	2.4%	3.1%	2.9%
65-74 years	2.8%	2.7%	2.2%	2.9%	2.7%
75-84 years	2.1%	2.1%	1.9%	1.8%	2.1%

Females

Age Group	England and Wales	Great Britain	Scotland	Northern Ireland	UK (Total)
< 1 year	3.1%	3.1%	3.6%	3.5%	3.1%
1-4 years	3.1%	3.1%	2.4%	8.1%	3.2%
5-9 years	3.1%	3.2%	3.9%	2.3%	3.1%
10-14 years	2.0%	2.2%	3.9%	1.4%	2.2%
15-19 years	1.2%	1.0%	-0.2%	0.4%	1.0%
20-24 years	1.4%	1.2%	-0.8%	1.5%	1.2%
25-34 years	1.1%	0.9%	-0.7%	1.1%	0.9%
35-44 years	1.1%	1.2%	1.2%	1.2%	1.2%
45-54 years	1.6%	1.7%	1.9%	1.9%	1.7%
55-64 years	2.2%	2.2%	2.1%	3.2%	2.2%
65-74 years	2.0%	1.9%	1.8%	2.4%	2.0%
75-84 years	1.6%	1.6%	1.3%	1.9%	1.6%

B) Insured Population Mortality Improvements (UK)

The CMI studies published by this Institute of Actuaries research group are updated regularly and provide information on mortality and mortality improvement trends for life assurance (both permanent and temporary), immediate annuities, retirement annuities, and pension business. The group also publishes guidance regarding future rates of mortality improvement including the impact of emerging cohort patterns seen in the UK data. Results are available electronically through experience year 2000.

Due to the shorter select periods indicated in the UK data (five years or less for both permanent and temporary assureds), ultimate mortality is presented in this portion of the report.

For the UK, life insured mortality experience is provided for permanent assurances (whole life and endowments) separately from temporary assurances (term coverage). For both males and females, data is provided for permanent assurances beginning with experience year 1980.

From 1980 to 2000, for permanent assurance, female mortality improvements were less than male mortality improvements for ages 45 and older (Table 18). During the most recent period (1992-2000), levels of improvement were lowest at the oldest attained ages (95 and older for males and 70 and older for females) with some deterioration exhibited for females at ages 80 and older.

For temporary assurances, data is available for both males and females from 1992-2000. Similar to permanent assureds, female improvements were less than male improvements at ages 50 and older.

Overall average annual mortality improvements are similar for temporary and permanent assurances.

Table 18: UK Average Annual Rates of Mortality Improvement
Life Insureds, Experience Period: 1980-2000
By Gender, Attained Age, Ultimate Mortality Only

Permanent Assurance

Male				Female			
			Full Period				*Full Period*
Attained Age	**1980-1992**	**1992-2000**	**1980-2000**	**Attained Age**	**1980-1992**	**1992-2000**	**1980-2000**
30	-0.5%	1.3%	0.2%	30	0.5%	1.7%	1.0%
35	0.0%	1.2%	0.5%	35	0.8%	2.3%	1.4%
40	1.6%	1.7%	1.6%	40	1.2%	2.6%	1.8%
45	2.9%	2.4%	2.7%	45	1.5%	2.6%	2.0%
50	3.4%	3.0%	3.3%	50	1.8%	2.4%	2.0%
55	3.4%	3.4%	3.4%	55	1.9%	2.1%	2.0%
60	3.1%	3.4%	3.2%	60	2.0%	1.6%	1.9%
65	2.7%	3.3%	3.0%	65	2.0%	1.1%	1.7%
70	2.3%	3.1%	2.6%	70	2.0%	0.6%	1.5%
75	1.9%	2.7%	2.2%	75	2.0%	0.1%	1.2%
80	1.7%	2.3%	1.9%	80	1.9%	-0.5%	1.0%
85	1.5%	1.8%	1.6%	85	1.9%	-1.0%	0.7%
90	1.3%	1.3%	1.3%	90	1.8%	-1.5%	0.5%
95	1.1%	0.8%	1.0%	95	1.6%	-2.0%	0.2%
All Ages	1.9%	2.3%	2.0%	All Ages	1.7%	0.9%	1.3%

Temporary Assurance

Male		Female	
Attained Age	**1992-2000**	**Attained Age**	**1992-2000**
30	2.0%	30	2.8%
35	1.0%	35	2.6%
40	1.1%	40	2.3%
45	1.9%	45	2.0%
50	2.7%	50	1.7%
55	3.0%	55	1.4%
60	3.0%	60	1.1%
65	2.9%	65	0.8%
70	2.7%	70	0.5%
75	2.5%	75	0.2%
80	2.5%	80	-0.1%
85	2.5%	85	-0.4%
90	2.7%	90	-0.7%
95	3.0%	95	-0.9%
All Ages	2.4%	All Ages	0.9%

Source: Continuous Mortality Investigations

Mortality experience for unit linked permanent assurances is available for the period 1992 through 2000. Unit linked permanent assurance products in the UK include an investment component linked to various market funds available through the product structure, similar in concept to variable life insurance products in the US. This is a relatively short period over which to measure improvement levels and there is no clear trend of greater improvement levels for either product type. (Table 19). For non unit linked products, improvements for males were greater than improvements for females at ages between 36 and 75. For unit linked products, male improvements outpaced female improvements for attained ages between 36 and 85.

Table 19: UK Average Annual Rates of Mortality Improvement
Life Insureds, Experience Period: 1968-2000
By Gender, Attained Age Group and Type of Permanent Assurance

Non Unit Linked Products (1968-2000)

Male				Female		
Age Group	**1968-1980**	**1980-1992**	**1992-2000**	**Age Group**	**1980-1992**	**1992-2000**
21-25	1.3%	1.0%	-0.6%	21-25	2.3%	5.3%
26-30	1.3%	0.5%	1.6%	26-30	1.6%	-1.1%
31-35	1.2%	-0.4%	2.3%	31-35	0.6%	3.3%
36-40	1.8%	0.6%	2.4%	36-40	-0.1%	4.0%
41-45	2.2%	2.4%	1.3%	41-45	0.8%	2.3%
46-50	2.1%	3.1%	2.7%	46-50	1.5%	1.7%
51-55	1.6%	3.6%	3.2%	51-55	2.6%	1.4%
56-60	1.7%	3.6%	2.7%	56-60	2.3%	1.6%
61-65	1.8%	2.7%	4.2%	61-65	1.7%	1.8%
66-70	2.0%	2.2%	3.4%	66-70	1.5%	1.0%
71-75	1.5%	2.3%	2.9%	71-75	1.1%	0.2%
76-80	0.8%	2.4%	2.3%	76-80	1.5%	-0.5%
81-85	0.7%	1.8%	1.9%	81-85	3.7%	0.0%
86-90	1.0%	1.3%	1.8%	86-90	2.9%	-1.8%

Unit Linked Products (1992-2000)

Male		Female	
Age Group	***1992-2000***	**Age Group**	***1992-2000***
16-25	-2.9%		
26-30	11.2%	16-30	9.7%
31-35	2.2%	31-35	3.7%
36-40	2.6%	36-40	1.6%
41-45	3.7%	41-45	3.3%
46-50	2.3%	46-50	0.2%
51-55	4.4%	51-55	0.3%
56-60	3.6%	56-60	1.8%
61-65	3.6%	61-65	2.3%
66-70	3.6%	66-70	2.9%
71-75	3.8%	71-75	0.9%
76-80	4.4%	76-80	1.4%
81-85	-0.9%	81-85	-1.0%
86-90	0.7%	86-90	2.2%

Source: Continuous Mortality Investigations, CMIR 21, Part 1

Note that for UK immediate annuitants, rates of mortality improvement were relatively low between 1955 and 1980. However, larger increases occurred both between 1980 and 1992 and between 1992 and 2000 for all but the oldest ages (Table 20). Reasonably large increases were also experienced by UK pensioners during these periods (Table 21).

Table 20: UK Average Annual Rates of Mortality Improvement
Immediate Annuitants, Experience Period: 1955-2000
By Gender and Attained Age
Underlying Mortality Based on Number of Policies

Male				Female			
Attained Age	**1955-1980**	**1980-1992**	**1992-2000**	**Attained Age**	**1955-1980**	**1980-1992**	**1992-2000**
60 years	0.1%	4.4%	1.9%	60 years	0.9%	5.0%	1.3%
70 years	0.3%	2.8%	5.2%	70 years	0.7%	2.9%	6.4%
80 years	0.8%	1.3%	2.7%	80 years	0.6%	1.4%	2.8%
90 years	0.8%	0.6%	-0.4%	90 years	0.3%	1.0%	-0.2%

Source: Continuous Mortality Investigations.

Table 21: UK Average Annual Rates of Mortality Improvement
Life Office Pensioners, Experience Period: 1980-2000
By Gender and Attained Age
Underlying Mortality Based on Number of Policies

Male

Attained Age	1980-1992	1992-2000	1980-2000
50	5.2%	3.7%	4.6%
60	3.4%	4.7%	3.9%
70	2.4%	4.5%	3.2%
80	1.7%	2.5%	2.0%
90	0.9%	1.6%	1.2%

Female

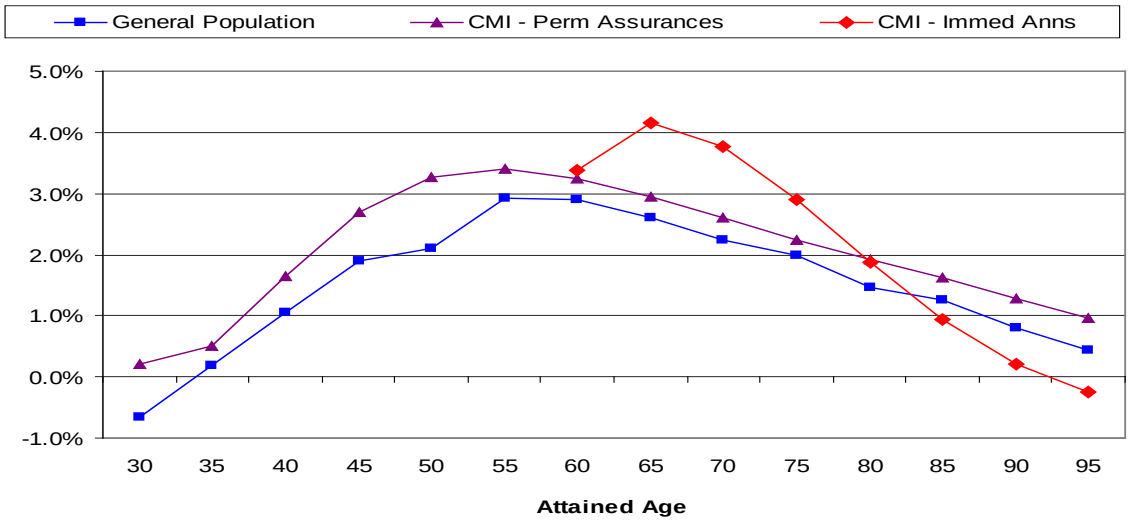
Attained Age	1980-1992	1992-2000	1980-2000
50	6.1%	-2.8%	2.7%
60	2.2%	3.8%	2.8%
70	0.5%	4.3%	2.0%
80	1.0%	2.3%	1.6%
90	1.6%	0.3%	1.1%

Source: Continuous Mortality Investigations

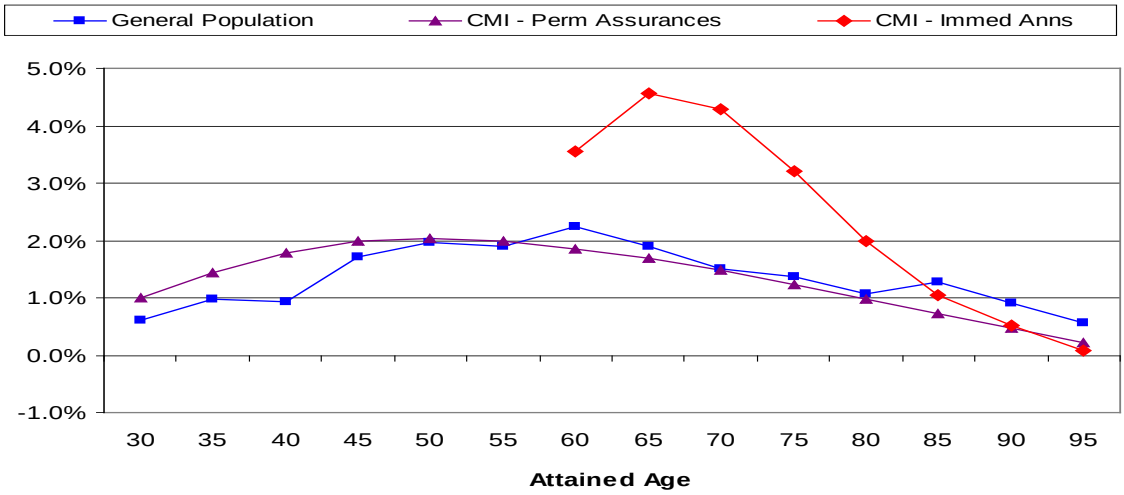
Comparing population and insured data in the UK between 1980 and 2000, we note that greater improvement levels were seen for male permanent assureds than the male general population for all ages, while for females the life insured results were very close to general population results. Immediate annuitants experienced greater improvement levels than life insureds or the general population for ages under 80 for males and under 85 for females.

Chart 20: UK Average Annual Rates of Mortality Improvement
Life Insured and Immediate Annuitants versus General Population Data, 1980-2000
By Gender and Attained Age Group

Males



Females



Source: Continuous Mortality Investigations, HMD

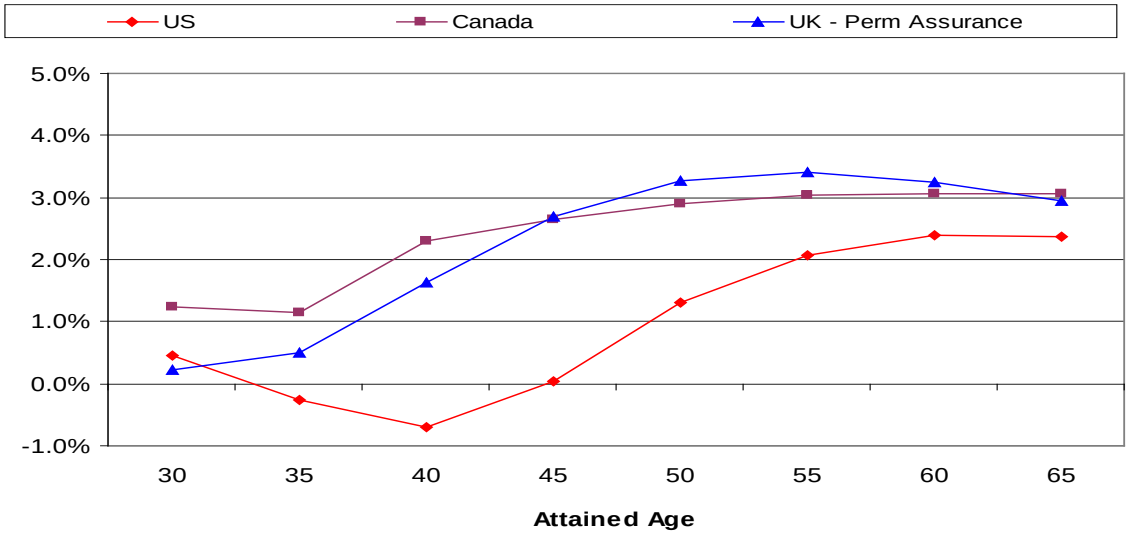
Note: Life assured data on a number of policies basis.

Part 4: Summary of Results for US, Canada and the UK

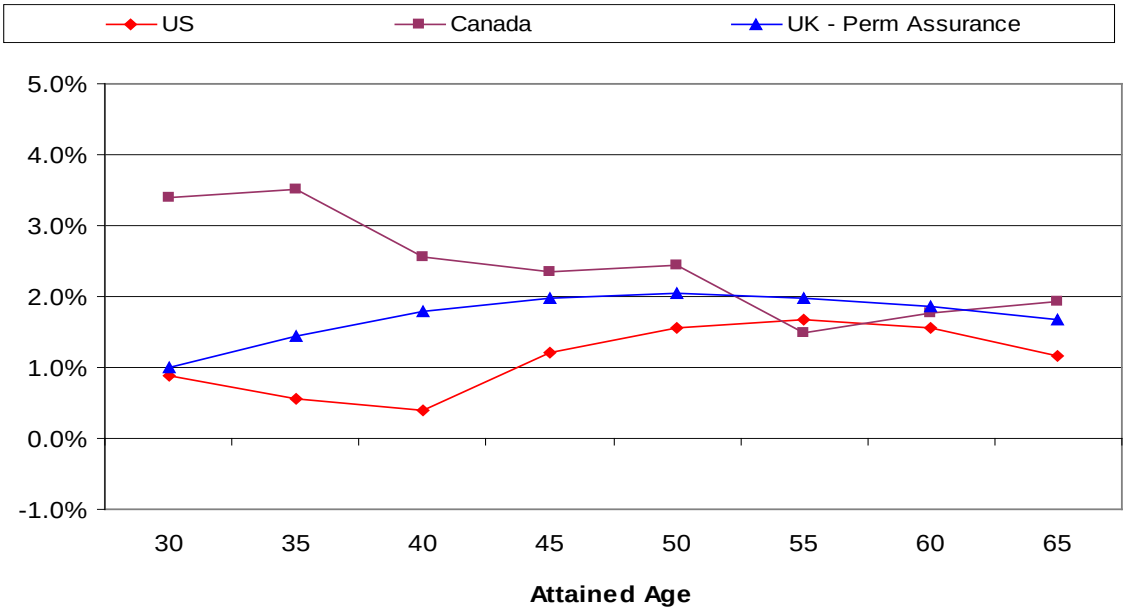
For life insureds, levels of improvement were lowest in the US for ages 35 and over for both males and females (Chart 21). The only exception is Canadian females between at age 55 and UK males at age 30 where mortality improvements dipped slightly below US levels. As it has been observed that developed countries tend to move toward similar levels of improvement over time, some theorize that the US will show stronger improvements over the next few decades both on a general population and insured basis.

Chart 21: Average Annual Rates of Mortality Improvement
Life Insureds in US, Canada and UK, 1978-2007
By Gender and Attained Age

Males



Females



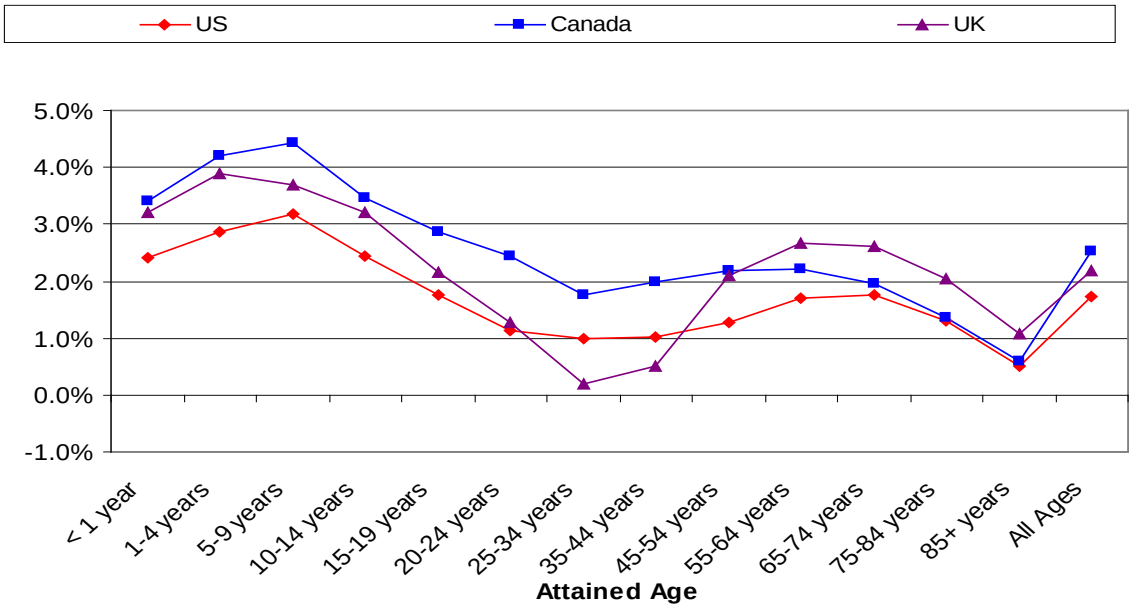
Source: Continuous Mortality Investigations, Table Manager, SOA Studies of Individual Life Mortality Experience, CIA Studies of Standard Ordinary Life Mortality Experience, US and Canadian results on an amount basis and UK results are on a number of policies basis.

Note: Experience years covered are US 1978-2006, Canada 1985-2007, UK 1980-2000, variations are due to differing start and end dates covered by individual insured studies in different countries.

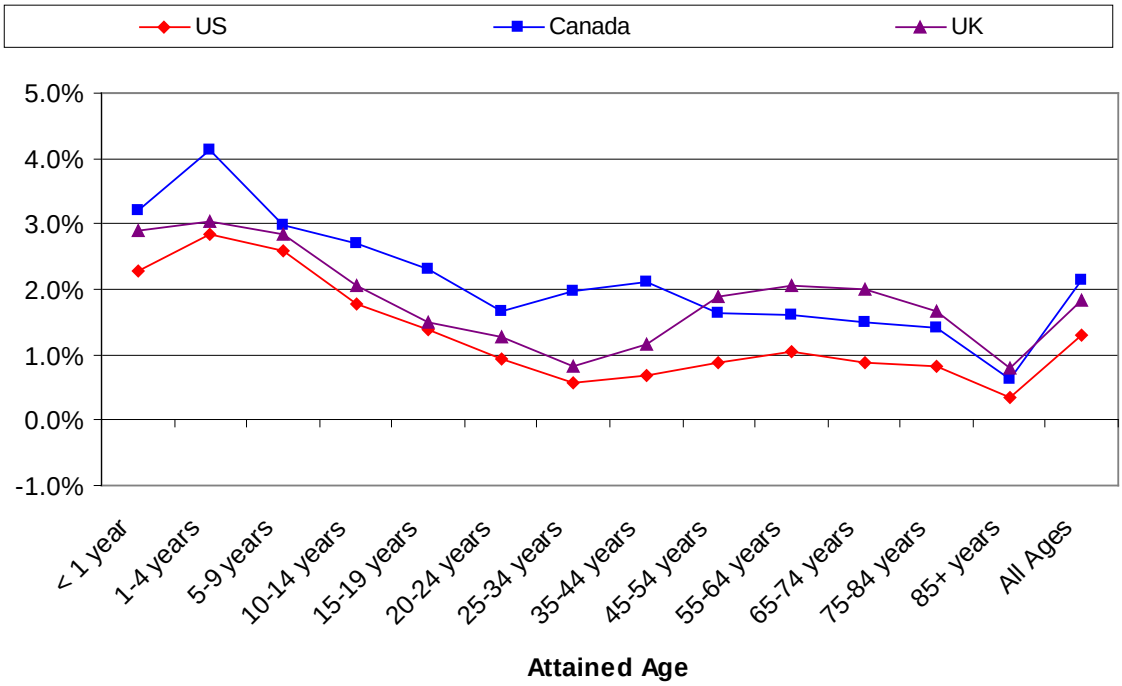
For the general populations in the US, UK and Canada, we note similar patterns by age and gender (Chart 22). As in the case of life insureds, with the exception of a few age groups, the US has exhibited the lowest rates of improvement while Canada has generally experienced greater improvements at ages under 45 and the UK at ages 45 and over.

Chart 22: Average Annual Rates of Mortality Improvement
General Population Data in US, Canada and UK, 1972-2009
By Gender and Attained Age Group

Males



Females



Source: HMD

Section 5: Projection of Future Mortality Improvement

Part 1: Considerations in Model Development

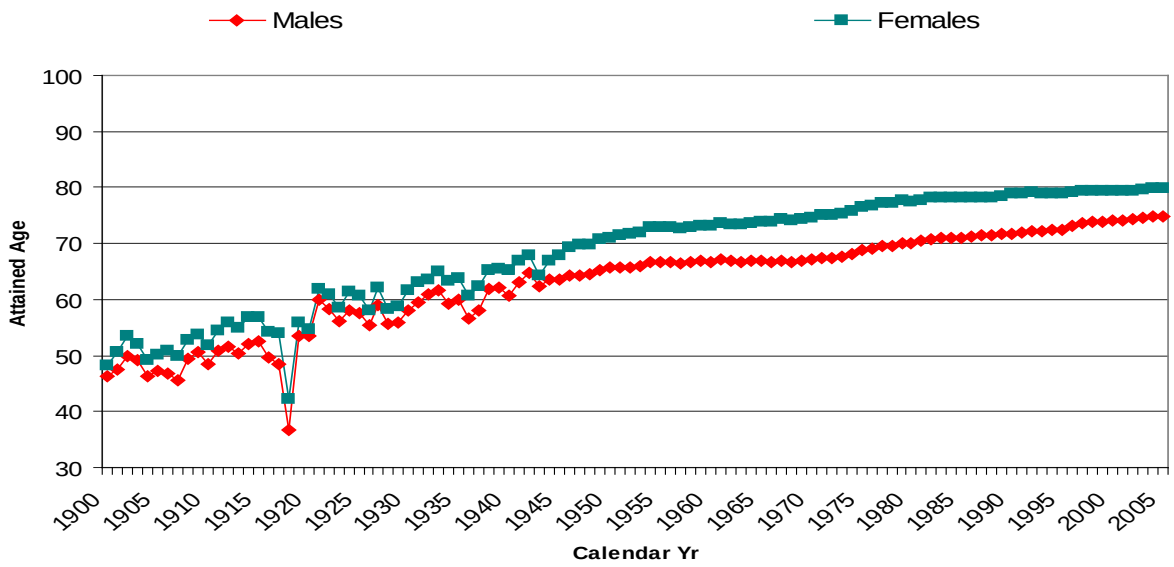
Demographic and socioeconomic differences in population mortality experience

A variety of demographic and socioeconomic characteristics have provided predictive value in analyzing mortality experience over time, and these factors have been the focus of a wealth of academic research in recent years. However, thus far, it has been difficult to interpret information and put results to practical use due to the complexity of interrelationships among factors as well as a general scarcity of consistent and comprehensive data. In this section, we focus on US data.

The following discussion describes those factors where potential predictive value has been observed.

Gender — Variations in male and female mortality and mortality improvement is an accepted fact. However, the cause of these differences remains unclear. Some underwriters, demographers and medical professionals have postulated that the source of these differences is the stronger tendency of males toward unhealthy habits over the last century, including smoking and drinking as well as dangerous avocations. (Chart 23)

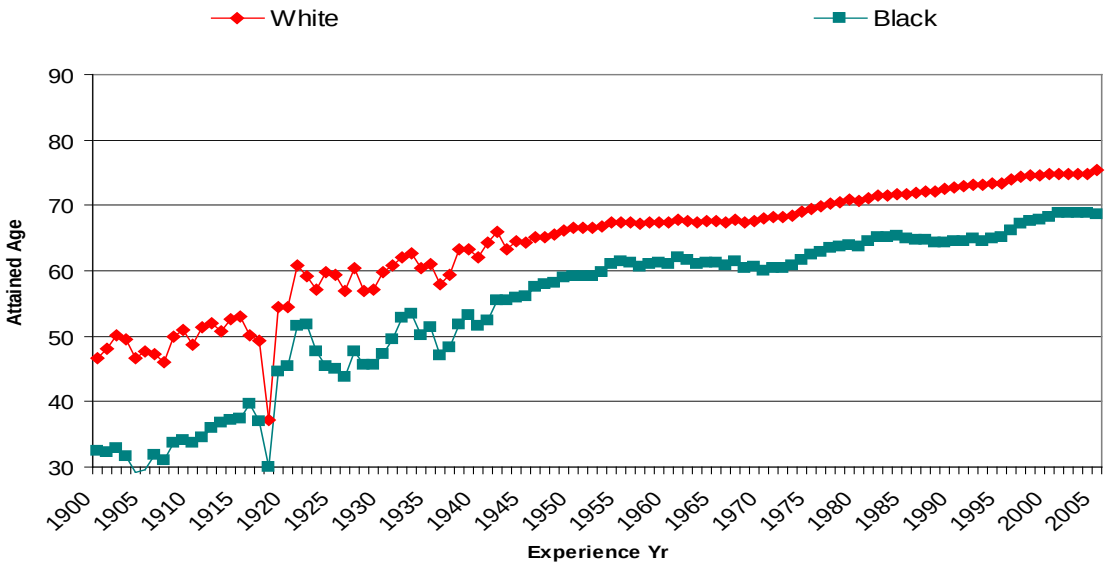
Chart 23: US Population Life Expectancies at Birth by Gender



Source: US National Vital Statistics, Vol 58, No. 10

Race or Ethnicity — Rates of mortality can be materially different for members of different races or ethnic groups within a country or region. This may be due to an inherent tendency toward specific diseases, differing diet, geographic location or socioeconomic status. For example, in the US there has historically been a large gap in mortality experience for blacks and whites. However, the gap has begun to narrow over time (Chart 24).

Chart 24: US Population Life Expectancies at Birth by Race



Source: US National Vital Statistics, Vol 58, No. 10.

Geographic Location — Levels of mortality and mortality improvement can vary widely by global region — likely due to differences in the level of economic and technological development or variations in the climate of the region and the diet of the people living there. This can be seen most clearly by tracking World Health Organization mortality trends over time.

Access to medical care — This factor is believed to impact mortality experience and is likely strongly correlated with population density and geography as well as financial ability to obtain the best care. Few sources are available in this area due to differences in opinion regarding the definition of "access" as well as a general lack of data available to support an investigation.

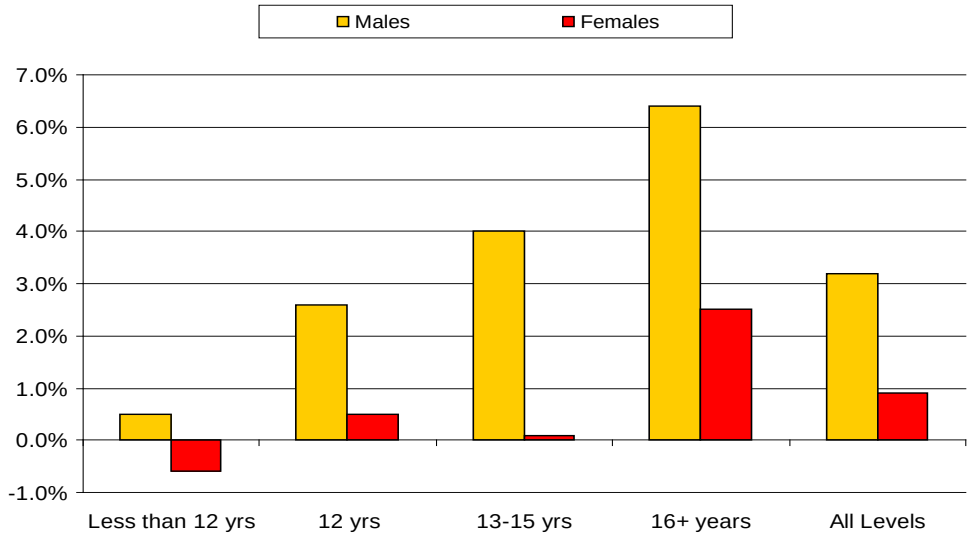
Financial/Socioeconomic Status — A variety of sources have studied the impact of financial factors including education level, income and wealth on mortality experience. A 2008 study, "Widening of Socioeconomic Inequalities in US Death Rates, 1993-2001" by Jemal et al., utilized data from the National Vital Statistics system to examine differences in death rates for the US population ages 25-64 (non-Hispanic whites and blacks) by level of education attained. Overall, the study results indicate that for both the male and female populations, for both whites and blacks, average annual improvements in

mortality were greater for individuals with an attained education level of college or higher (Charts 25 and 26).

Chart 25: Differences in Mortality Improvement by Level of Education Achieved
US White Population

Source: Widening of Socioeconomic Inequalities in US Death Rates, 1993-2001

Chart 26: Differences in Mortality Improvement by Level of Education Achieved
US Black Population



Source: Widening of Socioeconomic Inequalities in US Death Rates, 1993-2001

Marital status — There is also evidence to suggest that married individuals experience lower rates of mortality than single adults of the same age and gender. In studies reviewed for this report, marriage materially lowered mortality, even after controlling for health in early adulthood. This is often attributed to the fact that those who are married tend to have healthier lifestyles. In addition, if a couple remains married, they have a live-in caregiver which leads to better health outcomes as well as continued social interaction. Studies conducted in 1997 and 2000 (Murphy, et al. and Murray) reviewed for this report also indicated that the health benefits of marriage may be greater for men than women.

Medical Advances and Shifts in Cause of Death

Over the last century, mortality improvements have largely been driven by advances in medicine, and an increasing body of research has focused on changes in the patterns of cause of death over time. Understanding changes in primary disease and morbidity is important in developing a view regarding the source, direction and potential magnitude of future mortality improvements.

Examining death rates by cause for the past century in the US, we see that paralleling the development of treatment and prevention methods for various infectious diseases, age-adjusted rates of death due to diseases such as pneumonia and tuberculosis decreased significantly between 1900 and 1950. (Chart 27) At the same time, rates of death due to heart disease grew from 1900 to 1950 but then declined as advances in medicine led to the introduction of new pharmaceuticals for managing and preventing cardiovascular disease and changes in lifestyle occurred that also lowered the risk of contracting these types of disease.

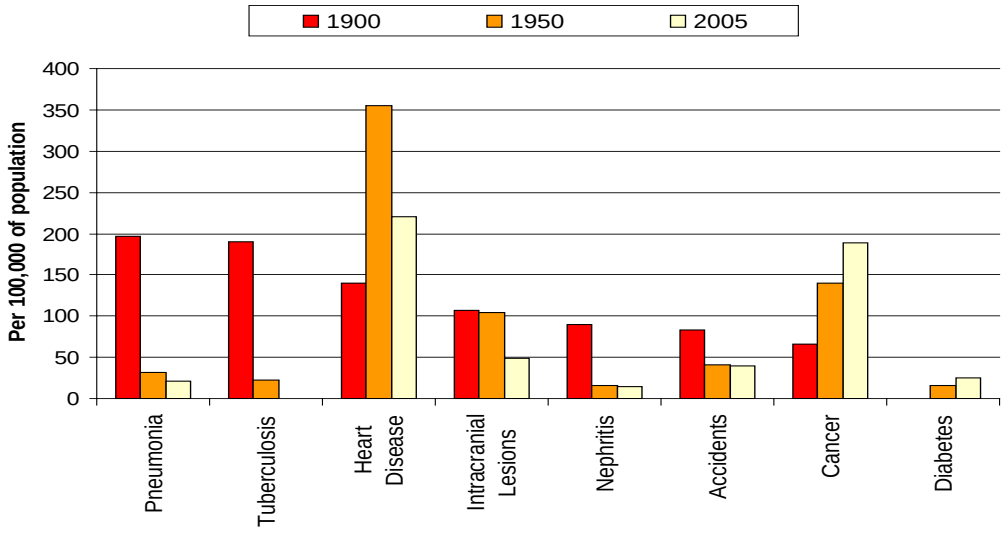
The change in rates of cancer raises an interesting point of discussion regarding future mortality improvement trends. Note that even as public awareness was raised and medical advances were being made, rates of cancer grew through the end of the 20th century. This may be an example of the fact that other impacts including lifestyle choices and environmental factors can have a significant impact on future trends.

Based on the most recent published Social Security Administration data, over the period 1981-2001, the average annual reduction in central death rates was lower for individuals over age 65 than individuals under 65 for all disease categories examined. The largest reductions in central death rates were seen at ages 0-14 for all disease categories except vascular disease and heart disease for males. Note that the number of deaths due to heart or vascular disease for this age group is small. At ages over 14, improvements averaged between 1 and 3 percent annually were seen for most cause of death categories, with the exceptions being cancer for those over age 65, respiratory disease for males over age 65 and females of all ages, and diabetes for both genders and all age groups.

Additional detail regarding average annual reduction in central death rates for various disease categories can be found in Appendix B of this report.

Chart 27: Primary Causes of Death in the US (CDC Data)

Age Adjusted Death Rates



Epidemiological Transition and Views regarding Future Mortality Improvement

Demographers have identified three major stages of epidemiological transition through which a population moves over its developmental lifetime. These stages are characterized by the types of diseases that lead to the greatest proportion of deaths each year:

- Stage 1 — Pestilence and Famine (e.g., before the beginning of the 19th century)
- Stage 2 — Pandemic and Infectious Disease (e.g., from middle of 19th to middle of 20th centuries)
- Stage 3 — Chronic Disease (cardiovascular disease, cancer) — (e.g., latter half of 20th century)

The question of the existence of a "Stage 4" has been a topic of academic debate among two opposing groups of demographers for several decades. Vaupel and demographers of his opinion believe that mortality will continue to improve at rates similar to the recent past and that this improvement will continue indefinitely into the future, thus allowing for the possibility that future levels of mortality improvements will eventually stop or even reverse aging. Olshansky and demographers in his camp believe that mortality will not continue to improve at recent rates but that a developed population will eventually enter a "Stage 4" where the longer term effects of degenerative diseases that are held in check by medical treatments and pharmaceuticals will take the lead in cause of death for older ages. Olshansky believes there is a finite limit to the human lifespan and that medical advances can only prolong life within limits.

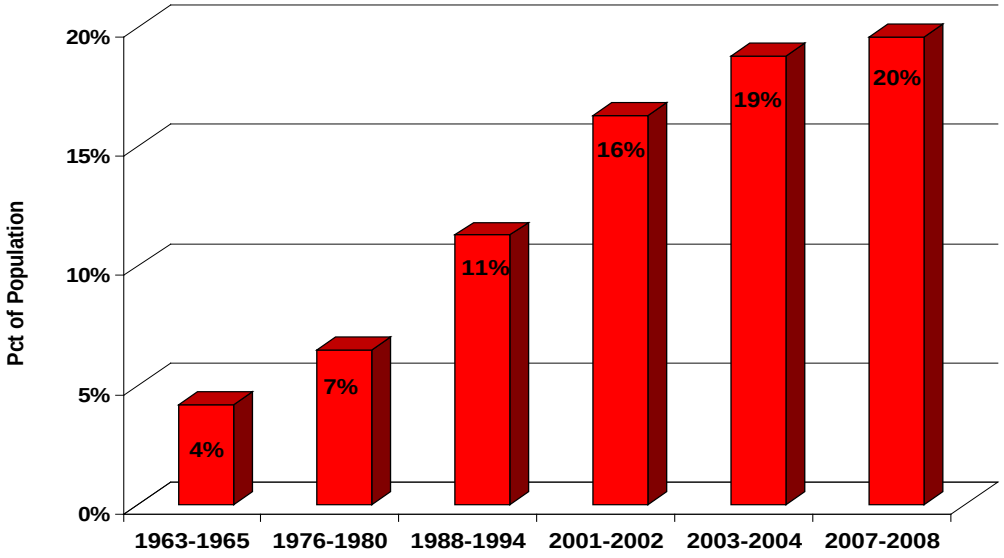
Lifestyle Changes

In support of his argument for the existence of a finite limit to the human lifespan, Olshansky points to the lifestyle changes we are seeing in highly developed countries such as the US, Canada and the UK, where rates of mortality improvement have been strong during the entire 20th century. Olshansky hypothesizes that as a society continues to develop, its general level of education increases and its population becomes wealthier. As a result, awareness regarding lifestyle impacts on health grows as well, resulting in declining rates of smoking as well as increased focus on the importance of diet and the benefits of regular exercise. However, at the same time, wealthier populations become more susceptible to diseases that are either caused or promoted by greater levels of stress and excesses in lifestyle habits, including eating or drinking habits.

National data in the US, including rates of obesity in both children and adults, has shown some consistency with these theories. The US has experienced significant increases in obesity over the past several decades across gender, age and racial groups. (Charts 28, 29, and 30)

Chart 28: US Rates of Childhood Obesity

Population, Ages 6-11

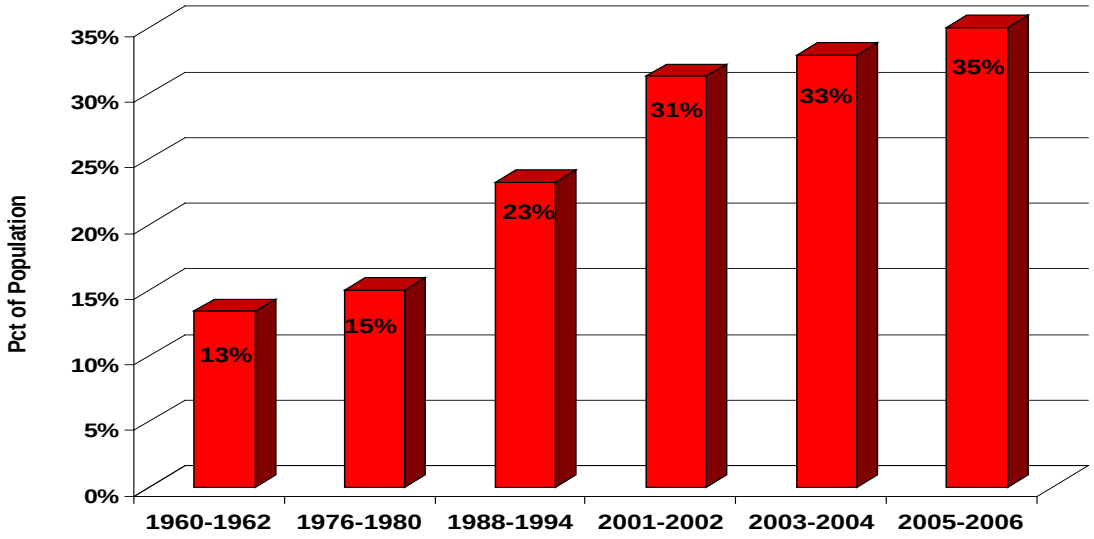


Source: CDC Data, NHANES (National Health and Nutrition Examination Surveys).

NOTE: For children, obesity is defined as body mass index (BMI) greater than or equal to sex- and age-specific 95th percentile from the 2000 CDC Growth Charts.

Chart 29: US Age Adjusted Rates of Adult Obesity

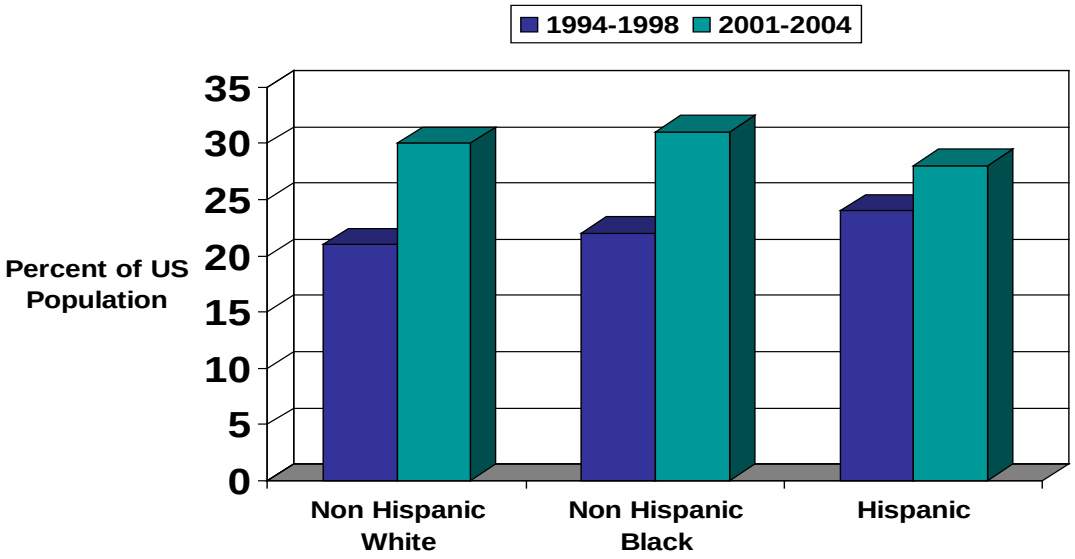
Population Ages 20-74



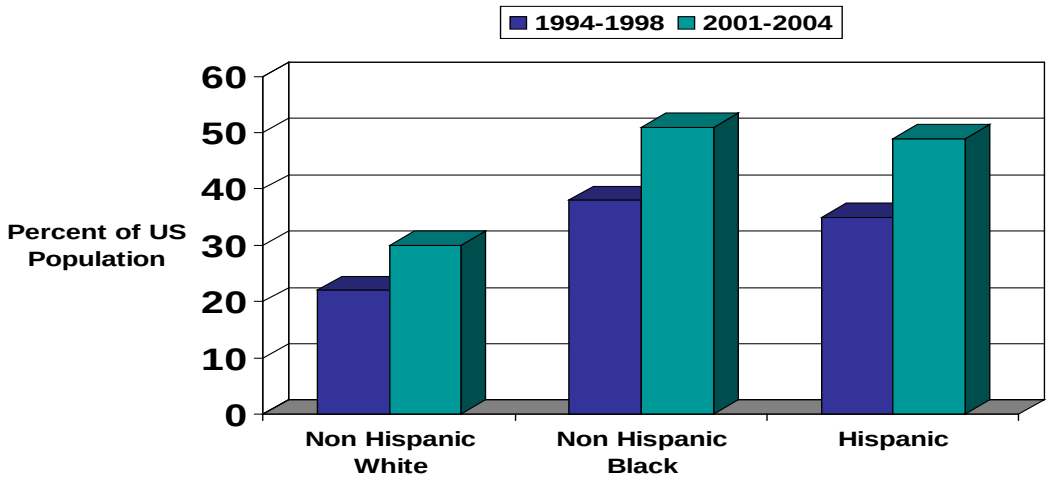
Source: CDC Data, NHANES

Chart 30: US Age Adjusted Rates of Adult Obesity by Race
Population Ages 20 and Over

Males



Females



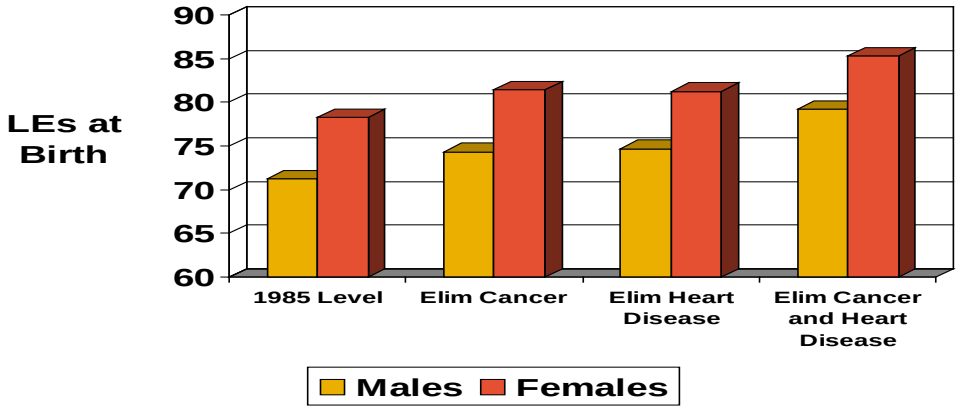
Source: CDC Data, NHANES

NOTE: For adults, obesity defined as body mass index (BMI) greater than or equal to 30, excludes pregnant females.

Obesity is a primary risk factor for Type 2 diabetes, and is likely a strong contributor to the increase in cardiovascular disease that has been seen over the past few decades in the US. Obesity is also believed to contribute to incidence of some types of cancer, including cancers of the breast, gall bladder and endometrium. Several sources indicate that long-term impacts of obesity on future life expectancy will likely outweigh the gains made with decreasing rates of smoking among developed country populations.

Olshansky used population life tables to estimate the effect on life expectancies at birth from the elimination of various diseases based on their estimated impact on mortality rates year over year. Olshansky's research indicates that even if both cardiovascular disease and cancer, the two leading causes of death in developed countries today, were eliminated, life expectancy at birth would only increase to approximately 85 (Chart 31).

Chart 31: US Life Expectancies at Birth, White Males and Females After Elimination of Heart Disease and Cancer



Source: Olshansky, 1985

In addition, some demographers believe that wealthier nations are susceptible to a new age of pandemics that cannot be easily controlled with currently available pharmaceuticals. Recent outbreaks including avian flu and SARS have increased awareness regarding the emergence of new pandemics. In the US, research performed by the Congressional Budget Office regarding past and potential future pandemic costs and mortality/morbidity levels indicate that this is another consideration. However, the impact of pandemics has historically been focused over a shorter period of time and is therefore likely to be smaller than other impacts such as reduction in risk factors for various non-communicable diseases. (Table 22)

The paper by Li, Hardy and Tan examined the impact and potential incorporation of external shocks to population mortality levels such as pandemic. Their results concurred with other work that has demonstrated the likelihood of a relatively short term impact from these types of events; however their projection methodology did ultimately incorporate a component for the effect of potential future shocks.

Table 22: Past and Potential Future Impact of Global Pandemic

	Spanish Influenza 1918-1919	Asian Flu 1957-1958	Hong Kong Flu, 1968-1969	H1N1 2009-2010	Mild Avian Influenza, Current, H5N1, Estimated	Severe Avian Influenza, Current, H5N1, Estimated
Deaths (Worldwide)	40,000,000-50,000,000	2,000,000	1,000,000	Unknown	Unknown	Unknown
Deaths (US)	500,000-675,000	70,000	36,000	11,000	100,000	2,000,000
Attack Rates	40%	20-70%	15%	20%	25%	30%
Population Most Affected	Adults 20-50	Adults > 65	Adults > 65	Adults 20-50	Unknown	Unknown
Case Fatality Rates	2.5%	.1%-.2%	0.1%-0.2%	<.1%	0.1%	2.5%

Source: Congressional Budget Office, National 2009 H1N1 Flu Survey and the Behavioral Risk Factor Surveillance System survey.

Part 2: Mortality Improvement Analysis and Projection Techniques

Traditional Actuarial Analysis Techniques

Traditional analysis techniques that actuaries use in reviewing insurance product experience primarily involve a one-way analysis that examines experience as a function of number of policies exposed and/or the actual to expected analysis that determines the ratio of actual experience to expected experience. In this process, the impact of various demographic and product-specific factors is analyzed in the presence of all other factors.

If actual to expected mortality by gender is examined under a traditional one-way analysis, the results do not necessarily provide a clear understanding of the impact of gender in the presence of other potential factors impacting results. For example, although females may have experienced lower rates of mortality than males, if most of the underlying female population has a higher level of education and a higher socioeconomic status, apparent differences in results may not have arisen solely from gender differences but from a combination of other potential underlying factors.

In addition, traditional analysis methods are limited in their ability to drill down and examine experience at a more detailed level due to credibility concerns.

Predictive Modeling Techniques

Predictive modeling is the process of using historical experience data to construct a statistical model that will be predictive of the future. The casualty insurance industry has developed multiple and extensive applications of predictive modeling, including generalized linear models, in the pricing, underwriting and strategic planning processes.

A predictive model begins with the identification of a group of variable factors (dependent variables) that are likely to influence future results. Focusing on life insurance mortality as an example, many of the variables available for traditional experience analysis work (e.g., age, gender, product type, risk classification) can be used, but other information may also be collected and analyzed to help predict future mortality and mortality improvement rates, including information from external databases or underwriting information such as credit score, education levels, income and wealth levels, occupation and other lifestyle factors.

Once data is collected for a wide range of factors, a statistical model is created. The process of developing and enhancing the predictive modeling framework includes model validation and revision as additional data becomes available. The model may involve a simple multiple linear regression or a complex modeling process using sophisticated software.

Within the P&C industry, generalized linear models (GLM) have so far been the predictive modeling methodology of choice and the discussion here is focused on this approach in particular. However, this is just one example of a predictive modeling approach that has worked well for insurance-related analyses.

Basically, the mortality rate (or mortality improvement rate, depending on what independent variable is directly modeled) is assumed to follow a probability distribution, often from the exponential family. The linear predictor consists of an intercept term and a set of multipliers that are applied to the values of the dependent variables called betas.

Under a GLM approach, first a “base cell” is selected (e.g., male, age 35, nonsmoker, contract year 10, risk class preferred). It is common to select a base cell that has a large amount of exposure for the database available, although this is not a requirement. The intercept term is the value of the linear predictor for this selected base cell. Then the combination of betas and covariates for every other policy are applied to the intercept term in order to determine results for combinations other than the base cell. The parameters and the intercept term are chosen such that they maximize the log-likelihood for the actual mortality represented by the current dataset using iterative numerical techniques.

Results are presented as a set of multiplicative relativities (multipliers) against the base level (Chart 32a).

Chart 32a: Sample GLM Model Output

Deaths Per 1000

	qx		Multiplier		Log of Multiplier	
Age	Male	Female	Male	Female	Male	Female
30	0.528	0.276	0.880	0.460	(0.128)	(0.777)
31	0.528	0.288	0.880	0.480	(0.128)	(0.734)
32	0.528	0.300	0.880	0.500	(0.128)	(0.693)
33	0.552	0.324	0.920	0.540	(0.083)	(0.616)
34	0.576	0.336	0.960	0.560	(0.041)	(0.580)
35	0.600	0.360	1.000	0.600	-	(0.511)
36	0.660	0.384	1.100	0.640	0.095	(0.446)
37	0.684	0.384	1.140	0.640	0.131	(0.446)
38	0.708	0.408	1.180	0.680	0.166	(0.386)
39	0.756	0.432	1.260	0.720	0.231	(0.329)
40	0.792	0.456	1.320	0.760	0.278	(0.274)

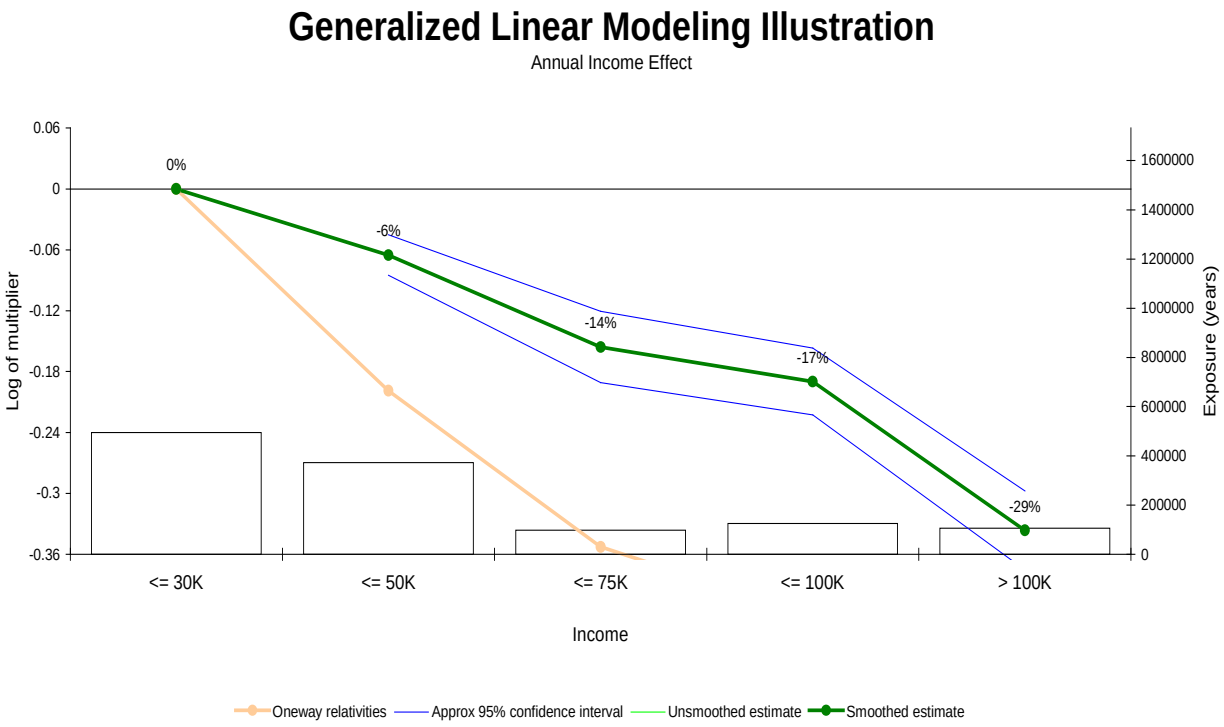
Source: Towers Watson, 2010, Pretium software

Relative mortality factors resulting from the GLM analysis are sometimes presented as the log (multiplier) to allow for ease of review both numerically and graphically. Chart 32b below indicates the relative difference in mortality from the base level attributable solely to gender differences in the presence of all the other factors (e.g., age, risk classification, smoker status, etc.).

The chart below presents the GLM results for the relative impact of annual income level on mortality results. The Predictive Model Estimate (the green line) shows the multiplicative impact of each level of income relative to the base level. The One Way Relativities (the orange line) show the relativities implied by a univariate analysis.

The 95% Confidence Interval for the GLM results (the blue lines) indicate two standard errors on either side of the smoothed estimate. Smaller confidence intervals imply a greater degree of certainty regarding results. A wider confidence interval implies greater uncertainty in the estimate due to: smaller amounts of exposure, the possibility that other correlated variables also explain the risk, or underlying experience that may be significantly random.

Chart 32b: Sample Generalized Linear Modeling Results



Source: Towers Watson, 2010, Pretium software

Other Projection Techniques

The insurance industry and the academic community have explored a variety of approaches to developing a view regarding future mortality improvements. These techniques generally fall into one of the following categories, and we will briefly review each category as well as the advantages and disadvantages of specific models.

- Extrapolative Methods
- Relational or Targeting Methods
- Cause-Specific Models
- Disease-Based Models

In addition to the above, some models are deterministic while others are stochastic. For example, the Social Security Administration produces a set of forecasts of future mortality based on a deterministic, cause-specific modeling technique. They also produce forecasts based on stochastic modeling.

A deterministic model typically projects future assumptions based on past experience, producing a single (baseline) forecast of the future. Often, there is also an interval forecast produced (consisting of a pessimistic, base and an optimistic scenario).

A stochastic model utilizes an assumed probability distribution for the quantity being projected (for example, future rates of mortality or mortality improvement). The stochastic forecast consists of an assumed statistical distribution for values of the quantity with the distribution parameters determined by past experience. So for stochastic forecasts, a probability can be associated with each possible range of outcomes.

Examples of deterministic models would include Gompertz, Perks/Kannisto, Heligman-Pollard and Weibull. Examples of stochastic models include P-spline, Lee-Carter & Cairns-Blake-Dowd. All these models are based on fitting past experience over a number of years in order to provide a basis for the projection of future mortality results.

Extrapolative Methods

All of the models discussed in this section are typically developed based on past trends in all-cause mortality experience, although some applications have considered past trends in cause-specific mortality experience.

The typical extrapolative approach would involve fitting a model to actual mortality experience in a single calendar year. That process is then repeated for each calendar year over the experience period and the parameters underlying the models for each calendar year are then plotted to determine any significant patterns in values of the model parameters.

This leads to the primary shortcoming associated with these methods, the fact that they rely entirely on the past to project the future.

Gompertz and Weibull have been popular models for mortality projection over time due to their flexibility. The Weibull approach assumes that survival rates at age x (S(x)) follow a 2-parameter Weibull distribution of the following basic form:

S(x) = $\exp(-(x/\alpha)^{\wedge}\beta)$

An estimation method is used to solve for the parameters for each single calendar year and the trends of the parameters are projected into the future using a single line to develop future mortality rates. A

benefit of this approach is that it is less complex; however, there are also specific weaknesses. This model is not intended to capture the cohort effect and the Weibull life model is a parametric model that produces a single best-estimate assessment of future mortality and projected rates of mortality improvement.

The Lee-Carter model has been used extensively on a global basis, and is employed by the Social Security Administration in the US and the Continuous Mortality Investigation in the UK. Lee-Carter is a stochastic projection model that considers separate effects on mortality for attained age and for calendar year. Since its introduction in 1992, the Lee-Carter model and its variants have become widely adopted for the development of long-term forecasts of age-specific mortality rates.

The basic Lee-Carter model assumes that the central death rate can be described by a function of the variables x (age) and t (calendar year) of the following form:

$\log m(x; t) = a(x) + b(x)k(t) + e(x; t)$

where m(x,t) is the central death rate at age x and in year t and e(x; t) is a random error term. Here the a(x) determines the average level of the mortality profile by age while b(x) is an age specific parameter that indicates the variance from the average level of a(x) as k(t) varies. Finally, k(t) is a time parameter providing information regarding the rate of improvement at time t. These parameters can be estimated by maximum likelihood techniques, typically assuming that the number of deaths follows a Poisson distribution.

After the parameters for the historical periods are determined, the time component k(t) is projected into the future using a time series model.

Because the first age component is independent of time, historical age patterns will be carried into the future. The model generates sample paths of mortality rates, and the mortality can be ranked for each combination of attained age and period to define statistical distributions, and confidence intervals of the mortality rates can be developed. With the uncertainty regarding future patterns of mortality, stochastic approaches help to quantify the financial impact of volatility in future experience. The model has also been shown to provide a good fit over wide ranges of attained ages for recent population data in the US and other developed countries. In their 2010 paper, Li, Hardy and Tan describe the development of a modified Lee Carter model for Canadian insured lives using a combination of population and insured experience.

One shortcoming of the Lee-Carter model is that it does not reflect mortality patterns that depend on year of birth or “cohort effect.” Also, under the Lee Carter approach, mortality rates over various attained ages are not smoothed, resulting in unsmoothed improvement rates by attained age.

A third concern with the Lee-Carter model is related to parameter uncertainty. The only uncertainty in the original Lee-Carter model is assumed to come from the random noise component; however, the

most important source of uncertainty in a mortality projection is the trend, which is represented by the parameter uncertainty. The lack of parameter uncertainty exists because there is only one set of historical data.

Another stochastic extrapolative method is the P-spline regression which attempts to achieve both smoothness and goodness of fit, based on attained age and either calendar year or year of birth. Therefore, the P-spline method can identify and incorporate the impact of differences by cohort. The model produces a best-estimate mortality projection as well as residuals for each combination of attained age and calendar year (or year of birth). Resulting expected mortality improvements are developed from these projections.

One important shortcoming of the P-spline model is that future projections of mortality are very strongly influenced by the most recent historical experience and therefore caution should be exercised when recent mortality experience deviates significantly from the past.

Cairns, Blake and Dowd also produced a number of models that provide for variations on the original Lee-Carter approach. The simplest of these models provides for a function of two time-dependent parameters, one of which is applied to the difference between the currently considered age and the average age of the mortality database to which the model is being applied. The form is as follows:

$$\log (u_{xy}) = k(0,y) + k(1,y)(x - \text{mean}(x))$$

where x is age, k(0,y) is the rate of change in mortality at age x over time, and k(1,y) indicates changes to the rate of change in mortality with age,

Software Available

Public use software exists for the Lee-Carter and other models.

Lee-Carter Fitter: http://lcfit.demog.berkeley.edu/

Additionally, the Continuous Mortality Investigation Bureau, a mortality research group in the UK, publishes an excel add-in that provides the fitting and projections of Lee-Carter model. The underlying coding for the model is done in R — a free software for statistical graphics and computing. This version of the Lee-Carter model does not capture “cohort effects,” but it includes a bootstrapping approach implemented to address the parameter uncertainties. The time series model used for the forecasting component is ARIMA (1, 1, 0), a differenced first-order autoregressive model.

Relational or Targeting Techniques

The basic approach for relational models is to develop a function $F(m(x))$ that relates mortality in a specific population under study to that in a reference population. The development of the function F is typically dependent on testing the fit of the relationship between the population being modeled and the reference population.

Reference populations could be based on:

- Long-term historical averages for a specified country (e.g., low mortality countries such as Sweden and Japan are often used in this capacity)
- Historical international comparisons.

Another common approach that has been used for assessing population mortality improvements is to assume that future mortality improvements trend from their current levels to a long-term target assumption such as the Oeppen/Vaupel rule of thumb regarding overall ultimate levels of improvement of 2.5 years per decade.

In developing such an assumption, subjective judgments have to be made in a number of areas, including the following:

- Choosing an appropriate target, having regard to differences between cohorts and the likely potential of continued improvements in longevity.
- Choosing an appropriate date by which current mortality improvements are expected to blend into the long-term target assumption.
- Assembling a group to provide expert opinion to support the choice of target, involving perhaps actuaries, doctors, epidemiologists and demographers.
- Identifying an appropriate methodology to blend current mortality improvements with long-term assumptions.

The Office for National Statistics (“ONS”) develops regular population projections that include mortality improvement assumptions. The 2006-based ONS projections extend the “cohort effect,” and mortality improvement assumptions are set according to internal analyses and consensus views of experts. The 2006-based ONS projections include a long-term assumption for those born in the early 1930s of 2.5% per year, which reduces gradually to 1% per year for those born either before 1925 or after 1945.

Cause-Specific Models

It has been standard practice to apply all of the models discussed above to all-cause insured or population mortality experience. However, it has been argued that future all-cause mortality experience can only be reasonably analyzed if trends in specific cause-of-death mortality and future likely changes are understood. In theory, any of the models that we have presented could be applied to the mortality experience for a specified grouping by cause of death and then combined across all the groupings to produce aggregate assumptions. However, this approach requires significantly more detailed data including cause of death by individual. Limiting the number of major groupings by cause of death would be an important consideration in maintaining a sufficient level of credibility.

Another concern about the use of cause-specific mortality for modeling purposes is the consistency of death certificates completion due to differences in views of doctors or differences in approaches or direction over varying time periods. This concern is lessened if modeling is restricted to relatively broad categories, although there is still the potential for variations in the completion of death certificates for the elderly who may have a number of different co-morbidities.

In the US, the National Vital Statistics System of the National Center for Health Statistics produces a public-use multiple cause-of-death mortality database by calendar year available through the CDC Wonder website discussed earlier in this report. This database records all illnesses that were provided on a death certificate, and provides a basis to consider the impact on all-cause mortality of future changes in the importance of particular causes of death.

Disease-Based Models

A limitation of both all-cause and cause-specific mortality models is that data is restricted to the death itself and, therefore, there is no consideration of the potential impact of timing and development of diseases that may have led to the death. It can be strongly argued that better estimates of future mortality can be produced by considering changes in the progression of diseases, and the interactions between different diseases. These models would necessarily be more complex. A major limitation of this approach is the lack of availability of large longitudinal patient databases on which to derive assumptions.

For example, in the UK extensive work has been done in this area using the General Practice Research Database, which has electronic medical records for 4 million patients. This has been used to produce historical disease incidence rates and subsequent mortality rates for various disease groups that are used in a multi-state model of disease and mortality. There are significant similarities in the relative importance of different causes of death between the UK and US, and some of the predictive scenarios that would be developed for a UK disease-based mortality model would have relevance to the US. However, the full application of disease-based mortality models to US experience would require identification of and access to equivalent large databases of patient medical records and expert medical opinion specific to the US on developments in clinical practice and the introduction of new treatments.

One of the advantages of disease-based mortality models is that such models can consider the impact of different predictive scenarios. Predictive scenarios might involve convergence in mortality experience between one country and another, or changes in the population level of risk factors for a particular disease or the introduction of new treatments.

Projection of Mortality Improvements — Comments and Conclusions

The rate of mortality improvement or decline has sometimes varied substantially from one decade to the next. Some of this variation has been examined and explanations have been put forth to help both understand the past and project the future.

In our view, the following considerations should be addressed in developing a reasonable methodology for projecting future mortality improvement levels.

- Recent or historical rates of mortality or mortality decline don't always provide the best basis for long- or medium-term projections.
- Most models currently used for projection of mortality and mortality improvements rely extensively on past experience to predict the future, in terms of both age-specific patterns and sources of future improvement. This characteristic will not provide for accurate estimates if future trends are not in line with the past, and it is therefore dangerous to rely on these methods without some consideration of potential sources of future variation.
- There is a good case for incorporating an element of variability of rates of decline (insured vs. population, gender, age, smoker status, etc.) when making projections.
- Causal analyses like those described in this section tend to be specific to a particular historical context and are not necessarily appropriate to apply going forward.

Based on the review of potential approaches for projecting mortality and mortality improvements for the insured population, we suggest the following methodology:

1. *Data Gathering.* Compile data regarding the historical impact on mortality for the populations under consideration of specific lifestyle trends, behaviors, medical advances, demographic and societal changes, and underwriting/risk classification techniques from both insurance industry and other outside sources. This data should be maintained and regularly updated in order to allow for better understanding of the impact of changes in these areas.

   A partial list of potential items that are expected to impact future mortality improvement levels includes the following:

   - Medical advances — New advances in health care that are expected to impact mortality improvements (diagnostic tests, treatments, cures). Consider not just the potential reduction

in mortality but also the population that will be impacted and the period of time over which the reduction is expected to emerge.

- Lifestyle changes — Changes in levels of smoking (number of new smokers and rates of quitting in adulthood), drinking, as well as exercise and diet including the impact on obesity.
- Changes in prevalence of disease incidence including emerging new diseases — Track new diseases and disease types as well as growth or decline in current disease diagnoses.
- Shifts in primary causes of death and disease (e.g. obesity and diabetes)
- Access to medical care — Follow the development of the health care reform initiative in order to gauge its potential impact on future mortality and mortality improvement levels.
- Changes in education, wealth, marital status and income levels of the population
- Shifts in the ethnic mix of the population
- Underwriting methodology and guideline changes with respect to insured lives

2. *Model Development.* Select a projection methodology such as Lee-Carter that provides a reasonable fit to recent population and/or insured mortality experience.

3. *Apply information from data trends.* Explore approaches to modifying the initial results developed in 2. using judgment regarding future expectations based on data collected regarding the factors outlined in 1.

4. *Update models.* Monitor actual results versus projected levels and modify the method as necessary over time.

This approach allows for the application of a rigorous modeling methodology while retaining an element of professional judgment that is based on more rigorous data regarding current and potential future trends.

Section 6: Views Regarding Future Insured Mortality Improvements in the US

We conclude the report with the development of a medium-term estimate (10-15 years) of future mortality improvement levels for the insured population, focusing on life insureds and individual payout annuitants at the typical insurance buying ages. We do not provide a view regarding group annuitants as fewer data points are available at this time. At this point in time, a recommendation regarding future mortality improvement levels beyond the medium term is necessarily more judgment-based than model-based.

As the information contained in this report indicates, there is no clear agreement regarding the overall level or the age pattern of future mortality improvement for population or insured data.

The discussion below details our approach to developing estimates based on the data reviewed for this report.

Part 1: Expected Improvement in Population Mortality

In our view, population mortality data provides the most appropriate basis for an estimate regarding future mortality improvement for both the general and insured populations. This is because it represents the richest source of data in terms of the length of time covered and just as importantly, it allows for consistency in the underlying population studied.

In developing the future general population assumption, we focused on the period 1980-2007, as this utilizes more recent results but also includes sufficient data so that the mortality improvement projection base demonstrates a smoother pattern by age. In addition, we have assumed that past differences in the level of mortality improvement between males and females will continue for the medium-term future.

The population assumption varies by age group and gender with median annual improvement levels of 1.5 percent for males and 1 percent for females. (Table 23)

Table 23: US General Population Mortality Improvement – Medium Term View

Age	Males	Females
<1	1.5%	1.5%
1-4	2.5%	2.5%
5-9	2.5%	2.0%
10-14	2.5%	2.0%
15-19	2.5%	2.0%
20-24	0.5%	0.5%
25-34	1.5%	1.0%
35-44	1.0%	0.5%
45-54	1.0%	0.5%
55-64	1.5%	1.0%
65-74	1.5%	1.0%
75-84	1.5%	1.0%
85-89	1.0%	0.8%
90-94	0.7%	0.5%
95-99	0.3%	0.3%
100+	0.2%	0.2%

Part 2: Considerations in Adjusting General Population Mortality Improvement Results for Insured Populations

Underwriting and Selection for Insureds

Since in most cases applicants for life insurance go through an underwriting process that selects individuals who represent favorable risks, mortality experience for life insureds is expected to be lower than for the population in general during the select period and life insureds in the ultimate period appear to have experienced similar or slightly higher levels of mortality improvement (on an amount basis) than the general population.

However select period data is, at best, difficult to interpret in terms of understanding what portion of the changes in mortality level across studies are related to different underlying mixes of business (companies participating, distribution channels, markets), changes in underwriting and selection techniques, and pure mortality improvement. Although this report provides the data that is available, at this point in time, it is not possible to draw conclusions regarding relationships between life insureds and the general population during the select period.

Based on these considerations, our current best estimate view for future insured mortality improvements does not include a distinction by policy duration.

Socioeconomic Status

As discussed in Section 5, there is growing evidence to support the assertion that mortality and mortality improvement experience varies by socioeconomic status, whether this is measured in terms of level of education achieved, wealth, or income. Results from several studies suggest that these differences may be driven by the fact that those individuals with greater economic means have better access to medical care.

Since the insurance-buying population tends to be focused at the higher education and income levels, it would not be unreasonable to assume that on this basis alone, there should be a distinction made between insureds and the general population with regard to future mortality improvement expectations.

Based on data from the 2008 study discussed in Section 5, we estimate that the generally higher socioeconomic status of individual life insureds could substantiate mortality improvement levels between 0.5% and 1% per year greater than the general population.

Smoker Status

Clearly, a contributing factor in the improvements seen in general population mortality since the 1970s is the reduction in the percentage of smokers in the US. Several studies have examined differences between smoker and nonsmoker mortality experience and data indicates that mortality for smokers ranges between 1.5 and 2.5 times the level seen for nonsmokers. Unfortunately, national population databases do not yet reliably collect smoker status information, and other studies have only examined experience over relatively limited periods of time, precluding a direct analysis of improvement level impacts.

The Society of Actuaries Individual Life Experience Committee studies began to collect and publish data regarding smoker and nonsmoker mortality distinctions in the early 1990s. However, most of this business remains in the select period where the impact of underwriting changes limits our ability to distinguish true smoking-related differences.

However, if we examine data from the most recent SOA study, and focus on results for the latest policy durations available in order to limit the impact of underwriting, there does appear to be emerging evidence for a difference in improvement levels. For the 21 common companies submitting data over the 5-year period 2002-2007, only the male data has sufficient credibility in the later policy durations for an analysis by smoker status. For males, overall results seem to indicate that mortality improvements for smokers have been about 50% of the levels seen for nonsmokers. And at durations 16-20 where there is least underwriting impact, the differences appear to be increasing with attained age (Table 24).

Table 24: US Life Insured Smoker vs. Nonsmoker Average Annual Mortality Improvement, 2002-2007 Data, SOA Individual Life Experience Studies
21 Common Companies, Face Amounts $25K+

Policy Durations 11-15

Attained Age	NS	SM	Difference	Ratio SM/NS
Male Ages 25-59	6.0%	4.5%	1.5%	75.0%
Male Ages 60+	3.6%	2.0%	1.6%	55.6%
Male Total	4.5%	3.4%	1.1%	75.6%

Policy Durations 16-20

Attained Age	NS	SM	Difference	Ratio SM/NS
Male Ages 25-59	4.7%	3.4%	1.3%	72.3%
Male Ages 60+	2.2%	-0.1%	2.3%	n/a
Male Total	2.9%	1.1%	1.8%	37.9%

Source: Analysis of SOA Individual Life Experience Studies data, 21 common companies, 2002-2007

Keeping in mind that the general population mortality improvements used as the basis for developing the population expected improvement level do include the impact of declines in the percentage of smokers over time, we recognize that some portion of any difference in smoker and non smoker experience has been accounted for in the general population estimate. Another consideration is that in practice, if rates of improvement for smokers are reduced, we would also need to increase rates of improvement for nonsmokers in order to come to the same aggregate view.

For purposes of this exercise and taking into account the relatively small proportion of smokers in the life insured population, we believe a case could be made for assumed improvement levels for nonsmokers approximately 0.5% to 1% greater than for smokers.

Impact of Obesity

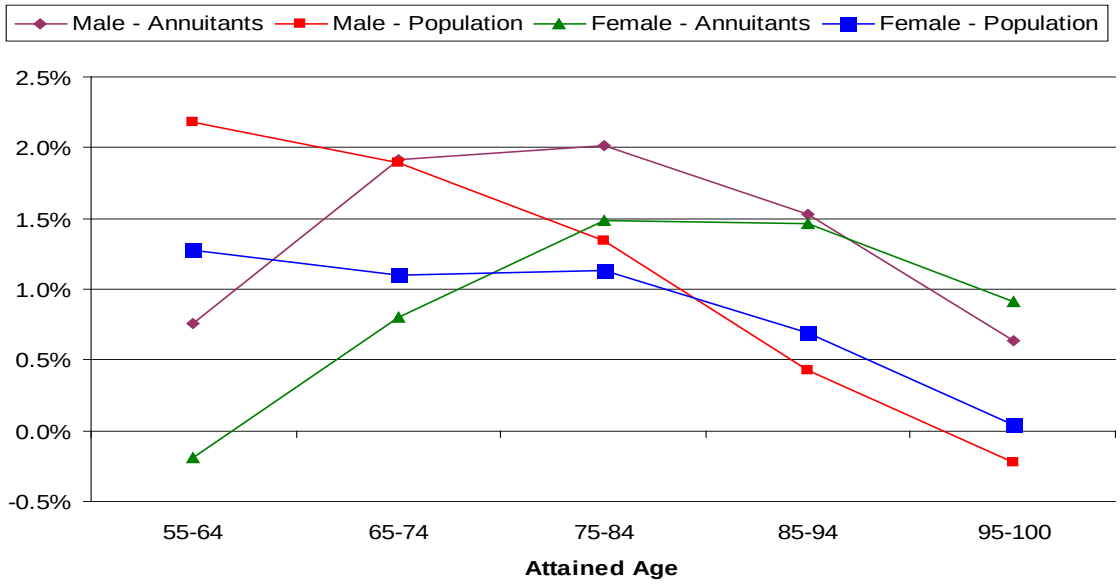
Obesity is commonly cited as a potential source of deterioration in rates of future mortality improvement for the US population in particular. The greatest area of concern is related to the impact of childhood and young adult obesity on future results. As this analysis focuses on medium-term projections and as the life insurance underwriting process tends to select healthier individuals, we have not made an adjustment for this factor in the current insured mortality improvement estimate.

Individual Payout Annuitants (Immediate Annuities and Settlement Options)

Using the available studies produced by the SOA Individual Annuity Experience Committee over time, we reviewed rates of mortality improvement for this population between 1973 and 2002. For attained

ages 75 and older, individual annuitants appear to have exhibited rates of improvement between 0.25% and 1% higher than those of the general population over this period for attained ages over 65 for males and over 75 for females (Chart 33). This may be due to socioeconomic status differences, self-selection effects or both. Based on this information, we have included an additional 0.25% improvement over general population levels for individual annuitants at attained ages 75 and older.

Chart 33: US Individual Annuitant vs. Population Mortality Improvement Experience Period 1973-2002



Source: SOA Individual Annuity Experience Studies, Table Manager, HMD

Part 3: Medium-Term Future Mortality Improvement View for Insured Populations

For individual life insurance, we are suggesting a moderately higher assumption for improvement levels for nonsmokers (0.5% above population level at ages between 25 and 84) than that for smokers (equal to population level mortality improvement levels). At the older ages, where improvement levels have historically been lower, we maintained the same average relationship between smokers and nonsmokers. This implies nonsmoker improvement levels approximately 33% higher than smokers.

For nonsmokers, this suggestion is intended to include a combination of both the higher socioeconomic class of life insureds as well as any additional health benefits due to their nonsmoking status. For smokers, we make the assumption that any socioeconomic benefit will be less significant and even nullified by the negative impact of smoking on health.

Tables 25 presents our suggested best estimate mortality improvement levels for the US general population, individual life insureds and individual annuitants including variations by gender and attained age group.

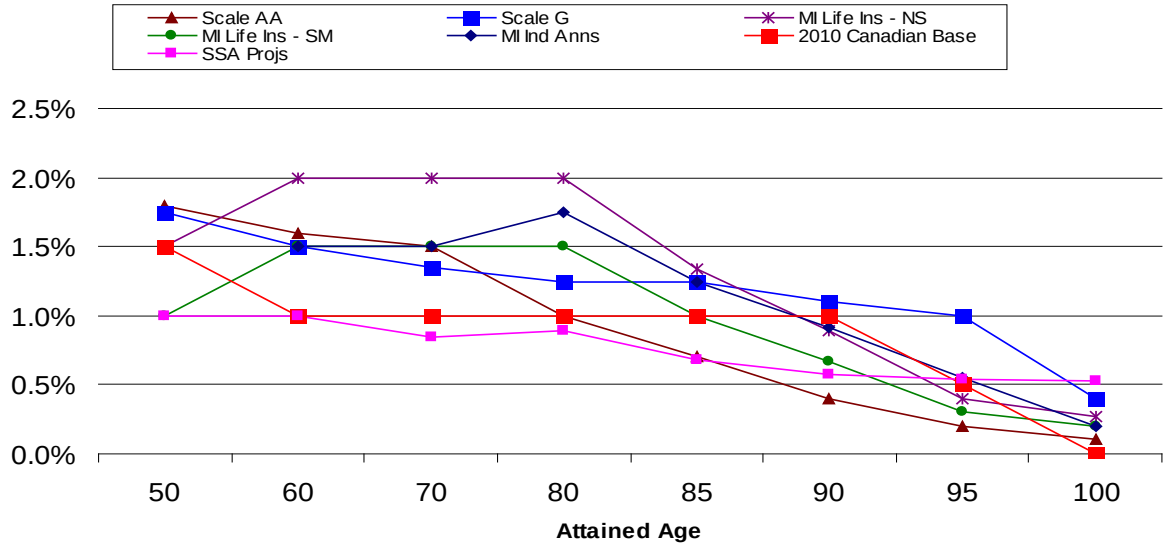
Table 25: US Population and Individual Life Insureds
Mortality Improvement Best Estimates
2011-2025

	General Population		*Ind Life Insureds Non Smokers*		*Ind Life Insureds Smokers*		*Individual Annuitants*	
Attained Age	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
25-34	1.50%	1.00%	2.00%	1.50%	1.50%	1.00%		
35-44	1.00%	0.50%	1.50%	1.00%	1.00%	0.50%		
45-54	1.00%	0.50%	1.50%	1.00%	1.00%	0.50%		
55-64	1.50%	1.00%	2.00%	1.50%	1.50%	1.00%	1.50%	1.00%
65-74	1.50%	1.00%	2.00%	1.50%	1.50%	1.00%	1.50%	1.00%
75-84	1.50%	1.00%	2.00%	1.50%	1.50%	1.00%	1.75%	1.25%
85-89	1.00%	0.75%	1.33%	1.00%	1.00%	0.75%	1.25%	1.00%
90-94	0.67%	0.50%	0.89%	0.67%	0.67%	0.50%	0.92%	0.75%
95-99	0.30%	0.25%	0.40%	0.33%	0.30%	0.25%	0.55%	0.50%
100+	0.20%	0.20%	0.27%	0.27%	0.20%	0.20%	0.20%	0.20%

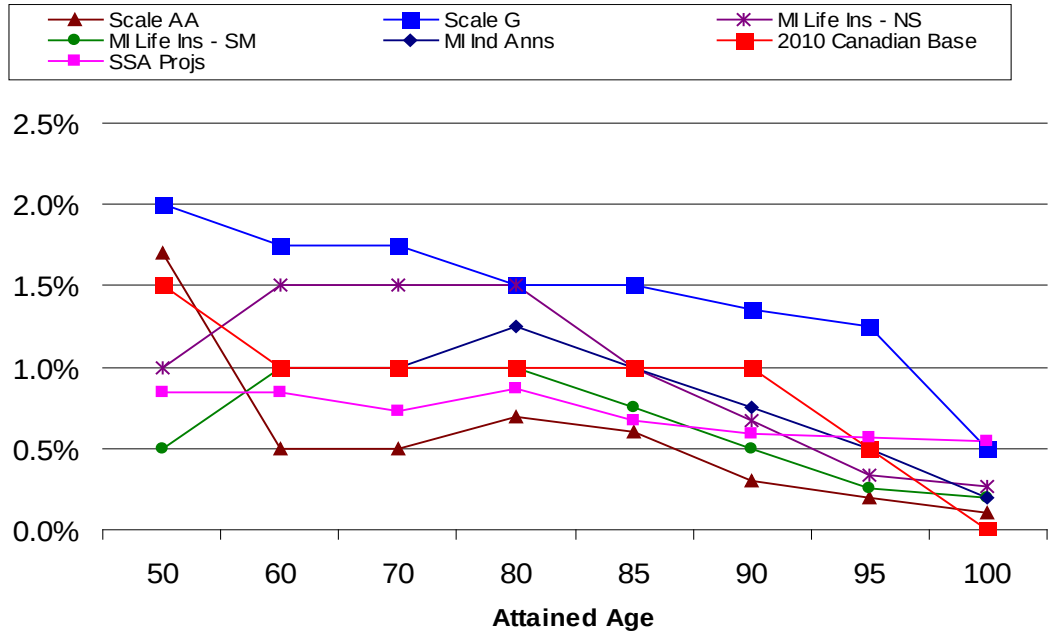
Chart 34 provides a comparison for the US population age 50 and older of our mortality improvement best estimate view with current improvement scales in use in the US insurance industry as well as recent Social Security Administration forecasts as published in Actuarial Study No. 120 in 2005, and the recent Canadian Institute of Actuaries Committee on Life Insurance Financial Reporting best estimate recommendation to be utilized in developing mortality improvement levels for Canadian valuation purposes.

Chart 34: US Individual Life and Annuity Future Mortality Improvement Assumption vs. Alternative Projections of Insured and Population Mortality Improvement*

Males



Females



Source: SSA Life Tables, Table Manager, CIA Paper (September 2010)

*Social Security Administration Forecast covers the period 2010-2030.

A few comments on the Canadian Institute of Actuaries recommendation:

- The basis of the Canadian base improvement levels covered a longer period of time, 1921-2002.
- Separate assumptions for males and females were not developed since the relationship of male to female improvements has varied from decade to decade in Canada.
- With even more limited data than the US on smoker status, separate rates for smokers and nonsmokers could not be examined.
- The objective of the CIA committee was to develop mortality improvement levels to be used for valuation purposes. Therefore, for life insurance, improvement rates were limited to 25 years, while for annuities the improvement rates have no limit.

Comments on other scales presented in Chart 34:

- Projection Scale AA was designed to be used in valuation of retirement plans in conjunction with the 1994 Group Annuitant Mortality Table and is based on experience of the Civil Service Retirement System and of Social Security from 1977-1993.
- Projection Scale G was developed during the creation of the 1983 Individual Annuitant Mortality Table with the factors set at a level expected to keep the table reasonably up to date during the remainder of the 20th century. The table was largely based on US white population experience between 1971 and 1979.
- Social Security Administration Actuarial Study No. 120 provides life tables based on historical and projected mortality in the area covered by the United States Social Security program. The projected mortality levels are used in estimating future costs for the Old-Age, Survivors, and Disability Insurance (OASDI) program included in the 2005 Report of the OASDI Board of Trustees to Congress. The data in the SSA life tables may allow for better tracking of actual trends over time for the US population at ages 50 and older.

Appendix A: Mortality Improvement Data Sources

This section outlines the primary data sources available for historical mortality improvement across the general population, life insureds, annuitants, and pensioners from an international perspective. As discussed earlier, both insured and population information are more extensive in the US, Canada and the UK and more sparse in continental Europe, Asia, and Australia. Most of the data takes the form of life tables, of which there are two general types:

1. Cohort or generational tables that show experience for a particular birth cohort (e.g., all persons born in 1950) over time or,

2. Period tables that show the experience of a hypothetical cohort if it experienced the mortality of a particular time period.

In addition, data sources will provide either complete life tables that show data for every year of age, or abridged life tables that provide data for age groupings only (e.g., 5 year or 10 year age groups).

Reporting Problems/Cautionary Notes

The three primary reporting problems that have been identified in reviewing data and data sources across various countries are:

- Age Heaping — This is a situation where there appears to be an unusual number of reported ages ending in either 0 or 5.

- Age Exaggeration and Misreporting — This situation is primarily seen at the older ages and involves either overstatement or understatement of mortality levels due to misreporting of age or birth or death dates. This is the primary reason for changes in the methodology for developing mortality data over time. For example, the 2005 US Life Tables Report indicates a change in the method of determining deaths at older ages. A comparison of mortality improvement rates based on the new US Life Table methodology (which determines deaths at ages over 65 based on Medicare data) and the rates of improvement based on the HMD (which determines deaths based on US Vital Statistic data only) demonstrates that differences in mortality improvement trend estimates can materialize, especially at older ages.

- Estimation of Complete Ages for Grouped Data — The format of available information can vary significantly across countries and sources. For example, data for some nations is only available in 5- or 10-year age groups. This requires that procedures be employed to estimate data for each complete age.

- Categorical Definition Changes - Data that allows for a presentation of results by factors such as race or ethnicity requires a careful review of changes in the definitional categories used over time. For example, in both the US and Canada, government sources of population data have made one or more major revisions to the level of detail and/or categories used in collecting information regarding race over the past few decades.

Finally, even in cases where information regarding deaths and exposures may be available at a very low level of detail (e.g., county level data in the US), credibility of results can often become an issue due to a small number of deaths in each category.

For each of the sources discussed in this section, we provide a summary of the input data, experience period covered, level of detail available, expected timing of updates, and any identified data shortcomings including potential reporting problems or credibility concerns.

A) Global General Population Mortality Improvement Data Sources

We first discuss the Human Mortality Database and the World Health Organization Statistical Reports, as these are two primary sources for comparison of population data on a global basis. As these sources are generally developed from national vital statistics and census information, accuracy of reporting is of much greater concern in utilizing the data than credibility.

The Human Mortality Database

The HMD was developed by the University of California at Berkeley, Center for Demographic Research to document longevity developments over time and to provide a basis for research into the causes and potential outcomes of these developments.

The database contains life tables for national populations across the world, including US, UK , Canada, Denmark, Austria, Belgium, Finland, France, Germany, Hungary, Ireland, Italy, Poland, Netherlands, Norway, Portugal, Sweden and Spain. Populations included in the HMD are those for which there exists an expectation that census and vital statistics data are reasonably complete for the years of experience examined. HMD researchers make no attempt to correct the data for misreporting and coverage errors.

The following information is made available to the public via the HMD website:

- Births — Annual counts of live births by sex are collected for each population over the longest possible time period and are used for making population estimates at younger ages.
- Deaths — Death counts are collected at the lowest level of detail available. Death counts are provided by completed age (age-last-birthday at time of death), calendar year of death and calendar year of birth.

- Population size — Annual estimates of population size on January 1st are obtained from the best available source or are derived from census data plus birth and death counts.
- Exposure-to-risk — Estimates of the population exposed to the risk of death during some age-time interval are based on annual (January 1st) population estimates, with a small correction that reflects the timing of deaths within the interval.
- Death rates — Death rates are always a ratio of the death count for a given age-time interval divided by an estimate of the exposure-to-risk in the same interval.
- Life tables –To build a life table, probabilities of death are computed from death rates. These probabilities are used to construct life tables, which include life expectancies and other useful indicators of mortality and longevity.

Experience Period and Level of Detail Available

The experience periods available for mortality information vary by country and in many cases cover most of the 20th century through more recent years. In all cases, data is provided by age, gender and calendar year of experience.

Input Data

The data used in developing the HMD consists of death counts from vital statistics, census counts, birth counts, and population estimates. In the case of the United States, this information is based on National Center for Vital Statistics data combined with the most recent US Census data. The database is limited to populations where death registration and census data are available and reliable. As a result, the countries and areas for which data is provided tend to be the more developed nations of the world.

Potential Data Issues

Researchers constructing life tables for the HMD found evidence of both age heaping and age exaggeration. Age exaggeration is more difficult to deal with than age heaping. In developing the life tables included in the HMD, researchers assumed that death registrations provide better data regarding older ages than census estimates. The HMD population estimates at older ages are therefore developed from official death counts rather than from national census data.

Methodology

HMD mortality rates and life tables are developed using a consistent methodology across the various countries to allow for maximum comparability over time.

World Health Organization Statistical Reports

Beginning with the year 1999, the World Health Organization (WHO) began producing annual life tables for all Member States. These life tables form the basis for WHO estimates regarding life expectancy and mortality patterns worldwide.

Based on these life tables, the World Health Statistics publications report regularly on the following indicators for each Member State:

- Life expectancy at birth, by sex
- Probability of dying under age 1, by sex
- Probability of dying under age 5, by sex
- Probability of dying between ages 15 and 60, by sex.

In addition, detailed data files are available for public use and download, along with instructions regarding file layouts and field descriptions.

Experience Period and Level of Detail Available

The experience periods (or reference years) available are 1990-2008, with annual data available for 1999-2008. Information is available by age, gender, cause of death and calendar year of experience.

Input Data

Life tables have been developed based on a systematic review of all available evidence from national surveys, censuses, sample registration systems, population laboratories and vital registration on levels as well as trends in under-five and adult mortality rates.

Potential Data Issues

As the data is based on varying sources across countries, data inconsistencies should be expected as well as misreporting, especially in the less developed nations.

Methodology

Procedures for producing life tables differ for Member States depending on the data available to assess child and adult mortality.

B) US Population Mortality Improvement Data Sources

Compressed Mortality File (CMF)

The Compressed Mortality File (CMF) is a county-level national mortality and population database spanning the years 1968-2006.

The CDC makes mortality and health information available electronically through "CDC Wonder" (cdcwonder.org), an interactive website that allows for user downloads of information. Public-use data sets include data related to mortality (deaths), cancer incidence, HIV and AIDS, tuberculosis, vaccinations, births, and population statistics. Mortality experience from the compressed mortality file is available by cause of death, age, gender, race and geographic region based on information provided in standard death certificates.

Experience Period and Level of Detail Available (CDC Wonder)

Data are available for the years 1979-2006. The number of deaths, crude death rates or age-adjusted death rates can be obtained by place of residence (total US, state, and county), age group, race (white, black, and other), gender, year of death, and underlying cause-of-death (4-digit ICD code or group of codes).

Input Data

Results are based on census data for population estimates and vital statistics data from standard death certificates. Cause of death on the CMF is defined as "the disease or injury which initiated the train of events leading directly to death, or the circumstances of the accident or violence which produced the fatal injury." Cause of death is classified in accordance with the International Classification of Disease coding system. Deaths for 1979-1998 are classified using the Ninth Revision (ICD-9 codes). Deaths for 1999 and later are classified using the Tenth Revision (ICD-10 codes).

Care should be taken in using this information to develop age-specific information as there is evidence that this data is subject to age misreporting, especially at the older ages (65 and older).

National Vital Statistics System ("NVSS") Reports

The National Vital Statistics reports (formerly Monthly Vital Statistics Reports) are published by NVSS on a regular basis and include the annual United States Life Tables reports.

Experience Period and Level of Detail Available

The most recent life tables for which detailed mortality information is available are included in the 2006 report published in 2010. Data is presented by age, gender and race. Electronic copies of reports are available on the NVSS website for free download from 1997 onward.

Input Data

Data used to prepare the life tables include final mortality statistics, the 2000 decennial census for population estimates, and annual Medicare data for ages 66-100. Methods used to estimate mortality experience at younger ages (0-65) are the same from 1997 through 2004. In 2005, the methodology for estimating mortality for the population at older ages (66-100) was revised.

First, Medicare data were used to supplement vital statistics and census data beginning at age 66 rather than age 85, as was done from 1997 through 2004. Second, probabilities of death were based on current Medicare data. And finally, the smoothing and extrapolation of the probabilities of death for ages 66 and over utilized a nonlinear least squares model rather than the linear model of the rate of change of the probabilities of death for ages 85 and over that had been employed in past years.

Social Security Administration Reports

Each year, the SSA provides Congress with estimates of future income and expenditures of the Old-Age, Survivors, and Disability Insurance (OASDI) program.

Information from the life tables presented in Actuarial Study No. 120 was used in the some of the analysis underlying this report. Note that the historical calendar year life tables in presented in the SSA study differ from those published by the National Center for Health Statistics (NCHS). NCHS prepares U.S. Decennial Life Tables based on the decennial census of population and deaths for a three year period containing the census year. NCHS also prepares annual life tables.

Input Data

Annual tabulations of numbers of deaths by age and sex are made by the National Center for Health Statistics (NCHS) based on information supplied by States in the Death Registration Area, and are published in the volumes of Vital Statistics of the United States.

National Longitudinal Mortality Study (NLMS)

The National Longitudinal Mortality Study ("NLMS") is sponsored by the National Cancer Institute, the National Heart, Lung, and Blood Institute, the National Institute on Aging, the National Center for Health Statistics and the US Census Bureau for the purpose of researching the impact of differences in demographic and socio-economic factors on mortality.

The NLMS Public-Use CD may be obtained for research purposes by special request. However, some variables are not available in the public use files in order to protect the confidentiality of survey participants. Variables were permitted for use on the file if they would not lead to a record linkage potential with other public-use files. Important variables missing on the NLMS Public-Use file, which exist in the full NLMS study, include all geographical information and the complete NLMS follow-up history.

Experience Period and Level of Detail Available

Experience years include 1973 through 1998, with updates every two years from 1998 through 2006.

Factors available for analysis in the full study file include: age, gender, cause of death, urban/rural location, land use (farm/non-farm), veteran status, county code, residence type (house/apartment/trailer), number of persons in household, family income, geographic region of the country, occupation, industry, employment status, race/ethnicity, marital status, education level achieved, state of death, and poverty threshold (i.e., where the family income puts the household on the current poverty index).

Input Data

The NLMS is based on specific survey months of the Current Population Survey (CPS), the Annual Social and Economic Supplement, and a subset of the 1980 Census. Individuals are then matched up with the National Death Index database to determine mortality experience.

Potential Data Issues

The surveys on which the study is based are point-in-time survey data collection processes with no subsequent data collection follow-up procedures.

C) Canadian Population Mortality Improvement Data Sources

Statistics Canada

Statistics Canada provides statistics relating to the Canadian population, resources, economy, society and culture, including the Canada Life Tables. In Canada, providing statistics is a part of the federal responsibility and Statistics Canada has been legislated to serve this function for the whole of Canada and each of its provinces.

Experience Period and Level of Detail Available

The life tables are available for experience years 1990 through 2006 on a periodic basis; however, the most recent data available for free download through CANSIM covers the period 2000-2002. CANSIM is an electronic database service provided by Statistics Canada that is updated daily for new information. There is a fee charged for each download of more recent content.

Mortality experience is provided by age, gender and province/territory.

Input Data

Life tables are developed from the following sources: Canadian Vital Statistics, the national Birth and Death Databases and the Demography Division (population estimates).

D) UK Population Mortality Improvement Data Sources

Office for National Statistics (ONS)

Interim life tables are produced annually by the ONS for the United Kingdom and its constituent countries. These tables provide statistics on period life expectancy by age and sex. Each interim life table is based on the population estimates, births and deaths data for a period of three consecutive years, and then graduated life tables are prepared every ten years based on the collection of census data.

Experience Period and Level of Detail Available

Data is available covering the approximate period 1980-2008. Experience is available by age, gender, calendar year of experience and UK constituent country.

Input Data

Data sources for the interim and complete life tables include the vital statistics and census-based population estimates.

E) Asian Population Mortality Improvement Data Sources

HMD contains some data regarding mortality experience over time for Japan and Taiwan. Statistics Singapore produces reports regarding population mortality experience for the national population.

F) Australian Population Mortality Improvement Data Sources

The Bureau of Statistics Australia publishes Life Tables covering the Australian population mortality experience.

G) US Insured Population Mortality Improvement Data Sources

In general, data available for insured populations is not as comprehensive or as consistent as population data.

Society of Actuaries (SOA) Studies

Individual Life Insurance Experience Committee Reports on Mortality Experience for Standard Individually Underwritten Life Insurance

The SOA Individual Life Experience Committee collects data on a biannual basis for all standard, individually underwritten life insurance excluding rated, converted, and other guaranteed or simplified issues. Policies inforce under non-forfeiture provisions are also excluded.

Experience Period and Level of Detail Available

Experience is available for the period 1930-2007. Mortality data is generally available by age, gender, smoker status, policy year, face amount band and experience year.

Input Data

The studies typically report actual to expected experience relative to a current standard table (often the most recent published valuation basic table for individually underwritten life insurance). In addition to the reports, excel files containing experience mortality are often made available.

Mortality data is requested from all individual life insurance carriers by the SOA on a biannual basis.

Potential Data Issues

Data contributions for these ongoing studies are made on a voluntary basis, and therefore the group of companies providing data may not be consistent from study to study. In addition, companies sometimes will not be able to provide their entire inforce block and/or may not be able to provide all the SOA requested data items. Therefore, care needs to be taken in making comparisons of mortality experience from report to report.

Also, the definition of a "standard" life insurance policy may not be consistent across companies.

In addition, higher mortality ratios at the lower face amount bands for recent issues suggest that the data may include policies that are not fully underwritten.

Individual Annuity Experience Committee Reports on Immediate and Matured Deferred Annuities and Life Income Settlements for Life insurance

The SOA Individual Annuity Experience Committee collects mortality experience for these products on a periodic basis. The most recent report focuses on individual payout annuities and includes experience for calendar years 2000 through 2004.

Experience Period and Level of Detail Available

Historical reports are available for various periods between 1967 and 2004; however, mortality experience includes both issues in the US and Canada for years 1975 and prior. Data is split by age, gender, annuity type, income band and policy year.

Input Data and Potential Data Issues

Like the studies of standard individually underwritten life insurance, the individual annuity studies are based on data contributions from individual annuity carriers and are therefore subject to the same issue of the consistency of underlying data from study to study.

Group Annuity Experience Committee Reports

These reports present the mortality experience of retired individuals in the United States and Canada who are covered under group pension contracts issued in the United States and Canada.

Experience Period and Level of Detail Available

Historical reports are available for various periods between 1950 and 2002 for the US and Canada combined. Mortality data is generally available by age, gender, income level, retirement class, survivor continuance, years from retirement and guaranteed status.

Input Data

The studies typically report actual to expected experience relative to a current standard table (often the most recent published valuation basic table). In addition to the reports, excel files containing experience mortality may be made available.

Potential Data Issues

Data contributions for these ongoing studies are made on a voluntary basis, and therefore the group of companies providing data may not be consistent from study to study. In addition, companies sometimes will not be able to provide their entire inforce block and/or may not be able to provide all the SOA requested data items. Therefore, care needs to be taken in making comparisons of mortality experience from report to report.

Individual Long-Term Care Experience Committee Reports

These reports present the mortality and morbidity experience of lives insured under private long-term care insurance (LTCI) plans in the United States.

Experience Period and Level of Detail Available

The most recent report covers the 20-year period 1984-2004 and an update is currently under way. Mortality data is generally available by age, gender, policy year and active or disabled status.

Input Data

The studies typically report actual to expected experience relative to current standard tables. In addition to the reports, excel files containing experience mortality may be made available.

Potential Data Issues

Data contributions for these ongoing studies are made on a voluntary basis, and therefore the group of companies providing data may not be consistent from study to study. In addition, companies sometimes will not be able to provide their entire inforce block and/or may not be able to provide all

the SOA requested data items. Therefore, care needs to be taken in making comparisons of mortality experience from report to report.

For LTCI in particular, where there are few policies with nonforfeiture benefits, data contributors have had difficulty in splitting terminated policies into deaths and voluntary lapses. This is seen most clearly in the later policy durations, where deaths appear to be low relative to expectation and anecdotal evidence while voluntary lapses appear to be high.

H) Canadian Insured Population Mortality Improvement Data Sources

Canadian Institute of Actuaries (CIA) Studies

Research Committee's Individual Life Subcommittee Mortality Studies for Standard Ordinary Life Insurance

The Individual Life Subcommittee of the Research Committee reports detailed intercompany mortality experience for Canadian standard ordinary life insurance policies.

Experience Period and Level of Detail Available

Experience is available for the period 1950-2006, although not all data is in electronic format. Mortality data is generally available by age, gender, smoker status, policy year, underwriting type, life insurance product type and face amount band.

Input Data

The studies typically report actual to expected experience relative to a current standard table (often the most recent published experience table).

Mortality data is requested from all individual life insurance carriers on an annual basis.

Potential Data Issues

As with SOA studies, data contributions for these ongoing studies are made on a voluntary basis, and therefore the group of companies providing data may not be consistent from study to study. Therefore, care needs to be taken in making comparisons of mortality experience from report to report. In some cases, comparisons are made for the group of companies that remain consistent across study periods.

I) UK Insured Population Mortality Improvement Data Sources

Continuous Mortality Investigation — Institute of Actuaries

The CMI studies conducted by this Institute of Actuaries research group are published every two to three years and cover mortality and mortality improvement trends for life assurance (both permanent and temporary), immediate annuities, retirement annuities and pension business.

This group also publishes guidance regarding future rates of mortality improvement and the cohort effect based on various assumptions going forward.

Experience Period and Level of Detail Available

Data is available for some plans beginning in the 1920s and continues through 2006.

Input Data

Mortality data is requested from all insurance carriers and pension plans, including self-administered plans, on a regular basis.

J) European Insured Population Mortality Improvement Data Sources

France

The TGH/F05 annuity valuation table was produced by Professor Daniel Serant and includes projected rates of mortality by age and year of birth for future calendar years. The original data was based on a combination of general population and insured experience.

Germany

The DAV2004 annuity valuation table was published by the German Institute of Actuaries and provides mortality rates by age and year of birth. The results are based on data provided by 20 insurance companies and the state pension scheme over the period 1995-2002.

Austria

The AVO 2005R annuity valuation table was published by the Actuarial Association of Austria and is derived from Austrian population data adjusted by various annuitant selection factors.

K) Asian Insured Population Mortality Improvement Data Sources

China

The Chinese Life Insurance Mortality Tables are published approximately every 10 years. However, the experience available is limited and doesn't cover the significant period of time necessary to understand changes in levels of mortality.

Singapore

The Singapore Mortality Investigations provide periodic data regarding insured mortality experience.

India

The Indian Institute of Actuaries publishes mortality rates for life and annuity products in India every two to three years via IndiaStat.com. This site requires a membership to access data.

Australia

The Institute of Actuaries Australia publishes studies of life insured mortality experience every two to three years. However, these studies have so far been made available only to study participants.

L) Insured Older Age Mortality

Older age mortality sources are scarce, even in the US, Canada and the UK. In the US, there are a few studies that include information regarding older age mortality experience. These include:

- SOA Individual Life Experience Committee (ILEC) Reports — There is some older age data included in these reports, although much of the life insurance business issued at ages 65 and later was issued more recently.
- Tillinghast Older Age Mortality Studies — These studies contain significant information regarding older age insured mortality experience; however, they are currently available for purchase only. In addition, these studies do not yet cover a significant experience period and therefore are not yet of significant value in reviewing long-term trends in mortality improvement experience.

In addition to these regularly published reports, the SOA Living to 100 Symposium provides a regular source of research and information focused on the older age population.

Data Sources

In addition to the databases and electronic information discussed above, the following sources were reviewed for this report. Some sources were relied on more heavily than others in the actual information presented, but all were reviewed in detail to form the basis of the discussion regarding mortality improvements.

Population Mortality and Mortality Improvement Data

- "Patterns of Mortality Improvement over Age and Time in Developed Countries: Estimation, Presentation, and Implications for Mortality Forecasting", Andreev and Vaupel, February 2005.
- "Population Mortality and Morbidity in Ireland: A Summary of the Report of the Working Party", Armstrong, Harney, Jeffery, O'Donnell, O'Neill, and Walsh, Transactions of the 27th International Congress of Actuaries, Cancun Mexico, 2002.
- "Actuarial Study No. 120: Life Tables for the United States Social Security Area: 1900-2100", Bell and Miller, Social Security Administration, August 2005.
- "The Economic and Demographic Transition, Mortality and Comparative Development", Cervellati and Sunde, University of St. Gallen Department of Economics Working Paper Series, October 2008.
- "Marital Status and Mortality in British Women: A Longitudinal Study", Cheung, International Epidemiological Association, 2009.
- "Differential Mortality in Europe and the US", Delavande and Rohwedder, RAND Labor and Population Working Paper Series, July 2008.
- "Smoking Behavior and Socioeconomic Status: A Cohort Analysis: 1974-1998", Evandrou, M. and Falkingham, J., 2002, Health Statistics Quarterly, Summer 2002.
- "The Ageing Process: Major Risk Factor for Disease and Death", Harman, Proceedings of the National Academy of Sciences, 1991.
- "Widening of Socioeconomic Inequalities in US Death Rates, 1993-2001", Jemal, Ward, Anderson, Murray, and Thun (2008), PLoS ONE.
- "Changes in Life Expectancy: 1900-1990", Kinsella, American Journal of Clinical Nutrition, 1992.
- "Educational Differences and All Cause Mortality by Marital Status", Kohler, Martikainen, Smith and Elo, *Demographic Research*, December 2008.
- "Projections of global mortality and burden of disease from 2002 to 2030", Mathers C.D., Loncar D., PLoS Med 3(11): e442. doi:10. (2006).

- "Marital Protection and Marital Selection: Evidence from a Historical-Prospective Sample of American Men", Murray, J., Demography - Volume 37, Number 4, November 2000.
- "Marital Status and Long-Term Illness in Great Britain", Murphy, M., Glaser, K., and Grundy, E., Journal of Marriage and the Family 59(1): 156-164, 1997.
- "Prevalence of Overweight, Obesity and Extreme Obesity in Adults: US Trends 1976-1980 through 2005-2006", National Center for Health Statistics, 2008.
- "US Leading Causes of Death: 1900-1998", National Office of Vital Statistics.
- "Prevalence of Obesity Among Children and Adolescents: US Trends 1963-1965 through 2007-2008", Ogden and Carroll, National Center for Health Statistics, 2010.
- "A Potential Decline in Life Expectancy in the US in the 21st Century", Olshansky, et al., *New England Journal of Medicine,* 2005.
- "Actuarial Study No. 120: Life Tables for the United States Social Security Administration Area 1900-2010", Bell and Miller, Social Security Administration, August 2005. (www.socialsecurity.gov/OACT/NOTES/actstud.html)
- "Technical Panel Report on Assumptions and Methods (2007)", Report to the Social Security Advisory Board ,Washington D.C., October 2007.
- "The Cohort Effect: Insights and Explanations", Willets, R. 2003.
- World Health Statistics, World Health Organization, 2010.

Insured Mortality and Mortality Improvement Data

- "Health Expectancy", Albert, Bragg, and Brooks, The Actuarial Practice Forum, February 2010.
- "Mortality Experience Around Age 100", Bayo and Faber, Transactions of the Society of Actuaries, 1983.
- "Older Age Underwriting: Frisky vs. Frail", Bennett, Journal of Insurance Medicine, 2004.
- "Mortality Improvement Research Paper", Canadian Institute of Actuaries, September 2010.
- "Canadian Standard Ordinary Life Experience 2006-2007", Canadian Institute of Actuaries, August 2010.
- "Canadian Standard Ordinary Life Experience 2007-2008", Canadian Institute of Actuaries, August 2010.

- "Continuous Mortality Investigations Report, Number 19, Part 1: Mortality of Holders of Permanent Policies of Assurance 1995-1998", Institute of Actuaries Continuous Mortality Investigations, 2000.
- "Continuous Mortality Investigations Report, Number 20, Part 1: Mortality of Holders of Permanent Policies of Assurance 1987-1994 by Cause of Death", Institute of Actuaries Continuous Mortality Investigations, 2001.
- "Continuous Mortality Investigations Report, Number 21, Part 1: Mortality of Holders of Permanent Policies of Assurance 1999-2002", Institute of Actuaries Continuous Mortality Investigations, 2004.
- "Report on Mortality Improvement Scales for Canadian Insured Lives", Hardy, Li and Tan, Society of Actuaries, 2006.
- "The New Austrian Annuity Valuation Table AVO 2005R", Kainhofer, Predota, Schmock.
- "Coping with Longevity: The New German Annuity Valuation Table, DAV 2004R", Kruger and Pasdika, 2005.
- "The Impact of the Determinants of Mortality on Life Insurance and Annuities", Kwon and Jones, Insurance Mathematics and Economics, 2005.
- "Reinsurance Large Amount Mortality Study: 1996 Intercompany Experience", Laverdiere, Bhatia, Luff, Society of Actuaries, 1999.
- "US Insured Mortality Improvements and their Interpretation", Mast, Product Development News, 1994.
- "Inference about Mortality Improvements in Life and Annuity Portfolios", Oivieri and Pittaco, Parma University Department of Economics Working Papers Series, 2001.
- "German Annuities", Pasdika and Spivak, The Actuary, 2005.
- "Singapore Actuarial Society Mortality Investigation 1997-2002", Singapore Actuarial Society Mortality Study Work Group.
- "TOAMS 2: 2007 Tillinghast Older Age Mortality Study Summary of Key Findings", Towers Perrin, 2007.
- "Report of the Society of Actuaries Task Force on Preferred Underwriting", Transactions of the Society of Actuaries 1988-1990 reports.
- Report on Development of the 1965-70 Basic Tables, Transactions of the Society of Actuaries, 1973 Reports, pages 199-223.

- Report on Development of the 1975-80 Basic Tables, Transactions of the Society of Actuaries, 1982 Reports, pages 55-76.
- 1990-95 Basic Tables (SOA Website under Experience Studies)
- "Society of Actuaries 2002-2004 Individual Life Experience Report"
- "Society of Actuaries 2005-2007 Individual Life Experience Report"
- "SOA 2000-04 Individual Payout Annuity Experience Report", April 2004.
- "Mortality Under Individual Immediate Annuities", TSA 1969 Reports, 1963-67 experience.
- "Mortality Under Individual Immediate Annuities", TSA 1972 Reports, 1967-71 experience.
- "Mortality Under Individual Immediate Annuities", TSA 1979 Reports, 1971-76 experience.
- "Mortality Under Individual Immediate Annuities", TSA 1991-92 Reports, 1976-86 experience.
- 1997-1998 Final Report of the SOA Group Annuity Experience Committee, SOA website (soa.org)
- 1999-2000 Final Report of the SOA Group Annuity Experience Committee, SOA website (soa.org)
- 2001-2002 Final Report of the SOA Group Annuity Experience Committee, SOA website (soa.org)

Projections of Mortality and Mortality Improvement

- "Has Canada Entered the Fourth Stage of the Epidemiological Transition?", Bah and Rajulton, *Canadian Studies in Population*, 1991.
- "A Realist's View of Aging Mortality and Future Longevity", Carnes and Olshansky, Population Development Review, June 2007
- National 2009 H1N1 Flu Survey and the Behavioral Risk Factor Surveillance System Survey, Centers for Disease Control and Prevention.
- "Generalized Linear Models in Life Insurance: Decrements and Risk Factor Analysis under Solvency II", Cerchiara, Edwards, and Gambini, 2008.
- "Estimating Mortality Risk Using Predictive Modeling," Edwalds, Craighead, and Adams, *2008* Enterprise Risk Management Symposium Monograph, Society of Actuaries, 2008.
- "The Human Life Span Stopped Increasing: Why?", Gavrilov, Gavrilova, and Nosov, *Gerontology*, 1983.

- "Smooth Models of Mortality with Period Shocks," Kirkby and Currie, Herriot-Watt University, Edinburgh, Department of Actuarial Mathematics and Statistics and the Maxwell Institute of Mathematical Sciences.
- "The Lee-Carter Method for Forecasting Mortality: With Various Extensions and Applications", Lee, North American Actuarial Journal, Volume 4, No. 1.
- "Evaluating the Performance of the Lee-Carter Method for Forecasting Mortality". Demography 38: 537–549.
- "Modeling and Forecasting U.S. Mortality", Lee, R., and Carter, L.,1992, Journal of the American Statistical Association 87: 659–671
- "United Kingdom Population Mortality Projections: Review of Methodology for Projecting Mortality", National Statistics, March 2002.
- "Pursuing Longevity – Delay vs Elimination of Degenerative Diseases", Olshansky, 1985, American Journal of Public Health
- "In search of methselah: estimating the upper limits of human longevity" SJ Olshansky and Ch. Carnes, BA Castel. Science, (250):634-40, 1990.
- "Longevity Risk and Annuity Pricing with the Lee Carter Model", Richards and Currie, The Actuarial Profession, 2009..
- "Literature Review of Long-Term Mortality Projections", Social Security Administration Bulletin, Volume 66, No.1, 2005.
- "Projecting Mortality Trends: Recent Developments in the United Kingdom and the United States", Wong-Fupuy and Haberman, North American Actuarial Journal, Volume 8, No. 2.

Projections of Mortality and Mortality Improvement using Disease Based Modeling

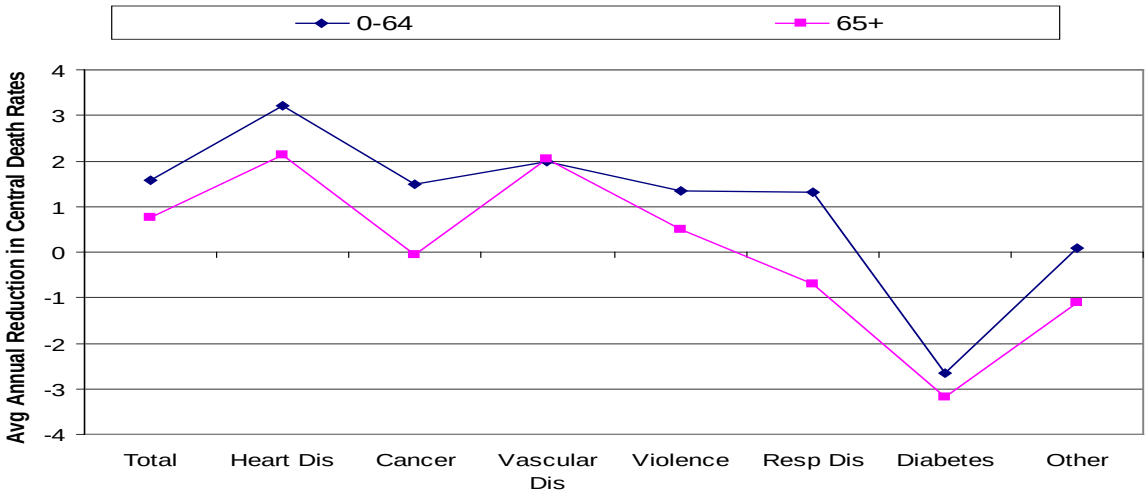
- ''Estimating the Strength of Expert Judgment: The Case of U.S. Mortality Forecasts", Alho, 1991, *Journal of Forecasting* 10:157–67.
- "Cancer Death Rates among 50 Countries", American Cancer Society, 1992.
- "On the Distribution of Underlying Causes of Death," Gittelsohn, *American Journal of Public Health*, 1982.
- "Age Adjusted US Cancer Death Rate Predictions", *Journal of Data Science*, 2010, pp. 339-348.

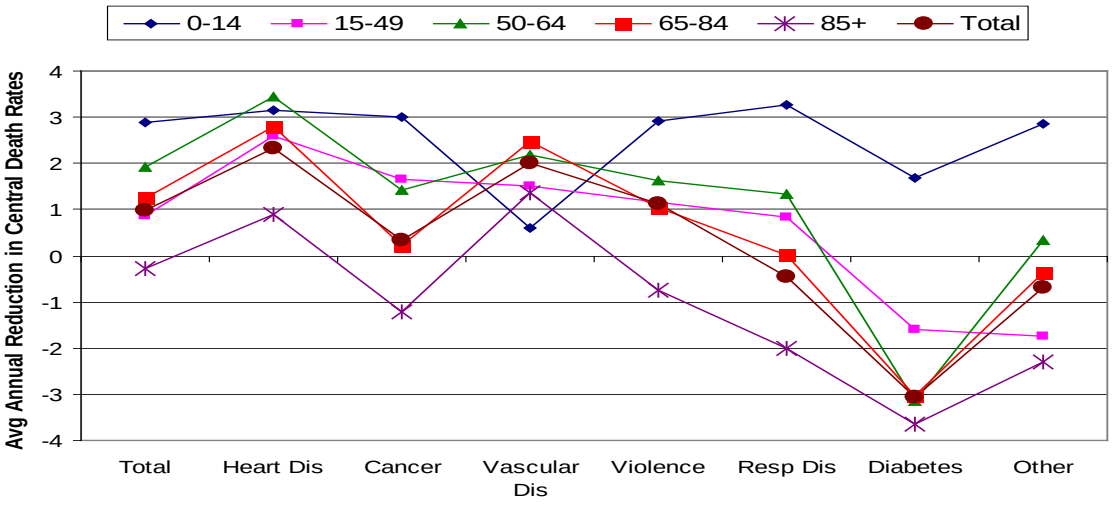
- "Life Expectancy of Persons with Chronic Disabilities", Strauss and Chavelle, *Journal of Insurance Medicine*, 1998.
- "Alcohol Abuse and Liver Enzymes: Results of an Intercompany Study of Mortality", *Journal of Insurance Medicine*, 2001.
- "Life Tables for People with Traumatic Brain Injury," *Journal of Insurance Medicine*, 1999.
- "Mortality from Cerebrovascular Disease: A Study based on Data from Hospitalization Benefits", Kobayashi, Maeda, and Fujimoto, *Journal of Insurance Medicine*, 1995.
- "Mortality Model based on Delays in Progression of Chronic Diseases: Alternative to Cause Elimination Model," Manton, Patrick and Stallard, *Public Health Reports*, 1980.
- "Cancer Mortality in Various Countries," Philipps and Owchar, *Bulletin of the World Health Organization*, 1957.
- "The Changing Mortality of Myocardial Infarction", Rouleau, *Journal of Insurance Medicine*, 1994.
- "Mortality Change and Forecasting: How Much and How Little Do We Know?", Tuljaparkar and Boe, North American Actuarial Journal, Volume 2, No. 4,

Appendix B: Additional Mortality Improvement Data for the US

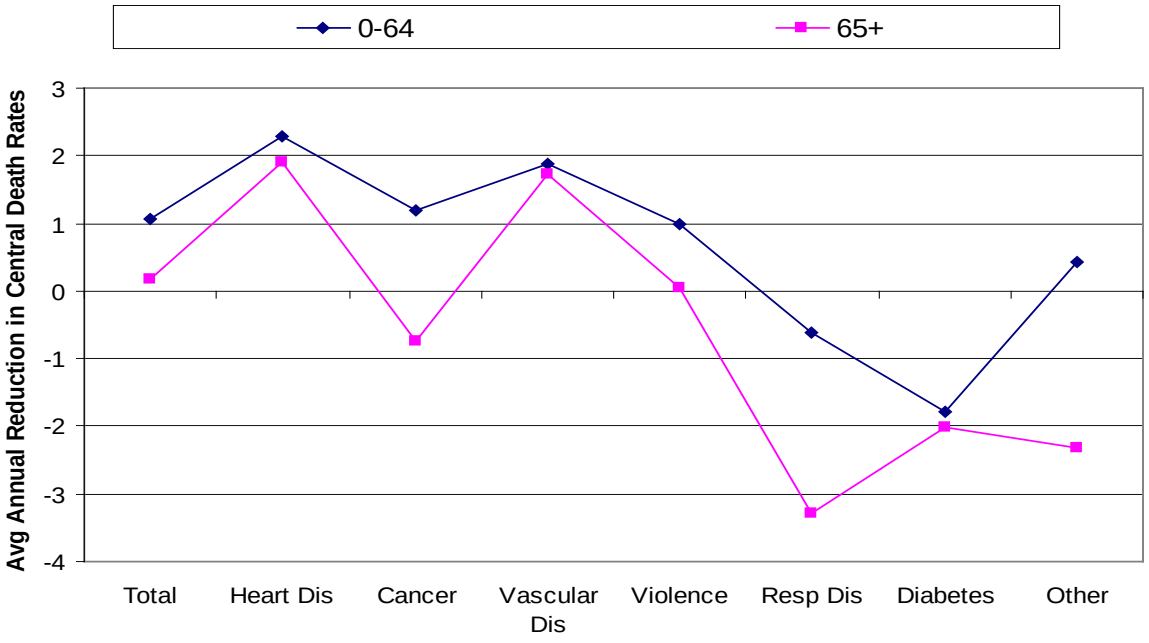
Chart B-1: US General Population Average Annual Percent Reduction in Death Rates
Social Security Administration, Actuarial Study 120
Experience Period: 1981-2001
By Gender, Age Group and Cause of Death

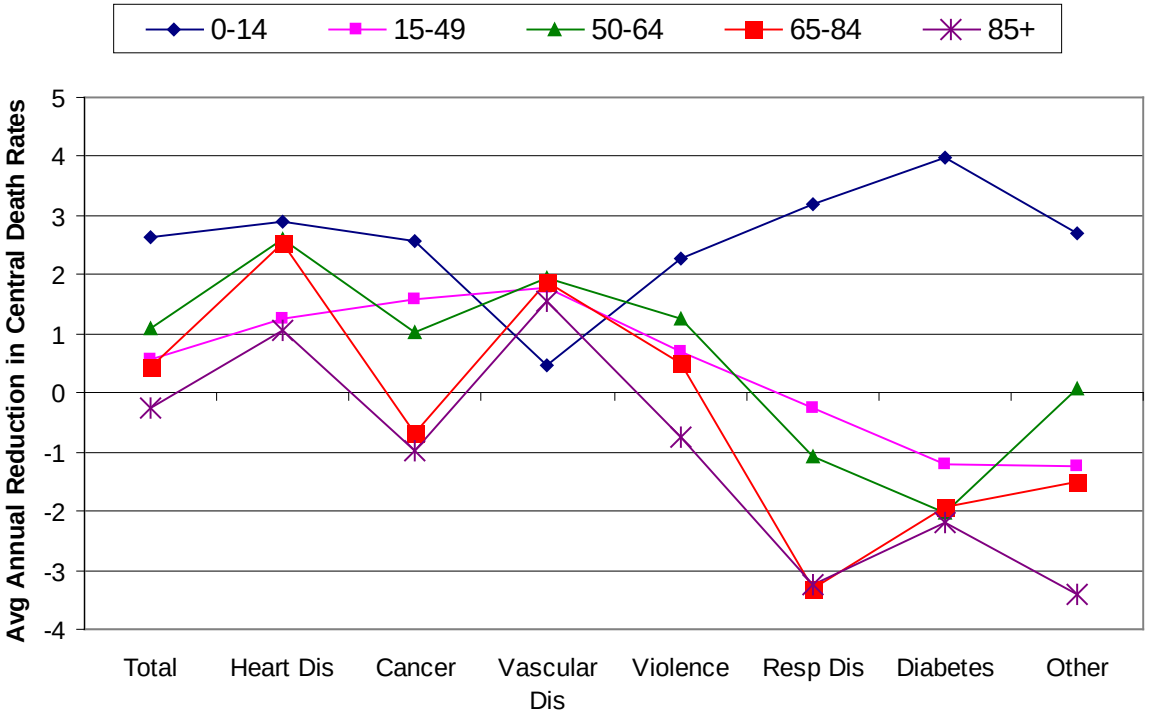
Males





Females





Source: SSA Report 120, Table 2

Appendix C: Additional Mortality Improvement Data for Canada

Table C-1: Canadian Average Annual Rates of Mortality Improvement
Based on Age Adjusted Mortality Estimates
General Population, Experience Period: 2000-2004
By Gender and Selected Cause of Death

Male		Female	
Cause of Death		**Cause of Death**	
Acute myocardial infarction (AMI)	5.3%	Acute myocardial infarction (AMI)	5.4%
All stroke	4.6%	All stroke	4.5%
Cerebrovascular diseases	4.9%	Cerebrovascular diseases	4.4%
Colorectal cancer	0.5%	Colorectal cancer	0.2%
Female breast cancer	*	Female breast cancer	*
Lung cancer	1.5%	Lung cancer	-1.3%
Prostate cancer	*	Prostate cancer	*
Total All Causes	3.6%	Total All Causes	2.8%

Table C-2: Canadian Average Annual Rates of Mortality Improvement
Canadian Pension Plan, Experience Period: 1960-2005
By Attained Age Group and Gender

Male				Female			
Age Group	**1960-1975**	**1975-1990**	**1990-2005**	**Age Group**	**1960-1975**	**1975-1990**	**1990-2005**
<1	4.5%	4.8%	1.8%	<1	4.5%	4.90%	1.4%
1-14	5.0%	4.6%	3.6%	1-14	1.7%	4.10%	3.8%
15-44	2.1%	2.6%	2.6%	15-44	0.4%	2.70%	1.4%
45-64	0.3%	2.7%	2.3%	45-64	1.1%	1.90%	1.5%
65-84	0.3%	1.2%	2.2%	65-84	1.7%	1.30%	1.3%
85-89	0.7%	0.5%	1.2%	85-89	1.3%	1.10%	0.7%
90-109	0.3%	0.2%	0.6%	90-109	0.7%	0.7%	0.2%
All Ages	1.7%	2.2%	1.7%	All Ages	1.4%	2.2%	1.3%

Appendix D: Additional Mortality Improvement Data for the UK

UK Average Annual Rates of Mortality Improvement
Life Insureds, Experience Period: 1992-2000
By Gender, Attained Age Group and Level of Underwriting
Ultimate Mortality Only

Standard Medical Evidence

Male

Age Group	Non Linked	Linked
26-30	2.6%	10.3%
31-35	1.7%	0.4%
36-40	1.7%	2.6%
41-45	1.4%	1.2%
46-50	2.6%	-0.1%
51-55	3.2%	2.5%
56-60	3.1%	2.3%
61-65	3.7%	2.6%
66-70	3.5%	3.1%

Female

Age Group	Non Linked	Linked
26-30	0.4%	4.9%
31-35	3.4%	4.2%
36-40	3.7%	1.9%
41-45	1.7%	-1.3%
46-50	0.9%	-0.4%
51-55	1.3%	0.4%
56-60	1.9%	2.0%
61-65	2.5%	3.1%
66-70	1.7%	4.0%

Minimal Medical Evidence

Male

Age Group	Single Life	Joint Life
26-30	2.6%	*
31-35	3.2%	3.4%
36-40	1.9%	2.3%
41-45	0.1%	2.8%
46-50	-0.2%	2.6%
51-55	0.5%	1.7%
56-60	1.0%	1.4%
61-65	-1.2%	2.3%
66-70	-1.7%	1.3%

Female

Age Group	Single Life	Joint Life
26-30	0.3%	*
31-35	1.2%	2.9%
36-40	2.5%	2.2%
41-45	-1.0%	2.9%
46-50	-0.2%	1.2%
51-55	0.1%	1.3%
56-60	0.9%	2.2%
61-65	-1.4%	4.7%
66-70	-2.8%	-0.8%

Guaranteed Acceptance

Male

Age Group	
26-30	*
31-35	*
36-40	*
41-45	4.7%
46-50	1.7%
51-55	-13.8%
56-60	-12.6%
61-65	-10.3%
66-70	-8.1%

Female

Age Group	
26-30	*
31-35	*
36-40	*
41-45	2.6%
46-50	*
51-55	-13.5%
56-60	-12.7%
61-65	-9.9%
66-70	-9.0%

* Data based on less than 10 deaths.

Source: CMIR 21, Part 1

Appendix E:Additional Mortality Improvement Data by Country/Region

Appendix E provides additional information regarding countries other than the US, UK and Canada, based on HMD data through November of 2010.

Table E-1: Israel General Population Mortality
Average Annual Rates of Mortality Improvement
By Gender and Attained Age Group, 1985-2008

Male

Age Group	1985-2000	2000-2008	1985-2008
< 1 year	4.6%	4.3%	4.5%
1-4 years	3.1%	2.2%	2.8%
5-9 years	4.2%	0.8%	3.0%
10-14 years	3.1%	1.0%	2.4%
15-19 years	1.1%	3.4%	1.9%
20-24 years	0.6%	1.8%	1.0%
25-34 years	0.0%	3.9%	1.3%
35-44 years	-0.7%	4.2%	1.0%
45-54 years	1.7%	1.7%	1.7%
55-64 years	2.4%	2.9%	2.6%
65-74 years	1.4%	3.2%	2.0%
75-84 years	1.4%	1.8%	1.5%
85+ years	0.7%	0.9%	0.8%
All Ages	1.8%	2.5%	2.0%

Female

Age Group	1985-2000	2000-2008	1985-2008
< 1 year	5.5%	4.1%	5.0%
1-4 years	4.3%	3.3%	4.0%
5-9 years	3.2%	0.9%	2.4%
10-14 years	2.6%	2.9%	2.7%
15-19 years	2.0%	8.3%	4.2%
20-24 years	3.1%	1.4%	2.5%
25-34 years	1.4%	3.7%	2.2%
35-44 years	2.5%	2.8%	2.6%
45-54 years	1.7%	2.1%	1.9%
55-64 years	2.7%	2.5%	2.6%
65-74 years	2.5%	3.6%	2.9%
75-84 years	1.8%	2.3%	2.0%
85+ years	1.0%	0.5%	0.8%
All Ages	2.6%	2.9%	2.8%

Table E-2: German General Population Mortality
Average Annual Rates of Mortality Improvement
By Gender and Attained Age Group, 1968-1980

Male		Female	
Age Group		**Age Group**	
< 1 year	4.4%	< 1 year	4.3%
1-4 years	3.7%	1-4 years	4.0%
5-9 years	3.4%	5-9 years	3.9%
10-14 years	3.2%	10-14 years	2.6%
15-19 years	0.6%	15-19 years	1.1%
20-24 years	0.6%	20-24 years	1.7%
25-34 years	0.9%	25-34 years	1.6%
35-44 years	0.4%	35-44 years	1.9%
45-54 years	0.1%	45-54 years	1.6%
55-64 years	1.3%	55-64 years	1.5%
65-74 years	1.2%	65-74 years	2.0%
75-84 years	0.6%	75-84 years	1.6%
85+ years	0.8%	85+ years	1.1%
All Ages	1.6%	All Ages	2.2%

Table E-3: Poland General Population Mortality
Average Annual Rates of Mortality Improvement
By Gender and Attained Age Group, 1968-1980

Male		Female	
Age Group		**Age Group**	
< 1 year	3.4%	< 1 year	3.8%
1-4 years	2.5%	1-4 years	3.0%
5-9 years	1.7%	5-9 years	0.9%
10-14 years	0.9%	10-14 years	1.8%
15-19 years	0.2%	15-19 years	1.4%
20-24 years	-0.2%	20-24 years	2.3%
25-34 years	-1.0%	25-34 years	0.8%
35-44 years	-2.4%	35-44 years	0.4%
45-54 years	-3.0%	45-54 years	-0.1%
55-64 years	-1.1%	55-64 years	-0.1%
65-74 years	-0.4%	65-74 years	0.6%
75-84 years	-0.9%	75-84 years	-0.1%
85+ years	0.8%	85+ years	1.1%
All Ages	0.0%	All Ages	1.2%

Table E-4: Hungary General Population Mortality
Average Annual Rates of Mortality Improvement
By Gender and Attained Age Group, 1968-2007

Male

Age Group	1968-1980	1980-2000	2000-2007	1980-2007
< 1 year	4.6%	2.9%	0.8%	3.0%
1-4 years	2.8%	3.4%	2.0%	2.9%
5-9 years	3.2%	3.4%	2.3%	3.1%
10-14 years	2.7%	2.2%	2.8%	2.5%
15-19 years	0.9%	2.1%	0.9%	1.5%
20-24 years	0.6%	2.0%	-0.8%	1.0%
25-34 years	0.9%	1.7%	-0.7%	1.0%
35-44 years	2.3%	0.9%	1.4%	1.4%
45-54 years	2.2%	1.6%	0.2%	1.6%
55-64 years	2.1%	1.9%	1.5%	1.9%
65-74 years	1.6%	1.6%	2.5%	1.8%
75-84 years	1.2%	1.1%	2.3%	1.3%
85+ years	0.8%	0.2%	1.8%	0.7%
All Ages	2.0%	1.9%	1.3%	1.8%

Female

Age Group	1968-1980	1980-2000	2000-2007	1980-2007
< 1 year	4.3%	2.8%	0.7%	2.9%
1-4 years	3.5%	3.1%	1.7%	3.0%
5-9 years	2.8%	2.9%	2.2%	2.8%
10-14 years	2.3%	1.7%	2.1%	2.0%
15-19 years	1.1%	1.5%	1.4%	1.3%
20-24 years	1.4%	1.4%	-0.5%	1.1%
25-34 years	2.6%	0.9%	-0.3%	1.2%
35-44 years	3.1%	0.6%	0.7%	1.4%
45-54 years	2.2%	1.3%	-0.2%	1.3%
55-64 years	1.6%	0.9%	1.9%	1.3%
65-74 years	1.8%	0.6%	2.0%	1.2%
75-84 years	2.0%	0.6%	1.8%	1.3%
85+ years	1.2%	0.1%	1.3%	0.7%
All Ages	2.3%	1.4%	1.1%	1.6%

Table E-5: Australia General Population Mortality
Average Annual Rates of Mortality Improvement
By Gender and Attained Age Group, 1968-2007

Male

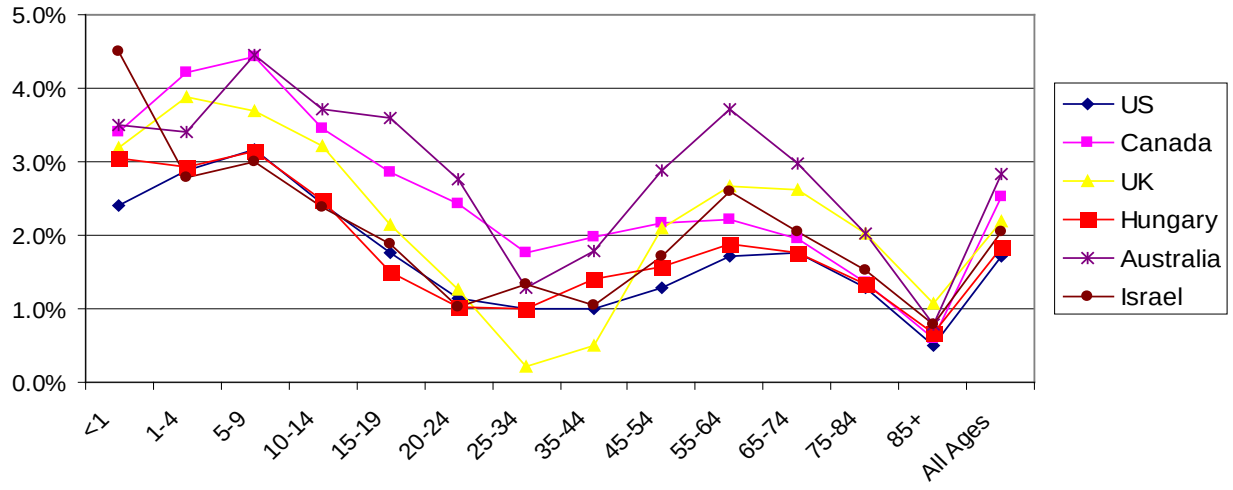
Age Group	1968-1980	1980-2000	2000-2007	1980-2007
< 1 year	4.3%	3.7%	2.8%	3.5%
1-4 years	1.2%	5.7%	-4.0%	3.4%
5-9 years	2.9%	4.3%	8.5%	4.5%
10-14 years	4.3%	3.7%	2.0%	3.7%
15-19 years	0.2%	3.2%	6.1%	3.6%
20-24 years	2.0%	1.3%	7.4%	2.8%
25-34 years	2.3%	-0.5%	6.5%	1.3%
35-44 years	1.8%	2.0%	3.1%	1.8%
45-54 years	0.6%	3.6%	0.9%	2.9%
55-64 years	2.4%	3.8%	0.8%	3.7%
65-74 years	2.3%	2.6%	4.7%	3.0%
75-84 years	1.1%	2.4%	2.3%	2.0%
85+ years	1.5%	0.7%	2.0%	0.8%
All Ages	2.1%	2.8%	3.3%	2.8%

Female

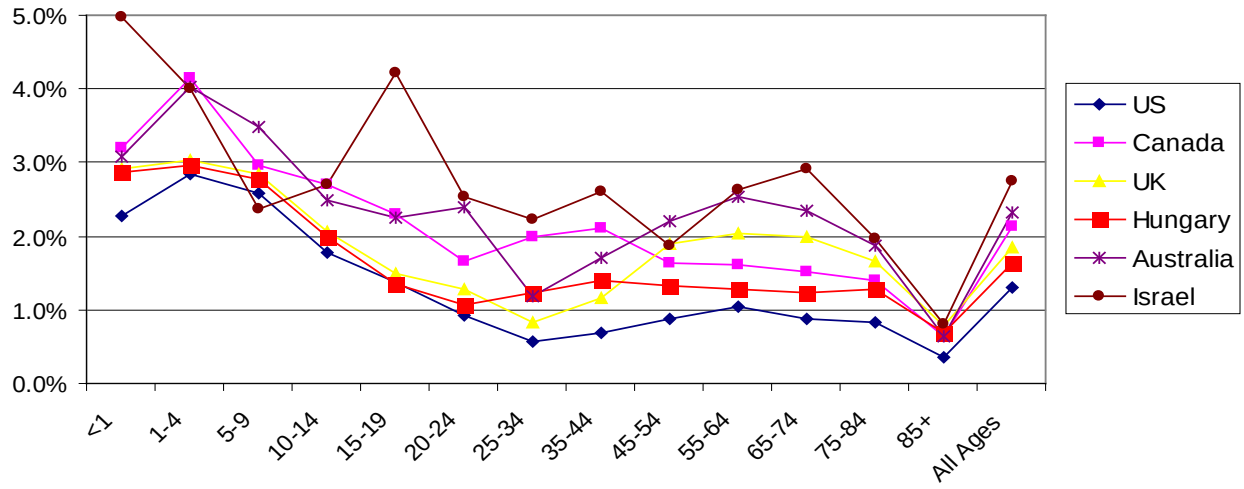
Age Group	1968-1980	1980-2000	2000-2007	1980-2007
< 1 year	4.3%	3.5%	1.8%	3.1%
1-4 years	7.8%	2.7%	0.0%	4.0%
5-9 years	3.0%	2.1%	10.3%	3.5%
10-14 years	7.1%	-2.0%	9.4%	2.5%
15-19 years	3.3%	0.2%	5.2%	2.2%
20-24 years	-1.2%	1.4%	7.8%	2.4%
25-34 years	2.8%	0.5%	2.4%	1.2%
35-44 years	3.0%	2.9%	-0.5%	1.7%
45-54 years	3.8%	2.2%	2.0%	2.2%
55-64 years	2.1%	2.8%	-0.7%	2.5%
65-74 years	2.0%	2.5%	3.1%	2.3%
75-84 years	2.5%	2.0%	1.7%	1.9%
85+ years	2.2%	0.6%	1.6%	0.6%
All Ages	3.3%	1.6%	3.4%	2.3%

Chart E-6: General Population Experience by Country
Average Annual Rates of Mortality Improvement
By Gender, Attained Age Group, 1972-2009

Males



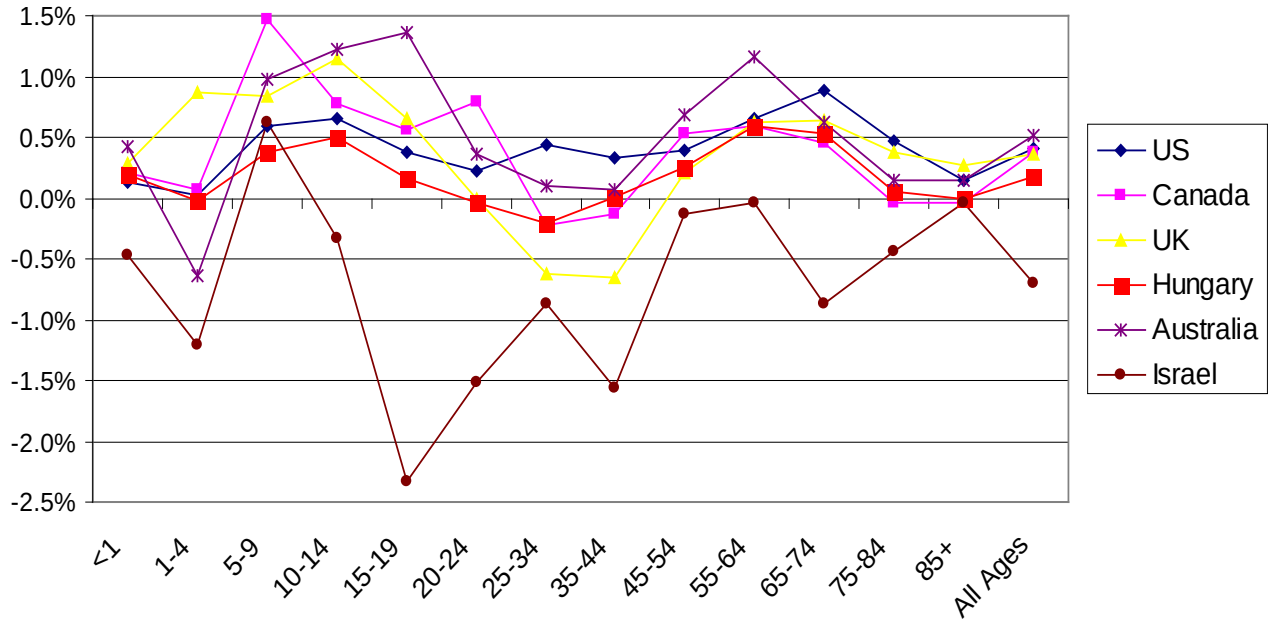
Females



Source: HMD

Note: Experience years vary by country – Australia and Hungary:1980-2007, Israel: 1985-2008, US: 1979-2007, Canada: 1972-2007, UK:

Chart E-7: General Population Experience by Country
Differences in Average Annual Rates of Mortality Improvement
Male Improvement Levels over Female Levels
Attained Age Group, 1972-2009



Source: HMD

Note: Experience years vary by country – Australia and Hungary: 1980-2007, Israel: 1985-2008, US: 1979-2007, Canada: 1972-2007, UK: