Past, Present and Future of Risk Factors

Actuarial science and the assessment of mortality risk has evolved slowly over the past few centuries. This is all set to change. Exponential growth of data coupled with massive increases in computer processing power are accelerating the ability of insurers to understand and quantify mortality risk.

This paper presents a brief history of life insurance risk assessment, highlighting the major chronological milestones (see Figure 1). The last 50 years have seen important innovations and a rapid and relentless acceleration in the rate of change. Gazing into the future, wearable devices, genetic testing, and digital health data will have a transformational impact on life insurance risk selection processes.

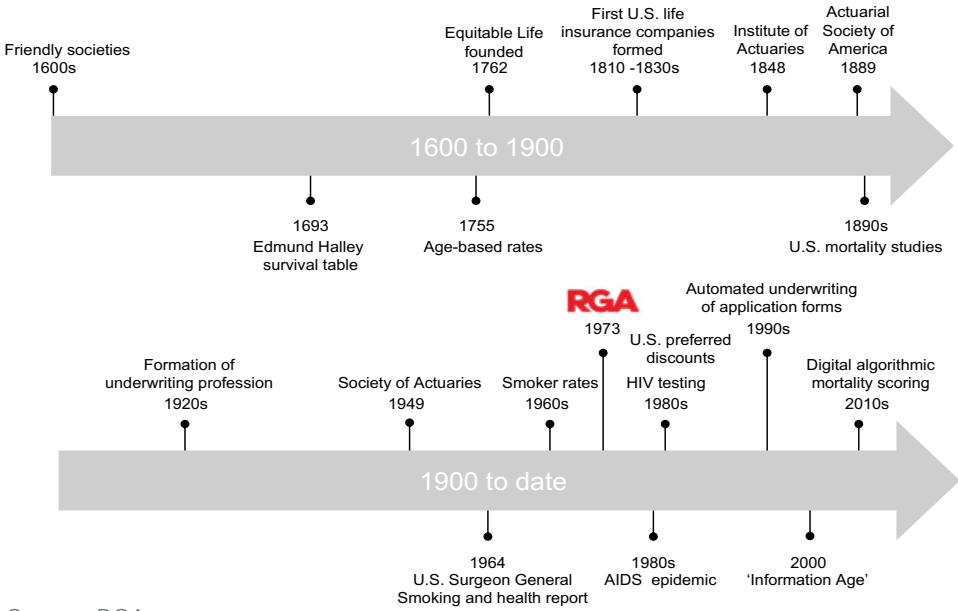


Figure 1

Major milestones in the modern history of life insurance

Source: RGA

Creation of modern insurance and age-based premiums

In the early days of formal life insurance there were virtually no underwriting barriers to obtaining life insurance cover. In the 1600s and 1700s, in England, friendly societies provided financial and social services. In exchange for money collected from members, they paid out emergency funds to help survivors with burial costs. The contributions did not vary by age and group sizes were fixed, limiting the ability to bring in new members. This meant most friendly societies struggled to keep up with rising claim costs as mortality rates increased as their members aged. To reduce the risk inherent in an aging portfolio, membership (both new and existing) was restricted to a maximum age of 45 or 50.

Royal astronomer and mathematician Edmund Halley made the first important attempt to quantify human mortality when he created the first survival table in 1693.[1] But it wasn't until another 70 years had passed that age-based life insurance premiums were introduced.

In 1755, English mathematician James Dodson, a Fellow of the Royal Society, was declined due to being over age 45. Undeterred and building on Halley's earlier work, Dodson demonstrated how insurance applicants could be accepted regardless of age as long as the annual premium reflected the applicant's mortality risk. Sadly, Dodson died soon after he was unable to buy life cover. Five years after Dodson's death, Equitable Life was founded in 1762 as the world's first mutual insurer. Using Dodson's mortality tables, age-based premiums allowed Equitable Life to offer cheaper cover, older ages at issue and for longer terms than ever available previously.[2]

Gender mortality

Due to the prevailing gap in gender mortality rates, evidence suggests gender-differentiated premiums were introduced in the U.K. before the mid-19th century and many years later in the U.S. The gender mortality gap grew steadily in both countries until the 1970s, primarily due to higher male smoking rates and major improvements in maternal mortality. Since the 1970s, the gender gap has tapered due to better male working conditions and lower tobacco consumption by men. [3, 4]

In pursuit of fair and equal treatment of the sexes, gender-neutral life insurance pricing was introduced throughout the European Union in 2012, resulting in unisex rates based on the gender mix within each insurer's portfolio.

Physician "gatekeepers"

For most of the 18th and 19th centuries, infectious diseases were the top causes of death. Epidemics of tuberculosis, malaria, cholera, typhoid fever, diphtheria, and scarlet fever occurred frequently. No one knew what caused these diseases, and unfortunately effective treatments and prevention (vaccines) were not yet available.

During this period an insurer's primary concern was to avoid the risk of insuring someone already suffering from an infectious disease. An insurance company physician, who was also typically a major shareholder of the company, acted as gatekeeper by medically examining all applicants to assess their acceptability. Additionally, this time period also saw the first crude attempts to screen out higher mortality risks. Applicants provided personal statements about their own and their family's health history, along with written references from friends about their health, lifestyle and habits.

Although most applicants were either accepted or rejected, the concept of "rating up" riskier-than-average lives was introduced. This was typically achieved by "years to age" ratings; i.e., charging applicants as if they were older than their actual age.[5]

Birth of underwriting

The insurance industry changed very little until the beginning of the 20th century. Mortality data remained scarce, and without meaningful experience data insurers had to rely heavily on the clinical experience of their company medical doctors.

These doctors used medical knowledge and intuitive observations about family history and individual habits to form an opinion of a proposed risk. Actuaries worked alongside the doctors to set premiums for those accepted.

In the Roaring Twenties (1920s), increasing business volumes and rising medical fees made it impractical for every applicant to be assessed by a doctor and an actuary. To deal with the demand, insurers created clerical roles to take over the assessment process, leading to the formation of the underwriting profession in that decade.

At about the same time, an increasing number of insurers introduced detailed application forms. This allowed insurers to accept applicants who could not be easily assessed in person (e.g., those living in rural areas). Indeed, more than 150 years after the formation of Equitable Life, insurance applicants could now be accepted without a medical examination and without involving a doctor or an actuary.

The rise of non-communicable diseases

In the early 20th century a major shift occurred in the most common causes of death, which changed the focus of insurance underwriting. Along with the benefits of economic development came better disease control through cleaner water, better sanitation and improved personal hygiene. The emergence of antibiotics (1928) and the launch of large-scale vaccine production (1940s) supported the fight against the deadly infections that had plagued humans for millennia. For the first time in history, non-communicable diseases such as heart disease, stroke and cancer surpassed infectious diseases as the primary causes of death.

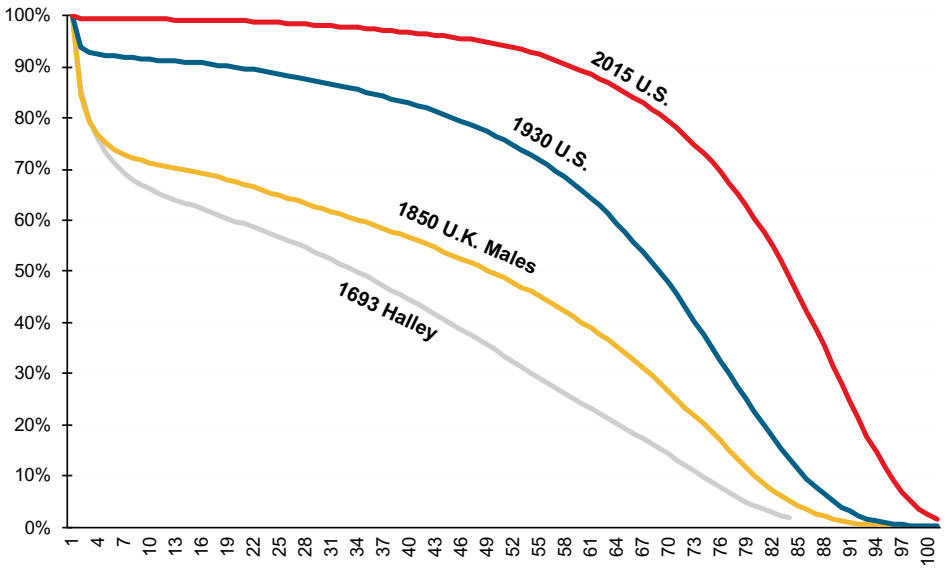


Figure 2

Life survival curves 1693 to 2015

Smoker mortality (1960s)

The British Doctors Study established the link between smoking and lung cancer in the 1950s.[6] In 1964, U.S. Surgeon General Luther Terry issued the landmark report alerting the nation to the deleterious health consequences of tobacco use.[7] The smoking of tobacco had been growing in popularity since the 1920s; consequently, between 1940 and 1980, male incidence rate of lung cancer increased by a factor of seven.

Female lung cancer incidence rates did not take off until the late 1960s. At that point, a few U.S. and Canadian carriers started to differentiate premiums for applicants by whether they were cigarette smokers, and doing so became common by the late 1970s. It should be noted that in many countries aggregate rates are still used, due to insufficient medical evidence obtained at underwriting stage to allow reliable classification of non-smokers.

Fluid collection, laboratory testing and the AIDS epidemic (1970 - 2000)

In the 1970s, fluid collection and laboratory testing was first introduced as an underwriting tool for large amounts of cover. By the 1980s however, the AIDS epidemic had led insurers to institute widespread laboratory testing at much lower policy amounts.

Insurance companies were quick to realize the advantages of laboratory testing beyond screening for HIV. Important mortality insights were gained from lipid profiles, liver and renal function tests and other blood biomarkers, and screenings for tobacco and recreational drugs.

The 1980s also saw the widespread introduction of “preferred rates” in North America. Using the additional information available from medical examinations and laboratory tests, insurers could now offer a preferred customer discount to applicants in excellent health. However, preferred segmentation was also a marketing tool: it was not uncommon for 75% to 80% of applicants to qualify.

In the 1980s and 1990s, companies assessed mortality risk using three main categories of data:

- Medical history: obesity, diabetes, high cholesterol, hypertension, cancer, heart disease, stroke, and mental and nervous disorders
- Family history: parents or siblings suffering from inherited diseases such as Huntington’s disease or from the early onset of diseases with a hereditary predisposition such as coronary artery disease, certain types of cancers and type 2 diabetes
- Lifestyle: tobacco use, excessive use of alcohol and/or recreational drugs, driving records, personal aviation, involvement in hazardous avocations, sports, or occupations, foreign residence or travel, and past felony conviction(s).

The 1990s also saw an increasing number of insurers introduce rules-based expert systems to automate the assessment of application forms. For the first time, underwriters were replaced by computerized processes.

The latter third of the 20th century saw significant advances in medicine’s understanding of human mortality and ability to extend life. Insurers also gained a more comprehensive view of mortality but data was still lacking. Reductions in tobacco use, better detection and treatment of numerous diseases, and socioeconomic progress allowed U.S. life expectancy at birth to increase by six years in the 30-year period from 1970 to 2000, according to the National Center for Health Statistics.[8]

The Information Age (2000 to date)

The new millennium saw the advent of the Information Age. Big data, data analytics, data lakes, data science, and digital data are all now commonplace in insurance.

Greater access to data and better tools to analyze the data means life actuaries and underwriters can gain a holistic view of mortality through multivariate analysis of ever-expanding datasets. Deeper and broader mortality analysis is also enabling insurers to confirm and refine assessment of traditional risk factors and to identify new risk factors.

As an example, recent expansion of the mortality data from the National Health Interview Survey (NHIS) supports granular risk assessment across the spectrum of smoker activity. Figure 3 shows hazard rates for a range of cigarette smoking activities, allowing more refined mortality assessment of this important risk factor.

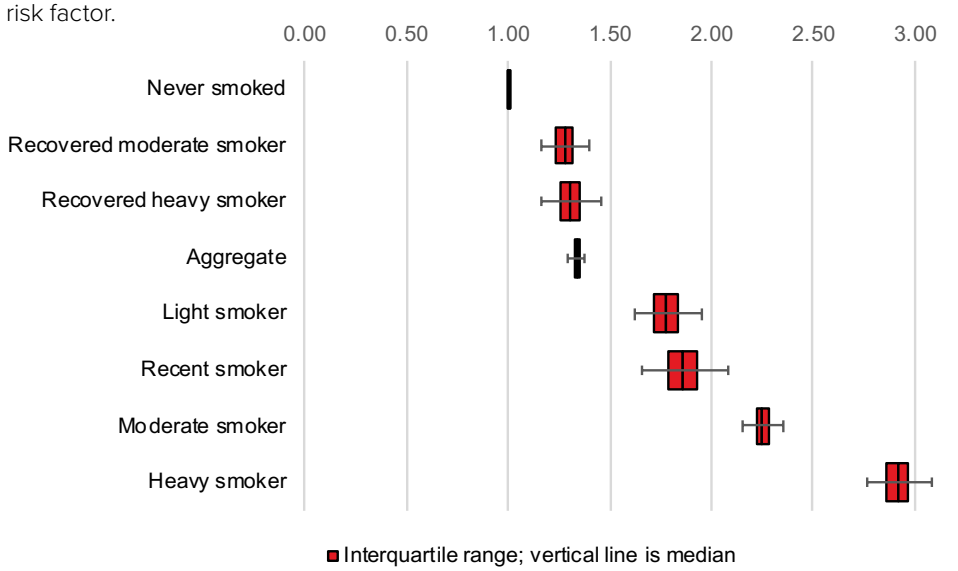


Figure 3

All-cause mortality by smoker status controlling for many health variables

Source: created by RGA from NHIS data

New data sources are allowing the introduction of mortality algorithms leading to the digital transformation of the underwriting process. Major examples include the use of prescription histories, credit-based data and clinical laboratory test results to digitally calculate algorithmic mortality scores.

Today's actuaries and underwriters need a good working knowledge of multivariate data modeling and the fundamentals of data science. Multivariate analysis is enabling a better segmentation of the business of life insurance, allowing underwriters to fine-tune applicant ratings at ever more granular levels (e.g., refining the assessment of people with diabetes based on their exercise, alcohol and smoking habits).

Gazing into the future

American inventor and futurist Ray Kurzweil, writing about exponential change in his 2001 article "The Law of Accelerating Returns," said: "We won't experience 100 years of progress in the 21st century - it will be more like 20,000 years of progress ... There's even exponential growth in the rate of exponential growth."[9]

Kurzweil's prediction has so far held true for the insurance industry. Exponential growth in data and computing technology looks likely to continue apace. Within the next decade wearable devices, genetic testing and digital health data are set to transform the risk assessment process. Other changes such as epigenetics, liquid biopsies, nanotechnology and our growing understanding of the microbiome, along with inventions that we cannot yet even imagine, will be important risk factors in the following decades.

Wearable devices offer unique opportunities for insurance companies to assess lifestyle and mortality risk. Currently these devices measure metrics with a known connection to mortality such as physical activity, heart rate and sleep. Future sensors are expected to offer even more data to evaluate mortality, such as blood pressure, heart rhythm, pulse wave velocity, sitting time, stress levels, and even attempts to detect smoking habits.

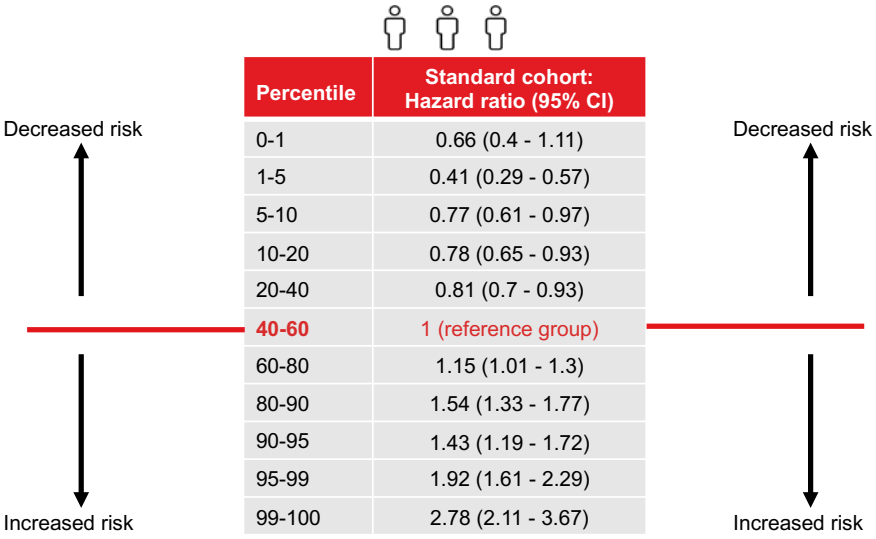
Insurers are already starting to use data from wearable devices to motivate customers to improve their lifestyles. In return, insurers are giving appropriate premium discounts to customers engaging in healthy habits. In the future, adoption of wearable devices is likely to grow as the devices become more advanced, cheaper, and better connected. Within the next few years we anticipate insurers will have much greater opportunities to use wearable data in the insurance assessment process.

During the past five years, direct-to-consumer genetic testing has seen extraordinary growth. More than 16 million people now have access to their genetic data, with upward of eleven million individuals tested since the start of 2017.[10] Although genetic data is not typically available to life insurance companies, genetics has the potential to transform all aspects of medicine, including prevention of disease manifestation, accurate diagnosis and prognosis of disease, pharmacogenomics, and motivating lifestyle changes to improve health. Genomic medicine will almost certainly lead to major improvements in human mortality and longevity.

The UK Biobank is a cohort study of over 500,000 U.K. volunteers.[11] It was established to identify the biometric, genetic and lifestyle determinants of disease and death. Through a joint research study on the UK Biobank data with King's College, London, RGA has quantified the importance of genetic risk information alongside traditional insurance underwriting risk factors. The study provided significant insights into the potential for genetic anti-selection.[12]

This research collaboration focused on the utility of polygenic risk scores (PRSs) for mortality risk assessment. PRSs combine information across many genetic variants to give a single measure of genetic liability to disease. For example, Figure 4 shows the coronary artery disease PRS can predict incidence and death above and beyond traditional underwriting risk factors: a PRS in the highest 1%, for example, confers almost a threefold increased risk of coronary artery disease compared to the reference range.

Total Participants: 261,204
Number of CAD events: 2,334 (0.89%)



Percentile	Standard cohort: Hazard ratio (95% CI)
0-1	0.66 (0.4 - 1.11)
1-5	0.41 (0.29 - 0.57)
5-10	0.77 (0.61 - 0.97)
10-20	0.78 (0.65 - 0.93)
20-40	0.81 (0.7 - 0.93)
40-60	1 (reference group)
60-80	1.15 (1.01 - 1.3)
80-90	1.54 (1.33 - 1.77)
90-95	1.43 (1.19 - 1.72)
95-99	1.92 (1.61 - 2.29)
99-100	2.78 (2.11 - 3.67)

Figure 3

PRS for coronary artery disease offers significant risk stratification

Source: RGA-KCL research collaboration

As genetic testing increases in importance in mainstream medicine, the insurance industry will need to find ways to mitigate the anti-selection risk.

Increased access to digital health data is already changing the risk assessment process. Prescription history reports grew in popularity starting in 2010 and are now commonplace in the U.S., with about 80% utilization by companies today. Online access to both current and historical clinical laboratory test results are becoming available as well.

Several leading U.S. insurers are exploring access to electronic health records, particularly coded data which is readily amenable to automated assessment using machine learning and other artificial intelligence techniques. In the U.K., access to electronic health records by insurers is more advanced due to centralized storage of medical data with the family doctor.

We predict that digital health data will likely have the biggest transformational impact on life insurance assessment since the introduction of age-based premiums in 1762. Digital health data, supported by data from wearable sensors and other novel sources, will enable real-time, automated risk assessment, leaving assessment of only the more complex risks to human underwriters.

Don't be left behind

Understanding the history of the life insurance industry can help explain where we are today and offer great insights into its future. Insurance assessment has seen massive changes over the previous two decades and even bigger and more exciting changes are sure to emerge in the next couple of decades. The major challenge for actuaries and underwriters alike is to keep pace with technological and medical advances.

More data available at the time of underwriting and advances in data-driven solutions will allow greater underwriting accuracy and allow pricing decisions to be tailored to the individual applicant. Just 250 years after the introduction of age-based premiums, perhaps actuarial tables based on age alone will be replaced by complex rating algorithms where age is just one factor.

Understanding the past and predicting the future can not only inform insurance and reinsurance companies' plans and investment strategy, but can also change how the industry might influence the future. Predicting the future is difficult, but as U.S. President Abraham Lincoln once said "the best way to predict your future is to create it".■

Authors

Yunus Piperdy
Bsc, FCII
Head of Underwriting Innovation Strategy
RGA UK

Scott Rushing
FSA, MAAA
Vice President, Head of Global Research, Global Research and Data Analytics

Endnotes

1 wikipedia.org/wiki/Edmond_Halley
2 wikipedia.org/wiki/James_Dodson_(mathematician)
3 How has life expectancy changed over time? ONS (2015)
4 United States Life Tables (2014)
5 Regulated Lives: Life Insurance and British Society, 1800–1914 - Alborn (book review (2011)
6 British Doctors Study
7 The 1964 Report on Smoking and Health - U.S. Surgeon General
8 National Center for Health Statistics
9 The Law of Accelerating Returns Ray Kurzweil (2001)
10 The DNA Geek
11 U.K. Biobank
12 The risk of anti-selection in protection business from advances in statistical genetics (2018)