Trends in all-cause mortality among people with diagnosed diabetes

Trends in all-cause mortality among people with diagnosed diabetes: a multi-country analysis of aggregate data from 21 million deaths in diabetes in high-income settings

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Research in Context

Evidence before this study

We reported a systematic review of published studies on the trends in all-cause mortality in people with diabetes from Jan 1 1980 to Dec 31 2019. This systematic review showed that declining mortality was present in nearly 80% of the predominantly white populations with diabetes from 2000 to 2016, and nearly 60% of the reported populations with diabetes had a greater or similar annual mortality reduction as compared with those without diabetes. However, this systematic review is limited by different study periods, different age and sex structures of the populations studied, and limited data on younger age groups and non-white populations.

Added value of this study

This is the first multi-country, unit-record analysis of trends in contemporary all-cause mortality data in people with diagnosed total or type 2 diabetes. It shows that all-cause mortality in diabetes has declined in the vast majority of high-income countries we assessed. In nearly 50% of the datasets analysed, mortality decreased more rapidly in people with diabetes than in those without diabetes.

Implications of the available evidence

Maintaining and continual improving cardiometabolic management in diabetes is critical for achieving ongoing reductions in mortality in people with diabetes. It is important to note that there are very limited published data in low and middle-income countries where trends of all-cause mortality among those with diabetes may be different.

ABSTRACT

Background Population-level trends in mortality among people with diabetes are inadequately described. Using a multicountry analysis, we aimed to examine the magnitude and trends in excess mortality related to diabetes.

Methods We collected data from 1995-2016 on all-cause mortality in people with diagnosed diabetes from 19 data sources in 16 jurisdictions. Data were from administrative sources, health insurance records, registries and a health-survey. Excess mortality was estimated as the standardised mortality ratio (SMR).

Findings There were 21 million deaths during 0.5 billion person-years among people with diagnosed diabetes. Seventeen of nineteen data sources showed declines in the age- and sex-standardised mortality rates in people with diabetes, with an annual percentage change in mortality ranging from -4.2% to -0.5%. The largest declines in mortality were observed in East and South East Asia (Hong Kong, South Korea, Taiwan, Singapore). Mortality decreased over time at all ages in most countries, with a suggestion in some countries that the rate of decrease may have been greater at younger ages. Among the 17 data sources with declining mortality among persons with diabetes, we found a significant SMR increase in 5, no significant SMR change in 4, and a significant SMR decrease in 8 jurisdictions.

Interpretation and funding All-cause mortality in diabetes has declined in most of the high-income countries we assessed. In nearly 50% of the datasets analysed, mortality decreased more rapidly in people with diabetes than in those without diabetes. Further longevity gains will require continued improvement in prevention and management of diabetes.

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INTRODUCTION

Mortality among those with diabetes, and how it changes over time, is an important indicator of quality of, and access to, healthcare.[1] Reports examining all-cause mortality among people with diabetes have shown declining rates in some countries for the last decade,[2] with similar trends observed in general populations, but whether these trends differ by age and sex is not known.[3] Data from these studies are also complicated by differences in how mortality analyses were conducted. The most robust method to examine mortality draws both the numerator and the denominator from those with diabetes. Many studies, however, use a general population denominator in the calculation of death rates and identify diabetes deaths using diabetes-specific International Classification of Disease (ICD) codes on death certificates,[4] rather than ascertaining mortality among people with verified diabetes status.

To address these limitations, we previously undertook a systematic review, and found that declining mortality was reported in nearly 80% of populations of predominantly European descent from 2000 to 2016, and that annual mortality reduction was greater than or similar to those without diabetes in over half the populations studied.[3] These findings were limited by differences in study periods, in definitions of age and sex strata, and limited data on younger age-groups and non-European populations. Further, we were not able to provide comparisons with mortality trends in the general population.

One significant limitation with systematic reviews is publication bias and inappropriate influence of studies with notable findings. Consequently, we established the first-ever, multi-national assembly of individual-level data to investigate diabetes mortality and incidence.[7] With this resource, we aimed to examine the magnitude and trends in excess mortality related to diabetes.

METHODS

Data sources

We collected aggregate data on all-cause mortality in people with diagnosed total or type 2 diabetes (referred to as diabetes hereafter) from an international diabetes consortium across 16 high-income countries or jurisdictions.[5] The details of the consortium database have been described elsewhere.[5] Nineteen sources (16 jurisdictions) (Table 1) provided aggregate data for each individual calendar year on population size, counts of prevalent diabetes, death counts and person-years in people with and without diagnosed diabetes by sex and 5-year age-group (<20, 20–24, 25–29, …, 80–84 and 85+ years) for 1995–2016 (or a subset of the period).

Assessment of diabetes status and vital status

Diabetes status and, where available, type of diabetes was determined by various definitions, including blood glucose, $HbA_{1c,}$ linkage to medication or reimbursement registries, clinical diagnosis records provided by physicians, self-report in health surveys, or algorithms based on several of these elements. Type of diabetes was determined using clinical diagnosis (by ICD codes or healthcare professionals) or algorithms using age at diabetes onset and age at starting insulin treatment. Death in people with diabetes was determined by linkage to the national death registries or national population registers.

Quality of the included data

Two authors independently assessed risk of bias using a modified Newcastle-Ottawa Scale (NOS)[6] (appendix, section 1). Disagreements were resolved with discussion with a third author. Risk of bias was classified as high (score 0-5), medium (6-7), or low (8-9).

The Human Ethics Committee of Alfred Health, Melbourne, Australia approved this study.

Statistical Modelling

We modeled mortality rates, using age (defined as the midpoint of each 5-year age-group) and calendar time as continuous variables, and calendar time interval (one year) in men and women separately for each data source. We used Poisson regression for multiplicative models with death as the outcome and log (person-years) as the offset. We fitted age-period-cohort models[9] using cubic splines for the effects. Knots for the splines were placed at evenly spaced quantiles of the marginal distribution of the event times for each of the three variables in the model (age, period [calendar time] and cohort [period minus age]). For each data source and sex, we plotted the estimated mortality rates by age for a select set of dates four years apart, spanning the observation period, as well as mortality rates by period for five ages (40, 50, 60, 70 and 80 years). The estimated rates from the age-period-cohort models for each data source were used to compute age-standardised mortality rates using direct standardisation (using the total diabetes population formed by pooling the consortium data) by calendar time, both for men and women separately as well as jointly. We also fitted a set of age-period models with smooth age-effects but a linear effect of calendar time for each data source, providing an overall summary of the annual changes in mortality rates by sex for each data source. 95% confidence intervals were computed as Wald CIs (back transformed from log rates ±1.96 SE). We computed the standardised mortality ratio (SMR) by calculating the ratio of the observed number of deaths in the diabetes population to the expected number if mortality was the same as in the non-diabetes population. An SMR of 1 implies identical mortality in people with and without diabetes.

The SMR was modeled in a similar way as the mortality rates, using Poisson regression for multiplicative models with observed number of deaths as the outcome and the log (expected

number of deaths) as the offset. SMR was modelled by fitting models with a linear effect of calendar time for each data source, providing an overall summary of the annual changes in SMR by sex for each data source. A description of statistical models used is available in the appendix material (http://bendixcarstensen.com/IDI/global/ESM-m.pdf).

Stata software version 15.1 (Stata Corporation, College Station, TX, USA) was used for data management, and R software version 3.6.3 (R Foundation for Statistical Computing, Vienna, Austria) was used for statistical analyses and graphics.

RESULTS

Characteristics of the included data sources

Mortality data in people with diagnosed diabetes were available from 19 data sources from 16 jurisdictions (table 1). Three of the data sources were from East Asia (Hong Kong, South Korea and Taiwan) and one was from South East Asia (Singapore). Data were included from a variety of sources: nine of 19 (47%) were administrative data, four (21%) were registries, five (26%) were health insurance data, and one was a nationally representative survey (5%). 12 of the 19 data sources included the whole population with diabetes in the relevant countries or jurisdictions. A further three data sources are nationally representative samples. The remaining four include two health insurers from Israel, which collectively cover 70% of the national population, a US health insurer and the US Medicare (appendix, table A1).

Diabetes was defined by algorithms incorporating at least two different criteria in nine (47%) data sources; clinical diagnosis in seven (37%); diabetes medication use in two (11%); and by self-report of a health-care provider diagnosis in one (5%). Ten datasets (53%) provided death counts specifically in people with type 2 diabetes while the remainder had counts in people with all types of diabetes. Quality scores ranged from 5 to 9, with a median of 7 (IQR: 6–8) (appendix, table A1). There were approximately 21 million deaths during 0.5 billion person-years in people with diabetes (appendix, tables A2-A4).

Trends in all-cause mortality rates in people with diagnosed diabetes

Figure 1 and appendix tables A5-A7 show the age- and sex-standardised mortality rates in people with diabetes. These ranged from 13.3–42.1 deaths per 1000 person-years. During the period for which data were available, all-cause mortality in people with diabetes declined in all data sources except Spain and Norway (figure 1; appendix table A8). Trends in age-standardised mortality rates did not differ materially by sex (appendix figure A2, tables A9-

A10). The annual estimated change in mortality rates among those with diabetes over the whole study period ranged from -0.5% to -4.2% in the data sources with declining mortality (figure 2; appendix, table A8). For Spain, annual mortality in those with diabetes increased in men and women (figure A6; appendix, tables A8-A10). For Norway, the annual percentage change declined in men but was stable in women (Figure A6, appendix, table A8-10). Figure 2 also shows mortality in diabetes fell more rapidly in the countries from East Asia and South East Asia. The four jurisdictions in these regions (Hong Kong, South Korea, Taiwan and Singapore) had the four largest reductions in mortality, and Hong Kong and Singapore were also among those jurisdictions with the largest falls in SMR (figure 2 right panel).

Trends in mortality in people with diagnosed diabetes by age and sex

Age-specific and calendar time-specific mortality trends by sex are shown for each data source in the appendix (figures A9-A27). Among the 17 data sources with a declining mortality in people with diabetes, 16 showed a downward trend at most ages in both sexes. In Spain, mortality in people with diabetes increased for all age/sex groups, while mortality trends were relatively stable at all ages for men and slightly declining in women in Norway.

In some countries, the rate of decline appears to have been greater at younger ages than at older ages (appendix, figure A47-A48).

Trends in mortality in people with diagnosed diabetes relative to people without diabetes

Figure 2 (right panel) and appendix table A8 (right panel) show the annual estimated change in SMR (excess mortality) in people with diabetes relative to those without diabetes over the study period. Over the whole period, the SMRs declined in 9/19 data sources, were stable in four, and increased in six data sources (appendix, table A8). The annual estimated change in

SMR between diabetes and non-diabetes ranged from -3.0% (US Medicare) to 1.6% (Lombardy, Italy) (appendix, table A8).

Among the 17 data sources with declining mortality among persons with diabetes, we found a significant SMR increase in 5, no significant SMR change in 4, and a significant SMR decrease in 8 (figure 2, right panel; appendix, figure A5, table A8). In Spain, mortality in diabetes increased (1.1% per year), but at a slower rate than they did in those without diabetes (1.9% per year) (table A8). Trends in the SMRs were broadly similar in men and women (appendix tables A9-A10, figures A4).

Trends in mortality in people with diagnosed diabetes relative to people without diabetes (SMR) by age and sex

SMR trends by age and sex are shown for each data source in the appendix (figures A28-A46). In most data sources, women had a higher SMR than men at the five selected ages. The SMRs were highest in the youngest ages in all countries except for Australia (women) and Israel (MHS), both of which had the highest SMR at 50 years of age. The trends in SMR over calendar time were similar across ages for most countries. Denmark (figure A30) showed a slight decrease in older ages, but stable SMRs in younger ages; Hungary (figure A32) showed an increase in younger ages and stability in older ages, whereas Taiwan (figure A43) and South Korea (figure A41) showed a decrease in SMR among younger (<50 years) and a slight increase in older persons.

DISCUSSION

Among people with diabetes from 19 data sources in 16 high-income countries or jurisdictions, we show that absolute mortality declined in all but two countries (Spain and Norway) over the study period of 2002 to 2016. Spain showed increases in mortality and in Norway there was a non-significant fall in mortality. The greatest mortality declines were observed among people with diabetes in East Asia (Hong Kong, South Korea, Taiwan) and South East Asia (Singapore), among which Hong Kong and Singapore also showed statistically significant reductions in SMR. Annual mortality declines among those with diabetes were greater or similar to those without diabetes in 12 of the 17 data sources with an overall declining mortality trend, including all of the data from East and South East Asia.

These findings are consistent with our systematic review, in which we reported declining mortality in nearly 80% of predominantly European populations with diabetes from 2000 to 2016. In that analysis, nearly 60% of the populations with diabetes had greater or similar annual mortality reduction as people without diabetes.[3]

We found substantial variation of mortality between populations of people with diabetes, though much of this reflects similar levels of variation in the general populations (data not shown). In Catalonia (Spain), mortality in people with diabetes increased, however, it increased more rapidly in the non-diabetic population (in both Catalonia and Spain).[7] Increasing mortality in Spain has been attributed to increased influenza activity in these years as well as restrictions in the healthcare system following the global financial crisis.[8] In Norway, mortality declined, but this was not significant, presumably due to the small number of years of data from this country.

We found that the mortality reduction in people with diabetes surpassed or was similar to the mortality reduction in the population without diabetes in two thirds of data sources examined. The narrowing of the gap in mortality rates between people with and without diabetes suggests that health care in diabetes continues to improve over time, at least in the high-income countries represented here. The absence of this narrowing of the mortality difference in some countries warrants further research.

While our findings are consistent with several country-specific publications of mortality with diabetes, such as those from Scotland,[9] US[10], UK[11] and Denmark,[12] the Global Burden of Disease, Injuries, and Risk Factors Study (GBD) reports an increase in global death rates for diabetes from 1990 to 2015.[4] However, the GBD uses the total national population as the denominator for estimating mortality rates, and therefore does not account for increases in diabetes prevalence.

An unexpected finding from this study is that the greatest mortality declines in diabetes were seen in East Asia and South East Asia. In addition, in these regions, mortality reductions in diabetes were greater than or comparable to mortality changes in people without diabetes. Possible reasons for these observations are that these jurisdictions have had stronger improvements in models of care for those with diabetes or that each jurisdiction has improved their health care system which may have led to better management of risk factors. A recent Hong Kong study showed improvements in metabolic control in those with diabetes.[13] Further, in Hong Kong, in 1993 universal health coverage was introduced, and there have been major changes in integrating diabetes management, expanding services across primary, secondary and tertiary care. These services included regular and structured \risk assessment and education programs delivered by non-physician staff. Systematic data collection was also implemented

which helped identify trends and unmet needs to inform decision-making.[14] In 2016, the Singapore government established the national Diabetes Prevention and Care Taskforce, which includes a government and primary care network collaboration providing more services to people with diabetes, as well as support for primary care.[15] [16]Similar programs exist in Taiwan.[17] It is unclear if these programs have been more effective than programs and policies in other countries. It is also possible that the higher prevalence of diabetes in high-income East and South East Asian countries, and the high burden of renal complications of diabetes in Asia, could have led to more concerted efforts towards improving diabetes management. Increased screening for diabetes in these countries could also lead to apparent reductions in mortality, due to an increase in individuals with lower mortality among the diabetic population. However, since the incidence of diabetes is decreasing in three of the Asian jurisdictions in which we see rapid declines in mortality,[5] this explanation seems unlikely.

Improved survival was similar across all ages, in contrast to the findings in our systematic review on mortality trends.[3] US national data also showed significant declines in mortality in elderly people and a smaller magnitude of decline in younger age groups.[10] Similarly, in the Hong Kong Diabetes Surveillance Database, all-cause death rates decreased by 50–80% between 2001 and 2016, except for those aged 20–44 years in which they remained stable.[18]

Several factors could explain the declining mortality in people with diabetes observed. Population-level health promotion on tobacco cessation and lifestyle modification certainly has led to reductions in levels of some risk factors, including smoking[19], blood pressure[20] and cholesterol,[21] which may have translated into improved mortality. Further, the use of antihypertensive[22] and lipid-lowering medications[23] for the prevention of CVD events among high-risk people has increased in the last decades. Hypertension, hypercholesterolaemia, and

hyperglycaemia have been managed more aggressively in recent decades[24,25,26] which also may have contributed to reductions in the rates of diabetes-related complications[10] and, ultimately, improved survival. Lastly, there have been significant advances in medical interventions and care for individuals with acute CVD events and chronic diseases.[27] There have also been major changes in the way health is managed in some countries which could contribute to declining mortality.[14] Changing diagnostic criteria over the last two decades, particularly lowering the diagnostic threshold for fasting glucose, may have identified people at an earlier stage in the natural history of diabetes who have an inherently lower mortality risk. However, the reduction in the fasting glucose diagnostic criterion took place over 20 years ago, and the more recent shift towards $HbA1_c$ as a diagnostic test may have partially offset this by leading to diagnoses later in the disease course.[28] Irrespective of diagnostic criteria, increases in screening activity might also lead to more "early" diagnoses of diabetes, again resulting in falling mortality due to lead-time bias. Also, earlier diagnosis of diabetes, with such changes particularly occurring in the late 1990s and early 2000s, might have facilitated earlier use of interventions with long-term benefits for survival.

There are several strengths of this study. The vast majority of the datasets used are large, and population-based, enabling stratification by age and sex. Further, we employed a standardised approach to collection and assembly of these data. We also performed a rigorous assessment of quality of these data sources and showed the majority of sources were of good quality (median quality score 7/9). In addition to this, among the 19 centres included, 10 (53%) have published reports validating their approach to diabetes diagnoses, with sensitivities and specificities of >85% in all but one centre where it was 75%. A further two (11%) centres are registries of pharmacologically treated type 2 diabetes, which are likely to be highly specific for diabetes. Finally, the *a priori* decision to report on all data sources of adequate quality limits

the impact of publication bias that can arise from the perceived interest in results from a single source. Publication bias refers to the propensity to publish positive compared to non-positive findings.[29,] Systematic reviews, especially those which do not examine the grey literature, are particularly prone to such bias. Our inclusion of datasets without knowledge of their mortality trends, has, at least in part, overcome this bias.

Our study is not without limitations. First, we were unable to ascertain data on diabetes treatment patterns and whether changes in parameters used to assess quality of diabetes care, i.e., the HbA_{1c} levels, blood pressure and LDL-cholesterol levels, were greater in the countries with larger declines in mortality among those with diabetes. Second, methods of diagnosing diabetes vary across the data sources and could even be subject to variation over time within a data source. Although each centre applied the same diagnostic criteria to their data over time, this does not rule out the possibility of changes in coding and clinical practice which may affect diagnostic practice. Also, our data sources report only on clinically diagnosed diabetes and as such are vulnerable to influences from changes in diagnostic behaviour. Third, although we report on diabetes as a whole, it is noteworthy that our findings mainly represent type 2 diabetes as the prevalence of type 2 diabetes is much higher than that of type 1 diabetes. Fourth, we were not able to obtain data on the age at diabetes diagnosis and thus could not examine the relationship of mortality with duration of diabetes. Fifth, not all of the data sources can be confidently extrapolated to the full national population of people with diabetes. Sixth, data were only available from high-income countries, and mortality trends may be different in middle- and low-income countries. Interestingly, data from the PURE study shows that mortality in those with diabetes from middle-income countries has also declined, while mortality in low-income countries is unchanged.[30]

In conclusion, we show that in most of the high-income countries for which data were available, mortality rates among people with diabetes have declined; jurisdictions within East Asia and South East Asia showing the strongest declines. Further, the gap in mortality rates between diabetes and non-diabetes is narrowing in the majority of data sources examined. Our findings highlight the progress in managing diabetes over the last couple of decades and indicate that further longevity gains and reductions in disparities will require continued improvement in prevention and management of diabetes. Lastly, this multi-centre analysis emphasises the value of systematic data collection in driving policies to improve detection, diagnosis and management of diabetes as well as in identifying trends and unmet needs for continuing improvement.

Author contributions:

DJM, EWG, MEP, and JES conceived the study and made contacts with contributing centres. DJM and LC oversaw the practical gathering of data from the centres. LC was responsible for the database. BC and DJM designed and undertook the statistical analysis. LC applied the quality scales to the data from the centres. DJM and LC wrote the manuscript. All other authors curated data from centres into the standardised form. All authors contributed to data interpretation and critical evaluation; contributed to the editing of the report; and approved the final submitted version of the manuscript. DJM, LC, and BC verified the data and had access to raw data (aggregate). DJM, LC, and BC are guarantors of data and analysis integrity JES had final responsibility for the decision to submit for publication.

Disclaimer: The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the US Centers for Disease Control and Prevention.

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Declaration of interests

We declare no competing interests.

Data sharing

Aggregated data may be available upon reasonable request to the corresponding author. Approvals must be obtained from all collaborators with a signed data access agreement.

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Figure legends

Figure 1: Age- and sex-standardised mortality rates among people with diagnosed diabetes per 1000 person-years (standard population was derived from pooled study population with diagnosed diabetes, with equal weights for men and women). Standardisation is based on annual age-specific mortality rates from age-period-cohort models fitted separately for each data source and sex. Shaded areas represent 95% confidence intervals around mortality trends. CHS=Clalit Health Services. KPNW=Kaiser Permanente Northwest. MHS=Maccabi Healthcare Services. NHIS=National Health Interview Survey.

Figure 2: Estimated changes in mortality rates in people with diagnosed diabetes (% per year) and estimated changes in standardised mortality ratio (SMR) (% per year). CHS=Clalit Health Services. KPNW=Kaiser Permanente Northwest. MHS=Maccabi Healthcare Services. NHIS=National Health Interview Survey.

Table 1: Summary characteristics of the 19 data sources

Country /Region	Origin of data	Type of data	Years analysed for mortality	Age range (years)	Person years (1000s)	Number of deaths in diabetes	Diabetes definition	Diabetes type
Australia	National Diabetes Services Scheme	Registry	2002–2015	≥0	10,222	292,628	Clinical diagnosis	Type 2 diabetes
Canada	Canadian Chronic Disease Surveillance System*	Administrative	2000–2015	≥1	27,111	789,710	Algorithm	All diabetes
Denmark	National Register, prescription data base, health insurance data base, diabetes quality database, and eye screening database	Registry	1996–2016	≥0	3,517	158,749	Algorithm	Type 2 diabetes
Hong Kong	Hong Kong Hospital Authority (Hong Kong Diabetes Surveillance Database)	Administrative	2003–2016	≥0	5,375	171,749	Algorithm	All diabetes
Hungary	National Institute of Health Insurance Fund Management database	Administrative	2009–2016	≥0	5,906	246,429	Hypoglycaemic medications	Type 2 diabetes
Israel	Clalit Health Services	Health insurance	2004–2016	≥0	4,252	172,182	Algorithm	All diabetes
Israel	Maccabi Healthcare Services	Health insurance	2001–2015	≥0	1,160	26,033	Algorithm	Type 2 diabetes
Lombardy, Italy	Administrative health databases	Administrative	2002–2012	≥0	3,962	182,439	Algorithm	All diabetes
Latvia	Latvian Diabetes Registry	Registry	2000–2016	≥0	986	47,446	Clinical diagnosis (ICD-10)	Type 2 diabetes
Lithuania	National Compulsory Health Insurance Fund Information System	Administrative	2003–2016	≥0	1,274	58,625	Clinical diagnosis (ICD-10)	All diabetes
Norway	Norwegian Registry, Primary Care Database and Norwegian Prescription Database	Administrative	2009–2014	≥0	1,116	39,452	Clinical diagnosis (ICD-10, ICPC-2)	Type 2 diabetes

Country /Region	Origin of data	Type of data	Years analysed for mortality	Age range (years)	Person years (1000s)	Number of deaths in diabetes	Diabetes definition	Diabetes type
Scotland	Scottish Care Information-Diabetes database	Registry	2004–2015	≥0	2,393	95,285	Clinical diagnosis (Read codes)	Type 2 diabetes
Singapore	National administrative data held by the Ministry of Health of Singapore	Administrative	2012– 2016	≥0	1,436	37,959	Clinical diagnosis (ICD-10)	All diabetes
South Korea	National Health Insurance Service – National Sample cohort	Health insurance	2008– 2015	≥0	414	10,431	Hypoglycaemic medications	All diabetes
Spain	Information System for the Development of Research in Primary Care	Administrative	2007–2016	≥0	3,265	114,294	Clinical diagnosis (ICD-10)	Type 2 diabetes
Taiwan	National Health Insurance Research Database (LHID 2000)	Health insurance	2002–2011	≥0	656	17,630	Algorithm	Type 2 diabetes
USA	KPNW (Integrated managed care consortium)	Health Insurance	1995–2016	≥0	589	18,011	Algorithm	Type 2 diabetes
USA	Medicare (claims data for beneficiaries)	Administrative	2001–2015	≥68	83,231	6,979,017	Algorithm	All diabetes
USA	NHIS[#]	Survey	1995–2015	≥20	325,319	11,463,555	Self-report	All diabetes

ICD-10=International Classification of Diseases, version 10. ICPC-2=International Classification of Primary Care, second version. KPNW=Kaiser Permanente Northwest. LHID 2000=Longitudinal Health Insurance Database randomly sampled from the registered beneficiaries in the year 2000. NHIS=National Health Interview Survey. *This Canadian data source excluded data from Yukon Territory, Saskatchewan and Quebec. Furthermore, data from Nova Scotia excluded people aged 1-19 years. [#]The weighted numbers of deaths were generated from a sample of 226,698 people aged >= 20 years in 1995-2015.

Figure 1: Age- and sex-standardised mortality rates among people with diagnosed diabetes per 1000 person-years (standard population was derived from the pooled study population with diagnosed diabetes, with equal weights for men and women). Standardisation is based on annual age-specific mortality rates from age-period-cohort models fitted separately for each data source and sex. Shaded areas represent 95% confidence intervals around mortality trends. CHS=Clalit Health Services. KPNW=Kaiser Permanente Northwest. MHS=Maccabi Healthcare Services. NHIS=National Health Interview Survey.

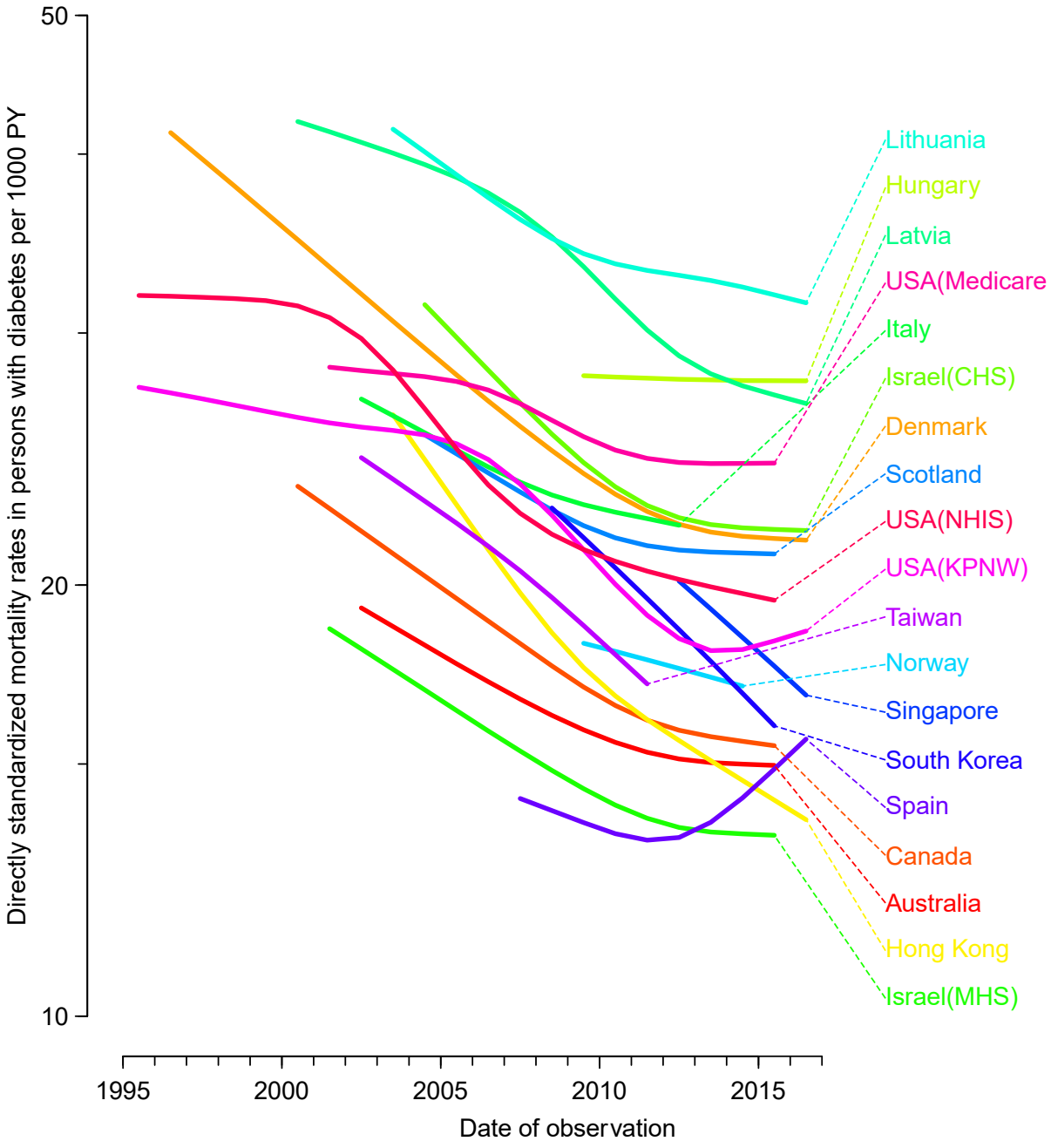

Figure 2: Estimated changes in mortality rates in people with diagnosed diabetes (left panel), and estimated changes in standardised mortality ratio (SMR) (% per year) (right panel). CHS=Clalit Health Services. KPNW=Kaiser Permanente Northwest. MHS=Maccabi Healthcare Services. NHIS=National Health Interview Survey.