Lifetime risk, life expectancy, and years of life lost to type 2 diabetes in 23 high-income jurisdictions: a multinational, population-based study

Dunya Tomic, Jedidiah I Morton, Lei Chen, Agus Salim, Edward W Gregg, Meda E Pavkov, Martti Arffman, Ran Balicer, Marta Baviera, Elise Boersma-van Dam, Ralph Brinks, Bendix Carstensen, Juliana C N Chan, Yiling J Cheng, Sandrine Fosse-Edorh, Sonsoles Fuentes, Hélène Gardiner, Hanne L Gulseth, Romualdas Gurevicius, Kyoung Hwa Ha, Annika Hoyer, György Jermendy, Alexandra Kautzky-Willer, Ilmo Keskimäki, Dae Jung Kim, Zoltán Kiss, Peter Klimek, Maya Leventer-Roberts, Chun-Yi Lin, Paz Lopez-Doriga Ruiz, Andrea O Y Luk, Stefan Ma, Manel Mata-Cases, Dídac Mauricio, Stuart McGurnaghan, Tomoaki Imamura, Sanjoy K Paul, Anna Peeters, Santa Pildava, Avi Porath, Cynthia Robitaille, Maria Carla Roncaglioni, Takehiro Sugiyama, Kang-Ling Wang, Sarah H Wild, Naama Yekutiel, Jonathan E Shaw, Dianna J Magliano**

Summary

Background Diabetes is a major public health issue. Because lifetime risk, life expectancy, and years of life lost are meaningful metrics for clinical decision making, we aimed to estimate these measures for type 2 diabetes in the high-income setting.

Methods For this multinational, population-based study, we sourced data from 24 databases for 23 jurisdictions (either whole countries or regions of a country): Australia; Austria; Canada; Denmark; Finland; France; Germany; Hong Kong; Hungary; Israel; Italy; Japan; Latvia; Lithuania; the Netherlands; Norway; Scotland; Singapore; South Korea; Spain; Taiwan; the UK; and the USA. Our main outcomes were lifetime risk of type 2 diabetes, life expectancy in people with and without type 2 diabetes, and years of life lost to type 2 diabetes. We modelled the incidence and mortality of type 2 diabetes in people with and without type 2 diabetes in sex-stratified, age-adjusted, and calendar year-adjusted Poisson models for each jurisdiction. Using incidence and mortality, we constructed life tables for people of both sexes aged 20–100 years for each jurisdiction and at two timepoints 5 years apart in the period 2005–19 where possible. Life expectancy from a given age was computed as the area under the survival curves and lifetime lost was calculated as the difference between the expected lifetime of people with versus without type 2 diabetes at a given age. Lifetime risk was calculated as the proportion of each cohort who developed type 2 diabetes between the ages of 20 years and 100 years. We estimated 95% CIs using parametric bootstrapping.

Findings Across all study cohorts from the 23 jurisdictions (total person-years 1 577 234 194), there were 5 119 585 incident cases of type 2 diabetes, 4 007 064 deaths in those with type 2 diabetes, and 11 854 043 deaths in those without type 2 diabetes. The lifetime risk of type 2 diabetes ranged from 16·3% (95% CI 15·6–17·0) for Scottish women to 59·6% (58·5–60·8) for Singaporean men. Lifetime risk declined with time in 11 of the 15 jurisdictions for which two timepoints were studied. Among people with type 2 diabetes, the highest life expectancies were found for both sexes in Japan in 2017–18, where life expectancy at age 20 years was 59·2 years (95% CI 59·2–59·3) for men and 64·1 years (64·0–64·2) for women. The lowest life expectancy at age 20 years with type 2 diabetes was observed in 2013–14 in Lithuania (43·7 years [42·7–44·6]) for men and in 2010–11 in Latvia (54·2 years [53·4–54·9]) for women. Life expectancy in people with type 2 diabetes increased with time for both sexes in all jurisdictions, except for Spain and Scotland. The life expectancy gap between those with and without type 2 diabetes declined substantially in Latvia from 2010–11 to 2015–16 and in the USA from 2009–10 to 2014–15. Years of life lost to type 2 diabetes ranged from 2·5 years (Latvia; 2015–16) to 12·9 years (Israel Clalit Health Services; 2015–16) for 20-year-old men and from 3·1 years (Finland; 2011–12) to 11·2 years (Israel Clalit Health Services; 2010–11 and 2015–16) for 20-year-old women. With time, the expected number of years of life lost to type 2 diabetes decreased in some jurisdictions and increased in others. The greatest decrease in years of life lost to type 2 diabetes occurred in the USA between 2009–10 and 2014–15 for 20-year-old men (a decrease of 2·7 years).

Interpretation Despite declining lifetime risk and improvements in life expectancy for those with type 2 diabetes in many high-income jurisdictions, the burden of type 2 diabetes remains substantial. Public health strategies might benefit from tailored approaches to continue to improve health outcomes for people with diabetes.

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*Joint senior authors

Baker Heart and Diabetes Institute, Melbourne, VIC, Australia (D Tomic MBBS(Hons), J I Morton BSc(Hons), L Chen PhD, A Salim PhD, Prof J E Shaw MD, Prof D J Magliano PhD); **School of Public Health and Preventive Medicine** (D Tomic, J I Morton, Prof J E Shaw, Prof D J Magliano) **and Centre for Medicine Use and Safety** (J I Morton), **Monash University, Melbourne, VIC, Australia; Melbourne School of Population and Global Health** (A Salim), **School of Mathematics and Statistics** (A Salim), **and Department of Medicine** (Prof S K Paul PhD), **University of Melbourne, Melbourne, VIC, Australia; Department of Epidemiology and Biostatistics, School of Public Health, Imperial College London, London, UK** (Prof E W Gregg PhD); **Division of Diabetes Translation, Centers for Diseases Control and Prevention, Atlanta, GA, USA** (M E Pavkov MD, Y J Cheng PhD); **Welfare State Research and Reform, Finnish Institute for Health and Welfare, Helsinki, Finland** (M Arffman MSc, Prof I Keskimäki PhD); **Clalit Research Institute, Clalit Health Services, Tel Aviv, Israel** (Prof R Balicer MD, M Leventer-Roberts MD); **Laboratory of Cardiovascular Prevention, Mario Negri Institute for Pharmacological**

Research, IRCCS, Milan, Italy (M Baviera PharmD, M C Roncaglioni MSc); Department of General Practice, Netherlands Institute for Health Services Research, Utrecht, Netherlands (E Boersma-van Dam MSc); Institute for Biometrics and Epidemiology, German Diabetes Center, Duesseldorf, Germany (Prof R Brinks PhD); Institute for Medical Biometry and Epidemiology, University Witten/Herdecke, Witten, Germany (Prof R Brinks); Clinical Epidemiology, Steno Diabetes Center Copenhagen, Herlev, Denmark (B Carstensen MSc[Stat]); Department of Medicine and Therapeutics, Li Ka Shing Institute of Health Sciences, Hong Kong Institute of Diabetes and Obesity, Chinese University of Hong Kong, Prince of Wales Hospital, Hong Kong Special Administrative Region, China (Prof J C N Chan MD, A O Y Luk MD); Department of Non-Communicable Diseases and Trauma, Santé Publique France, Saint-Maurice, France (S Fosse-Edorh PhD, S Fuentes MPH); Centre for Surveillance and Applied Research, Public Health Agency of Canada, Ottawa, ON, Canada (H Gardiner MPH, C Robitaille MSc); Department for Chronic Diseases, Norwegian Institute of Public Health, Oslo, Norway (H L Gulseth MD, P Lopez-Doriga Ruiz MD); Center of Health Information, Institute of Hygiene, Vilnius, Lithuania (Prof R Gurevicius PhD); Faculty of Public Governance and Business, Mykolas Romeris University, Vilnius, Lithuania (Prof R Gurevicius); Department of Endocrinology and Metabolism, Ajou University School of Medicine, Suwon, South Korea (Prof K H Ha PhD, Prof D J Kim MD); Biostatistics and Medical Biometry, Medical School EWL, Bielefeld University, Bielefeld, Germany (Prof A Hoyer PhD); Third Medical Department, Bajcsy-Zsilinszky Hospital, Budapest, Hungary (G Jermendy DSc); Department of Medicine III, Endocrinology and Metabolism (Prof A Kautzky-Willer MD) and Section for Science of Complex Systems (Prof P Klimek PhD),

Research in context

Evidence before this study

We searched PubMed for articles published in English between Jan 1, 1990, and March 31, 2022, using the search terms "diabetes" AND "lifetime risk" OR "life expectancy" OR "years of life lost". We found 15 country-level studies reporting on lifetime risk, life expectancy, or years of life lost with respect to type 2 diabetes. Few studies investigated trends with time by use of actual contemporary data and none compared observations across jurisdictions.

Added value of this study

Using data from 24 population-based data sources from 23 high-income jurisdictions across Europe, Asia, North America, and Oceania, we estimated the lifetime risk of type 2 diabetes, life expectancy in people with and without type 2 diabetes, and years of life lost to type 2 diabetes for each jurisdiction and, where possible, at two timepoints 5 years apart in the period 2005–19. We showed that the lifetime risk of type 2 diabetes declined between the two timepoints in most jurisdictions but remained around 50% in Israel and Hong Kong. Life expectancy for people with type 2 diabetes increased with time in most jurisdictions, which was generally in line with the increase observed for people without type 2 diabetes. However, in Latvia and the USA, the increase in life expectancy was substantially greater for those with versus without type 2 diabetes. We found great variation in years of life lost to the disease.

Implications of all the available evidence

With the incidence of type 2 diabetes declining in the high-income setting, there has been a corresponding decrease in lifetime risk in many high-income jurisdictions. However, the burden of diabetes remains high. This substantial individual burden should be considered in future public health strategy and emphasised in patient counselling to improve health outcomes for people with type 2 diabetes.

Introduction

Diabetes is a major public health issue. In 2017, an estimated 451 million adults lived with diabetes, a number that is projected to increase to nearly 700 million by 2045.[1] Incidence, prevalence, and mortality data have underpinned our understanding of the burden of diabetes. However, other metrics, such as lifetime risk, life expectancy, and years of life lost, often provide a more meaningful perspective for clinical and public health decision making. These metrics have been reported in several jurisdictions, including the USA,[2] Australia,[3] Denmark,[4] Brazil,[5] and Germany,[6] but, to date, no analysis has incorporated data on diabetes from multiple jurisdictions. Because these metrics are a consequence of both incidence and mortality, they need to be estimated from models that integrate the impact of incidence and mortality across the life course. We aimed to estimate the lifetime risk of type 2 diabetes, life expectancy in people with and without type 2 diabetes, and years of life lost to type 2 diabetes in high-income jurisdictions.

Methods

Study design and data sources

For this multinational, population-based study, we identified data sources through a previously published systematic review[7] of the incidence of type 2 diabetes and networks of investigators. In that systematic review, the authors searched MEDLINE, Embase, and CINAHL without language restrictions for articles published between January, 1980, and December, 2017 (appendix p 2). All titles and abstracts of the articles found were screened by at least two authors. To be eligible for inclusion in our analysis, data sources needed to have ongoing enrolment of new members; record incident diabetes; record sex-specific and age-specific data; and include at least 5000 people in the population at risk of developing diabetes each year. We sourced data from 24 databases for 23 jurisdictions (either whole countries or regions of a country): Australia; Austria; Canada; Denmark; Finland; France; Germany; Hong Kong; Hungary; Israel; Italy; Japan; Latvia; Lithuania; the Netherlands; Norway; Scotland; Singapore; South Korea; Spain; Taiwan; the UK; and the USA. Five data sources did not capture whole countries. The two Israeli data sources captured data from two of Israel's four health services (Clalit Health Services and Maccabi Healthcare Services), the Canadian data source excluded Yukon Territory and Saskatchewan, the Italian data source only included the Lombardy region, and the Spanish data source only included the Catalonia region. We assessed all data sources for quality in a previous analysis[8] using a modified Newcastle–Ottawa scale. Summary characteristics of the jurisdictions' data sources, including how diabetes types were separated where possible, can be found in the appendix (p 3). Diabetes definitions varied across jurisdictions (appendix p 4) and either used clinical diagnosis, prescriptions for diabetes medications, various algorithms (eg, a combination of hospital discharge codes, prescriptions for diabetes medications, and laboratory tests), or self-report (USA only). The measurement of incidence within each dataset was consistent across time. The Alfred Health Human Research Ethics Committee provided ethics approval for this study. Patient consent was not required.

Procedures

We collected aggregated data from these 23 jurisdictions on population size, counts of prevalent diabetes, death counts, and person-years of follow-up in people with and without diagnosed diabetes by sex and age group

(20–24 years, 25–29 years, 30–34 years, 35–39 years, 40–44 years, 45–49 years, 50–54 years, 55–59 years, 60–64 years, 65–69 years, 70–74 years, 75–79 years, 80–84 years, and ≥85 years) for each individual calendar year between Jan 1, 2005, and Dec 31, 2019 (or a subset of this period).

Outcomes and statistical analysis

Our main outcomes were lifetime risk of type 2 diabetes, life expectancy in people with and without type 2 diabetes, and years of life lost to type 2 diabetes. For incident diabetes cases, data on type 2 diabetes were used when data were available on diabetes type. For the 11 jurisdictions that did not split data by diabetes type, all diabetes, rather than type 2 diabetes specifically, was used as a proxy in the analysis. This approach was justified by the fact that around 90% of prevalent diabetes is type 2 diabetes[9] and that people with type 2 diabetes in our study represented an even higher proportion of all people with incident diabetes for the data sources in which diabetes was split by type.

We modelled the incidence (λ) and mortality of type 2 diabetes in those without type 2 diabetes (μ_{ND}) and those with type 2 diabetes (μ_{DM}) using events (incident cases and deaths) as outcomes and person-years as the offset in Poisson regression, with a spline effect of age (coded as the midpoint of the age class) and calendar time (coded as the midpoint of the year) as independent variables. Estimates were made separately for each sex and jurisdiction. For four jurisdictions (France, Germany, the Netherlands, and the UK), mortality data for those with and without type 2 diabetes could not be provided due to the low quality of information on the date of death. For these jurisdictions, we obtained all-cause mortality rates from the Human Mortality Database (HMD) and age-specific relative risks of mortality in those with and without type 2 diabetes from articles[10–13] published in the relevant jurisdictions. Using these data, we derived age-specific and sex-specific mortality in people with and without type 2 diabetes through the relationships $\mu_{HMD}=\mu_{DM}p+\mu_{ND}(1-p)$ and $\mu_{DM}=\mu_{ND}RR$, where μ_{HMD} is the overall mortality from the HMD, p is the age-specific prevalence of type 2 diabetes provided by the data sources, and RR is the age-specific relative risk of mortality associated with type 2 diabetes. These equations lead to $\mu_{DM}=\mu_{HMD}\times(1-\delta)$ and $\mu_{ND}=\mu_{HMD}\times\delta$, where $\delta=1/(1+p[RR-1])$. RR and p were assumed known without error.

We predicted the incidence of type 2 diabetes and mortality in those with and without type 2 diabetes for fixed dates at the midpoints of 1-year age intervals. These data were used to compute 1-year transition probabilities from the state of No type 2 diabetes to the states of Type 2 diabetes and Dead and from the state of Type 2 diabetes to Dead (figure 1). For people in the state of No type 2 diabetes, the probability of remaining in this state was $\exp(-[\lambda+\mu_{ND}]\ell)$. For people in the Type 2 diabetes state, the probability of remaining in this state was $\exp(-\mu_{DM}\ell)$. Transition probabilities were used in transition probability matrices for a multi-state life table with three states (No type 2 diabetes, Type 2 diabetes, and Dead).

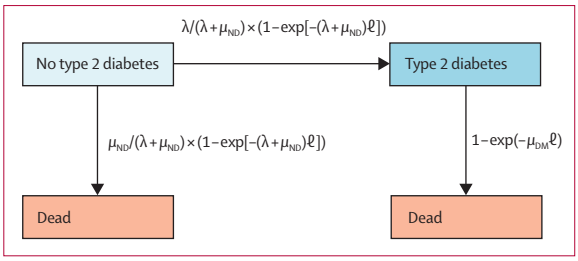

Figure 1: **Life table states and associated transition probabilities for a period of time ℓ**

ℓ=period of 1 year. λ=type 2 diabetes incidence. μ_{ND}=mortality in people without type 2 diabetes. μ_{DM}=mortality in people with type 2 diabetes.

We used our model to compute the survival of people in the No type 2 diabetes state or the Type 2 diabetes state at a given age, the probability of being in the No type 2 diabetes or Type 2 diabetes states, the cumulative risk of diabetes, and the probability of being in either the Type 2 diabetes or Dead states after having been in the Type 2 diabetes state. Calculations were done along the age-scale for fixed calendar time (by use of cross-sectional rates).

We used life table models[14] to simulate the progression of a cohort of 20-year-olds free of type 2 diabetes at a certain timepoint. The cohort was followed up until death or an age of 100 years. Analyses were done separately in men and women from two timepoints per jurisdiction where possible. Each timepoint was an aggregate of two consecutive calendar years. The later timepoint combined the latest year of data available from a jurisdiction with the preceding calendar year. This combination was used instead of a single year to increase accuracy. The earlier timepoint was a combination of years exactly 5 years before the later timepoint. For jurisdictions with fewer than 7 years of data, a single timepoint was used, which combined the latest 2 years of data. For Austria, life tables started from age 50 years as accurate data were only available for individuals aged 50 years or older. The lifetime risk of type 2 diabetes was calculated as the proportion of each cohort who developed type 2 diabetes between the ages of 20 years and 100 years. We ran two sets of life tables for those with and without type 2 diabetes. Life expectancy from a given age (20 years, 40 years, and 60 years) was computed as the area under the survival curves and lifetime lost was calculated as the difference between the expected lifetime of people with and without type 2 diabetes at a given age (20 years, 40 years, and 60 years). In an additional sensitivity analysis, we ran life tables to age 80 years instead of 100 years and calculated the lifetime risk of developing type 2 diabetes.

Medical University of Vienna, Vienna, Austria; Gender Institute, Gars am Kamp, Austria (Prof A Kautzky-Willer); **Faculty of Social Sciences, Tampere University, Tampere, Finland** (Prof I Keskimäki); **Second Department of Medicine and Nephrological Center, University of Pécs, Pécs, Hungary** (Z Kiss MD); **Complexity Science Hub Vienna, Vienna, Austria** (Prof P Klimek); **Department of Pediatrics** (M Leventer-Roberts) **and Department of Environmental Medicine and Public Health** (M Leventer-Roberts), **Icahn School of Medicine at Mount Sinai, New York, NY, USA; General Clinical Research Center, Taipei Veterans General Hospital, Taipei, Taiwan** (C-Y Lin MSc, K-L Wang MD); **Department of Endocrinology, Morbid Obesity and Preventive Medicine, Oslo University Hospital, Oslo, Norway** (P Lopez-Doriga Ruiz); **Epidemiology and Disease Control Division, Public Health Group, Ministry of Health, Singapore** (S Ma PhD); **CIBER of Diabetes and Associated Metabolic Diseases, Instituto de Salud Carlos III, Barcelona, Spain** (M Mata-Cases MD, Prof D Mauricio MD); **Institut Català de la Salut, Unitat de Suport a la Recerca Barcelona Ciutat, Institut Universitari d'Investigació en Atenció Primària Jordi Gol, Barcelona, Spain** (M Mata-Cases, Prof D Mauricio); **Department of Endocrinology, Hospital de la Santa Creu I Sant Pau, Autonomous University of Barcelona, Barcelona, Spain** (Prof D Mauricio); **Usher Institute, University of Edinburgh, Edinburgh, UK** (S McGurnaghan PhD, Prof S H Wild PhD); **Department of Public Health, Health Management and Policy, Nara Medical University, Nara, Japan** (Prof T Imamura MD); **Institute for Health Transformation, Deakin University, Melbourne, VIC, Australia** (Prof A Peeters PhD); **Research and Health Statistics Department, Centre for Disease Prevention and Control, Riga, Latvia** (S Pildava Mg.Soc); **Research Institute, Maccabi Healthcare Services, Tel Aviv, Israel** (Prof A Porath MD, N Yekutiel MSc); **Faculty of**

Health Sciences, Ben Gurion University, Beer-Sheva, Israel (Prof A Porath)**; Diabetes and Metabolism Information Center, Research Institute** (T Sugiyama MD) **and Institute for Global Health Policy Research, Bureau of International Health Cooperation** (T Sugiyama)**, National Center for Global Health and Medicine, Tokyo, Japan; Department of Health Services Research, University of Tsukuba, Tsukuba, Japan** (T Sugiyama)

Correspondence to: Dr Dunya Tomic, Baker Heart and Diabetes Institute, Melbourne, VIC 3004, Australia **Dee.Tomic@baker.edu.au**

See **Online** for appendix

For the **Human Mortality Database** see https://www.mortality.org/

	Men			Women		
	Lifetime risk at first timepoint (95% CI)	Lifetime risk at second timepoint (95% CI)	Difference across timepoints	Lifetime risk at first timepoint (95% CI)	Lifetime risk at second timepoint (95% CI)	Difference across timepoints
Australia (2013–14; 2018–19)	29·3% (28·9–29·8)	23·0% (22·6–23·5)	–6·3%	22·6% (22·2–23·1)	16·5% (16·1–16·8)	–6·1%
Austria* (2016–17)	27·3% (26·7–27·9)	..	..	24·1% (23·5–24·6)	..	..
Canada (2011–12; 2016–17)	47·6% (47·3–48·0)	45·6% (45·2–46·0)	–2·0%	41·4% (41·0–41·8)	38·7% (38·4–39·1)	–2·7%
Denmark (2013–14; 2018–19)	27·5% (26·7–28·3)	27·4% (26·6–28·2)	–0·1%	22·6% (21·8–23·3)	21·6% (20·8–22·3)	–1·0%
Finland (2011–12; 2016–17)	43·5% (42·6–44·3)	35·1% (34·3–36·0)	–8·4%	40·5% (39·7–41·3)	29·7% (28·9–30·6)	–10·8%
France (2016–17)	30·5% (30·3–30·8)	..	..	25·1% (24·8–25·3)	..	..
Germany (2013–14)	50·0% (49·8–50·2)	..	..	46·0% (45·8–46·2)	..	..
Hong Kong (2013–14; 2018–19)	52·4% (51·6–53·2)	57·0% (56·2–57·8)	4·6%	50·8% (49·9–51·6)	52·5% (51·7–53·3)	1·7%
Hungary (2018–19)	35·5% (34·9–36·0)	..	..	35·7% (35·1–36·2)	..	..
Israel (Clalit Health Services; 2010–11; 2015–16)	58·6% (57·4–59·7)	50·2% (48·9–51·4)	–8·4%	58·1% (57·0–59·1)	45·9% (44·7–47·1)	–12·2%
Israel (Maccabi Healthcare Services; 2009–10; 2014–15)	52·0% (49·8–54·1)	54·7% (52·7–56·7)	2·7%	47·7% (45·6–49·8)	46·8% (44·9–48·8)	–0·9%
Italy (2013–14; 2018–19)	33·1% (32·2–33·9)	35·8% (34·9–36·6)	2·7%	31·0% (30·2–31·9)	35·2% (34·3–36·1)	4·2%
Japan (2017–18)	52·3% (52·1–52·5)	..	..	37·6% (37·5–37·8)	..	..
Latvia (2010–11; 2015–16)	17·9% (17·0–18·9)	17·2% (16·2–18·2)	–0·7%	26·7% (25·6–27·7)	21·9% (20·9–22·9)	–4·8%
Lithuania (2013–14; 2018–19)	17·3% (16·4–18·1)	22·8% (21·8–23·8)	5·5%	21·7% (20·7–22·6)	25·6% (24·6–26·6)	3·9%
Netherlands (2015–16)	32·9% (31·3–34·5)	..	..	30·0% (28·4–31·7)	..	..
Norway (2013–14)	26·8% (25·9–27·6)	..	..	20·8% (20·0–21·6)	..	..
Scotland (2013–14; 2018–19)	28·4% (27·6–29·2)	22·5% (21·7–23·3)	–5·9%	21·5% (20·8–22·3)	16·3% (15·6–17·0)	–5·2%
Singapore (2015–16)	59·6% (58·5–60·8)	..	..	58·3% (57·1–59·5)	..	..
South Korea (2009–10; 2014–15)	43·6% (41·4–45·9)	41·9% (39·6–44·1)	–1·7%	41·6% (39·3–43·9)	37·7% (35·5–39·9)	–3·9%
Spain (2010–11; 2015–16)	45·8% (45·0–46·7)	33·9% (33·0–34·7)	–11·9%	37·8% (36·9–38·7)	26·1% (25·3–26·9)	–11·7%
Taiwan (2005–06; 2010–11)	50·8% (48·5–53·0)	48·3% (46·0–50·5)	–2·5%	55·8% (53·2–58·2)	49·3% (46·7–51·8)	–6·5%
UK (2007–08; 2012–13)	32·4% (31·5–33·3)	27·0% (26·1–27·9)	–5·4%	23·4% (22·6–24·1)	18·6% (17·9–19·3)	–4·8%
USA (2009–10; 2014–15)	54·0% (53·8–54·2)	33·1% (33·0–33·2)	–20·9%	41·1% (40·9–41·2)	37·1% (36·9–37·3)	–4·0%

*Data for Austria represent lifetime risk from age 50 years.

Table 1: **Expected lifetime risk of developing type 2 diabetes from age 20 years to age 100 years by jurisdiction, sex, and timepoint**

We did sensitivity analyses in which we varied incidence and mortality inputs into the life table models for Israel Maccabi Healthcare Services 2009–10, Hungary 2018–19, Lithuania 2013–14, and men in the UK in 2007–08.

Estimates of lifetime risk, life expectancy, and years of life lost were derived from the estimated incidence and mortality from aggregated data for each jurisdiction. 95% CIs for all quantities were estimated by use of parametric bootstrapping. We drew 1000 estimates of parameters from the Poisson rate models from the normal distribution, with the mean equal to the maximum likelihood estimates and variance and covariance equal to the inverse of the observed Fisher information matrix. For each set of parameter estimates, we computed the predicted incidence and mortality rates and corresponding lifetime risk, life expectancy, and years of life lost. This calculation yielded 1000 estimates of all metrics (lifetime risk, life expectancy, and years of life lost), from which we used the median as the point estimate and the 2·5th and 97·5th percentiles as CIs. Stata (version 17.0) was used for all analyses.

Role of the funding source

The US Centers for Disease Control and Prevention is the employer of MEP and YJC, who were involved in study design, data collection, data interpretation, and editing of the report; MEP and YJC were not involved in data analysis or writing of the report. Diabetes Australia had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

Across all study cohorts from the 23 jurisdictions (total person-years 1 577 234 194; total population size 1 685 078 758), with the oldest cohort dating to 2005 and the most recent dating to 2019, there were 138 088 545 people with type 2 diabetes, 5 119 585 incident cases of type 2 diabetes, 4 007 064 deaths in those with type 2 diabetes, 1 546 990 213 people without type 2 diabetes, and 11 854 043 deaths in those without type 2 diabetes (appendix p 5). The peak prevalence of diabetes (13 268 [45·8%] of 28 956) occurred in Singaporean men aged 85 years or older in 2015–16 (full prevalence data to be published elsewhere).

	Men		Women	
	Life expectancy for people with type 2 diabetes (95% CI), years	Life expectancy for people without type 2 diabetes (95% CI), years	Life expectancy for people with type 2 diabetes (95% CI), years	Life expectancy for people without type 2 diabetes (95% CI), years
First timepoint				
Australia (2013–14)	57·5 (57·3–57·8)	61·9 (61·8–62·0)	61·2 (61·0–61·5)	65·2 (65·1–65·2)
Austria* (2016–17)	57·3 (57·0–57·6)	61·3 (61·2–61·4)	61·4 (61·1–61·7)	65·0 (65·0–65·1)
Canada (2011–12)	56·5 (56·4–56·7)	62·8 (62·7–62·8)	59·8 (59·6–59·9)	66·0 (65·9–66·0)
Denmark (2013–14)	52·8 (52·4–53·2)	60·5 (60·4–60·6)	57·2 (56·8–57·7)	63·6 (63·5–63·7)
Finland (2011–12)	54·4 (54·0–54·8)	58·9 (58·8–59·1)	61·2 (60·9–61·5)	64·3 (64·2–64·4)
France (2016–17)	54·3 (54·3–54·3)	59·4 (59·4–59·4)	60·9 (60·9–60·9)	65·3 (65·3–65·3)
Germany (2013–14)	50·6 (50·6–50·6)	59·6 (59·6–59·6)	56·2 (56·2–56·2)	64·0 (64·0–64·0)
Hong Kong (2013–14)	55·2 (54·8–55·5)	62·5 (62·4–62·7)	62·5 (62·1–62·8)	67·7 (67·5–67·8)
Hungary (2018–19)	47·2 (46·9–47·5)	53·7 (53·6–53·8)	54·9 (54·7–55·1)	60·4 (60·3–60·5)
Israel (Clalit Health Services; 2010–11)	52·6 (52·2–53·0)	65·3 (65·1–65·5)	57·0 (56·6–57·3)	68·2 (68·0–68·4)
Israel (Maccabi Healthcare Services; 2009–10)	58·3 (57·5–59·0)	64·5 (64·1–64·9)	61·0 (60·2–61·7)	67·5 (67·2–67·9)
Italy (2013–14)	55·8 (55·3–56·2)	62·8 (62·7–63·0)	61·0 (60·5–61·4)	66·9 (66·8–67·0)
Japan (2017–18)	59·2 (59·2–59·3)	65·2 (65·2–65·3)	64·1 (64·0–64·2)	69·7 (69·7–69·8)
Latvia (2010–11)	45·2 (44·0–46·4)	49·3 (49·1–49·5)	54·2 (53·4–54·9)	59·5 (59·3–59·7)
Lithuania (2013–14)	43·7 (42·7–44·6)	50·0 (49·8–50·1)	54·9 (54·3–55·5)	61·0 (60·9–61·2)
Netherlands (2015–16)	56·5 (56·5–56·5)	60·6 (60·6–60·6)	56·8 (56·8–56·8)	64·8 (64·8–64·8)
Norway (2013–14)	55·8 (55·3–56·2)	60·6 (60·5–60·8)	60·2 (59·7–60·6)	64·0 (63·9–64·1)
Scotland (2013–14)	54·7 (54·3–55·1)	58·5 (58·3–58·6)	56·5 (56·1–57·0)	62·1 (62·0–62·3)
Singapore (2015–16)	54·9 (54·3–55·4)	63·2 (63·0–63·5)	60·5 (60·0–60·9)	67·5 (67·3–67·7)
South Korea (2009–10)	52·0 (50·7–53·1)	59·1 (58·7–59·5)	60·2 (59·0–61·2)	65·1 (64·7–65·4)
Spain (2010–11)	58·1 (57·7–58·4)	62·3 (62·1–62·4)	63·9 (63·6–64·2)	67·4 (67·3–67·6)
Taiwan (2005–06)	50·0 (48·7–51·1)	62·1 (61·6–62·5)	58·3 (57·3–59·3)	67·6 (67·1–68·0)
UK (2007–08)	49·6 (49·6–49·6)	59·0 (59·0–59·0)	55·4 (55·4–55·4)	62·5 (62·5–62·5)
USA (2009–10)	51·6 (51·6–51·7)	61·5 (61·5–61·6)	56·9 (56·9–57·0)	65·2 (65·2–65·2)
Second timepoint				
Australia (2018–19)	58·3 (58·1–58·6)	62·7 (62·6–62·8)	61·8 (61·5–62·0)	65·9 (65·8–65·9)
Canada (2016–17)	57·4 (57·3–57·5)	63·1 (63·0–63·1)	60·4 (60·3–60·5)	66·2 (66·2–66·3)
Denmark (2018–19)	54·1 (53·7–54·5)	61·7 (61·5–61·8)	58·6 (58·2–58·9)	64·5 (64·4–64·6)
Finland (2016–17)	55·7 (55·4–56·1)	60·2 (60·1–60·4)	61·7 (61·4–62·0)	65·0 (64·9–65·1)
Hong Kong (2018–19)	55·8 (55·5–56·1)	63·8 (63·7–64·0)	63·0 (62·7–63·3)	68·8 (68·6–68·9)
Israel (Clalit Health Services; 2015–16)	53·5 (53·2–53·9)	66·4 (66·2–66·6)	57·8 (57·5–58·1)	69·0 (68·9–69·2)
Israel (Maccabi Healthcare Services; 2014–15)	58·9 (58·3–59·5)	65·7 (65·3–66·1)	61·9 (61·2–62·5)	68·1 (67·8–68·5)
Italy (2018–19)	56·9 (56·5–57·3)	63·8 (63·7–64·0)	62·0 (61·6–62·3)	67·2 (67·1–67·3)
Latvia (2015–16)	48·2 (47·1–49·2)	50·7 (50·5–50·9)	56·7 (56·1–57·3)	60·5 (60·3–60·7)
Lithuania (2018–19)	45·9 (45·0–46·6)	52·2 (52·0–52·4)	56·9 (56·4–57·4)	62·0 (61·9–62·2)
Scotland (2018–19)	54·5 (54·1–54·8)	58·7 (58·5–58·8)	56·0 (55·6–56·4)	62·2 (62·1–62·3)
South Korea (2014–15)	54·2 (53·1–55·2)	61·2 (60·8–61·6)	62·2 (61·2–63·0)	66·7 (66·3–67·0)
Spain (2015–16)	56·3 (55·9–56·6)	60·0 (59·9–60·1)	62·5 (62·2–62·8)	65·3 (65·1–65·4)
Taiwan (2010–11)	52·7 (51·6–53·7)	64·2 (63·7–64·6)	60·8 (59·9–61·6)	69·1 (68·7–69·5)
UK (2012–13)	51·8 (51·8–51·8)	60·4 (60·4–60·4)	56·9 (56·9–56·9)	63·5 (63·5–63·5)
USA (2014–15)	53·9 (53·8–54·0)	61·1 (61·0–61·1)	57·4 (57·4–57·5)	65·5 (65·5–65·5)

Life expectancy at age 20 years is an estimate of the number of years of life remaining at age 20 years. *Data for Austria represent life expectancy at age 50 years.

Table 2: **Life expectancy of people with and without type 2 diabetes at age 20 years by jurisdiction, sex, and timepoint**

There was great variation between jurisdictions, with the estimated lifetime risk being as high as 59·6% (95% CI 58·5–60·8) for Singaporean men in 2015–16 and as low as 16·3% (15·6–17·0) for Scottish women in 2018–19 (table 1). Lifetime risk decreased between the two timepoints for both sexes in most jurisdictions, with the decrease being highest in US men (table 1). Lifetime risk was generally higher for men than for women in the

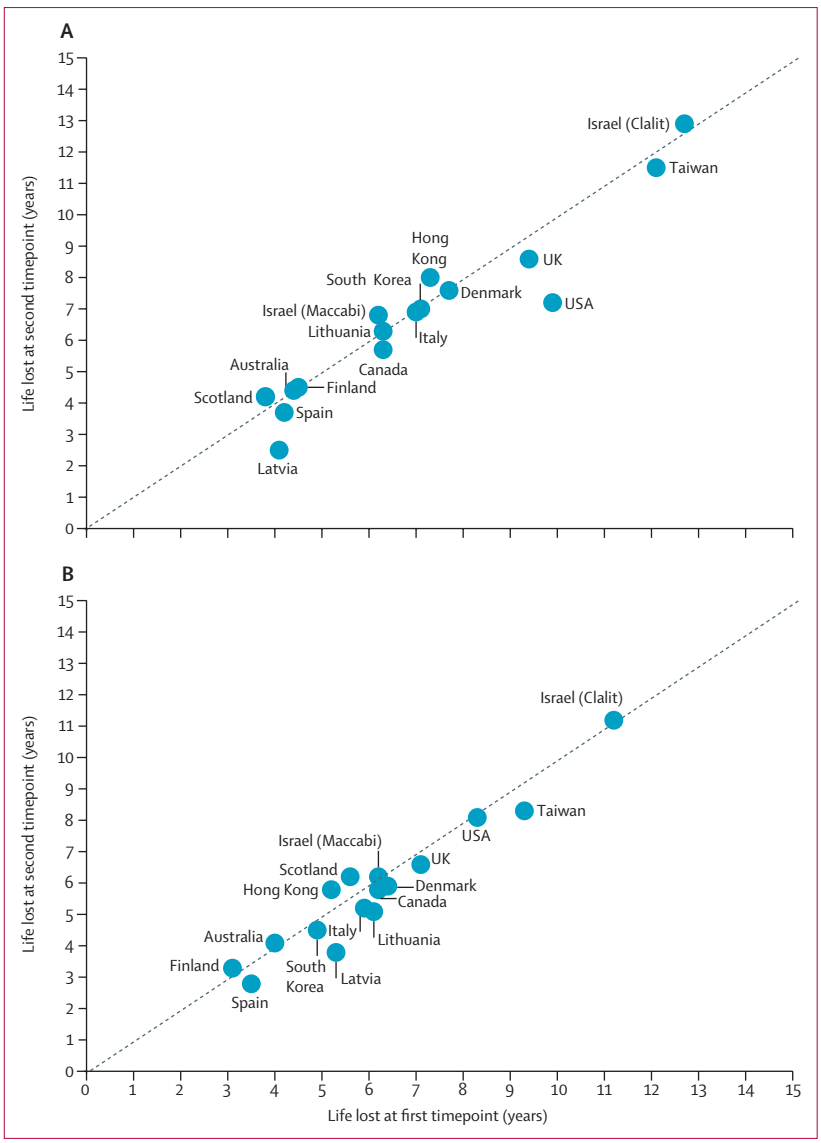

Figure 2: **Years of life lost to type 2 diabetes at age 20 years by jurisdiction and sex**
Years of life lost to type 2 diabetes for 20-year-old men (A) and women (B). The dashed line represents the line of unity, with points under the line representing a greater number of years of life lost at the first timepoint and points above the line representing a greater number of years of life lost at the second timepoint.

same jurisdiction (table 1). When life tables were run to age 80 years instead of age 100 years, the lifetime risk of diabetes before age 80 years ranged from 14·4% (95% 14·0–14·7) to 53·8% (52·8–54·7; appendix p 8).

Among people with type 2 diabetes, the highest life expectancies were found for both sexes in Japan in 2017–18, where life expectancy at age 20 years was 59·2 years (95% CI 59·2–59·3) for men and 64·1 years (64·0–64·2) for women (table 2). The lowest life expectancy at age 20 years for men with type 2 diabetes was observed in 2013–14 in Lithuania (43·7 years [42·7–44·6]). Among women with type 2 diabetes, the lowest life expectancy at age 20 years occurred in Latvia in 2010–11 (54·2 years [53·4–54·9]). Life expectancy in people with type 2 diabetes increased with time for both sexes in all jurisdictions, except for Spain and Scotland (appendix p 14). This change was generally commensurate with the increase observed for people without type 2 diabetes (table 2). However, in Latvia, substantially greater increases in life expectancy between timepoints were observed for those with versus without type 2 diabetes (table 2). Furthermore, in US men between 2009–10 and 2014–15, life expectancy increased by 2·3 years for those with type 2 diabetes and decreased by 0·4 years in those without type 2 diabetes (table 2). Tables for life expectancy in those with and without type 2 diabetes at ages 40 years and 60 years can be found in the appendix (pp 6–7). With increasing age at incident type 2 diabetes, the effect of type 2 diabetes in decreasing life expectancy was reduced (appendix pp 6–7).

The highest values for years of life lost for people with type 2 diabetes at age 20 years were observed in Israel (Clalit Health Services) for both sexes (figure 2A, B; appendix p 11). 20-year-old Israeli men with type 2 diabetes lost the most years of life (12·9 years) at the second timepoint (2015–16), compared with Israeli men of the same age without type 2 diabetes. 20-year-old women with type 2 diabetes in Israel (Clalit Health Services) lost 11·2 years of life compared with their counterparts without type 2 diabetes at both the first timepoint (2010–11) and the second (2015–16). The lowest number of years of life lost for men with type 2 diabetes occurred in Latvia in 2015–16 (2·5 years). The lowest number of years of life lost for women occurred in Finland in 2011–12 (3·1 years). With time, the expected number of years lost to type 2 diabetes decreased in some jurisdictions and increased in others. The greatest decrease in years of life lost to type 2 diabetes occurred in the USA between 2009–10 and 2014–15 for 20-year-old men (a decrease of 2·7 years) and in Latvia between 2010–11 and 2015–16 for 20-year-old women (a decrease of 1·5 years). The greatest increase in years of life lost occurred in Hong Kong between 2013–14 and 2018–19 for both men (an increase of 0·7 years) and women (an increase of 0·6 years). Fewer years of life were lost to type 2 diabetes among those with type 2 diabetes at age 40 years or 60 years than among those with type 2 diabetes at age 20 years (appendix pp 12–13, 15–16). In Austria, the expected number of years of life lost from age 50 years was 4·0 years in men and 3·6 years in women. In sensitivity analyses that tested the effects of varying inputs into the life table models, we found that incidence had the most substantial effect on lifetime risk, but changes to mortality and the relative risks of mortality altered results for years of life lost and also for life expectancy (appendix pp 9–10).

Discussion

Using life table modelling, we have estimated the lifetime risk of type 2 diabetes, life expectancy in people with and without type 2 diabetes, and years of life lost to type 2 diabetes in 23 high-income settings. At various timepoints between

2005 and 2019 and across jurisdictions, we found that the lifetime risk of type 2 diabetes varied from 16·3% to 59·6%, life expectancy for those with type 2 diabetes at age 20 years varied from 43·7 years to 59·2 years in men and from 54·2 years to 64·1 years in women, and years of life lost to type 2 diabetes varied from 2·5 years to 12·9 years. Our findings show the substantial burden of diabetes across many jurisdictions by use of metrics that can be easily interpreted by individuals in these jurisdictions and are valuable for use in prevention and disease counselling.

One of the most pertinent findings is the decrease with time in the lifetime risk of type 2 diabetes in most jurisdictions, which was driven by declining diabetes incidence in many high-income settings. In an analysis of 23 population-based studies published between 1995 and 2018 reporting trends in diabetes incidence, 19 data sources showed a downward or stable trend in diabetes incidence, with which our results are closely aligned.[8] Another important finding is the substantial magnitude of the lifetime risk observed in many jurisdictions. Despite declining lifetime risk in 11 of the 15 jurisdictions for which two timepoints were studied, lifetime risk remained greater than 30% in most jurisdictions and greater than 50% among both men and women in Hong Kong and among men in Israel. However, using methods like ours, even higher figures for lifetime risk have been reported in other studies. An Indian study reported a lifetime risk of diabetes of 55·5% in men and 64·6% in women.[15] Our findings are also understandable in the context of studies reporting the lifetime risks of other conditions. The cumulative risk of developing cancer by age 85 years among the British population born in 1960 was found to be 49·8% for men and 39·9% for women.[16] A US analysis found a 90% lifetime risk of hypertension among 55-year-olds and 65-year-olds.[17]

We also reinforce the great differences in life expectancy for people with diabetes between jurisdictions, which were generally commensurate to World Bank data[18] on government health expenditure as a proportion of gross domestic product. The observation that life expectancies decreased in those with and without type 2 diabetes in Spain between 2010–11 and 2015–16 aligns with the decrease in Spanish public health-care expenditure from 2009 following the global financial crisis.[19] The finding that Latvian and Lithuanian men had the lowest life expectancies is consistent with evidence showing a high prevalence of smoking and other high-risk behaviours among young and middle-aged men in these countries, increasing the risk of fatal accidents and injuries.[20] The most years of life lost due to type 2 diabetes were observed in Israel (Clalit Health Services), which could be in part explained by the fact that the Clalit health insurance database includes a high proportion of individuals of lower socioeconomic status.[21] Individuals of lower socioeconomic status with diabetes might face barriers in accessing the health care required to bring their life expectancies closer to those of the general population. Compared with higher socioeconomic status, lower socioeconomic status is also associated with decreased health literacy, a poorer diet, and a more sedentary lifestyle, which can lead to lower life expectancy.[22] The second most years of life lost occurred in Taiwan. A previous population-based Taiwanese study reported that life expectancy at age 30 years was 10·2 years fewer for men and 11·7 years fewer for women with diabetes and no chronic kidney disease compared with their counterparts with no diabetes and no chronic kidney disease.[23] The median age of the population and health system factors might also contribute to the wide range of observations for years of life lost across jurisdictions.

Our findings are consistent with observations from previous studies and subsequent trends in diabetes incidence and mortality. Compared with a 2008 Australian study,[3] we report a lower lifetime risk and fewer years of life lost to type 2 diabetes and higher life expectancies among those with type 2 diabetes, which is expected given improvements in diabetes care. Similarly, we found a higher life expectancy and fewer years of life lost than a Canadian study that used data from 2004 to 2006.[24] Compared with a US study that used data from 2000 to 2011,[2] we found a higher lifetime risk at our first US timepoint (2009–10), but a lower risk at our second US timepoint (2014–15). This result is in keeping with the finding that the incidence of diabetes increased in the USA from 1990 to 2007, but decreased between 2007 and 2017.[25] Concurrently, excess mortality in those with diabetes almost halved in the USA between 1994 and 2015.[26] Compared with a Danish study incorporating data from 1996 to 2016, we obtained similar results for lifetime risk.[4] Our lifetime risk results for the Netherlands are almost identical to those from an earlier analysis by Symen Ligthart and colleagues[27] that used data from 1997 to 2012. Because the study by Ligthart and colleagues[27] used ages 45 years and older in their life tables, we deduce that lifetime risk decreased in the Netherlands in the time between the analysis by Ligthart and colleagues[27] and our analysis, which simulated life tables from age 20 years in 2015–16. In Germany, a study that used data from 2015 to run life tables from ages 40 years to 100 years reported that, in a scenario in which incidence and mortality rate ratio were constant, men lost 5·8 years of life to type 2 diabetes and women lost 4·2 years.[6] Compared with this German study, we found a higher number of years of life lost from age 40 years for men (6·3 years) and women (6·4 years), which could be explained by the fact that we used earlier data from 2013–14 and a different equation to estimate mortality in those with and without diabetes.

A major strength of our study is the use of multiple population-based datasets. Unlike previous analyses that used modelled incidence and mortality data, our analysis used real-world populations. We assessed all data sources for quality in a previous analysis[8] using a modified Newcastle–Ottawa scale. The domains assessed were the

representativeness of the population; sample size; the assessment of diabetes status (whether by blood glucose measurement, clinical diagnosis, anti-diabetes medications, or self-report); the exclusion of gestational diabetes; and completeness (duration of the data provided). Of a maximum score of 8, all data sources received scores of 3–8. The lowest score of 3 was received by the Netherlands data source due to poor population representativeness, diabetes assessment limitations (diabetes was determined by clinical diagnosis and gestational diabetes was not excluded), and the short duration of data provided. Most data sources incorporated all people with known diabetes in a country.

Our study has limitations. First, we only measured diagnosed diabetes. The 2021 International Diabetes Federation Atlas showed that 29% of people with diabetes across 81 data sources from high-income countries were undiagnosed.[28] Second, because our life tables applied incidence and mortality rates from a single timepoint to a cohort, changes to these rates that would have occurred during the lifetime of the cohort could not be applied. Third, for sources that did not provide mortality data, we had to estimate mortality using relative risks. However, the relative risks used in our estimations were obtained from recent publications from the relevant jurisdictions and the mortality rates we calculated were similar to those from studies done in those jurisdictions. Life expectancy findings for people without type 2 diabetes also align closely with Global Burden of Disease data for life expectancy at age 20 years in the years and specific jurisdictions we analysed. Fourth, the methods used to diagnose type 2 diabetes varied across jurisdictions and, in some cases, within jurisdictions with time. Fifth, in jurisdictions in which the data included total diabetes rather than only type 2 diabetes, our estimates of the lifetime risk of type 2 diabetes and the number of years of life lost to type 2 diabetes will be slightly overestimated. Furthermore, in such jurisdictions, our results for the life expectancy of people with type 2 diabetes are slight underestimates because people with type 1 diabetes typically have shorter life expectancies than do people with type 2 diabetes.[29] Finally, our findings are limited in their generalisability because no data from low-income and middle-income countries were included.

For **Global Burden of Disease data** see https://vizhub.healthdata.org/gbd-compare/

Because the cohorts in the life table analyses represent a group of heterogeneous individuals, the findings represent an average member of the population. Each person will have a unique combination of risk factors that will affect their risk of mortality and of developing type 2 diabetes. However, our jurisdiction-specific results can be used to encourage individuals to take preventive action. Caution should be exercised in interpreting life expectancy estimates, as they are based on cross-sectional rates (from the study period). In this respect, our measures do not differ from other standard demographic measures such as prevalence, incidence, and mortality.

We have shown that, although the burden of type 2 diabetes at the individual level is declining, it remains substantial. Lifetime risk, life expectancy, and years of life lost are unique metrics that, in tandem with population-oriented metrics such as prevalence and mortality, provide a more rounded perspective of the disease burden of diabetes. These metrics are useful for governments and policy makers in directing healthcare resources and for disease counselling in the clinical setting. They might also encourage individuals with diabetes to take preventive action to optimise their future health outcomes.

Contributors

DJM and JES conceived the study. DT did the data analysis and wrote the manuscript. JIM developed the statistical models. LC assisted with data analysis and curation. AS provided specialist biostatistical advice with regards to the calculation of uncertainty. DT and LC accessed and verified the data. DJM and JES are senior authors who guided the direction of the manuscript and made revisions. All authors contributed to study design, data collection, data interpretation, and editing the report. All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Declaration of interests

SKP is currently a full-time employee of AstraZeneca. All other authors declare no competing interests.

Data sharing

Aggregated data will be available on reasonable request to the corresponding author. Approvals must be obtained from all collaborators, with a signed data access agreement. No date restrictions apply to data availability. US National Health Interview Survey data are publicly available.[30]

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