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Mortality improvement: understanding the past and framing the future

sigma 50 YEARS

Foreword

This year, we celebrate the 50th anniversary of *sigma*, the flagship publication of the Swiss Re Institute's research portfolio. Over the last half century, *sigma* has provided thought leadership spanning the rapidly evolving risk landscape facing society, the economic and regulatory environments and their impact on insurance markets, and industry-specific topics such as distribution channels. As an industry leading research publication, *sigma* supports Swiss Re's vision to make the world more resilient.

For the sixth edition of *sigma* in this anniversary year, we focus on the recent slowdown in mortality improvement (ie, falls in death rates) that has been observed in a number of developed countries, especially in the largest life and health (L&H) insurance markets. We explore whether the changes we have seen could be temporary or permanent in nature.

Previous L&H-related editions of *sigma* have analysed the structure of life insurance markets and new trends, such as unit-linked life insurance in Western Europe in the early 2000s. A *sigma* on mortality protection was published in 2004 that covered market developments in six countries and provided estimates of the mortality protection gap. A 2008 *sigma* focussed on innovative ways of financing retirement.

Alongside biometric risks like mortality, insurers face a number of market and interest rate risks. The global financial crisis hit L&H insurers hard prompting *sigma* to review in a series of articles profitability and growth prospects for the sector. The metrics typically used to measure profitability were covered in *sigma* No 1/2012 "Understanding profitability in life insurance". Solutions to tackle weak growth were addressed the following year in *sigma* No 6/2013 "Life insurance: focusing on the consumer". Last year, *sigma* No 6/2017 "Life in-force management: improving consumer value and long-term profitability" investigated both the levers to improve profitability and ways to increase consumer value that support business growth.

Swiss Re Institute remains committed to identifying key drivers and themes for the global re/insurance industry. Please visit the *sigma* 50-years section on the Swiss Re Institute website (institute.swissre.com/sigma50years) to find out more about the evolution of *sigma*, and the breadth and depth of our overall research offering.

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Executive summary

While life expectancy has steadily improved for over a century, recent data suggest that mortality improvements are slowing in many developed countries.

Excluding periods of war, life expectancy has steadily improved around the world for well over a century. In recent years, however, there are signs that the rate of improvement in mortality has slowed in a number of advanced countries. Since 2011, age-standardised mortality rates in the US, UK and Germany, while still declining, are doing so at a slower pace than in earlier decades. The slowdown across most countries has been more pronounced among older people and women. In the US, opioid abuse has increased the mortality rate among young and middle-aged adults. There is some evidence that individuals from higher socio-economic classes have been less affected by the recent slowdown.

If this slowdown proves persistent, it will have significant implications for households, insurers and governments alike.

It is not clear whether the recent worsening mortality experience is temporary or permanent. The longer this pattern persists, the more likely that it represents a fundamental shift in mortality trends. But it is simply too early to tell. Changes in mortality trends have dramatic societal implications for households as well as those firms, insurers and governments that are either expected to provide financial protection in case of premature death or meet the demands of retired populations for longer. For insurers, they have a significant impact on pricing and reserving. The ability to distinguish between shifts in the underlying mortality trend and short-term variability is crucial because a change in mortality trend is an aggregate risk that cannot be easily diversified away nor perfectly hedged.

Historical mortality improvements have been largely driven by public policy and advances in medicine.

Mortality improvements have largely been driven by public health initiatives and by improvements in the diagnosis and treatment of diseases, in particular heart disease and stroke. Deaths caused by circulatory diseases have been falling for decades, which has significantly contributed to all-cause mortality improvements. The cumulative effect of these improvements has exposed the historically lower rate of improvement seen in deaths from cancer, respiratory diseases and other causes. Circulatory diseases have been relatively easy to tackle compared with cancer or dementia, suggesting a step-up in medical innovation will be necessary to restore rates of mortality improvements achieved in earlier decades.

To understand the dynamics behind the recent slowdown in mortality improvement, a better understanding of the underlying mortality risk factors is needed.

Death certificates only capture the final cascade of events that led to death, but do not capture why the underlying disease or accident happened. To understand the dynamics behind the recent slowdown in improvements, we must look beyond cause of death data and examine changes in risk factors across the population – ie, those factors that affect the likelihood of disease or injury. We see evidence that behavioural risks (eg, physical inactivity, unhealthy food consumption) may play as big a role as biomedical risk (eg, high blood pressure) and explain some of the recent deterioration in all-cause mortality improvements.

Healthy populations provide the reference against which health interventions are judged. Such targets help to promote future gains in health and longevity.

We believe that future gains in health and longevity will be driven more by better public health policies and consumer choices, rather than by advances in treatment of late stage disease. Advances in technology and medicine will enable earlier diagnosis of the onset of disease. If government and society promote healthy lifestyle choices and use new strategies to influence behaviour, they could prevent disease from happening in the first place. Narrowing the mortality gap between healthy sub-groups and the general population could still unlock substantial mortality gains.

Insurers need to take a view on the effectiveness of new policies and availability of funding to target improvements in public health …

However, challenges over funding for diagnosis and treatment and lack of clarity on the optimal focus for public health policies may limit the capacity to emulate the mortality of healthy populations, and the recent slowdown in mortality improvement may well persist. Insurers and pension schemes need to consider how different the future could be, and form a view on the likely success and availability of public and private health interventions to influence behaviour and prevent disease and death.

… bearing in mind the uncertainties around the future path of longevity.

Uncertainty over future mortality trends has important implications for insurers. Overly conservative pricing to cover the range of future mortality outcomes will likely make annuities and life insurance unnecessarily expensive. Equally, prematurely adjusting assumption on mortality trends will stretch insurers' balance sheets once the liabilities are ultimately re-rated to reflect revised life expectancies.

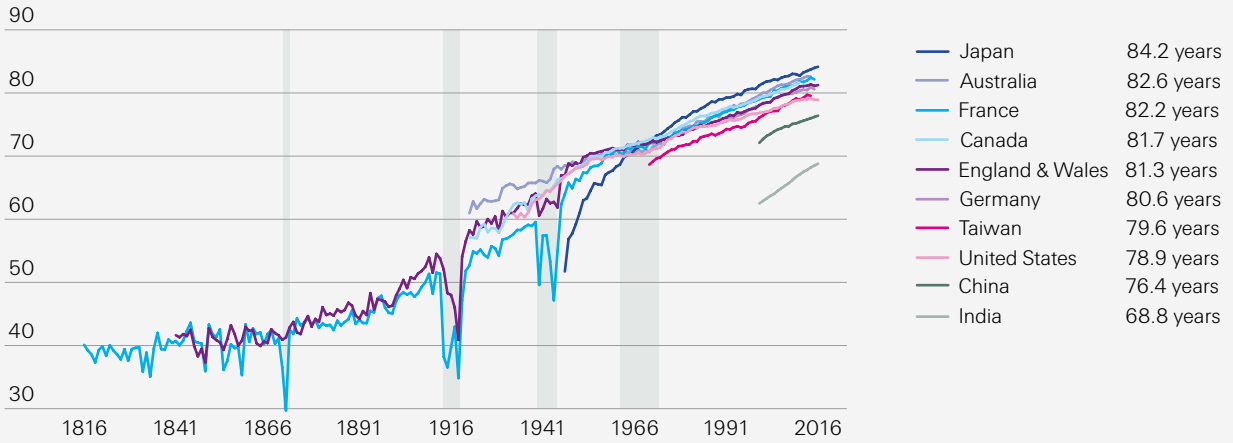
Recent developments in mortality

Slowdown in mortality improvement

Life expectancy has risen in all countries since the early 20th century.

Over the past half century, mortality rates – the number of deaths as a share of the population over a particular period – have been generally declining. In developed economies, this has led to a sustained improvement in life expectancy since at least 1850 (see Figure 1) linked in large part to the many advances in living conditions, medicine and health technology. In the post-war period, mortality improved on average by around 1–2% per year among developed countries. Advanced economies still enjoy longer life expectancy than developing countries, but the gap has narrowed in some regions.

Figure 1
Life expectancy at birth (in years, both sexes)



Notes: Life expectancy (in 2016 or latest available) shown in the legend. Grey areas indicate periods of war.
Sources: Human Mortality Database (HMD), UC Berkeley, and Max Planck Institute for Demographic Research, www.mortality.org (accessed 28 August 2018), World Health Organization (WHO)

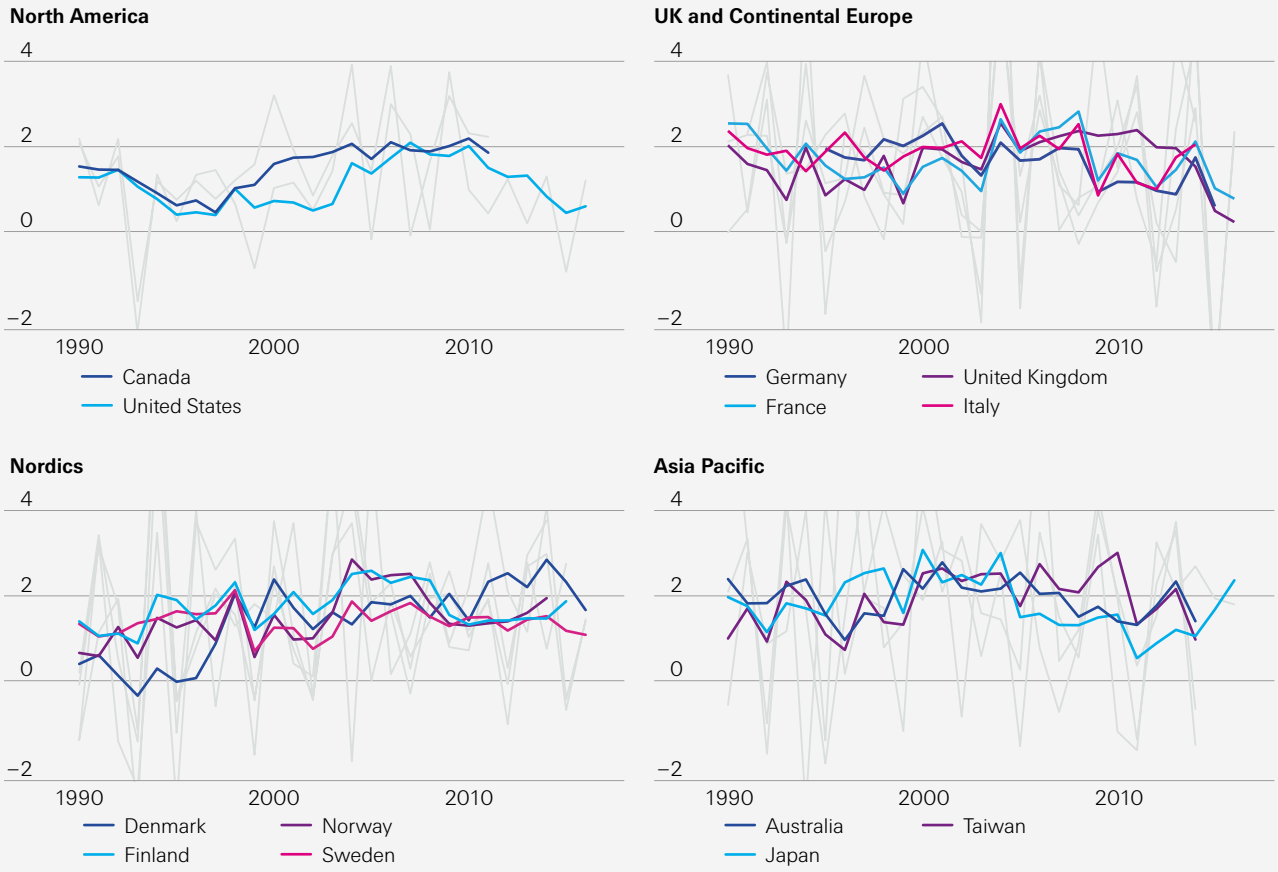
Recently, however, the rate of mortality improvement has slowed.

There are signs in many developed countries, however, that improvements in mortality have slowed in recent years compared with earlier decades. For instance, in England and Wales, standardised mortality rates (SMR), which take into account changes in the population's age structure, have drifted lower since 2011 but at a much slower pace than in the previous decade.[1] Similar slowdowns in the rate of mortality improvement (MI) – the annual relative change in the mortality

[1] *Deaths registered in England and Wales: 2017*, UK Office of National Statistics (ONS), July 2018, www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/bulletins/deathsregistrationsummarytables/2017

rate[2] – have also occurred in other countries (see Figure 2), for example, the US, Germany and France, where MI has fallen towards zero.[3] The slowdown in MI across most countries has been more pronounced among older people. Women in particular have been more affected by the slowdown than men.[4]

Figure 2
5-year moving averages of annual improvements in standardised mortality rates since 1990 (in percent)



Notes: Coloured lines are 5-year backward-looking moving averages. Grey lines show the high volatility of annual rates of improvement. Rates were standardised using the US population in 2016.
Sources: Human Mortality Database, Swiss Re Institute estimates

[2] Formally, the annual improvement in mortality is defined as $1-m_t/m_{t-1}$, where m_t is the mortality rate in year t. So if the mortality rate does not change, annual mortality improvement is zero. If the mortality rate falls, for example, from 10 to 9.8 per 10 000, the annual mortality improvement rate is equal to 1−9.8/10=2%. Likewise, if the mortality rate increases from one year to the next, then the annual mortality improvement rate is a negative number.

[3] More recent data for some countries also suggest that mortality dynamics are changing. For example, in the UK, the number of weekly deaths was unusually high in the first few months of 2018 relative to the same period in earlier years echoing developments in 2015 and 2017. See: O. Hawkins, "Mortality in the UK", April 2018, Briefing Paper, Number CBP8281, http://researchbriefings.files.parliament.uk/documents/CBP-8281/CBP-8281.pdf
According to the ONS, this translated into a significant increase in the provisional SMR to its highest level since 2009. See: *Quarterly mortality report, England: January to March 2018*, ONS, March 2018, www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths

[4] *Changing trends in mortality: an international comparison: 2000 to 2016*, ONS, August 2018, www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/lifeexpectancies/articles/changingtrendsinmortalityaninternationalcomparison/2000to2016

Change in trend or just volatility?

Different country experiences with the same mortality development might suggest transitory explanations are important.

Unfortunately, it is difficult to determine if the recent slowdown in mortality improvement is simply a short-term blip or more permanent. Moreover, the slowdown in mortality improvement has not been observed everywhere, even in economically similar countries from the same region (eg, some of the Nordic countries, see Figure 2). That may suggest that temporary factors are at work or at least that country-specific factors are important, which could unwind as policymakers take corrective action.

For example, deaths from opioid abuse varies by country …

Deaths caused by accidental opioid drug overdose have had an impact on the recent mortality experience in the US. Opioid deaths contributed significantly to a substantial increase in accidental deaths from 2000 to 2016 (see "Recent opioid crisis in the United States").[5] Canada has experienced a similar prescription opioid problem to the US, but only relatively recently has its population (all-cause) mortality rate associated with accidental deaths increased.[6] Similarly, despite a high rate of opioid use in Germany, there is little evidence of a sustained uptick in drug-related death rates.

… perhaps linked to different drug therapy policies.

The different outcomes across countries could be determined by the various policy actions taken. For example, past heroin epidemics (even though different in origin) prompted governments in Portugal and Switzerland to offer increased access to opioid substitution therapy and the implementation of a four-pillar strategy focused on prevention, treatment, repression and harm reduction. This led to a drastic drop in overdose deaths in these countries.[7] In the US, greater regulation of drugs and stricter law enforcement in the 1970s attempted to tackle an emerging drug epidemic at the time, albeit with limited long-term sucess.[8]

[5] After removing opioid deaths, the overall mortality rate (both genders) from accidents still increased 4.4% in 2016, after a 4.2% increase in 2015.

[6] S. Imtiaz and J. Rehm, "The impact of prescription opioids on all-cause mortality in Canada", *Substance Abuse Treatment, Prevention and Policy*, vol 11, 2016, p. 27, https://substanceabusepolicy.biomedcentral.com/articles/10.1186/s13011-016-0071-4 and National report: Apparent opioid-related deaths in Canada, Government of Canada, September 2018, www.canada.ca/en/public-health/services/publications/healthy-living/national-report-apparent-opioid-related-deaths-released-september-2018.html

[7] C. Renzoni, "Is the Opioid Crisis Only an American Issue?", *therecoveryvillage.com*, 30 March 2018, www.therecoveryvillage.com/recovery-blog/opioid-crisis-american-issue/#gref

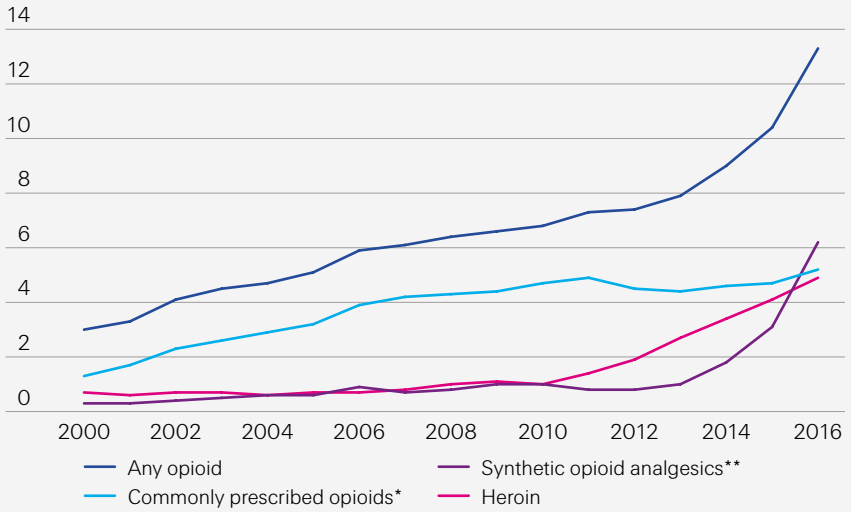
[8] "Opioid epidemic shares chilling similarities with past drug crises", Associated Press, October 2017, www.statnews.com/2017/10/29/opioid-epidemic-shares-chilling-similarities-with-past-drug-crises/

Recent opioid crisis in the United States

The US is in the midst of an opioid crisis with deaths from misuse of opioids rising sharply since 2000.

Opioids are drugs formulated to replicate the pain-reducing properties of opium. They include both legal painkillers like morphine, oxycodone, or hydrocodone prescribed by doctors for acute or chronic pain, as well as illegal drugs like heroin. The US in particular is in the midst of an opioid crisis with deaths related to the misuse of opioids having risen sharply over recent years. The Centers for Disease Control and Prevention (CDC) reported around 64 000 overdose-related deaths in the United States in 2016, nearly two-thirds of which involved a prescription or an illicit opioid.[9]

Figure 3
Overdose deaths involving opioids in the US (standardised mortality rates, per 100 000)



Notes: * Natural and semi-synthetic opioids and methadone. ** Excluding methadone.
Source: CDC/NCHS, www.cdc.gov/drugoverdose/data/analysis.html

Overdose deaths from prescription opioids were initially a significant driver, but this is less true in recent years.

The death rate associated with overdosing on opioids has risen sharply since 2000 (see Figure 3). The anatomy of the US opioid epidemic has, however, changed over time.[10] During the 2000s, the uptick in overdose deaths was largely linked with the misuse of commonly prescribed opioids. But since 2011, those deaths have broadly stabilised. More recently, a significant portion of the acceleration in deaths was due to increased deaths involving heroin and non-prescription, synthetic opioids, which likely includes illegally-made fentanyl.[11]

On top of skyrocketing overdoses, misuse opioids has caused a spike in communicable diseases such as HIV.

On top of skyrocketing overdoses, the use of opioids and heroin has caused a spike in new hepatitis C infections, as well as dangerous bacterial infections that, if left untreated, can cause strokes and require multiple open-heart surgeries. Doctors and public health officials also fear America is on the brink of more HIV outbreaks, driven by intravenous drug use and the sharing of dirty needles.[12]

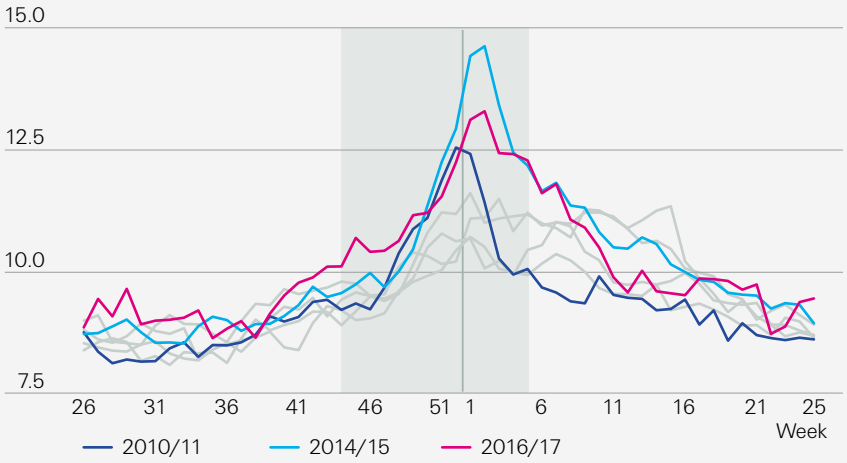
[9] "U.S. drug overdose deaths continue to rise; increase fueled by synthetic opioids", CDC, March 2018. www.cdc.gov/media/releases/2018/p0329-drug-overdose-deaths.html
[10] "Opioid Data Analysis and Resources", CDC, 2018, www.cdc.gov/drugoverdose/data/analysis.html
[11] P. Seth, R. Rudd, R. Noonan, et al., "Quantifying the Epidemic of Prescription Opioid Overdose Deaths", *American Journal of Public Health*, March 2018, vol 108, no 4, pp e1-e3.
[12] E. Nilsen, "America's opioid crisis has become an 'epidemic of epidemics'", *vox.com*, 6 March 2018, www.vox.com/2018/3/6/16453530/america-opioid-crisis-epidemic-bacterial-endocarditis-hepatitis-c

Recent developments in mortality

Adverse weather and inappropriate vaccines may also have contributed to short-term spikes in death rates across countries.

Mortality rates in particular years sometimes increase in several countries simultaneously due to common temporary shocks that lead to higher deaths. Adverse weather conditions and inappropriate vaccines, for example, often lead to higher death rates especially among the elderly, infants or other vulnerable segments of society. Particularly harsh winters in Europe, especially in 2010/11, 2014/15 and 2016/17, led to a spike in deaths from influenza-related illnesses (see Figure 4).[13] Provisional data for the UK (not shown in Figure 4) indicate another spike in 2017/18.

Figure 4
Weekly deaths in the UK (in thousands)



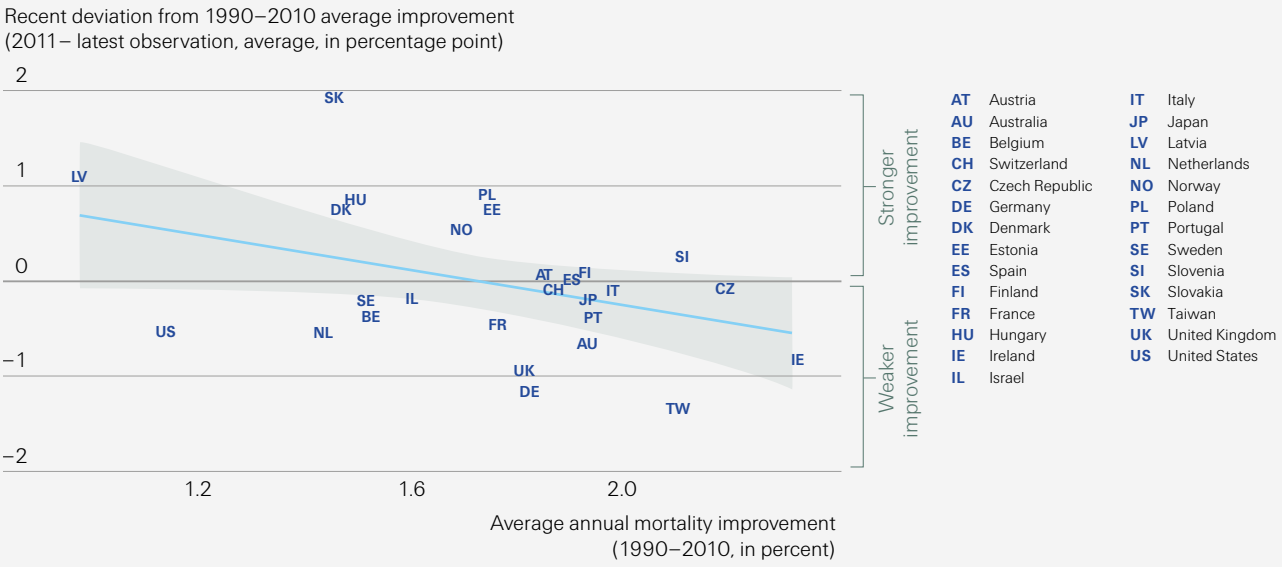
Notes: Shaded region represents winter season. Grey lines show weekly deaths in 2011/12, 2012/13, 2013/14 and 2015/16.
Sources: UK Office for National Statistics (ONS), Swiss Re Institute calculations

Cross-country analysis suggests mortality improvement has slowed unusually in the US, UK, Germany, the Netherlands and Taiwan...

To the extent that death rates in different countries reflect permanent as well as transitory factors – eg, successful medical advances in one country will typically be adopted over time by others – the mortality experience of some countries may shed light on shifts in mortality trends in others. Figure 5 shows on the horizontal axis the average annual improvement in mortality between 1990 and 2010. The vertical axis shows how this improvement has changed since 2011 compared to 1990-2010. A value below the horizontal zero line reflects a recent slowdown. There appears to be a relationship between historical improvements and more recent outturns as indicated by the light blue line. The lower recent rates of improvement in the US, UK, Germany, the Netherlands and Taiwan look somewhat unusual, deviating significantly from this empirical benchmark. By contrast, some formerly Communist countries in Europe (eg, Slovakia, Poland, Hungary and Estonia) have shown an extraordinarily strong improvement since 2011, possibly a sign of the economic benefits from their membership in the European Union.

[13] The six biggest countries in the European Union (France, Germany, Italy, Poland, Spain and UK), all saw a fall in their life expectancies on a comparable scale in 2015 for both sexes. Increased mortality disproportionately affected older people and older women more than older men. The US also reported a fall in life expectancy of 0.1 years in 2015. See: https://publichealthmatters.blog.gov.uk/2017/07/20/whats-happening-with-mortality-rates-in-england/ and www.kingsfund.org.uk/blog/2018/07/problem-excessive-winter-deaths-unique-uk

Figure 5
Average annual mortality improvement in 1990–2010 versus average deviation since 2011



Notes: Countries below the horizontal zero line experienced mortality improvements at a lower rate recently (ie, in the period since 2011) than in 1990–2010. The light blue line shows the linear relationship between 1990–2010 improvement and recent deviation. The shaded swathe represents the 95% confidence interval for this relationship.
Sources: Human Mortality Database, Swiss Re Institute estimates

… but the recent slowdown is typically not statistically significant.

However, comparing for each country the average improvement in 1990–2010 with that since 2011 suggests the recent changes in annual mortality improvement, while evident, are not statistically significant. This could reflect the limited number of annual country-specific observations since 2011, which are highly volatile.

Extrapolating future mortality trends solely from recent experience can be misleading unless we believe there has been a structural break.

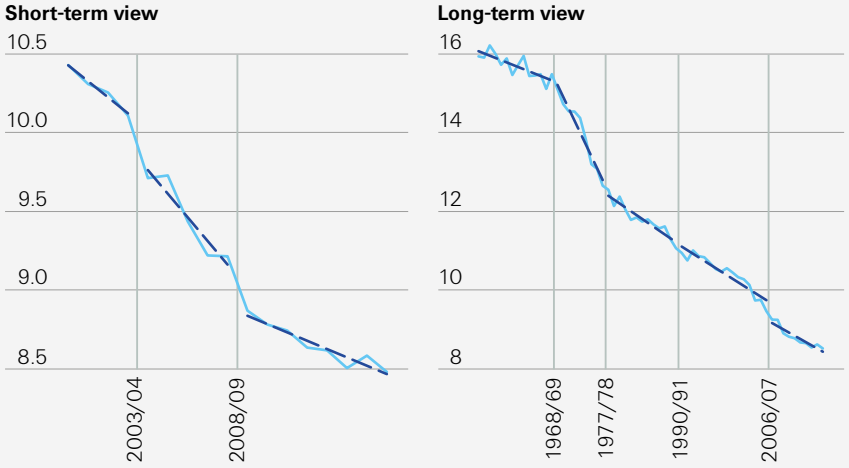
Looking back over a long sweep of history, there have often been periods when mortality rate improvements have stalled, sometimes for extended periods, only for the underlying trend subsequently to continue. As explained in "Evaluating trends requires a longer-term perspective", the recent dips in mortality improvement in the US are generally not out of line with the long-run trend. Extrapolating future developments in mortality solely from recent experience can therefore be misleading unless there are genuine reasons to believe there has been a structural break in mortality experience.

Annual mortality rates are highly volatile and developments need to be assessed over a long time period.

Evaluating trends requires a longer-term perspective

Annual mortality rates are highly volatile period to period. Therefore, mortality developments need to be assessed over a long time period. For instance, looking at how standardised mortality rates in the US have changed since 2000 may lead to the conclusion that there was a structural break in the linear trend in 2008/09 with slowed mortality improvement afterwards (see left panel of Figure 6, where the slope of the dark blue, dashed line representing the underlying trend changes). However, from a purely statistical perspective, recent improvements are broadly in line with the longer-term trends. Despite some evidence of structural shifts in the level of mortality rates around 1990 and again in 2006, the rate of improvement has remained largely unchanged since the late 1970s (see dashed line on the right in Figure 6).

Figure 6
US all-cause mortality rates: short-term and long-term perspectives



Notes: Vertical lines indicate possible structural breaks in the piecewise linear relationship.
Sources: Human Mortality Database, Swiss Re Institute estimates

Why are assumptions about future MI crucial?

Public and private defined benefit pensions as well as insurance annuities help insulate individuals from outliving their wealth in retirement.

Even if mortality improvement has slowed, continued increases in life expectancy should be positive, at least if people enjoy extended lives in good health. However, there is a chance that individuals outlive their accumulated wealth after they stop working and end up living in poverty.[14] To avoid such an outcome, in most advanced societies, the task of managing this longevity risk is partly taken on by governments via state pensions as well as employer-sponsored defined-benefit pension schemes that provide a guaranteed retirement income. Individuals can also insulate themselves from longevity risk by purchasing financial instruments such as annuities from life insurers. These typically allow retirees to transform their stock of wealth built up during their working years into a stream of income over the remainder of their lifetimes.

Uncertainty about trend increases in longevity represents an aggregate risk that cannot be easily diversified.

For governments, companies or private financial institutions that assume longevity risk on behalf of individuals, the ability to distinguish shifts in the underlying trend from temporary changes in mortality rates is crucial. This is because this aggregate (trend) risk cannot be easily diversified. Uncertainty about overall

[14] Individuals are notoriously bad at estimating their own life expectancy. A study by Aviva published in 2015 shows that 65-year old males underestimate their life expectancy by 3.3 years and 65-year old females by 1.8 years, compared with the UK average population.

rates of MI cannot be reduced by pooling the risk across a large number of individuals because there is a chance that everyone (or at least all those from a particular cohort) will live longer. Such systematic longevity risk needs to be quantified and managed.

This aggregate risk must be managed, including hedging with life protection insurance policies.

There may be natural hedges for some institutions that assume aggregate risk exposures – for example, the risk of adverse mortality experience on life insurance may to some extent be offset by the longevity risk associated with annuities sold by a life insurer. An unexpected rise (fall) in mortality rates increases the amount of death claims paid, but will be accompanied by a reduction (increase) in prospective future annuity payouts reflecting the reduced number of survivors. However, any negative correlation between mortality and longevity risk is less than perfect, not least because life insurance and annuity contracts do not usually cover the exact same group of people.

Ultimately, insurers need to hold additional reserves and capital if policyholders live longer than expected.

Pension sponsors and insurance companies need to set aside reserves to meet their future obligations to policyholders and ultimately hold financial capital against the potential for unexpectedly longer payouts associated with improved mortality. This is not just good actuarial practice. In many countries, regulators require annuity providers and pension plans to specify minimum levels of mortality and make explicit assumptions about future mortality improvements (see Table 1).[15] Where specific mortality tables are not mandated, industry bodies often play a role in setting sector-wide standards.

Table 1
Mortality assumptions required by regulation and used in practice

	Minimum mortality table required by regulation?		Mortality improvements required by regulation?		Mortality improvements used in practice?	
	Annuity providers	**Pension plans**	**Annuity providers**	**Pension plans**	**Annuity providers**	**Pension plans**
Brazil	No	Yes	No	No	No	No
Canada	No	Yes	Yes	Yes	Yes	Yes
Chile	Yes	Yes	Yes	Yes	Yes	Yes
China	Yes	Yes	No	No	No	No
France	Yes	Yes	Yes	Yes	Yes	Yes
Germany	Yes	Yes/No *	Yes	Yes	Yes	Yes
Japan	No	Yes	No	No	Yes	No
Korea	No	No	No	No	No	No
Mexico	Yes	No	Yes	No	Yes	No
Netherlands	No	No	Yes	Yes	Yes	Yes
Spain	No	No	Yes	Yes	Yes	Yes
Switzerland	No	No	No	No	Yes	Some
United Kingdom	No	No	Yes	Yes	Yes	Yes
United States	Yes	Yes	No	Yes	Yes	Yes

Notes: Mortality tables show age-specific probabilities of death within a year.
* Yes = non-regulated "Pensionskassen" (PK) and insurance-oriented pension funds (PF), No = regulated PK and non-insurance-oriented PF.
Source: OECD, 2014, op. cit.

[15] *Mortality Assumptions and Longevity Risk. Implications for Pension Funds and Annuity Providers*, OECD, December 2014, www.oecd.org/publications/mortality-assumptions-and-longevity-risk-9789264222748-en.htm

Recent developments in mortality

Small changes in mortality assumptions can dramatically influence liability valuations.

Relatively small changes to mortality assumptions can have significant financial implications. According to analysis by the OECD, each additional year of life expectancy not provisioned for can add around 3–5% to current liabilities.[16] In the light of recent experience, some actuarial estimates suggest future life expectancy for 65 year old males and females in England and Wales is about one year less than it was in 2014. On some estimates this equates to about a 3% reduction in the value of a typical pension scheme's liabilities.[17] This has prompted some UK insurers to reassess their longevity assumptions and look to release significant reserves.[18]

Life expectancy among insureds can also differ notably from that of the general population.

As well as routinely reviewing assumptions about future rates of mortality improvement, annuity providers and pension plan sponsors must be alert to peculiarities in their own portfolios. Mortality developments for the insured population often diverge from that of the general population (see "Mortality experience: life insured versus general populations"). Similarly, the mortality risk profile of pension scheme members or owners of annuities may not move in line with those for the wider population. For example, improvements in longevity among members of UK defined benefit pension schemes have typically been higher than for the wider population.[19] Some researchers have shown that people in higher socio-economic groups (which often form a significant share of the membership of private defined benefit pension funds and/or annuitants) have not experienced a noticeable slowdown in MI.[20]

[16] Ibid.
[17] "Trend or blip?", Royal London, 3 April 2018, www.royallondonconsulting.co.uk/Our-views/2018/180401_LifeExpectancy_LifeExpectancyFalling/
[18] For example, with the publication of its full year 2017 financial results UK insurer Legal & General announced it was releasing GBP 332m of reserves it had held back against customer longevity risk. See: www.ft.com/content/dc7337a4-1c91-11e8-aaca-4574d7dabfb6
[19] www.xpsgroup.com/media/1128/cmi-the-trend-continues.pdf
[20] *Longevity trends: Does one size fit all?*, Club Vita in collaboration with the Pensions and Lifetime Savings Association (PLSA), June 2017. See: www.clubvita.co.uk/collaborative-research/trends

Policyholders typically have lower mortality rates …

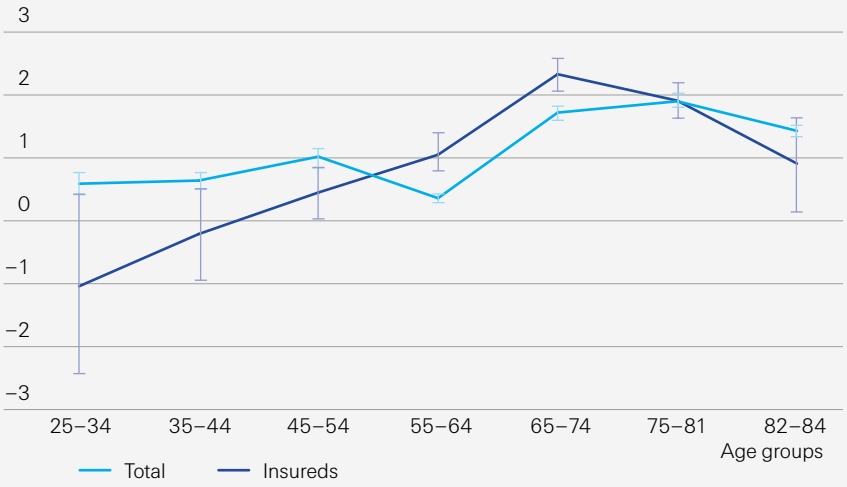
Mortality experience: life insured versus general populations[21]

Mortality among groups of people who typically buy life insurance products is often lower than the general population. Not all segments of society choose to insure themselves against the risk of death. Typically, the observed difference in all-cause mortality persists over time. Insureds tend to be drawn from higher socio-economic classes with access to better healthcare and living conditions and generally make healthier lifestyle choices.[22] Furthermore, insureds undergo a process of risk selection (ie, underwriting) that significantly modifies the health characteristics of the group who qualify for standard or preferred policies (at least at the inception of the policy).

… and may experience different rates of mortality improvement.

Policyholders may also experience different rates of improvements in mortality. Figure 7 demonstrates this for the US based on data from 1999 to 2013. The differential mortality improvements between the two groups differs across ages and is most noticeable among people in their fifties and sixties.

Figure 7
Average annual mortality improvement, by age groups for the US general population and a portfolio of insureds (in percent)



Notes: The insured data represent the aggregated experience of 97 US insurers from 1999 to 2013. Vertical lines indicate 95% confidence intervals for each age group.
Source: B. Ivanovic and A. Pinkham, op. cit.

In forming a view about life expectancies, it is therefore important to understand the underlying drivers of mortality.

As accurate as they strive to be, actuaries lack precognition, and there will always be some difference between future experience and current assumptions. This is why insurers, annuity providers and pension funds need to be careful in not naively extrapolating past mortality developments in the general population to evaluate their own risk exposures. Instead, in projecting forward the likely path of mortality rates, it is essential to try to understand the underlying drivers of mortality (and corresponding improvements) including the uncertainty surrounding them. There are many influences on mortality, including changes in standards of living and lifestyle, public health policies as well as technological and medical advances. Recent developments in these factors are considered in more depth in the next chapter.

[21] Based on "Mortality trends in general population and life insured groups" by B. Ivanovic and A. Pinkham, Swiss Re White Paper, April 2016.
[22] Scor,"Recent Mortality Trends by Cause of Death", April 2017, www.scorgloballifeamericas.com/en-us/knowledgecenter/Pages/Recent-Mortality-Trends-Cause-Of-Death.aspx

Drivers of slowing mortality improvements

Proximate causes of death

Cause of death information is helpful for understanding overall mortality developments.

Death typically occurs for multiple reasons and determining the primary cause – 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 – can be challenging.[23] Medical doctors can reach different conclusions about the cause of a patient's death, especially if the disease/injury is uncommon or the patient suffered from multiple co-morbidities.[24] Examining developments in the reported causes of death can nonetheless help shed light on all-cause mortality experience.[25]

Three types of causal factors are driving the deceleration in mortality observed in some countries.

Looking at the causes of death in selected countries where mortality improvement slowed in 2010–15 relative to 2005–10, three main contributory factors stand out:

I. Some major causes of death had lower average annual rates of improvement recently. These correspond to the observations lying above the dashed 45 degree line in the bottom left quadrant of Figure 8.

II. Others, such as ischaemic heart disease (HD), had a slightly higher rate of improvement over the later period (ie, are below the dashed line). But as these deaths account for a lower share of total deaths, the slightly higher rate of improvement still has less impact on overall mortality experience.

III. Finally, some causes are on the rise, meaning the number of people dying is increasing. These causes correspond to the observations in the upper half of Figure 8 (eg, hypertensive HD and Alzheimer's).

Ischaemic heart disease, the leading cause of death, is improving, but gains are diminishing in some countries.

Ischaemic HD – which is a medical condition of inadequate blood supply to the heart that can cause a heart attack – is the leading cause of death worldwide. But associated deaths have progressively fallen (see Figure 8) contributing significant gains to historical all-cause improvements.[26] Given the magnitude of past improvements, it is unsurprising that the gains in mortality (eg, from statins which are used to reduce levels of cholesterol in the blood) are starting to diminish in countries where larger improvements have already been achieved (eg, France and the Netherlands). In contrast, in countries where rates are still relatively high (eg, Latvia, Slovakia, Hungary and Estonia),[27] all-cause mortality improvement has recently increased. Other major causes of death show similar developments.[28]

[23] "Cause of death" definition by the WHO: www.who.int/healthinfo/cod/en/

[24] Typically only one cause of death is ever extracted from the death certificate. The US and the Netherlands are notable exemptions, where the chain of events is often explicitly mentioned on the death certificate.

[25] Cause-specific mortality rates were estimated combining WHO and UNDP data, which may bias the results if death and vital registrations cover populations with varying degrees.

[26] In OECD countries, for instance, mortality rates declined on average by more than 50% since 1990. See: *Health at a Glance 2017*, OECD, November 2017, p 24, www.oecd-ilibrary.org/social-issues-migration-health/health-at-a-glance-2017_health_glance-2017-en

[27] All these countries show non-slowing all-cause mortality improvements (see Figure 5).

[28] Eg, cerebrovascular disease also contributed less to all-cause mortality compared with earlier years.

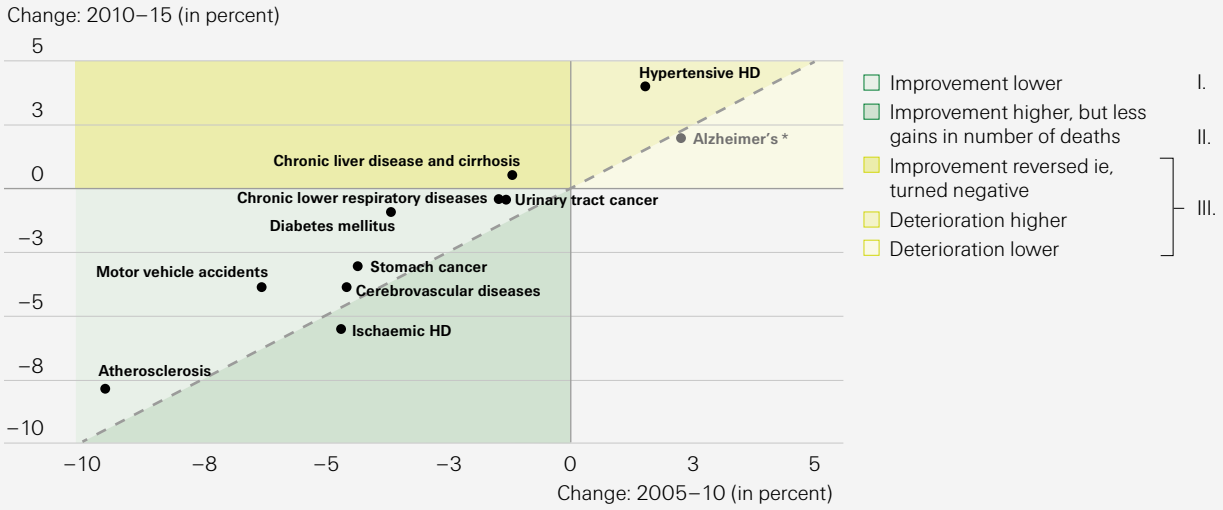
Diabetes-related deaths continue to fall, but there are signs that improvements are slowing.

Despite a rising prevalence of diabetes, the number of diabetes-related deaths have generally been falling over the past decade. This can be explained by better management of macrovascular complications and basic interventions at the primary care level (eg, medication, health and lifestyle counselling).[29] But there are signs that improvements are slowing. The average annual rate of improvement for the sample of countries investigated was lower in 2010–15 than in 2005–10, also contributing to the current slowdown in overall MI.[30]

Alzheimer's has become a leading cause of death among the elderly.

Alzheimer's, the leading cause of dementia, is on the rise. Research has shown that the rise of Alzheimer's can be traced back to lifestyle and other non-neurological medical conditions.[31] With no cure so far available, related deaths have increased in some countries (eg, US and UK) to such an extent that Alzheimer's has become a leading cause of death among those over 80.[32] However, the higher mortality from Alzheimer's can in part be explained by doctors being more aware of the disease than in the past. The higher number of deaths is likely to be offset by fewer deaths from other causes. This underscores the point that to understand the dynamics behind mortality improvements, we must look beyond cause of death data and examine changes in underlying risk factors across the population.

Figure 8
Average annual change in mortality rates of the 10 leading contributory causes of the recent slowdown



Notes: Based on 11 countries with slowed mortality improvements: US, UK, Ireland, Germany, Netherlands, Belgium, Sweden, Iceland, Israel, Taiwan and Australia. Average changes were derived using country-specific 3-year backward-looking moving averages of standardised mortality rates. * Alzheimer's disease is not among the 10 leading contributory causes but has become a leading cause of death among over 80-year olds.
Sources: WHO (mortality) and UNDP (vital) data, Swiss Re Institute estimates

[29] *IDF Diabetes Atlas*, 8th edition, International Diabetes Federation, 2017, http://diabetesatlas.org/resources/2017-atlas.html
[30] Diabetes-related deaths are often underreported in official statistics. A recent Korean study, for example, found that 78% of diabetes-related deaths in 2002-13 were not ascribed as such. See: Y. Kang et al., "Mortality and causes of death in a national sample of type 2 diabetic patients in Korea from 2002 to 2013", *Cardiovascular Diabetology*, vol 15, 2016, p. 131, https://cardiab.biomedcentral.com/articles/10.1186/s12933-016-0451-0
[31] For a review of the relevant research findings, see: "The dementia dilemma", Swiss Re, October 2018, http://media.swissre.com/documents/swiss_re_dementia_dilemma.pdf
[32] Recently, a connection between unstable blood sugar levels, insulin resistance, type-2 diabetes and a higher chance of developing Alzheimer's has been detected. If Alzheimer's is truly diabetes of the brain, it could probably be treated with insulin. See: D. Douda, "Is Alzheimer's Type 3 diabetes?", 2017, https://newsnetwork.mayoclinic.org/discussion/mayo-clinic-minute-is-alzheimers-type-3-diabetes/

Underlying mortality risk factors

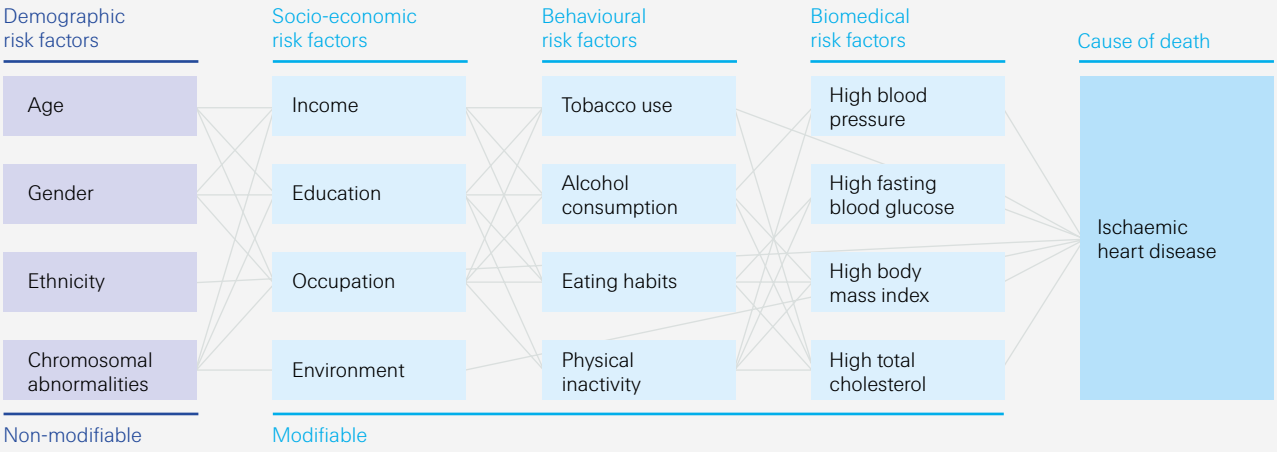
A risk factor is anything that affects the chance of a disease or injury, but does not necessarily cause death.

A risk factor is anything that affects someone's likelihood of getting a disease or injury that causes death.[33] Drunk driving, for instance, is associated with a higher risk of a fatal car accident, but does not cause death. The accident, not the alcohol, kills the person. However, tracing causes of death back to underlying risk factors is not straightforward. Most risk factors are highly interconnected, evolve over a long time horizon and can be an outcome of a complex chain of events.[34]

Mortality risks can be classified into interrelated demographic, socio-economic, behavioural and biomedical risks.

Figure 9 depicts a causal chain connecting risk factors associated with death from heart failure, grouping the former according to their demographic, socio-economic, behavioural and biomedical (metabolic) characteristics. For instance, a higher level of education has been found to be correlated with less risky health behaviours (eg, consumption of junk food, tobacco and alcohol) reducing the chance of high blood pressure and cholesterol that subsequently lead to heart disease and death. In contrast, a person with fewer years of education typically has a lower income and is less likely to undergo regular medical check-ups (at least in countries without universal healthcare coverage). So high blood pressure, for example, could remain undetected/uncontrolled, leading to heart disease and premature death.

Figure 9
Example of a causal chain of risk factors leading to death from heart failure



Note: Lines indicate some of the (dual-directional) interactions between risk factors that may lead to death.
Source: Swiss Re Institute based on WHO, 2009, op. cit.

[33] Definition from www.cancer.org/cancer.html
[34] *Global health risks: mortality and burden of disease attributable to selected major risks*, WHO, 2009, www.who.int/healthinfo/global_burden_disease/GlobalHealthRisks_report_full.pdf

The risk exposure to certain diseases changes as economies develop.

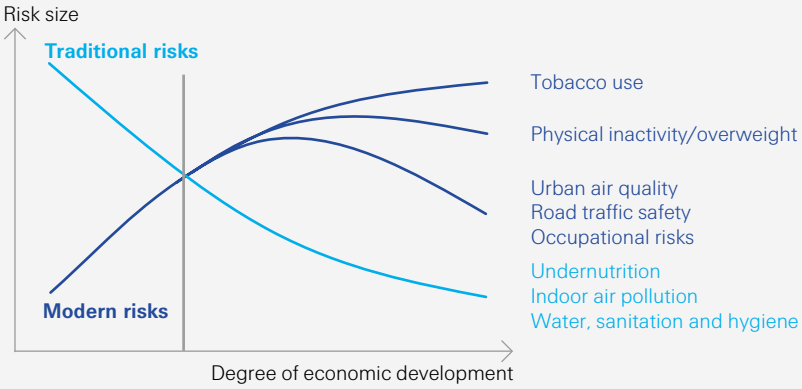
There are an infinite number of possible risk-factor causal chains, depending on the individual's genetic predisposition, own behaviour (eg, physical inactivity, high-caloric food intake) and his/her environment. This is not least because the risk landscape changes with the economic development of a country (see "Economic development changes the risk landscape"). As economies grow wealthier, improved access to new medical treatments (eg, cures for previously fatal conditions) and better public health interventions (eg, reduction in infectious diseases through vaccinations) typically reduce their populations' vulnerability to certain diseases and injuries. Apart from demographics, all risk factors shown in Figure 9 can be mitigated by individual and public policy choices (ie, they are modifiable).

The size of traditional mortality risks declines, while that of modern risks typically increases with economic development.

Economic development changes the risk landscape

Individuals living in developing countries are exposed to different risks than their counterparts in the developed world. For instance, they are more exposed to "traditional risks" such as undernutrition, indoor air and water pollution as well as low sanitation/hygiene standards. Those living in developed countries are more exposed to "modern risks" like physical inactivity, being overweight, urban air quality, road traffic safety and occupational risks (see Figure 10).[35]

Figure 10
Risk of mortality at different stages of economic development



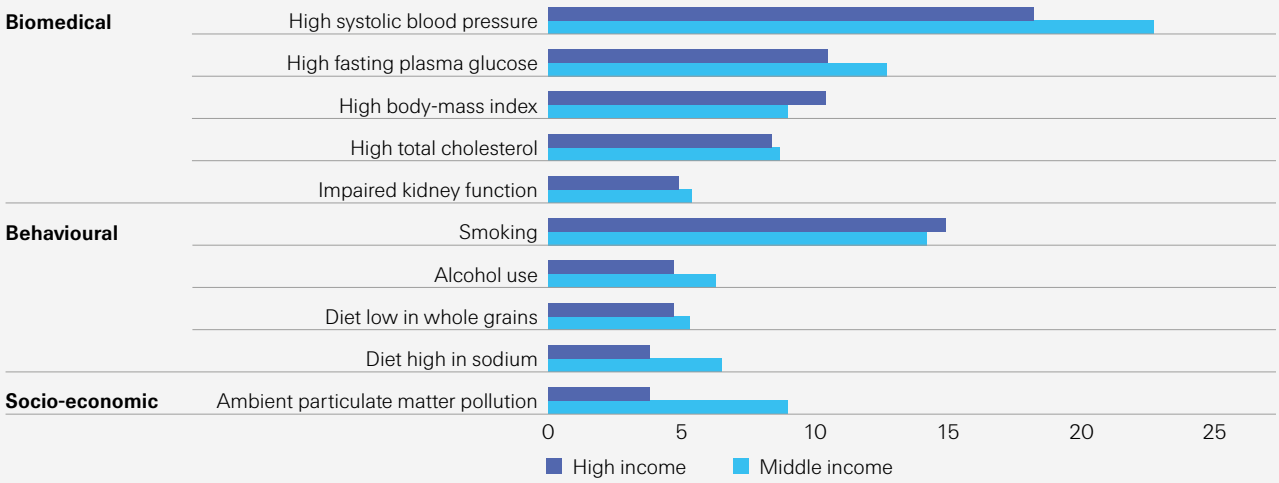
Source: WHO, 2009, op. cit.

[35] WHO, 2009, op. cit.

In developed countries, a significant share of deaths is attributable to behavioural risks.

According to the Global Burden of Disease (GBD) Study 2016 published by the Institute of Health Metrics and Evaluation (IHME), high systolic blood pressure was the leading mortality risk factor in high-income countries in 2016 (see Figure 11). Among the 10 leading risk factors were four other biomedical risks (high fasting plasma glucose, high body mass index, high total cholesterol and impaired kidney function) and four behavioural risks (smoking, alcohol consumption and a diet low in whole grains and high in sodium). Only one socio-economic risk (ambient particulate matter pollution) was among the leading factors.[36]

Figure 11
10 leading risk factors in high- and middle-income countries (2016, in % of total deaths)



Source: IHME, https://vizhub.healthdata.org/gbd-compare/, used with permission, all rights reserved.

In developing countries, environmental risks are more prevalent than behavioural ones.

In contrast, only one behavioural risk (unsafe sex) was among the 10 leading risks in low-income countries. The other major risks were high systolic blood pressure, household air pollution from solid fuels, short gestation for birth weight, child wasting, ambient particulate matter pollution, unsafe water, high fasting plasma glucose, unsafe sanitation and lack of access to handwashing facilities.

[36] "The Global Burden of Disease Study 2016", IHME, *The Lancet*, vol 390, no 10 100, 2017, p 1083-1464, September 2017, www.thelancet.com/journals/lancet/article/PIIS0140-6736(17)32154-2/fulltext

43% of total deaths in high-income countries in 2016 were attributable to biomedical risks.

Biomedical risk factors

The GBD Study 2016 estimates that around 43% of all deaths in high-income countries were attributable to biomedical risks in 2016. The five leading biomedical risks with the most attributable deaths were (in descending order):

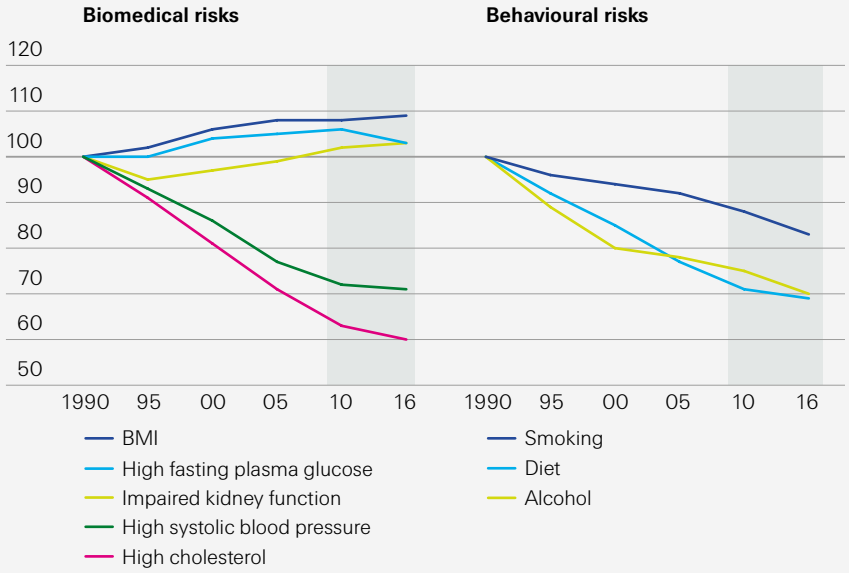
- **High (systolic) blood pressure,** which is often linked to the onset of heart disease, heart attacks and strokes.[37] It can be associated with chronic conditions such as diabetes, kidney disease and sleep apnoea.[38]
- **High fasting plasma glucose** (or prediabetes) is a condition of elevated blood sugar level that can progress to diabetes, and in turn to heart disease, stroke and kidney disease. It can also elevate blood pressure and cholesterol, prompting further health issues.[39]
- **High body mass index** (BMI) – a person's weight in kilogrammes divided by his or her height in meters squared – is a major risk factor for a number of chronic conditions like diabetes, cardiovascular diseases and cancer.
- **High cholesterol** can cause deposits on the walls of arteries and lead to complications such as heart attack and stroke.[40]
- **Impaired kidney function** can cause acute and chronic kidney failure and is driven by high blood pressure as well as chronic conditions such as cardiovascular disease and diabetes.[41]

High body mass index, impaired kidney function, high blood pressure and cholesterol all played a role in the recent slowdown in mortality improvement.

The underlying drivers for these major risk factors are often common. In particular unhealthy lifestyle choices such as smoking, physical inactivity, stress and diet, can all elevate exposure to these biomedical risks. The left panel of Figure 12 shows how each biomedical risk factor's contribution to total deaths in high-income countries has changed since 1990. Two biomedical risk factors – high BMI and impaired kidney function – have consistently become more significant over time and may have contributed to the recent slowdown in mortality improvement since 2010. The slower pace of improvement in deaths attributable to high blood pressure and cholesterol also played a role. In contrast, deaths linked to high fasting plasma glucose have decreased between 2010 and 2016.

[37] Systolic blood pressure refers to the pressure in the arteries during the contraction of the heart muscle.
[38] www.mayoclinic.org/diseases-conditions/high-blood-pressure/symptoms-causes/syc-20373410
[39] www.mayoclinic.org/diseases-conditions/prediabetes/symptoms-causes/syc-20355278
[40] www.mayoclinic.org/diseases-conditions/high-blood-cholesterol/symptoms-causes/syc-20350800
[41] A reduced capability to filter wastes and excess fluids from the blood can lead to kidney failure that is fatal without artificial filtering (dialysis) or a kidney transplant. See: www.mayoclinic.org/diseases-conditions/chronic-kidney-disease/symptoms-causes/syc-20354521

Figure 12
Changes in shares of total deaths linked to major risk factors (high-income countries, indexed: 1990=100)



Source: IHME, Swiss Re Institute calculations

In developed economies, behavioural risks are as important as biomedical ones.

Behavioural risk factors

In developed economies, behavioural risks are as important as biomedical ones, accounting for around 47% of all deaths in 2016.[42] In England, for instance, 80% of heart attacks and strokes are believed to be preventable if people would adopt healthier lifestyles.[43] The three leading behavioural risks in 2016 were smoking, alcohol consumption and dietary behaviour (eg, consumption of sugar-sweetened drinks and food that is low in whole grains and high in sodium).

Smoking and alcohol use are unlikely to have contributed to the recent slowdown in MI, but dietary behaviour has.

All three factors had lower shares of attributable deaths in 2016 than in 1990 (see right panel of Figure 12). The secular improvement in deaths associated with smoking and alcohol has continued throughout the period and even increased slightly since 2010. The lower smoking prevalence and exposure to second-hand smoking, a result of information campaigns, tobacco taxes, bans on advertising, picture warnings and prohibiting smoking in public places, could be an explanation. The share of all deaths linked to unhealthy diets has also fallen, but at a slower pace since 2010. Smoking and alcohol use are therefore unlikely to have contributed to the recent slowdown in all-cause MI, but dietary behaviour has had an impact.

[42] IHME, 2017, op. cit.
[43] "Four in five adults at risk of early death, heart-age test shows", *The Guardian*, September 2018, www.theguardian.com/society/2018/sep/04/four-in-five-adults-at-risk-of-early-death-heart-age-test-shows

Socio-economic risk factors

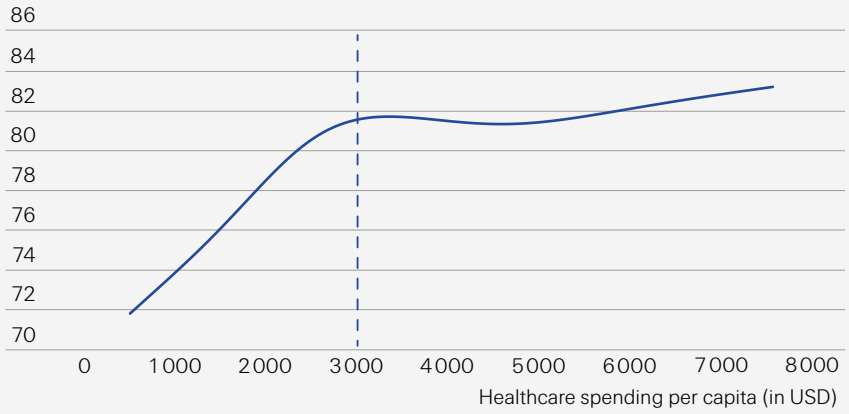
Lower healthcare spending might in principle lead to a deterioration of health outcomes …

However, biomedical and behavioural risk factors alone do not adequately explain different mortality experiences in recent years.[44] Adverse socio-economic conditions such as sharp recessions can also temporarily affect mortality experience. During difficult economic periods, the likely associated reduction in healthcare spending might compromise service provision, leading to a deterioration in health outcomes. Since the financial crisis, healthcare systems in most developed countries are strained by a rising demand amidst funding constraints, which is believed to have caused some of the recent slowdown in the improvement in mortality rates. For example, some researchers examining the case of Greece have found evidence that the recent financial crisis may have contributed to the slowdown, albeit the effect varies by age, gender and cause of death.[45]

… but for developed countries, other factors like quality of care are likely more important.

Figure 13 shows a positive correlation between healthcare spending per capita and life expectancy at least among developing countries.[46] But at higher spending levels (ie, around USD 3000 per person) the mortality gains diminish.[47] Hence, in developed economies reduced healthcare budgets alone may not be crucial in explaining recent mortality developments.[48] Rather, other factors such as the quality of care as well as the efficiency of healthcare systems may be more influential.

Figure 13
Life expectancy (at birth, in years) at different levels of total healthcare spending per capita



Note: Based on 31 countries (United States is an outlier and was not considered).
Sources: Human Mortality Database and OECD data, Swiss Re Institute estimates

[44] Japan and the US, for example, are both rich countries, but had different MI rate developments recently.
[45] I. Laliotis et al., "Total and cause-specific mortality rates before and during the Greek economic crisis: an interrupted time-series analysis", *The Lancet Public Health*, vol 1, no 2, 2016, doi: 10.1016/S2468-2667(16)30018-4 and T. Filippos et al., "Medium-term impact of the economic crisis on mortality, health-related behaviours and access to health care in Greece", *Scientific Reports*, April 2017.
[46] One needs to be cautious when making univariate comparisons. For instance, higher healthcare spending is correlated with higher GDP. In richer countries, other factors eg, availability and affordability of healthier food, less exposure to polluted environments etc. are driving the difference in longevity.
[47] Numerous studies have tried to quantify the link between health expenditure and mortality in advanced economies, but many did not find a significant correlation. Those who did reported substantially different magnitudes.
[48] At least as long as certain sub-groups of the population are not disproportionately affected.

Drivers of slowing mortality improvements

Reducing economic and social inequality is correlated with better health and MI.

Alongside GDP and total healthcare spending, the distribution of income and wealth as well as access to public social services among a country's population affects mortality experience, even in developed countries. There is a strong correlation between economic and social inequality and health outcomes.[49] For example, the introduction of Medicare and Medicaid in the US in 1965 boosted mortality improvement by granting access to previously unaffordable healthcare to the elderly and the poor (see Figure 6 on page 8). Similarly, rising social inequalities often lead to financial and relationship problems that trigger increased incidents of intentional self-harm, the 10th leading cause of death among 15–49-year olds in the US in 2016.[50]

Recent mortality developments in the US are in part driven by more deaths among those with fewer years of education.

Growing inequality may therefore be behind some of the observed slowdown in mortality improvement. For instance in the US, there were recently additional deaths from overdoses, suicides and alcohol-related liver diseases among individuals with fewer years of education. Some academics believe that higher mortality among the less educated may come from a long-standing process of "cumulative disadvantage" triggered by progressively worsening job opportunities at the time of market entry. If true, reversing this trend could take many years.[51]

Table 2
Overview of the main contributory drivers of the recent slowdown in mortality improvement

Causes of death	Risk factors		
Major contributors *	**Biomedical**	**Behavioural**	**Socio-economic**
Cerebrovascular diseases	High BMI **	Diet ***	Financial troubles
Diabetes mellitus	Impaired kidney function **	Physical inactivity	Higher social inequality
Ischaemic HD	High blood pressure ***		Lower healthcare budgets
Chronic lower respiratory diseases	High cholesterol ***		

Notes: * Based on selected countries underlying Figure 8. Share of total deaths increased (**) or fell more slowly (***).
Source: Swiss Re Institute

A number of drivers have collectively contributed to the recent slowdown in mortality improvement in developed countries.

Bringing the various pieces of evidence together, a number of underlying drivers have collectively contributed to the slowing mortality improvement in developed countries since the start of the decade (see Table 2). Excluding accidental deaths due to opioids – which while important in the US is not yet a global pandemic – worsening developments in circulatory-related disease have been a key contributor to the slowdown. To the extent that these can be linked to behavioural factors, unlike in previous decades, lifestyle choices regarding diet and physical exercise rather than smoking and alcohol consumption are the most obvious explanations. The challenging macroeconomic environment in recent years may also have played a role, although arguably this is most evident through its effect on economic and social inequalities rather than simply constraints on healthcare budgets.

[49] P. Aussel, "The Drivers of Future Mortality: An Underwriter's Perspective", July 2016, www.soa.org/Library/Newsletters/Product-Development-News/2016/july/pro-iss104-aussel.aspx
[50] A recent CDC study found that more than every second person committing suicide was not diagnosed with a mental health condition at the time of death.
[51] Anne Case and Angus Deaton, two Princeton economists, call this "deaths of despair" among the white non-Hispanic middle class. See: A. Case and A. Deaton, "Mortality and morbidity in the 21st century", Brookings Papers on Economic Activity, 2017, www.brookings.edu/wp-content/uploads/2017/08/casetextsp17bpea.pdf

Importance of targets in driving mortality

Actuaries continue to search for better approaches to estimate future longevity.

Actuaries throughout the world have investigated a variety of different methods to project future mortality improvements, often blending statistical analyses of past observations with expert judgment.[52] For example, one popular, practical approach has explored how recent mortality improvements can be seen to converge with an assumed long-term trend.[53] The resulting forward projections are subject to various sources of uncertainty, and are not necessarily linked to plausible biological explanations as to how mortality could change and what this means for both population life expectancy and achievable levels of longevity.

One way is to use a public health approach.

In this chapter, we present a public policy approach to examine the origins of historical and prospective mortality improvements. The subsequent chapter, will highlight how advances in technology and medicine together with public health policies to steer consumer behaviour may influence the future trajectory of mortality across the population.

The concept of target populations

Mortality improvements are an outcome metric rather than a target for governments and healthcare professionals.

Most healthcare systems are typically structured and designed around the identification and treatment of diseases rather than prevention.[54] This is evident through the hierarchical structure of primary, secondary and tertiary care. The rising degree of specialisation among doctors, in part fuelled by the depth of knowledge needed to diagnose and treat conditions, is reinforcing this situation. As a result no one stakeholder in the healthcare system is typically assessed or judged against the progress in all-cause mortality improvements across the population. Therefore, mortality improvements are typically an outcome metric rather than a target for governments and healthcare professionals.

But there are examples of targeting where treatment outcomes are assessed and compared.

The advent of evidence-based medicine together with rising costs of treatment because of ageing populations are catalysing change. In many jurisdictions, new medical interventions are evaluated against current treatments (by comparing treatment groups in double-blinded trials, where neither the health professional nor the patients know which treatment is actually used) in terms of both their potential efficacy and cost effectiveness.

Healthier groups in the general population act as targets to evaluate and focus medical intervention.

Underlying each trial is another group that drives forward the quest for even newer and better treatments – those without the condition and whose lower morbidity and mortality represent a desired target group that the medical professionals strive to emulate. In this way, differences in mortality between target groups and the wider population provide a lens through which to consider potential, but as yet untapped, mortality gains.

[52] For a broad discussion of forecasting approaches in the mortality field see "A window into the future: understanding and predicting longevity", Swiss Re, 2011, http://media.swissre.com/documents/A_window_in_the_future.pdf

[53] As demonstrated by the Continuous Mortality Investigation (CMI) Mortality Projection software developed by the UK Actuarial Profession.

[54] Preventative medicine, such as vaccinations and screening of population groups at risk of developing future diseases, represents less than 5% of total healthcare expenditure.

Importance of targets in driving mortality

A public policy goal should be to narrow the gap between the morbidity/mortality experience of target and wider populations.

Public health policies and clinical decisions addressing differences in mortality experience between population groups ultimately help improve overall mortality. This process is iterative but can be broken down into the following key stages:

- Identify an ideal (ie, target) population, either in terms of absence of disease or favourable risk factors
- Specify interventions, either behavioural or treatment, that might benefit groups with worse experience than the target population
- Evaluate through control studies how effective and efficient the intervention might be, and therefore how widely it should be adopted

The faster the gap is narrowed, the higher the mortality improvements during the projected period.

Any refinement of the definition of the target population, perhaps in terms of diet, blood pressure or biochemistry, implies a different reference for untapped gains and the associated mortality gap with the wider population. The faster we narrow any gap, the higher the mortality improvements will be during the projected period. If the gap widens through adverse behaviours or failed interventions, we will likely see mortality deteriorations. Mortality trend merely represents the cumulative success of these collective activities over time.

Examples of target populations and goal setting

Policies to address smoking prevalence provide a classic illustration of the benefits of identifying target populations.

Policies to address smoking prevalence provide a classic illustration of the benefits of the concept of target populations. The case study "Non-smokers as a target population" demonstrates that the mortality experience of "never smokers" is materially better than that of smokers. With a billion people across the world expected to die from smoking-related disease in the 21st century, policies aimed at promoting smokers to quit still have considerable promise in improving overall mortality. The challenge is achieving and supporting long-term cessation.

Non-smokers as a target population

The damaging impact of smoking was established by a landmark study in the 1950s.

Perhaps the most celebrated longitudinal study of population mortality was the British Doctors Study, which was initiated in the 1950s. In this study, the experience of around 40 000 British doctors was tracked according to smoking habits over successive decades. Periodic surveys contradicted prior beliefs and established the damaging impact of smoking.

The study identified "never smokers" as a desired target population.

The study identified "never smokers" as a desired target group. Smoking was endemic, with ever smoked rates approaching 85% for men and 50% for women in those birth cohorts alive in 1945 in the US. Current smokers experienced higher incidence rates of diseases such as lung cancer, heart attack and stroke, with mortality rates up to 100% higher. At the same time, the benefits of smoking cessation were clearly established, with ex-smokers showing increases in life expectancy even if smoking cessation occurred in their sixties.

The Swiss Re Institute developed a cohort model of the impact of smoking status on UK mortality experience.

These findings have been replicated in other studies across the world and encouraged researchers to develop large cohort studies to improve our understanding of the effects of smoking and smoking cessation. The Swiss Re Institute developed a cohort model of the impact of smoking status on mortality experience. The model used survey results from individuals tracked through the UK General Household Survey over the period 1972–2004 and mortality differentials between different smoker statuses established in the British Doctors Study.

32–45% of improvements in mortality from 1972 to 2004 are estimated to stem from changes in smoker status.

From this model, the fraction of mortality improvement attributable to smoker status was estimated. Table 3 indicates that for 30–79 year old men, between 32% and 45% of mortality improvements during the study period were driven by changes in smoker status. This highlights the advantages experienced by the never smoker population and the potential of behavioural change.

Table 3
Contribution to annual mortality improvement from change in smoker status (UK males, 1972-2004)

Annual mortality improvement (by age group, in percent)							
					Average		Contribution from status change [=2/1]
	1970s	1980s	1990s	2000s	Total [1]	From change in smoker status [2]	
20–29 years	1.2	–0.1	0.2	3.0	0.7	0.1	16%
30–39 years	1.6	0.0	–0.1	1.5	0.5	0.2	44%
40–49 years	2.2	2.0	1.0	0.9	1.6	0.7	45%
50–59 years	1.4	3.0	2.4	2.2	2.3	0.9	39%
60–69 years	1.5	2.0	3.2	3.4	2.4	0.8	34%
70–79 years	1.3	1.7	2.3	3.8	2.1	0.7	32%
80–89 years	0.6	1.2	1.3	2.5	1.3	0.2	19%

Source: Swiss Re Institute

The impact of e-cigarettes on smoking behaviour and health is still unclear.

Electronic cigarettes (e-cigs) could be an influential factor in further reducing the risk of smoking (ie, narrowing the mortality gap between the target and general population) by changing consumer habits. According to recent data from the CDC, Juul (the most popular e-cig manufacturer in the US) sold around 1.6 million devices in 2017, a more than six-fold increase from the year before.[55] By delivering nicotine without tar and other by-products, e-cigs are arguably a healthier alternative to cigarettes. Furthermore, some studies find that e-cigs make it easier to quit tobacco smoking.[56] However, the long-term health implications of e-cigs are still unknown. In addition, the marketing of e-cigs to young people may encourage smoking among those who otherwise would never smoke.

The Sustainable Development Goals for health and well-being could be transformative.

Beyond smoking, there has been particular interest in how the setting of diverse global targets can drive transformative change. In 2015, for instance, the United Nations set out 169 targets that would mark the successful completion of the 17 Sustainable Development Goals (SDGs), which cover social and economic development issues.[57] Goal 3 aspires to ensure health and well-being for all, including a commitment to end the epidemics of AIDS, tuberculosis, malaria and other communicable diseases by 2030. The goal includes the achievement of universal health coverage and providing access to safe and effective medicines and vaccines for all.[58]

[55] "Sales of JUUL e-cigarettes skyrocket, posing danger to youth", CDC, October 2018, www.cdc.gov/media/releases/2018/p1002-e-Cigarettes-sales-danger-youth.html
[56] Electronic cigarettes: promise and challenge, Swiss Re, 2014.
[57] Including poverty, hunger, health, education, global warming, gender equality, water, sanitation, energy, urbanisation, environment and social justice.
[58] A study investigating financing and focused investments for specific sub-populations in 67 low- and/or middle-income countries (LMIC) to achieve substantial health improvement found that 97 million premature deaths could be prevented if healthcare access was more equitable in those LMIC countries, and that 535 million years of healthy living would be added across the 67 countries.

Some developed countries have started to set national goals in targeting a lower exposure to leading mortality risk factors.

The SDGs are predominantly focused on closing the health and mortality gap between developing and developed countries. But decision makers in advanced economies are starting to set national goals too. Besides targeting a non-smoking society, they allocate resources to reduce the population's exposure to leading risk factors such as high blood pressure, high fasting plasma glucose, high BMI, ambient air pollution and diet.[59] In the UK, for instance, the Blood Pressure System Leadership Board has developed a strategy to reduce the internationally high share of adults with high blood pressure who are not aware of it and do not manage it to the levels recommended. The achievement of the goal will prevent or at least postpone a significant number of premature deaths.[60]

Aiming at target populations

Moving towards more cost-effective healthcare

Cost-effectiveness studies are increasingly used to optimally allocate healthcare resources.

The key concern in advanced economies is that further improvements in life expectancy would require significant investment in resources (eg, in terms of workforce, infrastructure and innovations). The UK's National Institute for Health and Care Excellence (NICE), for instance, uses a particular metric – the quality-adjusted life year (QALY)[61] – to evaluate a new intervention's effectiveness and compare it against existing treatments. Furthermore, the cost per QALY metric can be used to measure if investments yield the highest value for money.

The cost per quality-adjusted life years (QALY) varies significantly by treatment and disease.

Analysis of healthcare expenditure for different primary care trusts indicates that the cost per QALY varies significantly by disease, with circulatory disease being the lowest of the major disease groups. More specifically, the incremental cost per QALY of secondary coronary heart disease prevention was assessed at between GBP 10 000 and GBP 16 000. By contrast, the cost-effectiveness of cetuximab (plus supportive care) for the treatment of colorectal cancer has been assessed as GBP 98 000 per QALY.

Limited healthcare budgets mean that maximum cost per QALY thresholds are typically imposed.

The challenge is that healthcare budgets are increasingly insufficient to cope with both increased demand (eg, from ageing populations) and healthcare cost inflation. Every treatment comes with an opportunity cost. NICE sets a threshold of GBP 30 000 per QALY for any intervention to maximise the potential utility. As seen with cetuximab, the cost-effectiveness of more and more treatments is well in excess of this level and are therefore not recommended in the UK. Even where such treatments may be authorised by public health systems or insurers in other countries, it is not realistic to expect new treatments focused at advanced stages of disease to drive continuing mortality improvement across the population.

Shifting focus to prevention and early detection of diseases

Effective curative medicine will increasingly require early identification of latent diseases/conditions.

We would argue that the future of healthcare has to be focused on identifying early signs and symptoms of disease, and attempting to prevent disease progression and the development of extensive co-morbidity. Effective curative medicine will require greater differentiation between the truly healthy and those where the early signs of disease remain latent. Those experiencing a heart attack will already have coronary arteries that are 80% occluded. Such advances in the early diagnosis of disease will provide medical professionals and society with the most ambitious target to drive the future direction and focus of medicine.

[59] "Forecasting life expectancy, years of life lost, and all-cause and cause-specific mortality for 250 causes of death: reference and alternative scenarios for 2016-40 for 195 countries and territories", IHME, October 2016, http://dx.doi.org/10.1016/S0140-6736(18)31694-5

[60] "Tackling high blood pressure: from evidence into action", Public Health England, November 2014, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/527916/Tackling_high_blood_pressure.pdf

[61] QALYs are used in economic valuations of health outcome, where a QALY of one means perfect health and zero means death. Hence, if a treatment leads to a gain of one QALY this means that one year in perfect health is gained.

Quantifying the magnitude of mortality improvement

Longitudinal data on healthy target populations can help gauge how much more mortality could improve.

Could we estimate how dramatic the impact of the successful adoption of curative medicine on future mortality improvements would be? More and more countries are investing in the development and analysis of robust longitudinal electronic health records (EHR).[62] These EHR allow the early identification of those that will go on to develop disease and those who seem to be more resistant. Comparisons of these different populations allows us to anticipate the onset of disease/co-morbidity and mortality, and hence provides an indication of how much more mortality could improve if these differences were eliminated.

Benchmarking against target health groups suggest mortality improvements could return closer to rates enjoyed in earlier decades.

The box "The Health Improvement Network" uses anonymised EHR data for the UK to investigate mortality gains that might be achieved if the experience of the general population could be moved closer to that of healthy sub-groups. Specifically, if current mortality among a target healthy group with no diagnosis of 30 major diseases were replicated across the wider population (and this was realised over 20 years), the rate of mortality improvement would broadly return to that observed over the past four decades. Admittedly, some healthy characteristics may be easier to replicate than others; certain behavioural traits and medical conditions may simply be hard to address. Closing the gap with a less challenging target reference group (eg, people who have never suffered from a subset of the 30 diseases) could still see mortality improvement pick up from recent rates, but the pace of convergence would need to be faster.

The Health Improvement Network (THIN)[63]

THIN, a primary-care database, was used to identify a "healthy" target population …

An example of such a primary care database is THIN, a collection of 5 million de-identifed UK patient records routinely recorded during consultions with general practitioners. We defined a fully anonymised population on 1 January 2015 who had first registered at their general practitioner practices on or before 1 January 2010. We then compared the mortality experience of this population and a healthy sub-group. This sub-group had no history of diagnosis over the previous 5 years across 30 different diseases all associated with increased mortality.[64]

… and compare its mortality experience with that of the overall population.

Table 4 provides mortality comparisons at different age groups for women and men between this healthy sub-group and the defined total population. For the purposes of illustration only, we further indicate the level of annual mortality improvement that would be implied if the differences in mortality experience between these two groups were to be eliminated over a period of either 20 or 40 years. By way of comparison we have included the average rates of annual mortality improvement over the last 40 years (1977–2017) and between 2010 and 2017.

The rate of progress towards healthier populations will be a key driver of future mortality improvements.

Comparing the last two columns of Table 4 illustrates the slowdown of mortality improvements that has happened in the UK over the past 7 years. The table further shows how important the duration is over which any differences in the mortality experience are eliminated between the healthy sub-group and the overall population. If the necessary changes in behaviour, early diagnosis and treatment could happen over the next two decades, we would see mortality improvements returning closer to those we have seen over the last four decades.

[62] In some countries, eg, UK, health databases such as CPRD, THIN and QRESEARCH have been developed in the primary care sector. In others like the US, patient-centred legislation introduced by the Obama administration has led to Direct Project and Blue Button that enable individuals and medical professionals to construct the overall health record from fragments held by a constellation of healthcare providers.

[63] THIN is a registered trademark of Cegedim SA in the United Kingdom. The current study was reviewed and approved by the Scientific Review Committee U.K.

[64] The 30 diseases cover diabetes, chronic kidney disease, various malignant cancers, stroke, aneurysms, transient ischaemic attacks, cardiac arrhythmias, heart failure, heart attack, chronic obstructive pulmonary disease, pneumonia, peptic ulcer, systemic lupus erythematosus, liver disease, dementia, Parkinson's disease, encephalitis and multiple sclerosis.

Importance of targets in driving mortality

Further improvements in mortality experience add to dramatic gains in life expectancy over the last 40 years.

Further, our analysis is focused on relative mortality comparisons, so the absolute changes in mortality required in the future are only a fraction of those that have already been achieved over the last 40 years. Following the successes achieved for smoking and high blood pressure, the goal should be to unlock further mortality benefits for all.

Table 4
Comparisons of mortality experience between the general (Total) and the target (Healthy) population

	Mortality rate (per 1000)		Average annual rate of improvement			
			If gap is closed over: *		Actual rates **	
Women	**Total**	**Healthy**	**20 years**	**40 years**	**1977–2017**	**2010–2017**
25–29 years	0.34	0.28	0.83%	0.42%	0.50%	1.69%
30–34 years	0.52	0.44	0.82%	0.41%	0.56%	0.50%
35–39 years	0.59	0.50	0.79%	0.40%	0.79%	0.57%
40–44 years	0.92	0.53	2.72%	1.37%	1.02%	0.19%
45–49 years	1.61	1.02	2.27%	1.14%	1.51%	0.24%
50–54 years	2.36	1.48	2.32%	1.16%	1.58%	1.15%
55–59 years	3.79	2.27	2.52%	1.27%	1.77%	1.68%
60–64 years	5.72	3.55	2.35%	1.18%	1.65%	0.68%
65–69 years	8.81	5.24	2.57%	1.29%	1.72%	0.89%
70–74 years	14.95	9.59	2.20%	1.10%	1.79%	1.33%
75–79 years	23.23	16.45	1.71%	0.86%	1.68%	0.91%
80–84 years	43.30	32.23	1.47%	0.74%	1.56%	1.01%
85–89 years	80.86	64.14	1.15%	0.58%	1.05%	0.19%
Men						
25–29 years	0.62	0.58	0.31%	0.16%	0.64%	0.54%
30–34 years	0.63	0.55	0.74%	0.37%	0.24%	1.84%
35–39 years	0.89	0.79	0.57%	0.28%	0.32%	0.64%
40–44 years	1.16	0.97	0.90%	0.45%	0.74%	0.30%
45–49 years	2.13	1.61	1.40%	0.70%	1.40%	-0.07%
50–54 years	3.03	2.22	1.55%	0.78%	2.02%	0.98%
55–59 years	5.08	3.52	1.82%	0.91%	2.20%	1.59%
60–64 years	8.05	5.20	2.16%	1.09%	2.28%	1.08%
65–69 years	13.77	8.92	2.15%	1.08%	2.40%	1.52%
70–74 years	22.28	14.51	2.12%	1.07%	2.42%	1.76%
75–79 years	36.99	24.89	1.96%	0.99%	2.17%	1.31%
80–84 years	61.48	44.56	1.60%	0.80%	1.70%	1.17%
85–89 years	108.20	84.44	1.23%	0.62%	1.06%	0.57%

Notes: * (1-Healthy/Total)^(1/number of years). ** Data from the Life&Longevity Markets Association (LLMA): https://llma.org/index/
Sources: THIN and LLMA data, Swiss Re Institute estimates

Country-wide research also indicates the potential benefits of policy interventions in promoting public health.

Other researchers using country-wide data also show the potential benefits of targeted health policies in improving health outcomes. For instance, the GBD's central forecast is for global life expectancy to increase by 4–5 years by 2040 (1–3 years for high-income countries). According to their upside scenario, which uses cross-country information on possible achievable reductions in underlying risk factors, life gains could rise by over 7 years. Their downside scenario suggests that life expectancy could actually stall. The large difference in overall health outcomes based on alternative scenarios underscores the opportunities to boost gains if countries move their trajectories toward better health scenarios as well as the significant challenges if countries miss their targets.[65]

[65] IHME, October 2016, op. cit.

The future pace of mortality improvement

There are multiple factors that will influence the outlook for mortality improvement.

There are many factors that impact the future pace of mortality improvement. Table 5 summarises some of the possible drivers, including those that may delay or even prevent the attainment of targets. In this chapter, we will explore the extent to which innovations in technology and medicine affect the outlook for public health, and how individual choices and behaviour are potential obstacles that may be addressed by collective action on the part of government and society.

Table 5
Possible drivers of future mortality improvement

Area	Possible drivers
Environment	Climate change, air, water and land pollution, war/terrorism and crime rate
Healthcare	Availability, access, quality/effectiveness and usage of healthcare
Economic and social inequality	Socio-economic factors (eg, education, occupation, income), inequality within and across countries
Behaviour	Activities of daily living such as drug, tobacco (incl. e-cigarettes/vaping), alcohol use/addictions, diet/nutrition, avocations, physical activity, stress, sleeping pattern
Medical advances	New treatments (precision medicine: eg, CRISPR, immunotherapy), improved prevention (eg, genetic testing), early detection (eg, liquid biopsy), regenerative medicine, stem cells, 3-D organ printing
Technological advances	New types of and/or more accurate data (eg, electronic health records, wearables and (ingestible) biosensors), new statistical/analytical methods (eg, artificial intelligence in healthcare but also underwriting mortality risks of insureds), nano-technology, internet of things, robotics and automation (eg, self-driving cars that reduce accidental deaths)
Ageing	Anti-ageing (drugs), ambient assisted living arrangements (eg, supportive home environments that integrate sensors, actuators, alarms etc.), improved mental, physical and social care
Catastrophes	Natural catastrophes, man-made disasters, epidemics/pandemics (eg, antibiotic-resistant infections)

Sources: "Drivers of future mortality", Milliman, April 2017 and Swiss Re Institute

Development of new drugs will continue to play an important role.

The development of new drugs and treatments will continue to be an important influence on future mortality developments. However, the emergence of value-based reimbursement models means that new drugs must prove their superiority to existing (often already cost-effective) drugs. Pharmaceutical companies are increasingly focusing on areas where the chances of success are high and the financial return on the R&D is greatest, but the clinical benefit may be limited to a small patient group. Investments in research on rare diseases, including cancer, are typically expanding in areas that require less costly clinical trials and where potential prices are high.[66] Furthermore, the cost of emerging cancer treatments such as immunotherapy may be beyond the reach of the mass population.[67]

But new drugs for some emerging medical needs may struggle to attract R&D investment.

This shift in research activities means that new drug development to combat existing medical needs (eg, diabetes, depression and dementia) may struggle to attract investment funding. It can be hard to differentiate new drugs from already available therapies and therefore to charge high prices. Even where the market might sustain attractive pricing for drug companies, the associated research can be expensive and the risk of a costly failure high (eg, treatments for Alzheimer's), deterring investments.

[66] J. LaMattina, "Pharma R&D Investments Moderating, But Still High", *Forbes*, June 2018, www.forbes.com/sites/johnlamattina/2018/06/12/pharma-rd-investments-moderating-but-still-high/

[67] In the UK, immunotherapies reportedly cost more than GBP 100 000 per patient per year. See: Cancer Research UK (www.cancerresearchuk.org)

Better public health policies and consumer choices are likely to be more influential.

We believe that future gains in health and longevity will be driven more by better public health policies and consumer choices, rather than by advances in treatment of late stage disease. This includes the adoption of new technologies to promote disease management as well as applying precision medicine to facilitate more predictive and preventive care.

Enhanced longevity through technology

Technological innovation is likely to have a significant impact on future mortality improvement.

Technological innovation is a key driver for cost-effective, patient-centred healthcare. It opens up treatment access to the most vulnerable and is likely to have a significant impact on future mortality improvement. New technology can enable enhanced monitoring of health and foster improved management of chronic diseases (see "Continuous care with type-2 diabetes").

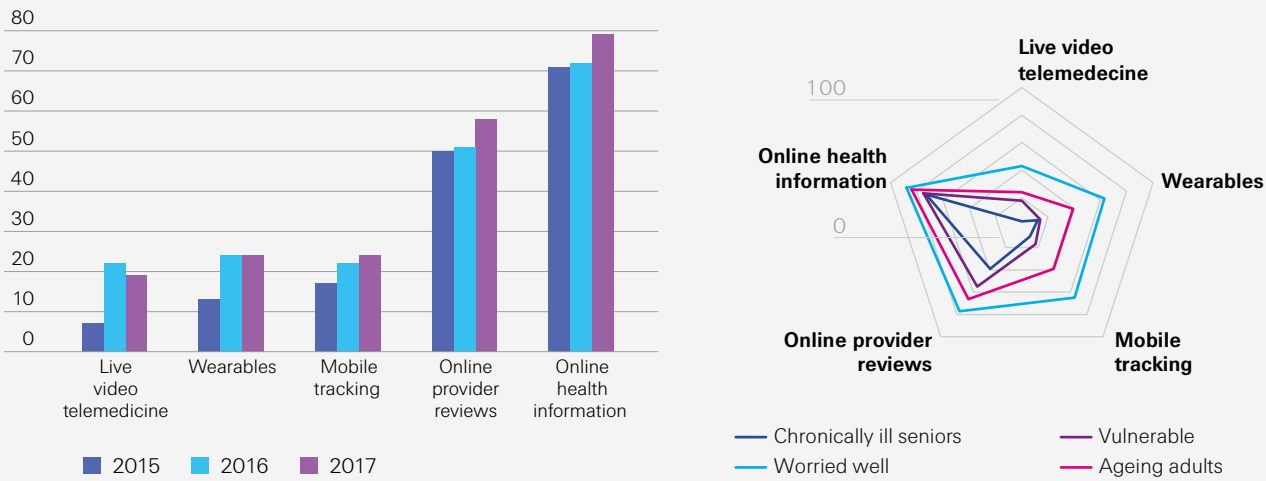
Currently, those who would benefit most from digital health tools are not making significant use of them.

A recent survey in the US shows a clear upward trend in consumers adopting digital health tools like telemedicine, wearables and online provider reviews (see left panel of Figure 14).[68] But not all consumer groups make use of them to the same extent (see right panel of Figure 14). Chronically ill seniors who might benefit most from digital health technologies are currently using them the least.

This could change, especially if such tools become part of the mainstream workflow of medical practitioners.

A key factor influencing the future take-up of digital health will be the willingness of medical practitioners to employ such tools. For example, a 2017 US survey shows that less than 5% of physicians in the US currently utilise technology like wearables to monitor their patients' health status.[69] Physicians struggle with both the sharing of data and making clinical sense out of them. Lack of evidence on long-term persistency with wearable usage and health outcome needs to also be addressed.[70]

Figure 14
Share of survey respondents making use of digital health (in percent)



Consumer groups: Chronically ill seniors (aged 65 or over with one or more chronic diseases), vulnerable (income < USD 25 000 or covered by Medicaid), worried well (aged 18–35 with income > USD 75 000), ageing adults (aged 35-55 with income > USD 50 000).
Source: Rock Health, 2017, op. cit.

[68] "Healthcare consumers in a digital transition", Rock Health, 2017, https://rockhealth.com/reports/healthcare-consumers-in-a-digital-transition/?mc_cid=dfebf72d21&mc_eid=9795147669
[69] "Making Wearables Valuable to Medical Practices", M.K. Pratt, July 2017, www.physicianspractice.com/technology-survey/making-wearables-valuable-medical-practices
[70] "Determinants for Sustained Use of an Activity Tracker: Observational Study", S. Hermsen et al., JMIR mHealth and uHealth, www.ncbi.nlm.nih.gov/pmc/articles/PMC5695980

Continuous care with type-2 diabetes

A recent study compared health metrics of type-2 diabetics that received digitally-enabled support with those without assistance.

A recent clinical study investigated the health of a cohort of patients who self-selected to participate in a metabolic and continuous care intervention (assisted cohort, AC) for type-2 diabetes. Continuous care intervention provides continuous care through intensive, digitally-enabled support, including telemedicine access to a medical provider, health coaching, nutrition and behaviour change education, individualised care plans, biometric feedback and peer support via an online community. The health outcomes of the assisted cohort was compared with a control group of patients who chose to maintain their prior care arrangement (unassisted cohort, UC).[71]

The results show how effective digital health technologies can be in delivering better health outcomes.

Table 6 presents selective mean one-year changes in biomarkers for the AC versus UC cohorts. Total HbA1c, blood pressure and insulin levels all decreased in the AC cohort when compared with the UC cohort. The average weight loss for the AC cohort was 14.2 kilogrammes. Moreover, this group used less diabetic medication, excluding metformin. Further replication of the continuous care intervention methodology is planned across a larger population with longer longitudinal follow-up to verify the impact of AC.

Table 6
Mean one-year changes in biomarkers for assisted (AC) versus unassisted (UC) cohorts

	Changes in biomarkers		
	Assisted cohort (AC)	**Unassisted cohort (UC)**	**Difference**
HbA1c (%)	–1.3	0.2	–1.5
Systolic blood pressure (mmHg)	–6.8	0.2	–7.0
Diastolic blood pressure (mmHg)	–3.6	–0.1	–3.5
Insulin (%)	–13.3	1.4	–14.7
Weight (kg)	–14.2	0.0	–14.2
Total cholesterol (mmol L)	0.2	0	0.2
Any diabetic medication, excluding metformin (%)	–27.5	6.9	–34.4

Source: S. Hallberg et. al., 2017, op. cit.

[71] "Effectiveness and safety of a novel care model for the management of type 2 diabetes at 1 year: an open-label, non-randomized, controlled study", S. Hallberg et al., *Diabetes Ther*, vol 9, no 2. 2018, pp 583-612.

Artificial intelligence perhaps provides the greatest opportunity for transforming health outcomes.

Doctors are increasingly challenged in making optimal decisions in guiding healthcare. Artificial intelligence (AI) provides perhaps the greatest opportunity for transforming health outcomes, supporting clinicians in choosing more precise, efficient and impactful interventions at exactly the right moment in a patient's care. Machine intelligence can highlight disease foci and health indicators that might not be observable by humans, looking at both structured and unstructured data to identify trends, determine clinical utility of treatment, and predict future health issues.

Machine-learning approaches are already being used to detect diseases.

Google's AI-company "DeepMind" has published research that describes an algorithm that can identify 50 eye diseases from retinal eye scans. DeepMind has entered an agreement with the UK's NHS for five years, allowing the technology to be widely used and further developed over the next 5 years.[72] DeepMind aims to make screenings more efficient and targeted.[73] Researchers are applying similar machine-learning approaches for the detection and treatment of even more serious diseases as well as in the development of new drugs.

Digital health encourages markets to compete for lower, more affordable and effective options.

Digital health not only improves access to care, but also encourages healthcare markets to compete for lower, more affordable options. Today's availability of smart health technologies goes beyond "traditional" wearables and mobile tracking devices. Smart earbuds, for instance, have built-in optical sensors that monitor heart rate by detecting changes in blood flow or clothing with embedded electronics that can measure biometrics.[74]

Last year, the FDA approved the first pill that facilitates the tracking of adherence.

Adherence to long-term therapy for chronic disease is a worldwide problem leading to avoidable costs and poor health outcomes.[75] Last year, the US Food and Drug Administration (FDA) approved the first drug with a digital ingestion tracking system.[76] The pill has an embedded sensor that records when medication is taken and sends a message from the pill's sensor to a wearable patch. The patch transmits the information to a mobile application so that the patient, but also healthcare professionals or family members with access, can track adherence through a web-based portal. The increase in adherence will improve future health outcomes and decrease the economic burden on healthcare systems.

[72] www.businessinsider.com/google-deepmind-ai-detects-eye-disease-2018-8?r=UK&IR=T

[73] The waiting time for a screening will also be reduced. To place this innovation into perspective, there are almost 100 million outpatient appointments in the NHS, and nearly 10% of these were for eye care. www.bbc.co.uk/news/health-35743550

[74] https://futurism.com/images/8-smart-technologies-that-exist-today/

[75] Up to 50% of patients in advanced economies fail to adhere to their treatment. *Adherence to Long-term Therapies, Evidence for action*, WHO, 2003, www.who.int/chp/knowledge/publications/adherence_full_report.pdf

[76] https://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm584933.htm

Benefits from personalised medicine

Personalised medicine promises to optimise diagnosis and treatment leading to better health outcomes.

The delivery of medical care is shifting from a one-size-fits-all to more personalised approaches that allow targeted therapies based on individuals' genetic make-up. Personalised medicine can mitigate many of the inefficiencies of conventional medicine, including wrong diagnoses, unnecessary treatments and adverse side-effects caused by imprecise medications.[77] By combining insights from patient-specific data with other data sources, precision medicine promises a more holistic view on the patient leading to better health outcomes.

A better understanding of epigenetics could help to prevent diseases or mitigate their effects.

Decoding the human genome sequence has been a catalyst for personalised medicine. The international Human Genome Project (1990–2003) identified 20 500 human genes at a cost of USD 3 billion through an illustrious international consortium of genetics experts. This research has spawned a number of similar investigations in different countries (see for example "The UK 100 000 Genome Project"). But there is more to genetics than coding DNA sequences. Epigenetics is the study of heritable changes caused by the activation and deactivation of genes triggered by environmental exposure or other mechanisms, but without any change in the underlying DNA sequence of the organism. A better understanding of epigenetics could unlock the complicated relationships between genomes, environment and health risks to prevent diseases or mitigate their effects.

Nutrigenomics may provide insights and potential solutions to reverse the obesity pandemic.

A novel sub-discipline, for instance, is nutrigenomics, the study of how genetics interacts with the foods we eat. It is particularly relevant given the pandemic of obesity, and both geneticists and clinicians see opportunities for this emerging science to provide key insights and potential solutions that might reverse upward trends in obesity. Some individuals may be genetically more susceptible to the onset of obesity and diabetes, whilst others appear to be resilient to the adverse effects of obesity, being metabolically healthy despite their degree of obesity. Nutrigenomics aims to understand the underlying mechanisms, and hence provide ways to deliver nutritional advice to different subpopulations and improve overall public health.[78]

The UK 100 000 Genome Project

The 100 000 Genome Project aimed to provide data for scientific discovery and to deliver benefits to patients.

Almost a decade ago, the UK House of Lords Science and Technology Committee called for a strategic vision for genomic medicine in the UK. In response, the UK government established "Genomics England", a company wholly owned by the Department of Health tasked with carrying out the sequencing of 100 000 genomes focusing on rare diseases, cancer and infectious diseases. The 100 000 Genome Project was the first of its kind, a research-clinical hybrid aiming to provide data for scientific discovery and to deliver benefits to patients.

Insights gained will also be used to make informed public health decisions that drive future mortality improvement.

Genomics England has by now sequenced close to 87 000 genomes with the expected 100 000th genome to be delivered by the end of 2019. The Project will have 21 petabytes of data collected from 70 000 patients and family members, and involves 2500 researchers around the world. Insights from the 100 000 genomes will be used directly to influence both policymaker decisions on public health and the optimal design of healthcare delivery.

[77] R. Das, "Drug Industry Bets Big on Precision Medicine: Five Trends Shaping Care Delivery", March 2017, www.forbes.com/sites/reenitadas/2017/03/08/drug-development-industry-bets-big-on-precision-medicine-5-top-trends-shaping-future-care-delivery/#6eebb8895d3a

[78] L. Ferguson, *Nutrigenomics and Nutrigenetics in Functional Foods and Personalized Nutrition*, CRC Press, 2013.

Importance of consumer behaviour

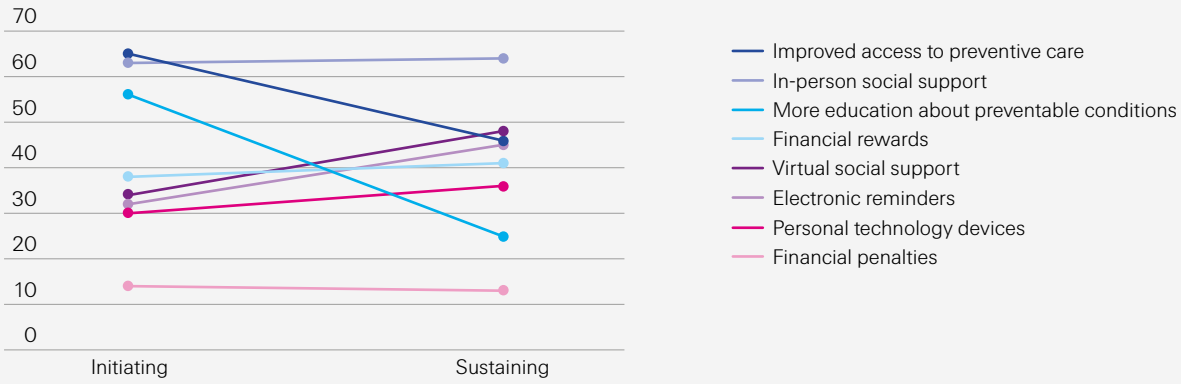
Our choices and behaviour continue to have an adverse effect on future health gains.

As seen with non-adherence to therapy, one of the key factors limiting the future impact of technology and medicine is individuals themselves and their choices. Although it has been known for over half a century that smoking is unhealthy, many still smoke, particularly in emerging economies. Similarly, public health messages promote the health value of daily exercise and lower consumption of sugary drinks and food. Yet the prevalence of overweight and obese individuals increases almost everywhere in the world. This suggests that individual choices and behaviour continue to have an adverse effect on future gains in health and longevity.

In-person social support is seen as the most effective intervention for both initiating and sustaining behavioural change.

A recent study involving healthcare executives, clinical leaders and clinicians looked at drivers of sustained (or lack of) behavioural changes for disease prevention and wellness.[79] It identified improved access to preventive care, in-person social support, and education about preventable conditions as most effective in initiating behavioural change (see Figure 15). In-person social support was the only intervention that consistently ranked high for both initiating and sustaining behavioural change. This suggests that public policies aimed at improving health outcomes and extending life expectancy need to include targeted social programmes.

Figure 15
Different ways of initiating and sustaining behavioural change (percent of survey respondents)



Source: NEJM Catalyst, 2018, op. cit.

Future mortality improvement will also depend on the success of taxes on unhealthy products in discouraging consumption.

Fiscal measures can also play a role in promoting healthy lifestyle choices – imposing so-called "sin" taxes on products such as tobacco and alcohol alters behaviour and improves life expectancy. In 2012, for instance, the US government published an analysis showing that raising the excise tax on cigarettes simultaneously helped discourage smoking and increased tax revenues.[80]

[79] "What Creates Behavior Change May Not Sustain It", *NEJM Catalyst*, May 2018, https://catalyst.nejm.org/survey-sustaining-behavior-change/

[80] The study estimated that people's behaviour had a price elasticity of –0.3, meaning that a 1% rise in the price of cigarettes results in 0.3% decline in the number of smokers. *Raising the excise tax on cigarettes: effects on health and the federal budget*, Congressional Budget Office, June 2012. http://www.cbo.gov/sites/default/files/cbofiles/attachments/06-13-Smoking_Reduction.pdf

Governments are employing taxes on products with a high sugar content in a bid to reduce the burden of obesity.

More recently, taxes on foods with high sugar content have been introduced in order to tackle the burden of obesity.[81] For example, the UK government passed the Soft Drinks Industry Levy in April 2018, a taxation on sugary soft drinks to tackle the obesity epidemic. Similar regulatory action has been taken in several countries (see Table 7).

The jury is still out on how far these taxes will ultimately improve health outcomes.

The efficacy of such sugar taxes in discouraging consumption is still unproven, although there are some promising signs. In California, annual consumption of sugary beverages declined by 21% after the tax was introduced.[82] Ultimately, the impact on consumer health will depend on whether manufacturers adapt their products to avoid paying taxes, and/or how far they pass the cost onto consumers and this changes behaviour, especially among lower socio-economic groups where obesity levels are highest. Taxing certain food categories may prompt consumers to shift towards other, cheaper foods that are not necessarily healthier.

Table 7
Examples of sugar taxes introduced in selected countries

Country	Year of implementation	Products taxed	Implications
UK	2018	Drinks with >5g of sugar per 100 ml	Tax revenue expected to increase by an average of GBP 385 mn per year
US	2018 (San Francisco), 2017 (Philadelphia/Oakland) 2015 (Berkeley)	Sugary soft drinks sold in food stores or vending machines	Berkeley's soda tax reduced sales of sugary soft drinks by 9.6% in 2015
US	2017 (Cook County, IL)	Sugary soft drinks	Repealed two months after introduction as it was deemed harmful to small businesses and ineffective
Mexico	2014	Non-alcoholic and non-dairy drinks with added sugar	Estimated to have reduced sugar consumption by 5.5% in 2014 and 9.7% in 2015
France	2012	Added sugar and sugar-free drinks	
Finland	2011, 2012, 2014	Soft drinks, sweets and ice-cream	Estimated 4.7% decrease in sales of sugary soft drinks and sweets
Hungary	2011	Sugary food and drink	Sales decreased by 27% and consumption fell by 20% to 35% between 2011–13
Norway	1981 (increased in 2011)	Added sugar beverages, chocolate, sweets	Average consumption of soft drinks decreased from 2.3 to 1.6 times per week between 2001 and 2018

Source: *Tackling Obesity: The world's growing challenge*, Goldman Sachs, January 2018.

Insurers and pension schemes must assess the future path of all possible drivers of longevity including the uncertainty surrounding them.

Overall, the outlook for mortality improvement will be shaped by a combination of technological and medical advances, consumer choices as well as the effectiveness of public health policies. Insurers and private pension schemes must take a view on the future path of all possible drivers of longevity including the uncertainty that surrounds them. Failure to do so leaves them vulnerable to surprise future shifts in mortality that affect the appropriate level of reserves and capital they need to hold.

[81] Within Europe, the WHO highlights "the loss of the traditional Mediterranean diet patterns in Southern Europe [and] to the increased intake of sugar and energy-dense foods combined with particularly low levels of physical activity". www.cnn.com/2018/09/11/health/world-health-organization-europe-report-intl/index.html

[82] See: www.ncbi.nlm.nih.gov/pmc/articles/PMC5024386/

Conclusions

From a statistical perspective, it is too early to tell if the recent slowdown in mortality improvement is permanent.

The recent data suggest a slowdown in mortality improvement in many developed countries relative to past trends. Statistically however, it is difficult to conclude whether this represents a genuine structural change or simply reflects annual volatility in death rates. The longer it persists, the more likely it is that the underlying trend has changed. But it is too early to tell. Even with richer data analytics and increased understanding of the underlying drivers of mortality, predicting future developments in life expectancy will remain challenging.

This slowdown might reflect diminishing returns from past medical innovations …

At face value, the slowdown in mortality improvement should perhaps not come as too much of a surprise. A large contributor to the recent slowdown in mortality improvement since the late 2000s has been smaller improvements in mortality related to circulatory disease. As these deaths account for a lower share of total deaths, the same rate of improvement has less impact on overall mortality experience. Moreover, it was always possible that at some point additional longevity gains from technological medical breakthroughs would start to moderate. Circulatory diseases have been relatively easy to tackle compared with cancer or dementia, which suggests that medical innovation will be necessary to achieve comparable mortality gains.

… but tech-led innovation aimed at early detection of diseases could support future mortality gains.

The discovery of such medical innovations could yet prolong lives further. However, new drugs and treatments are increasingly expensive to develop and the associated clinical benefits may be limited to a relatively small patient group. Therefore, we believe that major gains in health and longevity in the future will be driven more by better public health policies and consumer choices, rather than by advances in treatment of late stage disease. Advances in technology and medicine will enable earlier diagnosis of the onset of disease.

Public health policies to promote healthy lifestyles will be important.

Effective public health policies will play an important role in promoting healthy lifestyle choices. New strategies to influence behaviour could prevent disease from happening in the first place. Narrowing the mortality gap between healthy sub-groups and the general population could still unlock substantial mortality gains. But the efficacy of such policies and the speed at which the gap is closed will be crucial.

Insurers need to be mindful of the significant uncertainty when adjusting assumptions about mortality.

Insurers and pension schemes need to consider how different the future could be, and form a view on the likely success and availability of public and private health interventions to influence behaviour and prevent disease and death. This is especially the case given that the reported slowdown in mortality improvement for the general population has yet to be echoed among people in higher socio-economic classes, who typically make up the bulk of insureds. Overly conservative pricing to cover the range of future mortality outcomes will make products such as annuities and life insurance unnecessarily expensive. At the same time, prematurely adjusting assumptions about underlying mortality trends will almost inevitably stretch insurers' balance sheets once the liabilities are ultimately re-rated to reflect revised life expectancy realities.

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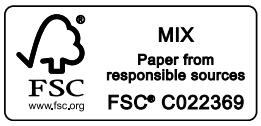

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